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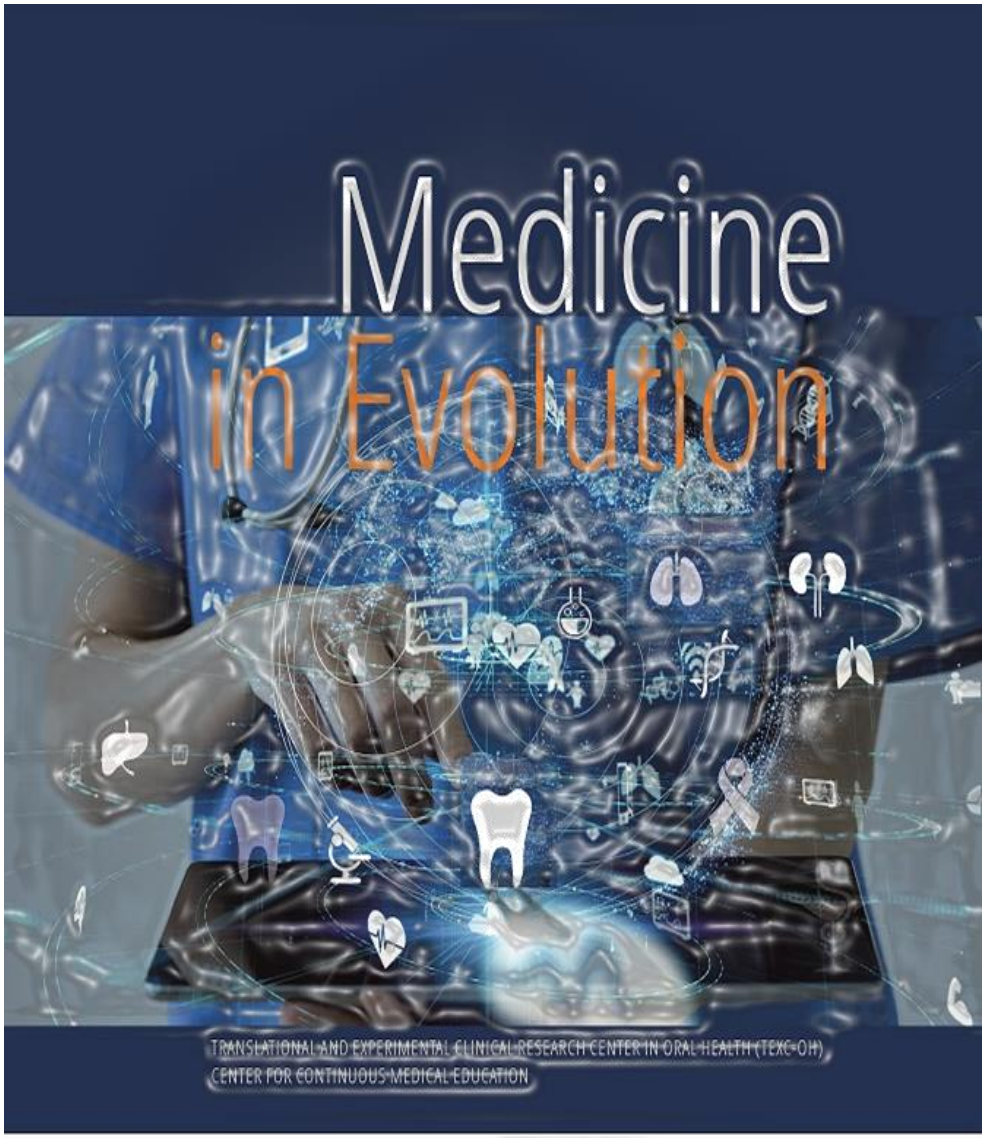

TRANSLATIONAL AND EXPERIMENTAL CLINICAL RESEARCH CENTRE IN ORAL HEALTH

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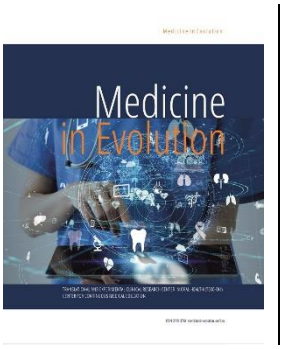
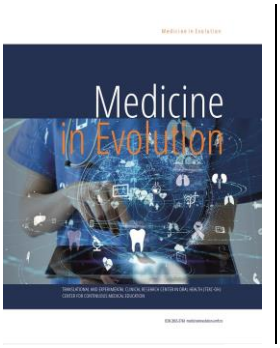


Background



The current journal was established by Prof. Dr. Mircea Ancusa in 1999, with the aim of acquiring knowledge and sharing insights in the noble profession guided by the principle "primum non nocere" (first, do no harm). In 2005, it was entrusted to a group of dedicated researchers at the Center of Health Education and Motivation for Prevention in Dentistry, under the leadership of Prof. Angela Codruta Podariu, DMD, PhD, at the Department of Preventive Dentistry of the University of Medicine and Pharmacy "Victor Babes" in Timisoara, Romania.

The inception of the journal stemmed from a dedication to exchange experiences in both professional and research domains. It was envisioned to encompass all medical specialties, with the aspiration that the published manuscripts would exhibit exceptional quality, elevating the journal's reputation. Esteemed professionals were enlisted to the editorial board and the review committee, individuals recognized for their expertise in the realm of research. The decision to publish papers in English was made to broaden accessibility to the global research community and enhance international recognition.

Since then, the journal has been regularly published under the auspices of the Center of Health Education and Motivation for Prevention in Dentistry, disseminating national and international research studies with the objective of evolving into a comprehensive evidence-based publication. Presently, the journal has transitioned to the stewardship of the Translational and Experimental Clinical Research Centre in Oral Health, situated within the Department of Preventive, Community Dentistry, and Oral Health. Its objectives are aligned with the vision of esteemed organizations such as the World Health Organization and the International Dental Federation, seamlessly integrating into the research strategy of Victor Babes University of Medicine and Pharmacy Timisoara.

"Medicine in Evolution" stands as a distinguished, peer-reviewed, open access journal dedicated to the dissemination of original theoretical research spanning the interdisciplinary spectrum of medicine and healthcare. Encompassing various topics within the realms of human life sciences, medical community, dental medicine, and pharmacology, the journal warmly welcomes original research papers, communications, letters, short notes, case reports, and reviews for submission. Committed to conducting rigorous peer reviews and expediting the publication of groundbreaking research, its mission is to advance the field of medicine through scholarly discourse.

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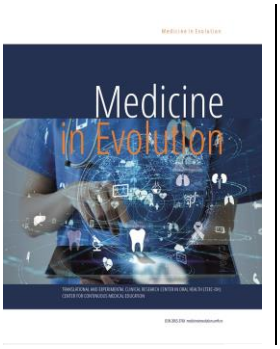
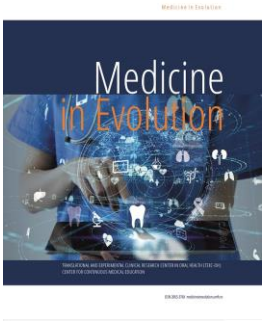


The Role of Preparation Geometry in Ceramic Veneers: A Comprehensive Literature Review



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Abstract

1.Background: Ceramic veneers are regarded as a conservative and esthetically favorable treatment modality for anterior teeth, particularly when tooth structure preservation is prioritized. Among the critical variables influencing their clinical performance, the preparation design—specifically the inclusion or omission of a cervical finish line—remains a subject of ongoing investigation. This narrative review aimed to evaluate the impact of preparation design on fracture resistance, marginal adaptation, and long-term survival of ceramic veneers. 2.Methods: A targeted literature search was conducted across PubMed, Scopus, and Web of Science for English-language publications from 2000 to 2024 using the terms "ceramic veneers," "preparation design," and "finish line." Inclusion criteria focused on in vitro and in vivo studies comparing at least two preparation designs with reported clinical outcomes, while case reports, reviews, and non-comparative studies were excluded. Of the 379 initially retrieved records, 28 studies met the inclusion criteria. 3.Results: Findings revealed that preparations incorporating a defined finish line, such as a shoulder or chamfer, consistently demonstrated superior marginal

adaptation and biomechanical stability, particularly under functional stress. In contrast, shoulderless and ultra-conservative designs preserved greater enamel substrate, which contributed to effective bonding and comparable survival outcomes in non-load-bearing regions. Across studies, ceramic veneers exhibited a mean 5- to 7-year survival rate exceeding 95%, irrespective of preparation design, provided that proper adhesive protocols were followed. 4.Conclusion: These results support a case-by-case approach guided by the principles of minimally invasive dentistry, emphasizing enamel preservation without compromising mechanical performance. A key limitation of this review is the absence of a pre-registered protocol, which should be addressed in future systematic evaluations.

Keywords: Ceramic veneers; finish line; preparation design; stress distribution; marginal adaptation.

INTRODUCTION

Traditionally, full-coverage crown restorations were considered the gold standard for managing a wide range of aesthetic concerns due to their capacity to offer complete encasement of the tooth structure, thereby enhancing both retention and visual outcomes when compared to direct restorative techniques. Since their introduction in the 1930s, dental veneers have emerged as a more conservative and esthetically refined alternative, designed to improve the appearance and function of anterior teeth. Contemporary aesthetic dental practice favors the use of ceramic veneers, which require selective removal of tooth structure and precise restorative planning. Indications for ceramic veneers typically include intrinsic or extrinsic tooth discolorations—such as those associated with tetracycline staining, fluorosis, or genetic enamel defects like amelogenesis imperfecta—along with restoration of fractured or worn dentition, correction of morphologic anomalies, minor alignment discrepancies, and esthetic rehabilitation of fractured prosthetic elements. Despite their many advantages, the long-term success of veneers can be compromised by factors such as parafunctional habits (e.g., bruxism), edge-to-edge occlusal relationships, suboptimal oral hygiene, and inadequate enamel substrate for bonding [1–8].

In parallel with the growing emphasis on minimally invasive dentistry, the demand for highly esthetic, metal-free restorative solutions has led to the widespread integration of all-ceramic systems into clinical practice. Among these, feldspathic porcelain veneers have gained particular prominence for anterior restorations, owing to their superior optical properties, high biocompatibility, mechanical performance, and long-term clinical success. These materials exhibit a translucency and light conductivity that closely mimic the natural dentition, thereby fulfilling both functional and esthetic expectations. Crucially, the biomechanical behavior of ceramic veneers is significantly influenced by the preparation design, with specific emphasis on the elimination of internal stress concentrators through the rounding of sharp line angles. Feldspathic porcelain veneers fabricated using the refractory die technique—currently the most prevalent laboratory method—allow for meticulous control over key restorative parameters, such as marginal adaptation, incisal translucency, and emergence profile. In terms of material properties, feldspathic ceramics demonstrate favorable flexural strength (62–90 MPa), compressive strength (approximately 172 MPa), shear strength (110 MPa), and an elastic modulus of around 69 GPa, rendering them suitable for thin-layer restorations in low to moderate stress-bearing zones [2, 3, 5, 6].

Preparation design remains a pivotal factor in the long-term success of ceramic restorations, with particular attention given to the configuration of the cervical margin. Vertical preparations, encompassing designs such as knife-edge, feather-edge, and other shoulderless approaches, are characterized by the absence of a distinct finish line and aim to recreate the anatomic contour of the tooth while facilitating a favorable prosthetic emergence profile. These designs have gained renewed interest in recent years due to their conservative nature, especially in clinical scenarios prioritizing enamel preservation. Nonetheless, despite their minimally invasive appeal, shoulderless preparations have faced limitations in terms of laboratory adaptability and precision, which has contributed to their decline in routine clinical application. In contrast, horizontal finish lines—including chamfer and shoulder designs—provide a clearly defined interface between the tooth and the restoration, thus ensuring optimal marginal integrity. The shoulder finish line, recognized by its wide and flat ledge with an internal angle of approximately 130 degrees, offers substantial support for brittle ceramic materials and is frequently indicated for all-ceramic restorations. The chamfer finish line, defined by its concave and sloped contour, facilitates a smoother transition between restorative and dental tissues and is commonly employed in metal-ceramic or full-

metal crowns. A modified version, the deep or heavy chamfer, features a greater axial depth and a cavo-surface angle exceeding 90 degrees, thus enabling improved marginal fit and mechanical stability—attributes especially relevant for ceramic materials requiring increased thickness. Ultimately, the selection of a finish line configuration should be tailored to each clinical case, considering the restorative material, biomechanical demands, and esthetic requirements [3, 4, 9].

Comparative investigations evaluating various finish line geometries—including chamfers, shoulders with acute axio-gingival angles, and shoulders with rounded axio-gingival contours—have yielded conflicting results regarding their influence on the mechanical performance of ceramic restorations. While some studies have reported that chamfer designs are associated with diminished fracture resistance, particularly in brittle ceramic systems, other research has demonstrated no statistically significant difference in load-bearing capacity between chamfer and knife-edge preparations. These discrepancies highlight the complexity of the relationship between margin design and structural integrity, suggesting that more invasive preparations are not always necessary to achieve reliable adhesion to enamel or to ensure adequate biomechanical behavior. As such, the decision to implement a specific finish line should be grounded in a comprehensive evaluation of clinical factors rather than adherence to a singular design philosophy [2].

The evolution of restorative dentistry has seen a progressive shift from full-coverage crowns toward more conservative treatment modalities, particularly in response to advancements in dental materials and adhesive technologies. Although traditional crowns were historically favored for their superior retention and esthetic outcomes in comparison to direct restorations, the introduction and refinement of ceramic veneers—first utilized in the 1930s—have transformed the standard of care in anterior aesthetic rehabilitation. Today, ceramic veneers represent the benchmark for minimally invasive prosthetic interventions, offering an optimal balance between preservation of healthy tooth structure and achievement of natural, long-lasting esthetic results [10].

The clinical indications for ceramic veneers are diverse and encompass a wide spectrum of aesthetic and functional challenges. These include intrinsic and extrinsic discolorations—such as those caused by tetracycline exposure, dental fluorosis, or developmental enamel anomalies like amelogenesis imperfecta—as well as the rehabilitation of fractured, abraded, or morphologically compromised teeth. Veneers are also employed in the correction of minor positional irregularities, offering a minimally invasive alternative to orthodontic or prosthetic interventions. Nonetheless, the long-term prognosis of veneer restorations may be adversely affected by specific clinical conditions, including parafunctional habits (e.g., bruxism), edge-to-edge occlusion, suboptimal oral hygiene, and inadequate enamel substrate, all of which can compromise bonding efficacy and increase the risk of mechanical or biological failure over time [11–16].

Among the available ceramic systems, feldspathic porcelain remains a preferred material for veneer fabrication, largely due to its excellent biocompatibility, superior optical characteristics, and favorable mechanical behavior when applied under appropriate clinical conditions. Its inherent translucency and ability to mimic natural enamel render it particularly suitable for high-demand aesthetic cases. However, the clinical performance of feldspathic and other ceramic veneers is closely tied to the geometry of the tooth preparation. Specifically, variations in preparation design—ranging from conventional shoulder margins to more conservative shoulderless approaches—can significantly influence key parameters such as stress distribution across the restoration, resistance to fracture under functional loads, and the marginal adaptation of the veneer to the underlying tooth structure. This review aims to elucidate the biomechanical and clinical implications of these differing preparation

techniques, offering a comparative perspective on their respective strengths and limitations in contemporary restorative practice [17–24].

The contemporary emphasis on minimally invasive dentistry and highly esthetic outcomes has positioned ceramic veneers as a compelling alternative to traditional full-coverage crowns. These restorations provide not only excellent optical properties and biocompatibility but also demonstrate favorable long-term performance, particularly when adhesively bonded to enamel. However, despite their widespread clinical adoption, the ideal preparation design for ceramic veneers remains a subject of ongoing debate. A key point of contention lies in whether to employ a defined finish line—such as a chamfer or shoulder—or to opt for a vertical, shoulderless preparation, which is often regarded as more conservative. In clinical decision-making, practitioners are frequently required to balance the competing priorities of enamel preservation and restoration durability.

The design of the tooth preparation has direct implications for several biomechanical and clinical factors, including the quantity of tooth structure removed, the internal stress distribution within the veneer and luting interface, the quality of marginal adaptation, and the overall resistance to fracture and debonding. Although numerous in vitro and in vivo studies have examined these variables, the evidence remains fragmented, with inconsistencies across methodologies and outcome measures.

At present, the literature lacks a comprehensive, narrative synthesis that systematically evaluates the clinical performance of ceramic veneers based on the presence or absence of a finish line. Such a review is essential to offer clinicians a clearer understanding of the biomechanical behavior, aesthetic outcomes, and long-term viability associated with each preparation strategy. This work focuses specifically on anterior restorations in patients presenting with moderate tooth wear, discoloration, or morphological deficiencies, where preserving sound dental structure is paramount. Within this context, the review analyzes the influence of preparation design—whether featuring a defined margin or not—on critical parameters such as internal stress distribution, fracture resistance under functional loading, marginal integrity over time, patient-reported satisfaction, and the overall clinical longevity of the restorations. By consolidating and interpreting the available data, the present review aims to provide a practical and evidence-based framework for guiding restorative decision-making in contemporary prosthodontic and aesthetic practice.

MATERIAL AND METHODS

This narrative literature review was based on a comprehensive search conducted exclusively through the Web of Science (WoS) database. The search included English-language articles published between 2000 and 2024 and employed combinations of the following keywords: “ceramic veneers,” “preparation design,” “finish line,” “stress distribution,” “fracture resistance,” “marginal adaptation,” and “clinical longevity.”

To ensure transparency and methodological clarity in the identification and selection of relevant studies, the review process adhered to the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Although this is a narrative review, the PRISMA framework was adapted to support a structured search strategy and a transparent reporting format. The study selection process—including the number of records identified, screened, excluded, and included—is visually summarized in the PRISMA flow diagram (Figure 1).

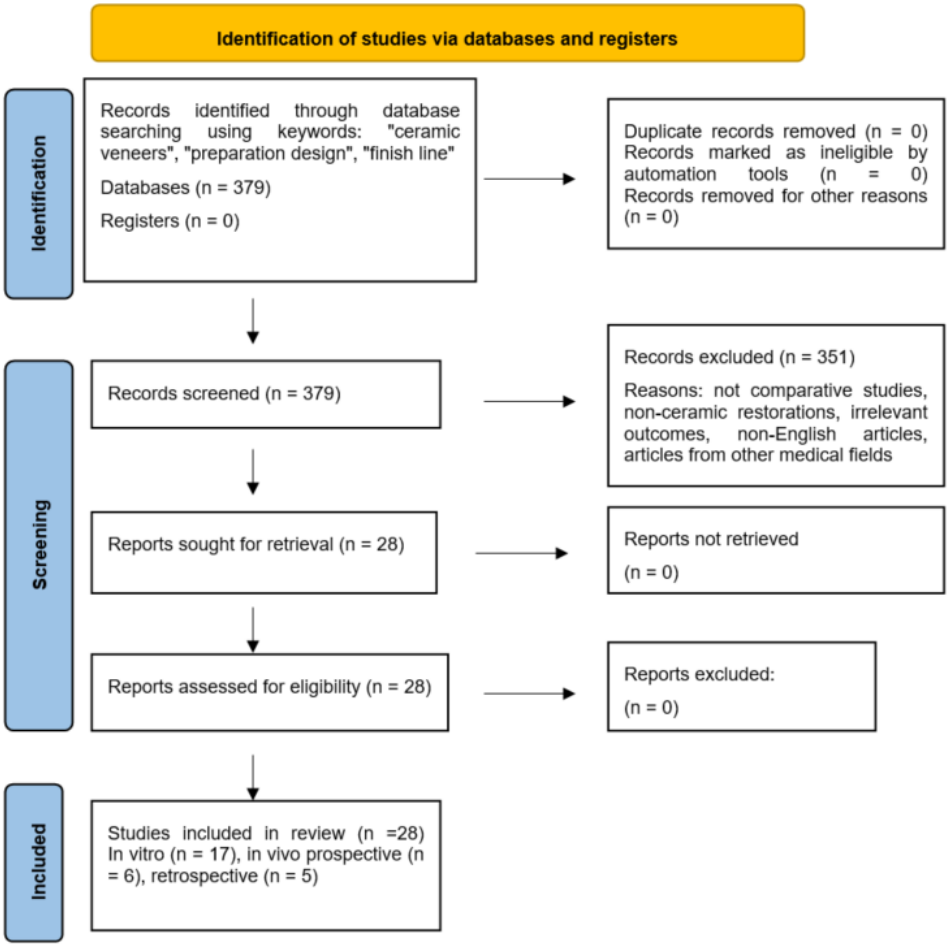

Figure 1. PRISMA 2020 flow diagram for a narrative review based on searches conducted exclusively in the Web of Science database

The inclusion criteria allowed for in vitro, in vivo, prospective, and retrospective studies that directly compared at least two different preparation designs for ceramic veneers, with clearly defined and quantifiable clinical or biomechanical outcomes. Case reports, narrative reviews, editorials, and non-comparative studies were excluded.

From an initial pool of 379 identified articles, 28 studies met the inclusion criteria. Study selection was performed independently by two reviewers, who screened titles, abstracts, and full texts. Discrepancies were resolved through discussion and mutual consensus to ensure consistency and reduce selection bias. The methodological quality and risk of bias in the included studies were assessed using a specialized software tool that evaluated criteria such as sample size adequacy, presence of control groups, appropriateness of statistical analyses, and transparency in outcome reporting.

This narrative review was not prospectively registered in a review protocol database such as PROSPERO, as protocol registration is not a mandatory requirement for narrative reviews, which inherently allow greater flexibility in scope and methodology. Nonetheless, the review adhered to a rigorous and transparent approach in defining objectives, inclusion criteria, literature search strategy, and data synthesis to reduce selection bias and enhance reproducibility. Future systematic investigations on this topic may benefit from formal protocol registration to further improve methodological standardization.

The risk of bias in the included studies was independently evaluated by two reviewers using a structured tool adapted from the ROBINS-I framework. The evaluation focused on key domains, including selection bias, comparability of groups, accuracy in exposure and

outcome measurement, and completeness of reporting. A visual summary of the overall risk of bias across studies is presented in Figure 2.

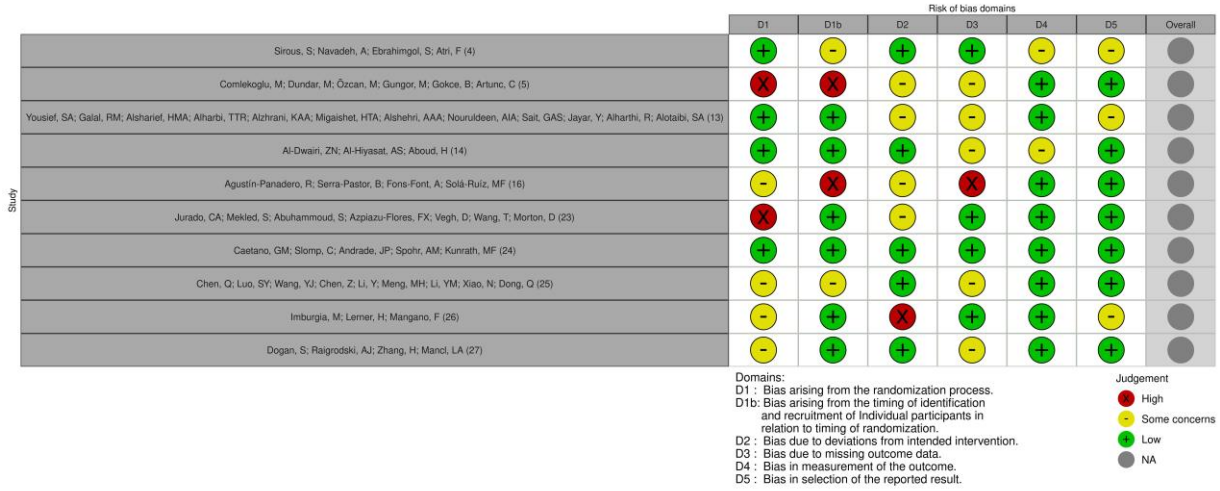

Figure 2. Summary of Risk of Bias Assessment Across Included Studies Based on Adapted ROBINS-I Criteria

Preparation designs were classified according to four key anatomical zones: the buccal surface (categorized as no preparation, minimal, conservative, or conventional), the proximal margin (slice versus chamfer), the incisal edge (overlap versus non-overlap), and the cervical finish line (shoulder, chamfer, or knife-edge). This classification served as the analytical framework for evaluating the influence of each variable on stress distribution, marginal adaptation, fracture resistance, and the overall clinical performance of ceramic veneers.

RESULTS

This narrative review incorporated 28 eligible studies encompassing a variety of study designs and methodologies. The included literature comprised 17 in vitro investigations, 6 prospective in vivo studies, and 5 retrospective clinical analyses. The studies exhibited methodological heterogeneity in terms of ceramic systems employed, preparation geometries, follow-up durations, and reported clinical or biomechanical outcomes. A detailed summary of the included studies is presented in Table 1.

Table 1. Summary of included studies evaluating the influence of preparation design on the clinical and biomechanical performance of ceramic veneers

No.	Article Title	Type of Study	Authors	Year	Main Focus
1	Marginal and internal adaptation of zirconium dioxide ceramic copings and crowns with different finish line designs	In vitro study	Komine, F; Iwai, T; Kobayashi, K; Matsumura, H	2007	Evaluates the adaptation of zirconia copings/crowns with different finish lines.
2	Fracture Resistance of Ceramic Veneers with Different Preparation Designs	In vitro study	Akoglu, B; Gemalmaz, D	2011	Assesses how preparation design affects fracture resistance in ceramic veneers.
3	Comparison of the Marginal Adaptation of Zirconium Dioxide Crowns in Preparations with Two Different Finish Lines	In vitro study	Euán, R; Figueras-Alvarez, O; Cabratosa-Termes, J; Brufau-de Barberà, M; Gomes-Azevedo, S	2012	Compares marginal fit of zirconia crowns with chamfer vs. shoulder margins.

4	Effect of preparation design on marginal adaptation and fracture strength of ceramic occlusal veneers: A systematic review	Systematic review	Sirous, S; Navadeh, A; Ebrahimgol, S; Atri, F	2022	Summarizes literature on how preparation design impacts ceramic occlusal veneers.
5	Influence of Cervical Finish Line Type on the Marginal Adaptation of Zirconia Ceramic Crowns	In vitro study	Comlekoglu, M; Dundar, M; Özcan, M; Gungor, M; Gokce, B; Artunc, C	2009	Investigates cervical finish lines' influence on marginal adaptation in zirconia crowns.
6	Tooth structure removal associated with various preparation designs for anterior teeth	In vitro study	Edelhoff, D; Sorensen, JA	2002	Quantifies tooth structure removal for different veneer preparation types.
7	INFLUENCE OF PREPARATION DESIGN AND EXISTING CONDITION OF TOOTH STRUCTURE ON LOAD TO FAILURE OF CERAMIC LAMINATE VENEERS	In vitro study	Schmidt, KK; Chiayabutr, Y; Phillips, KM; Kois, JC	2011	Explores preparation and tooth structure effects on veneer fracture resistance.
8	Effect of preparation design on marginal and internal adaptation of translucent zirconia laminate veneers	In vitro study	Kusaba, K; Komine, F; Honda, J; Kubochi, K; Matsumura, H	2018	Assesses impact of preparation geometry on veneer fit.
9	Comparison of Load-Fatigue Testing of Ceramic Veneers with Two Different Preparation Designs	In vitro study	Chaiyabutr, Y; Phillips, KM; Ma, PS; ChitSwe, K	2009	Compares fatigue resistance of veneers using different preparations.
10	THE EFFECT OF CEMENT THICKNESS AND PREPARATION DESIGN ON STRESS LEVEL AND STRESS DISTRIBUTION IN MAXILLARY CENTRAL INCISOR RESTORED BY LAMINATE VENEERS- A FINITE ELEMENT ANALYSIS	Finite element analysis	Ghasemi, S; Babaloo, AR; Negargar, S; Amini, S	2019	Analyzes stress distribution in veneers under different cement thicknesses and preparations.
11	Dentin Exposure after Tooth Preparation for Laminate Veneers: A Microscopical Analysis to Evaluate the Influence of Operators' Expertise	Microscopical analysis	Sorrentino, R; Ruggiero, G; Borelli, B; Barlattani, A; Zarone, F	2022	Assesses how operator experience affects dentin exposure during veneer prep.
12	Comparative Influence of Marginal Design and Digital Scanning Accuracy on the Clinical Longevity of Ceramic Restorations	Consensus statement	Pradies, G et al.	2025	Discusses how margin design and scan accuracy affect ceramic restoration survival.
13	Comparison of Two Types of Preparation for Laminate Veneer with Three Types of All-Ceramic Materials	In vitro study	Yousief, SA et al.	2023	Compares veneer performance across prep and ceramic types.
14	Standards of teeth preparations for anterior resin bonded all-ceramic crowns in private dental practice in Jordan	Observational study	Al-Dwairi, ZN; Al-Hiyasat, AS; Aboud, H	2011	Surveys clinical standards for all-ceramic prep designs in Jordan.
15	The Effect of Glass Ceramic Layering on the Marginal Leakage of Zirconia Supported Crowns	In vitro study	Elter, B; Paken, G; Cömlekoglu, ME	2024	Tests effect of ceramic layering on marginal leakage in zirconia crowns.

16	Prospective Clinical Study of Zirconia Full-coverage Restorations on Teeth Prepared With Biologically Oriented Preparation Technique	Prospective clinical study	Agustín-Panadero, R et al.	2018	Evaluates gingival health after BOPT prep and zirconia crowns.
17	Minimally invasive vertical preparation design for ceramic veneers: a multicenter retrospective follow-up clinical study	Retrospective clinical study	Imburgia, M; Cortellini, D; Valenti, M	2019	Assesses long-term outcomes of minimally invasive vertical preps.
18	Restoring Strength of Incisors with Veneers and Full Ceramic Crowns	In vitro study	Chun, YHP et al.	2010	Compares strength restoration via veneers vs. full crowns.
19	Porcelain-veneered computer-generated partial crowns	In vitro study	Denissen, HW et al.	2002	Examines partial crown design and material behavior.
20	In Vitro Comparison of Microleakage, Marginal Fit, and Cement Thickness of Conventional and Prepless Lithium Disilicate Veneers	In vitro study	Pierre, FZ et al.	2023	Compares prepless vs. conventional veneers on fit and microleakage.
21	Retrospective Long-Term Clinical Outcome of Feldspathic Ceramic Veneers	Retrospective clinical study	Mihali, SG et al.	2022	Reports long-term results for feldspathic veneers.
22	Interdisciplinary Approach to Retreatment of a Full-Mouth Rehabilitation	Case report	Gil, A et al.	2025	Shows retreatment approach using horizontal preps and mucogingival surgery.
23	Fracture resistance of partial and complete coverage veneers and ceramic crowns for maxillary central incisors	In vitro study	Jurado, CA et al.	2024	Compares fracture resistance in varying coverage restorations.
24	Partial Ceramic Veneer Technique for Challenging Esthetic Frontal Restorative Procedures	Clinical technique report	Caetano, GM et al.	2023	Describes esthetic veneer technique for difficult anterior cases.
25	Three-dimensional finite element analysis of occlusal stress on maxillary first molars with different marginal morphologies restored with occlusal veneers	Finite element analysis	Chen, Q et al.	2024	Simulates stress distribution for different margin designs in occlusal veneers.
26	A Retrospective Clinical Study on 1075 Lithium Disilicate CAD/CAM Veneers with Feather-Edge Margins Cemented on 105 Patients	Retrospective clinical study	Imburgia, M; Lerner, H; Mangano, F	2021	Evaluates clinical performance of feather-edge CAD/CAM veneers.
27	Prospective cohort clinical study assessing the 5-year survival and success of anterior maxillary zirconia-based crowns with customized zirconia copings	Prospective cohort study	Dogan, S et al.	2017	Assesses 5-year survival of zirconia crowns with custom copings.
28	Marginal, Internal Fit and Microleakage of Zirconia Infrastructures: An In-Vitro Study	In vitro study	Korkut, L; Cotert, HS; Kurtulmus, H	2011	Analyzes marginal/internal fit and microleakage in zirconia restorations.

Finite element analyses consistently revealed that shoulder-type preparations facilitated more favorable stress distribution across the ceramic restoration and the adhesive

interface. Compared to chamfer and knife-edge designs, shoulder margins reduced localized stress concentrations during axial loading. Additional geometrical features—such as incisal bevels and palatal chamfers—were shown to improve fatigue resistance, supporting their use in high-stress anterior regions.

Fracture resistance was strongly influenced by preparation geometry. Restorations based on shoulder preparations consistently demonstrated superior load-bearing capacity compared to chamfered or feathered margins. Feldspathic ceramic veneers showed higher average fracture strength when seated on preparations with clearly defined shoulder margins. Similarly, lithium disilicate ceramics exhibited increased mechanical resilience when deeper or modified chamfer designs were employed, as opposed to knife-edge configurations.

In terms of marginal adaptation, conservative preparations incorporating anatomical contours and rounded internal angles yielded smaller marginal gaps. Shoulder margins with a 90-degree finish line provided more consistent marginal integrity than deep chamfers, although the differences were often not statistically significant. Minimal chamfer and shoulder designs presented comparable fit at the tooth-restoration interface, with dimensional differences generally limited to a few microns, favoring adhesive reliability in minimally invasive approaches.

The long-term clinical performance of ceramic veneers across the analyzed studies was generally positive, with an average survival rate of 97.5% over follow-up intervals ranging from five to seven years. Common causes of failure included veneer fracture and adhesive debonding, with increased failure incidence noted in posterior segments. Preparations with defined cervical margins showed marginally higher longevity than those without, although the differences were not always statistically relevant.

Patient-reported outcomes reflected high levels of satisfaction regardless of preparation type. Both minimally invasive and conventional techniques were favorably rated in terms of esthetics, function, and comfort. These results reinforce the viability of conservative preparation designs, provided they are appropriately adapted to occlusal function and aesthetic requirements.

Material selection was a key factor influencing performance outcomes. Feldspathic porcelain was valued for its superior optical properties and natural enamel-like translucency, making it ideal for high-aesthetic anterior cases. However, its mechanical performance under dynamic loading was inferior to that of lithium disilicate or zirconia-reinforced ceramics. Lithium disilicate, in particular, demonstrated excellent fatigue resistance, making it suitable for patients with increased functional demands.

Finally, quality assessment of the included studies indicated moderate methodological variability. Limitations such as small sample sizes, inconsistent reporting, lack of standardization in preparation protocols, and short follow-up periods were common. Of the 28 studies reviewed, 18 were found to carry a moderate to high risk of bias. These findings underscore the need for standardized clinical protocols and well-designed longitudinal studies to more conclusively determine the impact of preparation design on the clinical success of ceramic veneers.

DISCUSSIONS

This narrative review underscores the pivotal role of preparation design in the clinical performance and longevity of ceramic veneers. As dental materials and adhesive technologies evolve, there is a notable shift toward minimally invasive techniques, particularly low-thickness ceramic restorations. These allow for preservation of enamel, enhance esthetics, and improve function in cases of anterior wear and minor discoloration.

A comparative analysis of preparation types reveals that shoulder designs consistently yield superior stress distribution and fracture resistance. Finite element analysis and in vitro tests demonstrate that shoulder margins—characterized by flat axial walls and wider marginal zones—help dissipate occlusal loads more effectively than chamfer or knife-edge designs [10,11,12,24]. Additionally, the integration of a palatal chamfer has been shown to improve load-fatigue performance, particularly in lithium disilicate veneers, supporting their application in functional zones subjected to higher occlusal stress [20].

Biomechanical evidence also highlights the significance of incisal preparation, especially in terms of overlap designs. Bevels and butt-joint configurations, particularly when paired with a palatal chamfer, distribute stress more uniformly and offer improved integration into incisal guidance. While feldspathic ceramics remain the gold standard for esthetic outcomes, their lower mechanical resilience compared to lithium disilicate or zirconia-reinforced ceramics necessitates careful case selection [14].

In terms of marginal adaptation, studies show that minimally invasive designs with anatomical reduction often yield fewer marginal gaps and better long-term bonding performance. Preparations with rounded shoulder margins demonstrate superior adaptation, although the differences between deep chamfers and conservative shoulders are not always statistically significant [25-29,31-33]. A poor marginal fit, exacerbated by improper cementation or over-preparation, can lead to luting degradation, secondary caries, and restoration failure [21,22,25,27].

Longitudinal clinical studies report high survival rates for ceramic veneers—averaging 97.5% over 5 to 7 years. Failures were primarily associated with fractures or debonding, especially in posterior regions such as premolars [17]. These findings affirm the reliability of well-executed ceramic restorations. However, patient-specific variables—such as parafunctional habits, oral hygiene, and smoking—play a crucial role in long-term outcomes [26,28,29].

Patient satisfaction remains consistently high across studies, with porcelain veneers receiving favorable evaluations regarding esthetic appearance and functional comfort. Interestingly, there appears to be no significant difference in satisfaction between conventional and minimal preparation techniques, suggesting that conservative approaches can meet both clinical and subjective expectations [19].

Despite these encouraging results, several methodological limitations must be acknowledged. Many included studies exhibited small sample sizes, inconsistent reporting, and varying follow-up periods. Moreover, the absence of standardized assessment tools, such as ROBINS-I or the Newcastle-Ottawa Scale, limited the objective evaluation of bias. As this review did not follow a registered protocol, it is also susceptible to selection and publication bias.

Clinically, the findings support a tailored approach to preparation design. Shoulder-type margins provide optimal mechanical support and marginal adaptation but require more extensive tooth reduction. Conversely, shoulderless or knife-edge designs conserve more enamel but may pose challenges in load-bearing areas. Therefore, preparation should be customized based on material properties, functional load, esthetic demands, and patient-specific anatomical considerations.

The cementation protocol further influences restoration success. The use of light-cured or dual-cure resin cements, proper enamel bonding, and meticulous isolation are critical to minimizing microleakage and ensuring long-term adhesion. Additionally, the type of preparation—buccal, proximal, incisal, or cervical—should be chosen based on the clinical need for thickness, emergence profile, and esthetic integration [13].

Overall, the review emphasizes that conservative preparation strategies—when combined with appropriate material selection, adhesive protocols, and patient management—

can yield outcomes comparable to traditional approaches. Future research should prioritize randomized controlled trials with standardized methodologies to validate these conclusions and enhance clinical guidelines for veneer preparation.

This review, while structured and protocol-based, is still subject to limitations commonly associated with narrative approaches. The lack of meta-analytic integration restricts the ability to perform quantitative synthesis and to evaluate heterogeneity across studies. Moreover, substantial methodological variability was present among the included articles, particularly in terms of study design, sample size, follow-up periods, and outcome measures. Although risk of bias was assessed systematically, differences in reporting quality and methodological rigor may influence the consistency and generalizability of the findings. Additionally, the absence of key statistical indicators—such as confidence intervals or significance values—in several studies limits the interpretative strength of the aggregated evidence. As such, while relevant clinical patterns and implications were identified, caution is advised in the extrapolation of results. Further standardized, long-term prospective clinical trials are recommended to consolidate the current evidence base and support clinical decision-making.

CONCLUSIONS

This narrative literature review explored the clinical and biomechanical impact of preparation design—specifically the presence or absence of a defined cervical finish line—on the performance of ceramic veneers. Analysis of 28 selected studies revealed that shoulder-type preparations consistently yield superior outcomes in terms of stress distribution, fracture resistance, and marginal adaptation. These benefits are particularly relevant in cases involving high occlusal loads, compromised enamel thickness, or parafunctional habits such as bruxism.

Minimally invasive and shoulderless designs, including feather-edge and knife-edge preparations, offer a viable option when enamel preservation is a priority and occlusal forces are minimal. Palatal chamfers and incisal bevels have shown potential in enhancing fatigue resistance and maintaining anterior guidance, particularly in esthetically demanding restorations subjected to functional stress.

Material selection plays a decisive role in the success of ceramic veneers. Feldspathic ceramics remain preferred for highly esthetic cases due to their superior translucency and natural enamel-like properties. However, for restorations exposed to increased functional demands, lithium disilicate and zirconia-reinforced ceramics provide enhanced mechanical strength and fracture resistance.

Adhesive protocol is equally critical. Bonding to enamel ensures greater longevity and durability compared to dentin bonding. As such, preparation strategies that retain maximum enamel while facilitating optimal adhesive conditions are strongly recommended to support long-term clinical success.

Clinicians are advised to select preparation designs based on a combination of anatomical, functional, and esthetic considerations, along with the specific ceramic material being used. Shoulder-type preparations are particularly suitable for patients with bruxism, deep discoloration, or extensive restorations, while feather-edge or minimal chamfer designs are well-suited to cases with intact enamel and lower functional risk.

This review highlights the importance of a comprehensive and individualized treatment approach that integrates preparation geometry, material properties, adhesive technique, and patient-specific factors. Such an integrative strategy forms the foundation for achieving durable, functional, and esthetically pleasing outcomes in contemporary restorative dentistry.

Conflicts of Interest

The authors declare no conflict of interest.

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Anxiety as a Determining Factor in Medical Specialty Choice: A Literature Review

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Abstract

1.Background: The choice of medical specialty is a pivotal decision in the professional development of medical students, with long-term implications for personal satisfaction, performance, and mental health. This decision-making process is influenced by a wide array of factors, including individual personality traits, socio-economic conditions, academic environment, and psychological states such as anxiety. This narrative review explores the relationship between anxiety and the process of selecting a medical or surgical specialty. 2.Material and Methods. A literature review was conducted using PubMed and Google Scholar databases. Articles were selected based on relevance, methodological rigor, and inclusion in peer-reviewed journals. Keywords included "anxiety," "medical specialty choice," "medical students," and "psychological determinants of career decision-making." 3. Results. Findings reveal that anxiety can significantly alter the perception of professional compatibility and impact decision-making capacity. Students with higher anxiety levels are more likely to avoid high-responsibility fields such as surgery or emergency medicine, despite having the competencies required. Additionally, stress levels vary significantly among specialties, with emergency medicine, surgery, and intensive care being among the most demanding, while dermatology, radiology, and pathology are perceived as lower-stress fields. Personal traits such as extroversion, neuroticism, and emotional resilience, as well as socio-cultural pressures and academic mentorship, also shape career preferences. 4.Conclusions. Given the complexity of factors involved in specialty choice, especially the influence of anxiety and perceived stress, it is essential to provide medical students with structured psychological support and vocational counseling. Further studies are needed to deepen the understanding of the psychological mechanisms influencing specialty choice and to inform educational policies aimed at reducing professional dissatisfaction.

Keywords: anxiety, stress level, medical specialty, future doctors

INTRODUCTION

Choosing a medical specialty is a crucial moment for future doctors, with a significant impact on their careers. The decision-making process is influenced by numerous internal factors, such as individual skills and competencies, as well as external factors, including socio-economic conditions and the pressure of the academic environment. Anxiety is a common emotion in the lives of medical students, affecting both academic performance and the perception of different medical specialties. The level of stress and degree of responsibility vary depending on the chosen field, which can exacerbate this state. Another important aspect is the long-term impact of this decision. A student who chooses to avoid medical specialties perceived as too demanding may later experience professional dissatisfaction or a lack of fulfillment.

Anxiety is an emotional state characterized by restlessness, agitation, and excessive concern about future events perceived as life-threatening. It is a natural psychological mechanism that prepares the body for risky situations. However, when its intensity and duration are disproportionate to the actual situation, anxiety can become pathological, negatively affecting emotional balance, decision-making, and performance in various areas of life. [1,2]. Anxiety can be classified based on several factors, such as duration, intensity, and causes, with each type manifesting differently from person to person. [1,3] It can also be situational, occurring as a reaction to a specific stressful or threatening event (such as an exam or an important decision), and it typically disappears once the triggering factor is eliminated

Anxiety manifests through a range of symptoms that can be classified into physiological, cognitive, emotional, and behavioral categories. Physiological (somatic) manifestations triggered by the activation of the sympathetic nervous system, preparing the body for a fight-or-flight response. Symptoms include tachycardia (rapid heartbeat), hyperventilation (rapid and shallow breathing), excessive sweating, muscle tension, gastrointestinal disturbances (nausea, abdominal pain), dizziness, fainting sensations, and sleep disorders. [1,2,4]. Also, anxiety affects information processing, impacting concentration and decision-making. These symptoms include catastrophic thinking (tendency to anticipate the worst-case scenarios), rumination (repetitive and obsessive thoughts about problems), difficulty concentrating, hypervigilance (a continuous state of alertness to potential dangers, even in the absence of real threats), and excessive self-criticism. [1] Anxiety influences mood and emotional balance, often resulting in depressive states, restlessness, irritability, and lack of self-confidence. [2,4] Behavioral manifestations influence how a person reacts to their environment. Symptoms include avoidance of anxiety-inducing situations, excessive agitation, changes in appetite, sleep disturbances, and substance use. [2,4]

At the same time, anxiety can also arise without an actual danger, as a stable predisposition. Individuals with this type of anxiety are more susceptible to stress and tend to overestimate risks. [2] To be diagnosed as a disorder, anxiety must be persistent (lasting more than six months), significantly impact daily functioning, and be disproportionate to the situation.

The main objective of this study is to examine based on published literature how anxiety and related psychological factors influence the decision-making process of medical students when choosing a specialty, with particular attention to the avoidance of high-stress medical fields.

MATERIAL AND METHODS

This study is designed as a narrative literature review. Relevant scientific articles and reviews were identified by searching the PubMed and Google Scholar databases. The search focused on studies addressing the relationship between anxiety and the choice of medical or surgical specialties among medical students, residents, and healthcare professionals. Keywords such as "anxiety," "specialty choice," "medical students," "surgical vs. medical specialties," and "psychological factors in career decision-making" were used in various combinations. Articles were selected based on relevance, methodological rigor, and publication in peer-reviewed journals. No restrictions were imposed regarding publication year, but only articles in English were included.

CAUSES AND PREDISPOSING FACTORS OF ANXIETY

Anxiety can have multiple causes, influenced by both internal factors (biological and psychological) and external factors (social and environmental). These factors can act individually or in combination, contributing to the development and persistence of anxiety states. [4] (Tabel 1)

1. **Biological and Genetic Factors**

Heredity – Studies show that predisposition to anxiety can be inherited genetically, with a higher risk of developing anxiety disorders among children whose parents suffer from similar conditions.

Neurochemical imbalances – Abnormal levels of neurotransmitters such as serotonin, dopamine, and gamma-aminobutyric acid (GABA) can influence the manifestation of anxiety. [1,4]

2. **Psychological Factors**

Traumatic experiences – Events such as abuse, the loss of a loved one, or other emotional traumas from the past can contribute to the development of persistent anxiety. [2,4]

Personality traits – Individuals with perfectionist tendencies, high emotional sensitivity, low self-esteem, intense fear of rejection, and excessive self-criticism are more prone to anxiety. [1,4]

Thinking patterns – Anxious individuals tend to engage in excessive rationalization, overanalyzing insignificant details. They often experience obsessive thoughts, a distorted perception of reality, and persistent, stressful ideas. [2,4]

3. **Social and Environmental Factors:**

Family environment – An unstable family climate, frequent conflicts, or lack of emotional support can contribute to the development of anxiety from childhood. [1,2]

Social pressure and high expectations – In a competitive society, individuals may feel constant pressure to succeed, leading to performance anxiety. [1,2]

Professional or academic stress – In demanding work environments, such as the medical field, high levels of responsibility and pressure can exacerbate anxiety symptoms. [2,4]

4. **Behavioral Factors and Lifestyle:**

Lack of sleep – Frequent sleep deprivation can lead to neurochemical imbalances that favor the onset of anxiety. [1,2]

Excessive caffeine and alcohol consumption – These substances can amplify anxiety symptoms and increase nervous system hyperactivity. [1,2]

Sedentary lifestyle – Lack of physical activity reduces endorphin production, which plays a crucial role in stress reduction and emotional regulation. [4,5]

Anxiety causes are complex, and each person has a unique combination of factors contributing to its development. In medical students, high responsibility levels, academic pressure, and fear of failure can be determining factors, influencing both academic performance and professional decisions. [3]

Table 1. Predisposing Factors of Anxiety

Category	Factor	Description
Biological and Genetic Factors	Heredity	Genetic predisposition; higher risk in children of anxious parents.
	Neurochemical imbalances	Imbalances in serotonin, dopamine, GABA affect anxiety levels.
Psychological Factors	Traumatic experiences	Past abuse, loss, or trauma contributes to chronic anxiety.
	Personality traits	Perfectionism, low self-esteem, emotional sensitivity increase risk.
	Thinking patterns	Over-rationalization, obsessive thoughts, distorted reality perception.
Social and Environmental Factors	Family environment	Conflictual or unsupportive family environments foster anxiety early.
	Social pressure and high expectations	Pressure to succeed fosters performance-related anxiety.
	Professional or academic stress	High demands in school or work amplify anxiety symptoms.
Behavioral and Lifestyle Factors	Lack of sleep	Sleep deprivation disrupts neurochemistry, increasing anxiety risk.
	Excessive caffeine and alcohol consumption	Stimulant use heightens nervous system activity and anxiety.
	Sedentary lifestyle	Lack of exercise lowers endorphins, impacting mood regulation.

FACTORS INFLUENCING THE CHOICE OF MEDICAL SPECIALTY

1. Personal and Emotional Factors

These play a very important role in choosing a medical specialty, influencing the compatibility of the doctor with professional requirements. Individual interests and aptitudes determine attraction to surgical, clinical, or laboratory specialties. Personality also influences the decision, as extroverted individuals tend to choose specialties that involve frequent interaction with patients, such as family medicine or pediatrics, while analytical and detail-oriented individuals prefer fields like medical imaging or pathology, where analysis and data interpretation predominate. Another important aspect is stress tolerance, as specialties like intensive care or surgery require a high ability to manage pressure and critical situations. [6,7,8,9]

Recent studies suggest that emotional resilience, conscientiousness, and openness to experience are strongly associated with the selection of complex, high-stakes specialties. Additionally, higher levels of neuroticism are inversely related to choices like emergency medicine or surgery, where uncertainty and risk are frequent. Medical students also report higher anxiety levels when there is a misalignment between their personality traits and specialty demands, which can lead to long-term dissatisfaction or burnout. [6,7,8,9]

2. Socio-economic and Cultural Factors

The financial status of the student or their family can influence their orientation toward more profitable and prestigious specialties, which offer financial stability, such as surgery or dermatology, as opposed to those with more modest incomes. Additionally, cultural factors and social norms influence students' decisions, with some communities promoting certain specialties as being more important or more suitable depending on gender. The availability of jobs and the healthcare needs of a specific region also play an important

role, as many graduates choose specialties with shortages to have more employment opportunities. [10,11]

Studies have shown that in lower- and middle-income countries, students often gravitate toward job-secure and high-paying fields, while in high-income countries, lifestyle flexibility may take precedence. Furthermore, gender stereotypes continue to shape specialty distribution, with male students overrepresented in surgical fields and female students in pediatrics, OB/GYN, or psychiatry. Social mobility goals also play a role, especially for students from disadvantaged backgrounds who may view high-income specialties as a path to economic advancement. [10,11,12]

3. Influence of the Academic Environment and Mentors

The academic environment and mentors have a strong influence on personal and professional development, providing access to knowledge, resources, and development opportunities. During the years of study, students are exposed to various disciplines and clinical experiences, which allows them to form a clear vision of the fields that attract them the most. Mentors have a significant impact, offering both theoretical and practical guidance, as well as personal experiences. The relationship between student and mentor can help clarify career expectations, providing a realistic perspective on working conditions, stress levels, advancement opportunities, and work-life balance. [10]

Mentorship has been shown to be one of the most influential non-curricular factors in specialty choice. Students with early positive mentorship experiences in certain specialties are more likely to pursue them. Conversely, lack of exposure or discouragement by role models can lead to underrepresentation of certain fields. The structure of the medical curriculum and the visibility of different specialties in teaching hospitals further influence students' final career decisions. [13]

4. Social Pressure and Family Expectations

Many students feel the pressure from their family to pursue prestigious specialties, even if their own interests differ. This pressure can cause anxiety, affecting the balance between vocation and external expectations. Students must make a conscious choice based on their own preferences, aptitudes, and values. [10] Family influence is often underestimated but remains a powerful determinant, especially in collectivist cultures. Parental expectations can override intrinsic motivation, leading to cognitive dissonance or emotional distress. Additionally, peer comparisons within competitive academic environments can intensify pressure, pushing students toward specialties with higher perceived status, regardless of their personal compatibility or interest. [14]

THE CORRELATION BETWEEN ANXIETY AND CHOOSING A SPECIALTY

1. The Impact of Anxiety on the Decision-Making Process

The decision-making process is strongly influenced by anxiety, causing students to lose their ability to assess risks, analyze options, and make an informed choice. In the case of medical students, academic pressure and uncertainty about the future intensify this effect. A high level of anxiety leads students to overanalyze each option and induces the fear of making the wrong choice, which can result in delaying decisions or avoiding specialties perceived as too demanding. [15]

Furthermore, anxiety affects the perception of one's abilities, leading students to underestimate their skills and exclude specialties that involve a high degree of responsibility, such as surgery or emergency medicine, even if these could be a good fit for them. Some students choose less stressful specialties, not out of passion, but due to a desire to avoid discomfort. This emotional influence can lead to decisions that do not truly reflect the student's desires and potential, increasing the risk of long-term professional dissatisfaction. [15,16]

In addition, high levels of anxiety are often associated with a phenomenon known as "decision paralysis," where the cognitive load of weighing too many options results in inaction or defaulting to seemingly safer, less demanding choices. For medical students, who are frequently under intense academic scrutiny, this state may be exacerbated by performance-related stress, perfectionism, and fear of failure. These factors may prevent students from engaging in reflective self-assessment or from pursuing meaningful mentorship, both of which are essential to informed specialty choice.

2. Stress Levels Associated with Different Medical Specialties

Stress is a factor present in medical practice, but the level varies depending on the specialty. Each medical field has its own particularities and requirements, with different work rhythms. The main factors determining stress levels are: workload, the urgency of cases, the duration of shifts, the pressure of making quick decisions, and interaction with critical patients. [10,17]

Emergency medicine is consistently reported as one of the most demanding specialties. Physicians working in emergency departments often confront unpredictable clinical scenarios requiring rapid decision-making under high-pressure conditions. A systematic review conducted in the context of the COVID-19 pandemic reported a burnout prevalence of 75% among emergency physicians in the United States, underscoring the chronic stress inherent in this specialty. [18]

Surgical specialties are also associated with very high stress levels. Surgeons typically endure long working hours in the operating room, perform complex procedures, and must make critical intraoperative decisions with precision and efficiency. A cross-sectional study among orthopedic surgeons revealed that 31% rated their stress levels as higher than 8 out of 10, with 40% describing these levels as unacceptable. [19]

Intensive Care Units staff operate in highly stressful environments where they manage critically ill patients under constant surveillance. Emotional fatigue, high clinical demands, and ethical decision-making contribute to significant psychological burden. During the COVID-19 pandemic, ICU professionals were among those most affected by burnout and psychological distress. [18]

Cardiology – Although it involves managing patients with serious conditions, the clinical and preventive aspects present a more controlled pace with lower stress levels. Stress levels in cardiology vary according to subspecialization. Interventional cardiology and acute cardiac care are associated with high workloads and emergency responses, whereas preventive cardiology and outpatient management offer more predictable routines. Although not quantified in the cited studies, cardiology is generally perceived as moderately to highly stressful depending on clinical context. [10,15, 20]

Psychiatry is often considered to have a lower baseline level of occupational stress, especially in outpatient settings. However, psychiatric emergencies—such as managing suicidal or aggressive patients—can be highly demanding. [8,12]

In **neurology** department depending on the subfield chosen, the stress level can vary. In outpatient care, where patients are treated in clinics, the stress level is minimal, while emergency neurology is extremely demanding due to the complexity of diagnostics and the unpredictable course of neurological diseases. [10,15]

Radiologists often operate in structured environments with reduced patient interaction, focusing primarily on diagnostic interpretation. While exact stress levels are less frequently reported in the literature, this specialty is generally perceived as less stressful due to consistent hours and limited emergency duties. [10,15]

Dermatology is widely acknowledged as one of the least stressful specialties. It typically involves non-urgent clinical cases, minimal emergency care, and regular working

hours. Despite the lack of large-scale data quantifying stress in this field, dermatology consistently ranks as a preferred specialty in lifestyle-centered career evaluations. [10,15]

Professionals in **laboratory medicine and pathology** engage primarily in analytical and diagnostic tasks with minimal patient contact. These specialties are associated with a relatively stable schedule and lower levels of workplace stress, though comprehensive empirical data on stress prevalence is currently limited. [10,15]

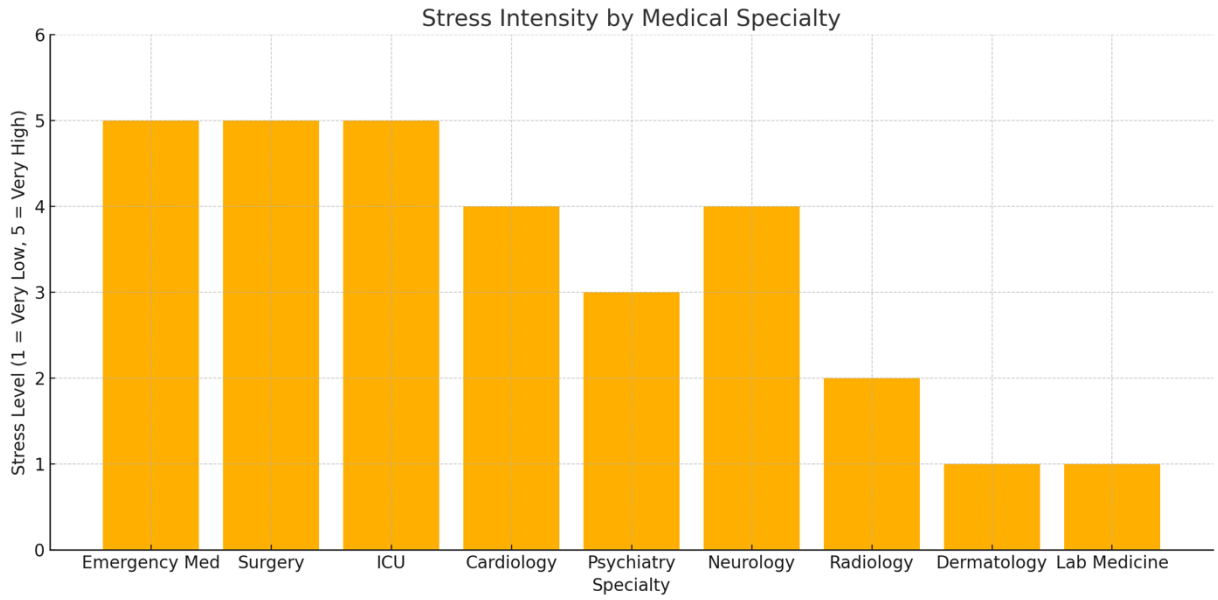

Figure 1. Stress intensity acording to medical and surgical specialties

DISCUSSIONS

Anxiety is a significant determinant in choosing a medical specialty, having a substantial impact on how students select their medical field. Students who experience high levels of uncertainty and stress are more likely to hesitate in choosing a specialty perceived as demanding and fast-paced. Those seeking a balance between personal and professional life will be more inclined to choose a specialty with a more stable schedule and a less hectic pace. [15].

One of the observations emerging from the literature is the avoidance behavior triggered by anxiety, particularly in relation to high-responsibility and high-stress specialties such as emergency medicine, surgery, and intensive care. Students with elevated anxiety levels may perceive themselves as less competent or emotionally unfit for demanding roles, even when objective skills and performance would suggest otherwise. This misalignment between potential and choice can lead to long-term dissatisfaction and burnout—a phenomenon well-documented in healthcare professions.

Moreover, the variation in stress levels among specialties acts as both a filter and a motivator for students. Specialties such as dermatology, pathology, and radiology offer a more predictable work schedule and reduced exposure to acute stress, making them more attractive to those seeking a balanced lifestyle. In contrast, specialties that require rapid decision-making under pressure, like trauma surgery or intensive care, appeal more to students with high emotional resilience and tolerance to uncertainty.

Another relevant factor discussed is the role of personality traits. Extroverted, empathetic individuals often lean toward people-centered specialties like pediatrics or psychiatry, while those who are analytical and detail-oriented may prefer laboratory-based or imaging specialties. When these personality traits are not aligned with the demands of a

chosen specialty, anxiety and dissatisfaction may be exacerbated, highlighting the importance of early personality and aptitude assessment during medical training.

Additionally, socio-economic pressures and family expectations continue to shape specialty selection, particularly in regions where certain specialties are associated with higher income, social status, or gender norms. This extrinsic pressure may conflict with students' intrinsic interests and capabilities, compounding the psychological burden of making such a significant career decision.

The academic environment and mentorship also play a pivotal role in career development. Exposure to positive role models and supportive mentors in clinical rotations can have a lasting influence on students' perceptions and confidence in pursuing a given specialty. Conversely, a lack of guidance or negative experiences can deter students from exploring potentially suitable fields.

To counter these negative effects, it is essential for future doctors to receive psychological support and have diverse clinical experiences that offer a realistic view of each specialty. A correct choice involves a balance between personal interests and professional requirements, enabling them to build a satisfying medical career based on real skills. [1,15,17]

While these findings offer valuable insights, this review is subject to several limitations. Firstly, the data is derived primarily from narrative and cross-sectional studies, which may not capture the longitudinal effects of anxiety on career choice and satisfaction. Secondly, much of the available literature is based on self-reported measures, which can be affected by social desirability bias and recall inaccuracies. Thirdly, there is a limited number of high-quality, large-scale studies exploring cultural variations and gender-specific dynamics in this context. Finally, while anxiety is a key focus of this review, other psychological constructs—such as depression, perfectionism, and resilience—are also relevant and warrant further investigation.

CONCLUSIONS

In conclusion, stress levels differ markedly across medical specialties, and this variability plays a critical role in shaping the career trajectories of future physicians. High-stress specialties—such as emergency medicine, surgery, and intensive care—demand rapid decision-making, long working hours, and the ability to manage life-threatening situations under pressure. In contrast, fields such as dermatology, radiology, and pathology typically provide a more structured and predictable working environment, associated with lower stress levels.

These differences underscore the importance of a thoughtful and individualized approach to specialty selection. To better understand the psychological mechanisms underlying specialty choice further research is necessary. Additionally, it is recommended that medical students have access to structured career and vocational counseling services.

Conflicts of Interest

The author declares no conflict of interest.

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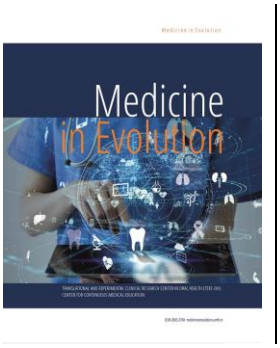
Facial Asymmetry Assessment in Orthodontic Patients with Posteroanterior Cephalometric Analysis



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Abstract

This study aimed to evaluate facial asymmetry parameters using posteroanterior (PA) cephalometric analysis in 15 orthodontic patients diagnosed with transverse dento-skeletal anomalies. Patients were selected based on the indication for frontal cephalometry at the Clinic of U.M.F. "Victor Babeş" Timişoara, with a distribution of 60% female and 40% male, aged between 15 and 37 years. Parameters were evaluated using the Ricketts and Grummons cephalometric analyses. Measurements were performed digitally using AudaxCeph software (versions 5.0 and 6.0), minimizing manual tracing errors. Statistical analysis included means, standard deviations, and independent t-tests, which revealed no significant gender differences but significant differences between age groups. Five cases demonstrated marked asymmetry. Statistically significant differences were observed between low and high asymmetry groups for maxillomandibular line deviation, facial symmetry, and nasal width.

Keywords: facial asymmetry, cephalometry, orthodontics, posteroanterior analysis

INTRODUCTION

The facial symmetry is an important component of a person's attractiveness, representing one of the determining factors in its evaluation. In reality, there is currently no perfect bilateral body symmetry in living human organisms. Any two congruent mirror images that exist in nature usually show right-left variations. People frequently show functional and morphological asymmetries in the shape of the right hand compared to the left, as well as a preference for one eye or one foot over the other. Functional asymmetry id favorable to aesthetic symmetry, but fluctuating asymmetry is common and more natural, even if some patients consider it noticeable.

The original concept of symmetry of the human face was first illustrated by the artist Leonardo da Vinci through the study of human anatomy. Based on mathematical and geometrical analysis, he put togheter in collaboration with Luca Pacioli in the asthetic traise "De Divina Proporzione", where for the first time it was invoked the role of the "golden proportion" [1].

Facial asymmetry in humans can arise from a complex interplay of genetic and environmental factors influencing bilateral development. Van Valen categorized asymmetries into three types: directional, antisymmetric, and fluctuating. Fluctuating asymmetry, which reflects an individual's reduced ability to develop identical bilateral structures, has been reported in craniofacial morphology and both primary and permanent dentition. While directional and antisymmetry are typically considered part of normal development, fluctuating asymmetry may signal underlying developmental instability. In clinical practice, the terms lateroocclusion and laterognathism help differentiate between apparent facial asymmetries of functional origin and true skeletal asymmetries, respectively. The former often arises from mandibular deviations related to occlusal disturbances, whereas true asymmetries are frequently associated with congenital skeletal conditions such as syndromes, hypoplasias, or hyperplasias [2].

The orofacial region undergoes dynamic growth and remodeling throughout life, leading to changes in both skeletal and soft tissues. Bone deposition, resorption, and soft tissue adaptation shape facial structures over time, creating age-related differences in facial form and occlusion. Facial asymmetry arises when the midline of the face is deviated, often due to abnormal jaw growth, and can affect features such as the jawline and dental alignment. While mild asymmetries are usually unnoticed, more pronounced deviations may impact both function and aesthetics [3]. The external appearance of the patient depends on the constitutional composition of his skeleton, the position of the facial bones in relation to the cranial base; the relationship between the upper and lower jaws; the way they intercuspate, the thickness of the soft tissue that lies over the facial skeleton and the size of the nose, lips and chin as well [4].

Facial analysis, alongside bite examination, guides diagnosis and treatment planning by highlighting key aesthetic features [5].

Occlusal harmony is guided by facial aesthetics, influencing orthodontic or surgical choices. Posteroanterior cephalograms aid in evaluating craniofacial symmetry, with digital analysis improving accuracy by automating measurements [6] .

To make an objective differentiation between minor and major asymmetry, quantification of it is recommended. This makes it possible to demonstrate the amount of asymmetry for diagnostic purposes, to observe the development of asymmetry during growth and to evaluate the results of treatment. On the other hand, qualitative analysis allows differentiation between problems of skeletal, dental or soft tissue origin thus suggesting the diagnosis, planning and design of mechanical treatment [7].

Various methods of assessing facial morphology have been used in the literature. The posteroanterior cephalogram has been considered one of the most valuable diagnostic aid for assessing asymmetry, to study the goals of treatment, as well as to evaluate improvements in facial or dental proportions. Grummons and Kappeyne Van De Coppello developed a major analysis system for assessing facial asymmetries. The main purpose of Grummons' analysis was to determine asymmetry rather than actual discrepancies to identify individual differences, and normative data were not presented in this system [8].

This study aimed to assess the effectiveness of cephalometric analysis—particularly posteroanterior techniques—in evaluating facial asymmetry and supporting accurate diagnosis. By analyzing specific parameters, the goal was to identify key indicators of asymmetry and enhance diagnostic precision and treatment planning in orthodontic patients.

MATERIALS AND METHODS

This retrospective, observational, and analytical study initially included 50 Romanian patients aged between 15 and 37 years, who presented at the "Victor Babeş" University of Medicine and Pharmacy, Timişoara, between 2013 and 2020. All patients underwent clinical and radiological assessments for diagnostic purposes, including facial and intraoral photographs, study models, orthopantomograms, and frontal cephalometric radiographs. All procedures were conducted in accordance with the Declaration of Helsinki and were approved by the Ethics Committee of the "Victor Babeş" University of Medicine and Pharmacy, Timişoara (Approval Code: Aviz CECS al UMFTVB 13/26.03.2021). Informed consent was obtained from all participants prior to inclusion in the study.

Posteroanterior (PA) cephalograms were acquired using the Cranex 3D (Soredex) device at the Dentavis Radiology Center in Timişoara. Patient positioning included head stabilization, use of a cephalometric light to align the Frankfurt plane, and incorporation of a calibration ruler on both sides of the image. All images were captured with the teeth in maximum intercuspation.

Out of the 50 initial PA cephalograms, 35 were excluded based on predefined exclusion criteria. The final sample included 15 cases. Digital linear, angular, and volumetric measurements were performed using AudaxCeph software—version 5.0 for Ricketts analysis and version 6.0 for the Grummons and Kappeyne Van De Coppello analysis.. The parameters and the results are illustrated in figure 1 and described in the table1.

The study focused on 15 dental and skeletal parameters described by Ricketts, as well as additional asymmetry-related landmarks used by Grummons, including:

CoR/CoL – condylion (the most superior point on the mandibular condyle);

Cg – Galli crest;

OccR/OccL – the point where the first molars occlude;

A1 – The most marginal point at the incisal level of the upper central;

B1 - The most marginal point at the incisal level of the lower central;

To evaluate the discrepancies of facial asymmetry, four components of the PA analysis described by Grummons and Kappeyne Van De Kopello were used, which present left-right values, which were generated by the AudaxCeph version 6.0 program, after tracing the analysis, locating the anthropometric points and plotting the bone counts, as you cand see in figure 2.

The reference planes that you can see in Figure 1 are defined as follows and grouped into the following cranial relationships, which they describe:

Dental relationships are represented by:

Left and right molar relationships (A6-B6/6B-6A): measures the distance between the upper and lower first molars at the most lateral point on the buccal surface of each.

Intermolar width – is measured from the occlusal surface of the lower first molar to its analogue and is helpful in determining the etiology of reverse occlusion.

Intercanine width – from the cusp tip of the right lower canine to the left. The distance has a normal value of 22.7mm at the age of 7 years (in unerupted teeth) and increases by 0.8mm/year until the age of 13 years when it reaches the normal adult value (27.5mm).

The **skeletal** relationships are defined by the following measured planes:

Right and left maxillomandibular width – represents the distance measured from the Jugal process (JL/JR) to the frontofacial plane (ZL-AG/ZR-GA).

Maxillomandibular midline: the angle formed between the ANS-Me plane perpendicular to the ZA-AZ plane (Facial width). The variation of this angle is significant in determination of the deviation of the mandibular midline from the mid-sagittal plane. If asymmetry is present, this could be the consequence of functional or skeletal problems.

Maxillary width (JL-JR) – its value indicates the transverse development and should be taken into account for planning and evaluating palatal expansion.

Mandibular width (AG-GA) – its value compared to the normal value described by Ricketts shows whether the mandible is developed correctly or not.

Dento-skeletal relationships: are mainly defined by the distance from the lower first molar to the JR-GA/JL-AG plane.

Cranio-facial relationship: is defined by the angle formed between the ZA-AG-ZL/AZ-GA-ZR reference points.

Symmetry is calculated by the difference between the values of the two angles - on the left and on the right - and has a mean value of 0°, and the standard deviation is +/- 2°.

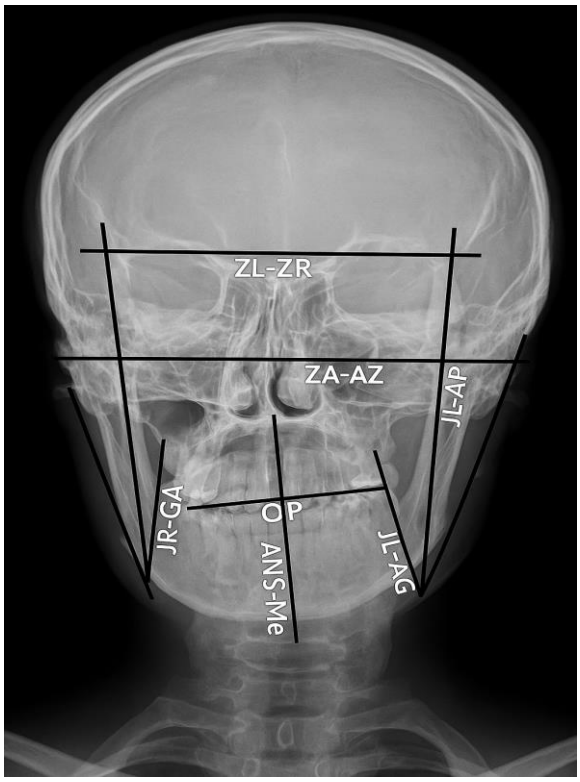

Figure 1. Results representation of the PA-Riketts measurement exported in pdf

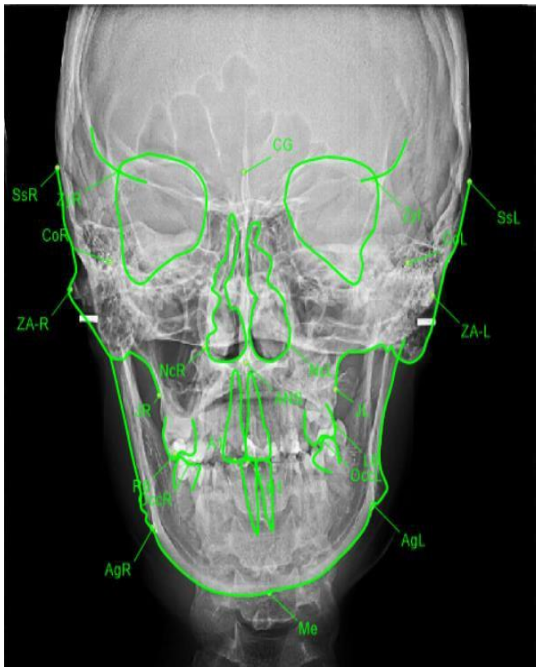

Figure 2. Cephalometric parameters and bone contouring in Grummons analysis

Table 1. Abbreviations and Anatomical Reference Points Used in Craniofacial Analysis

Abbreviation	*Anatomical Reference Point*
ZL/ZR	Innermost point on the fronto-zygomatic suture
ZA/AZ	Outermost (lateral) point of the zygomatic arch
ANS	Anterior nasal spine
CN/NC	Outermost point of the nasal cavity
JL/JR	Highest point on the maxillary alveolar process
AG/GA	Deepest point of the antegonial depression
Me	Lowest point of the mandibular symphysis
A6 / 6A	Outermost point on the vestibular surface of the upper first molar
B6 / 6B	Outermost point on the vestibular surface of the lower first molar
B3 / 3B	Cusp tip of the canine
CoR / CoL	Highest point on the mandibular condyle
Cg	Crista Galli
OccR / OccL	Point of occlusion of the first molars
A1	Most marginal point at the incisal edge of the upper central incisor
B1	Most marginal point at the incisal edge of the lower central incisor

RESULTS

The obtained data were grouped in the MS Office Excel 16.0 program and statistical analyses were performed in the SPSS 24.0 program (SPSS, Chicago, IL). For the 15 selected analyses, the mean value and standard deviation were calculated, then they were divided into 2 age groups: the first between 15-22 years and the second group between 24-37 years. The independent T-test was calculated to analyze the differences between sexes, for the 2 age groups. Pearson correlation coefficients were also calculated for both types of analyses.

The data were obtained from 15 PA cephalometric analyses, of which 40% were men and 60% were women, aged between 15 and 37 years. The mean age was 23 +/- 1 year, with the same mean value for women and 21 +/- 1 year for men.

The obtained data was grouped in the MS Office Excel 16.0 program and statistical analyses were performed in the SPSS 24.0 program (SPSS, Chicago, IL). For the 15 selected analyses, the mean value and standard deviation was calculated, then they were divided into 2 age groups: the first between 15-22 years and the second group between 24-37 years. The independent T-test was calculated to analyze the differences between sexes, for the 2 age groups. Pearson correlation coefficients were also calculated for both types of analyses.

After interpreting the measurements resulting from the Ricketts PA analysis, we observed that 5 patients had a significantly deviated maxillo-mandibular midline. Each subject presented, along with this significant deviation, reverse occlusion of mainly skeletal etiology, being accompanied in some cases by dental etiology. This anomaly in the transverse plane determined, moreover, the facial asymmetry of the evaluated patients.

The values measured in the Ricketts PA analysis were subjected to descriptive statistics that present the mean value (Mean Statistic), mean error value (Mean Std.Error) and standard deviation (Std. Deviation Statistic).

Table 2. Descriptive statistics of the measurements of the PA- Ricketts parameters

Descriptive statistics of the measurements of the PA-Ricketts parameters

	N	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Right molar relation	15	-.93	.539	2.086
Left molar relation	15	-.53	.456	1.767
Intermolar distance	15	53.40	.999	3.869
Intercanine distance	15	24.20	.509	1.971
Left maxillomadibular width	15	12.20	.763	2.957

Right maxillomandibular width	15	11.73	.771	2.987
Maxillomandibular line deviation	15	2.93	.714	2.764
Face symmetry	15	1.87	.446	1.727
Nasal width	15	28.87	.506	1.959
Maxilar width	15	56.93	1.110	4.301
Mandibular width	15	78.53	1.095	4.240
Valid N (listwise)			15	

The subjects were grouped into 2 groups, according to age: The first group was from 15 to 21 years old, and the second from 22 to 37 years old. The average values of the measurements of the 2 groups were then compared and represented by a diagram (Table 3). As we can see, differences between the age groups were in the maxillary, mandibular width and the angles of the internal structures measured in the maxilla (Max) and mandible (Mand), where the average value in the younger group was higher than in the mature group. In the intermolar and intercanine distances and the proportion of internal structures (Prop) the values are almost equal, the younger group exceeding the mature group by only a few decimals. In the values of the left and right maxillo-mandibular widths, the average values can be observed with a few decimals higher in the age group from 22 to 37 years old.

To study the correlation between each of the 15 PA (Ricketts) analyses, Pearson correlation coefficients were calculated (Table 3). The coefficient with the highest value was between the mandibular and left maxillomandibular widths (r = 0.929), and the one with the lowest value was found between the maxillary and left maxillomandibular widths (r = 0.01). Significant correlations were found between the intermolar and intercanine distances (r =32

0.607) at p=0.05. For the p=0.01 level, the significant coefficients with the highest value were found between the mandibular width (Ag-Ag) and the right maxillo-mandibular width (r=0.644), and the significant coefficients with the lowest value were found to be between the maxillary width (JL-JR) and the left maxillo-mandibular width (r= -0.752).

Table 3. Correlation between each of the 15 PA (Ricketts) analyses, Pearson correlation coefficients

Correlations

		Relaţia molară dreaptă	Relaţia molară stângă	Distanţa intermolară	Distanţa intercanină	Lăţimea maxilo-mandibulară stângă	Lăţimea maxilo-mandibulară dreaptă	Lăţimea nazală	Lăţimea maxilară	Lăţimea mandibulară
Relaţia molară dreaptă	Pearson Correlation	1	-.183	-.101	-.281	-.280	-.008	.125	.152	-.158
	Sig. (2-tailed)		.513	.721	.310	.312	.976	.658	.589	.575
	N	15	15	15	15	15	15	15	15	15
Relaţia molară stângă	Pearson Correlation	-.183	1	-.081	.094	.350	.066	-.187	-.259	-.026
	Sig. (2-tailed)	.513		.773	.738	.201	.816	.504	.352	.927
	N	15	15	15	15	15	15	15	15	15
Distanţa intermolară	Pearson Correlation	-.101	-.081	1	.607*	-.232	-.194	.187	.410	-.088
	Sig. (2-tailed)	.721	.773		.016	.405	.488	.506	.130	.755
	N	15	15	15	15	15	15	15	15	15
Distanţa intercanină	Pearson Correlation	-.281	.094	.607*	1	-.032	-.209	-.085	.187	-.082
	Sig. (2-tailed)	.310	.738	.016		.910	.456	.763	.504	.771
	N	15	15	15	15	15	15	15	15	15
Lăţimea maxilo-mandibulară stângă	Pearson Correlation	-.280	.350	-.232	-.032	1	.209	-.242	-.752**	.025
	Sig. (2-tailed)	.312	.201	.405	.910		.456	.386	.001	.929
	N	15	15	15	15	15	15	15	15	15
Lăţimea maxilo-mandibulară dreaptă	Pearson Correlation	-.008	.066	-.194	-.209	.209	1	-.434	-.469	.644**
	Sig. (2-tailed)	.976	.816	.488	.456	.456		.106	.078	.010
	N	15	15	15	15	15	15	15	15	15
Lăţimea nazală	Pearson Correlation	.125	-.187	.187	-.085	-.242	-.434	1	.330	-.275
	Sig. (2-tailed)	.658	.504	.506	.763	.386	.106		.230	.322
	N	15	15	15	15	15	15	15	15	15
Lăţimea maxilară	Pearson Correlation	.152	-.259	.410	.187	-.752**	-.469	.330	1	.143
	Sig. (2-tailed)	.589	.352	.130	.504	.001	.078	.230		.611
	N	15	15	15	15	15	15	15	15	15
Lăţimea mandibulară	Pearson Correlation	-.158	-.026	-.088	-.082	.025	.644**	-.275	.143	1
	Sig. (2-tailed)	.575	.927	.755	.771	.929	.010	.322	.611	
	N	15	15	15	15	15	15	15	15	15

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

DISCUSSIONS

A minor and major asymmetry is an important factor in quantifying asymmetry. For diagnostic and clinical purposes during growth, but also in adults and to evaluate the results of treatment, quantification is indispensable to visualize the amount of asymmetry. This is best observed and evaluated in the Grummons analysis. For the analysis of asymmetry to be qualitative, skeletal, dental or soft tissue origin problems help in the diagnosis and treatment planning. Comprehensive analysis of facial asymmetry, horizontal planes, mandibular morphology, maxillomandibular relationship, and evaluation of linear asymmetry parameters are important in many fields of medicine and dentistry, especially among plastic and reconstructive surgeons, dentoalveolar and maxillofacial surgeons, orthodontists, and maxillofacial prosthodontists [9]. Alexa et al. (2022) highlighted the relevance of accurate skeletal asymmetry evaluation through imaging techniques, supporting the continued use of posteroanterior cephalometric analyses for identifying mandibular deviations and guiding clinical interventions [10].

Cephalometric analysis procedures have been used to determine the dental, skeletal, lateral, and facial components of normal and malocclusion in individuals from different populations, using different types of analysis [11,12]. For severe cases, laterolateral cephalometric analysis is helpful in establishing orthodontic diagnosis, treatment planning, and follow-up. However, an accurate diagnosis of differences in a horizontal plane, mandibular morphology, maxillomandibular relationship and assessment of linear asymmetry may also require an estimate of postero-anterior cephalometry.

After evaluating the measurements obtained from the Ricketts analysis, we observed in the five patients a degree of increased asymmetry, due to the very inclined maxillo-mandibular midline and in one case the asymmetry of the upper face exceeding the critical value of 4. Each of these patients had unilateral reverse occlusion, some also bilateral of skeletal etiology, to which was also joined reverse occlusion of dental origin. The deviation of the maxillo-mandibular midline was towards the side where the reverse occlusion was present. In all these patients the maxillary width (JL-JR) presented significantly lower values, compared to the normal value. In some of these cases, the width of the piriform apertures (NC-CN) was also smaller than the normal value for the corresponding age. The mandibular width (AG-GA) was in most cases significantly increased compared to the normal value. In two of these patients, the mandibular width was also observed to be smaller than the average value, thus the maxilla and mandible were compressed. In these cases, it is necessary to intervene as soon as possible with expansion treatment, if growth still allows this.

These findings align with previous literature on the distribution of facial asymmetries. Severt and Proffit reported that facial asymmetry affects the upper, middle, and lower thirds of the face in approximately 5%, 36%, and 74% of cases, respectively, with the lower third being most commonly involved. This predominance in the lower facial region may be attributed to the prolonged period of mandibular growth. Additionally, Chew et al. found that 35.8% of patients with dentofacial deformities exhibited asymmetry, most frequently among those with Class III occlusal relationships [13,14] .

In patients with lateral reverse occlusion and midline deviation, orthodontic treatment aims to rehabilitate the asymmetry of muscle activity between the side with reverse occlusion and the other side, but also the changed position of the condyle caused by the deviation of the mandible. The muscular type of lateral reverse occlusion occurs as a result of the adjustment of the orofacial muscles at the first contact of some teeth. This premature contact determines the lateral deviation of the mandible, which is placed in a compensatory adaptive position. The mandible is displaced towards one side of the face, causing a distortion of the harmony of the patient's face. This type of lateral reverse occlusion is also called forced reverse occlusion,

and usually the first contact is in the canine area [15]. The mandible is positioned diagonally to the maxilla, as it moves in a sagittal and transverse position [16] .

Multiple studies [17–19] have confirmed that cephalometric radiography remains a cornerstone of orthodontic diagnosis and treatment planning. When facial asymmetry is clinically suspected, the use of posteroanterior cephalograms offers a reliable means to assess its presence and severity, guiding practitioners toward more accurate and individualized therapeutic approaches.

CONCLUSIONS

In conclusion, we consider posteroanterior (PA) cephalometric radiography to be one of the most accessible and valuable tools for identifying and assessing transverse skeletal and dental imbalances. The information it provides is essential for establishing a differential diagnosis in cases of lateral reverse occlusion—whether of dentoalveolar or skeletal origin—and for evaluating transverse deficiencies of the maxilla, mandibular overdevelopment, or a combination of both.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest. The study was supported by the "Victor Babeş" University of Medicine and Pharmacy, Timişoara. The institution had no role in the study design, data collection and analysis, manuscript preparation, or decision to publish the results.

Ethics Statement

The study was conducted in accordance with the Declaration of Helsinki, and the research protocol was approved by the Ethics Committee of the "Victor Babeş" University of Medicine and Pharmacy, Timişoara (Approval Code: Aviz CECS al UMFTVB Nr. 13/26.03.2021). All subjects gave their informed consent for inclusion before participating in the study.

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Mechanical Evaluations of Devitalized Teeth Reconstructed Using Direct and Indirect Techniques

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Abstract

1.Background/Objectives: This study evaluates the efficiency of direct and indirect corono-radicular reconstruction techniques for devitalized teeth, focusing on mechanical resistance, aesthetic outcomes, and cost-effectiveness. *2.Methods:* Two groups of extracted human teeth, previously endodontically treated, were restored using direct (fiberglass posts and composite resin) and indirect (zirconia-based) methods. Compression resistance tests were performed using a Zwick/Roell ProLine Z005 universal testing machine following ISO 7500-1 standards. Maximum force (F_{max}) and displacement at failure (Δl_{max}) were recorded, and compressive stress (S_{max}) was calculated by normalizing force with cross-sectional preparation area measured via radiographic analysis including CBCT. *3.Results:* Zirconia restorations exhibited significantly higher compressive strength (average S_{max} = 30.63 MPa) compared to fiberglass restorations (average S_{max} = 20.33 MPa). Fiberglass-based samples showed greater elasticity with lower displacement at failure. Both materials provided satisfactory initial aesthetics, though composite resin showed slight discoloration over time. Direct restorations were more cost-effective and time-efficient, while zirconia offered superior long-term durability. CBCT evaluation confirmed precise adaptation and placement of restorations. *4.Conclusion:* Direct techniques are effective for moderate-load applications due to affordability and flexibility, whereas indirect zirconia restorations are preferable for high-stress scenarios requiring enhanced mechanical resistance. Further studies should focus on optimizing material properties for improved longevity and aesthetic stability.

Keywords: corono-radicular reconstruction, devitalized teeth, direct technique, zirconia, fiberglass, mechanical resistance, aesthetic outcomes, cost effectiveness

INTRODUCTION

Restoring endodontically treated teeth remains a key challenge in dentistry, requiring both aesthetics and long-term functional stability [1,2]. Corono-radicular reconstruction plays a crucial role in preserving these teeth, preventing fractures, and restoring occlusal function [3]. The selection of an appropriate reconstruction technique depends on multiple factors, including the extent of structural loss, material properties, patient preferences, and cost considerations [4].

Two primary approaches are widely used in corono-radicular restorations: direct techniques and indirect techniques. Direct techniques involve the immediate reconstruction of the tooth structure using composite resins and prefabricated fiberglass posts, performed chairside by the clinician [5]. These methods offer advantages such as reduced treatment time, lower costs, and preservation of more dental tissue. Nevertheless, these restorations may present certain drawbacks, such as reduced fracture resistance and an increased chance of marginal leakage as time passes [6,7].

In contrast, indirect techniques involve the fabrication of custom-made restorations, such as zirconia or metal-based DCRs, in a dental laboratory [8]. These restorations are recognized for their excellent mechanical strength and greater resistance to fractures, yet they involve several clinical appointments, higher lab expenses, and more complicated cementation procedures [9,10]. While indirect restorations provide long-term benefits, their cost and procedural complexity often make them less accessible to patients [11].

Advancements in adhesive dentistry and biomaterials have significantly improved the clinical outcomes of both techniques [12]. Contemporary bonding agents and resin cements improve the adhesion of direct restorations, thereby increasing their durability [13]. At the same time, CAD/CAM technologies allow for highly precise fabrication of indirect restorations, optimizing their fit and resistance [14]. Despite these technological advancements, the ideal reconstruction technique remains a subject of debate, requiring further comparative studies to determine the most effective approach based on clinical performance, durability, and cost-effectiveness [15,16].

Aim and objectives

The primary objective of this study is to evaluate and compare the effectiveness of direct and indirect corono-radicular reconstruction techniques in devitalized teeth. The aim of the study is to perform an ex-vivo comparison on extracted human teeth with different morphologies (pulpal morphology, root canals), which, after endodontic treatment, were restored using direct and indirect techniques. The behavior of the samples was compared under mechanical stress.

Additionally, a fractographic analysis of the ex vivo tested samples will be conducted to identify fracture patterns and evaluate the structural behavior of the materials used. The study also seeks to assess the aesthetic performance of both techniques over time, focusing on factors such as color stability and translucency. Finally, a cost-effectiveness and procedural efficiency evaluation will be carried out, considering both short-term and long-term clinical implications.

By providing a comprehensive comparison of these techniques, the study seeks to offer evidence-based recommendations that can guide clinicians in selecting the most appropriate restorative approach based on individual patient needs and clinical scenarios.

MATERIAL AND METHODS

This primary ex vivo study was conducted using two groups of specimens, each consisting of four extracted human teeth that had undergone prior endodontic treatment. The selection criteria included teeth with intact roots, no significant fractures, and comparable anatomical dimensions to ensure consistency in the experimental conditions. A total of eight extracted human teeth with varying root and crown morphologies were selected for this study, as shown in Figure 1.

Figure 1. Extracted human teeth used in the study, divided into two experimental groups based on the restorative technique

Initially, all specimens were subjected to a standardized mechanical and chemical cleaning protocol, followed by obturation with gutta-percha cones at the established working length in combination with a root canal sealer (Root Canal Sealer ADSEAL MetaBiomed). The purpose of this step was to ensure optimal sealing of the root canal system before proceeding with corono-radicular reconstruction.

For the first group (S1, S2, S3, S4), a direct technique was employed using glass fiber posts (Nordin Glassix Radiopaque Glass Fiber Post), which were cemented within the root canal using a self-adhesive dual-cure resin cement (G-CEM One). The coronal portion of the tooth was then restored with a light-curing composite resin (RDC 3M ESPE Valux Plus). This approach aimed to evaluate the efficiency and adhesive properties of direct restorative materials, as well as their adaptation to the root canals and coronal structure. The fiberglass-reinforced direct restorations used in the study are illustrated in Figure 2, showing occlusal or incisal views of samples S1 to S4.

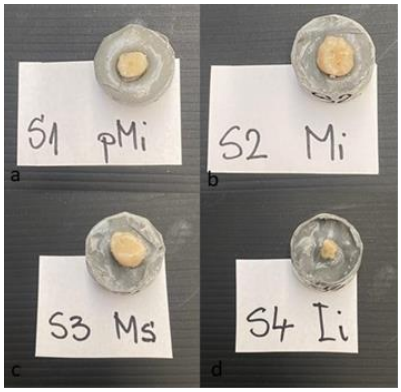

Figure 2. Occlusal and incisal views of the teeth restored using direct technique with fiberglass posts and composite resin. The samples were embedded in acrylic resin cylinders, labeled to identify their anatomical origin (S1–S4): a) S1 – inferior premo

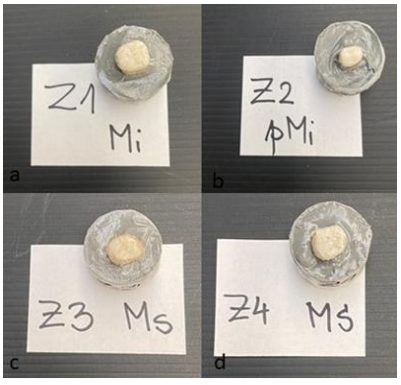

Figure 3. Occlusal views of teeth restored using the indirect technique with zirconia post-and-core systems. The samples (Z1–Z4) are embedded in acrylic resin blocks and correspond to various tooth types: a) Z1 – inferior molar, b) Z2 – inferior premolar, c) Z3 – superior molar, d) Z4 – superior molar

For the second group (Z1, Z2, Z3, Z4), an indirect technique was applied, utilizing zirconia-based corono-radicular restorations (CRRs). These restorations were fabricated through a digital workflow, which included scanning the prepared tooth models, followed by milling and sintering. The final restorations were cemented into the root canals using a universal dual-cure resin cement (Maxcem Elite Kerr). The primary objective of this technique was to assess the mechanical strength, durability, and resistance of zirconia restorations under masticatory stress conditions. The indirect restorations using zirconia posts and cores are shown in Figure 3, with occlusal views of samples Z1 to Z4.

Before conducting mechanical tests and fractographic evaluations, all samples were subjected to imaging analysis to examine the restorations and internal structure of the teeth. For each sample, both 2D retroalveolar radiographs were taken using an intraoral X-ray device (Planmeca ProX), and cone-beam computed tomography (CBCT) scans were performed with the Planmeca ProMax 3D Classic, allowing for a three-dimensional assessment. The CBCT analysis provided detailed visualization of the samples in three planes: coronal, sagittal, and axial, offering additional insights into the positioning and adaptation of the restorations. All radiographic evaluations were performed using the Planmeca ProX unit (Figure 4), allowing for consistent alignment and standardized imaging across all samples and CBCT imaging was performed using the Planmeca ProMax 3D Classic system (Figure 5), which enabled high-resolution 3D scans of the radicular structures and precise evaluation of material adaptation. Retroalveolar radiographs were taken for all samples to verify the position and integrity of the restorations within the root structure (Figure 6). These images provided comparative visual confirmation of material adaptation and post placement in both zirconia and fiberglass groups. Prior to the CAD/CAM workflow, all samples were visually inspected and photographed from multiple angles to document their morphology and preparation status (Figure 7). To evaluate the internal adaptation of the restorative materials and the structural integrity of the roots, CBCT scans were analyzed across three anatomical planes: coronal, sagittal, and axial (Figure 8). These images ensured proper orientation during the subsequent 3D scanning procedure. The resistance of the samples was calculated considering the diameter and length of the reconstructions. For stabilization during scanning, the teeth were fixed in a custom support made of condensation-cured silicone impression material. Each sample was oriented according to its natural anatomical position in the oral cavity, based on the experimental group to which it belonged. This step ensured the accuracy and reproducibility of the measurements, as well as proper alignment during imaging analyses and subsequent testing.

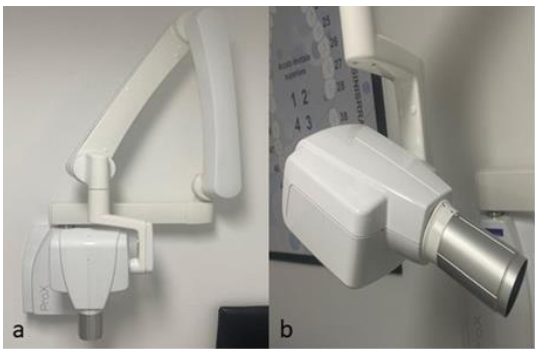

Figure 4. Extraoral radiographic device (Planmeca ProX) used for CBCT imaging. a) Frontal view showing the structural design and positioning arm; b) Lateral view illustrating the alignment and tube head orientation used during imaging of the samples

Figure 5. Cone-beam computed tomography (CBCT) system used for sample imaging: Planmeca ProMax 3D Classic. a) Lateral view illustrating the CBCT unit and patient positioning arm; b) Control display interface used for parameter adjustments and image acquisition monitoring

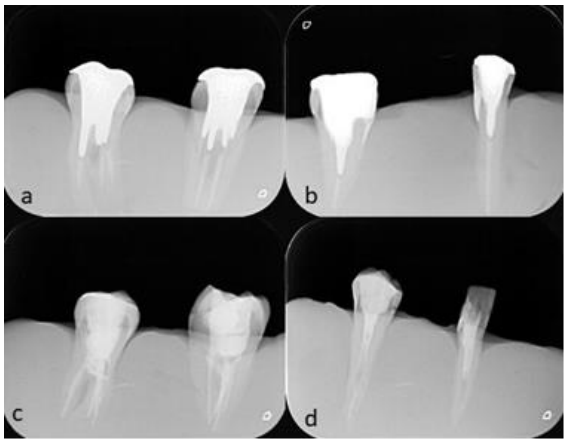

Figure 6. Retroalveolar radiographic images of the experimental tooth groups. a) Multi-rooted teeth restored with zirconia-based restorations; b) Single-rooted teeth restored with zirconia-based restorations; c) Multi-rooted teeth restored with fiberglas

Figure 7. Visualization of the two experimental tooth groups prior to 3D scanning. a) Occlusal (superior) view; b) Frontal view; c) Oblique view; d) Lateral view

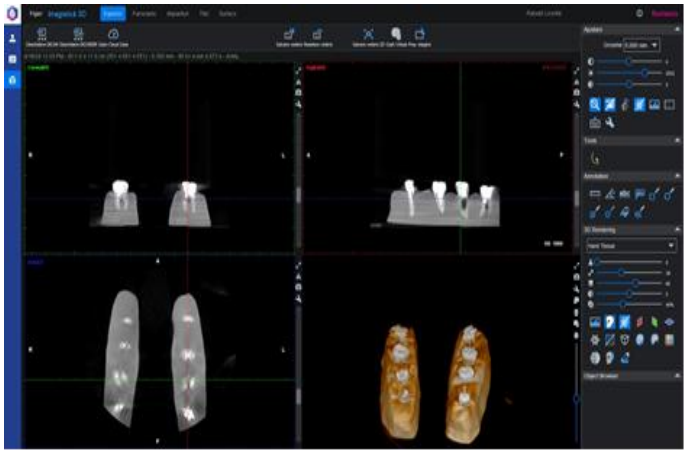

Figure 8. CBCT imaging planes used for sample evaluation: a) Coronal section; b) Sagittal section; c) Axial section

To evaluate the clinic performance of both techniques, the specimens underwent mechanical resistance testing, simulating masticatory forces under controlled conditions. Following mechanical testing, a fractographic analysis of the results was conducted using the universal testing machine at the Politehnica University of Timişoara (Zwick/Roell ProLineZ005). The goal was to examine the fracture surfaces and identify fracture patterns, providing insights into the structural behavior of the materials under stress. These observations are crucial for understanding the clinical implications and guiding restorative choices in dental practice. Additionally, digital microscopy was used to analyze the adaptation of the restorations to the root canal walls and the presence of microgaps at the interface.

The sample size used in this study was limited to four specimens per group due to the difficulty in obtaining extracted human teeth with similar anatomical characteristics and comparable endodontic conditions. While this relatively small sample size restricts the statistical power and generalizability of the findings, it is consistent with prior ex vivo studies that aim to establish preliminary mechanical and structural performance trends. This limitation is acknowledged and highlights the need for further research involving a larger cohort of specimens to confirm and expand upon the current results. Nevertheless, the experimental protocol was rigorously standardized, and CBCT analysis ensured consistent

internal morphology and adaptation across samples, thereby strengthening the internal validity of the study.

Each sample was carefully positioned in the universal testing machine to ensure consistent loading conditions (Figure 9). The fiberglass-reinforced composite group (S1–S4) and the zirconia group (Z1–Z4) were subjected to uniaxial compressive force until failure.

Figure 9. Positioning of samples from both groups - S (fiberglass-reinforced composite) and Z (zirconia-based) - in the universal testing machine prior to mechanical testing: a) S1, b) S2, c) S3, d) S4, e) Z1, f) Z2, g) Z3, h) Z4

RESULTS

This study aimed to identify potential differences in fracture patterns between single-rooted and multi-rooted teeth, both in the upper and lower arches. Several key parameters that could influence the occurrence and type of fractures were analyzed, including the direction and point of force application, force intensity, root canal diameter, number of root canals, and the material used for the DCR. The load–displacement curve of sample S1 (Scheme I) reveals a steady increase in compressive force up to approximately 1000 N, followed by a sharp fluctuation, suggesting the onset of structural failure. The load–displacement curve of sample S2 (Scheme II) shows a progressive rise in compressive force reaching just under 2000 N, followed by slight oscillations, which may indicate microfractures before complete failure.

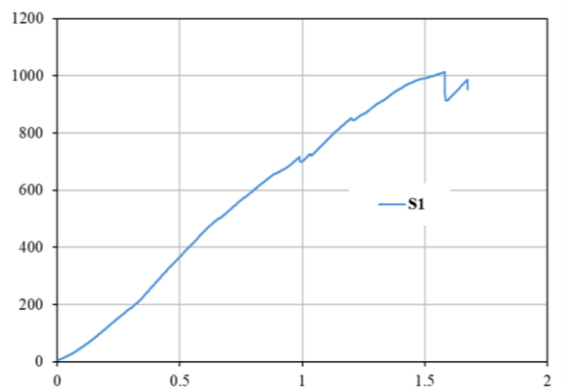

Figure 10. Force–displacement curve of sample S1 (fiberglass group), illustrating the mechanical response under compressive loading

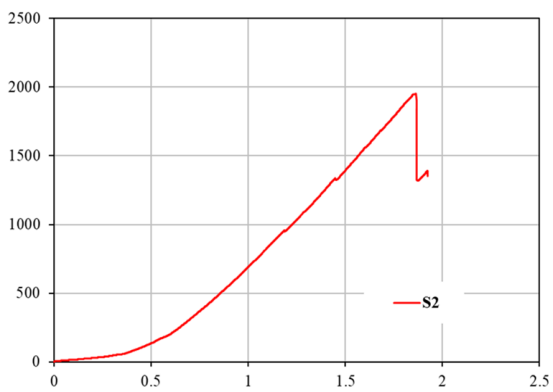

Figure 11. Force–displacement curve of sample S2 (fiberglass group), illustrating the mechanical response under compressive loading

Another crucial aspect considered was the alignment of upper and lower teeth. The maxillary arch circumscribes the mandibular arch, which results in an eccentric force application on the palatal surface of anterior maxillary teeth during normal occlusion. Consequently, maxillary anterior teeth are more susceptible to vertical coronal fractures. In contrast, multi-rooted teeth located in the lateral regions of the dental arches are more prone to horizontal fractures when restored with DCRs. The load–displacement curve of sample S3 (Scheme III) displays a consistent load increase up to around 1000 N, with a smoother decline, suggesting a more ductile failure behavior compared to the other samples.

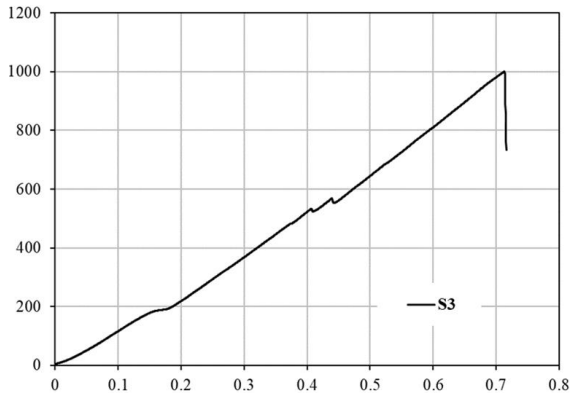

Figure 12. Force–displacement curve of sample S3 (fiberglass group), illustrating the mechanical response under compressive loading

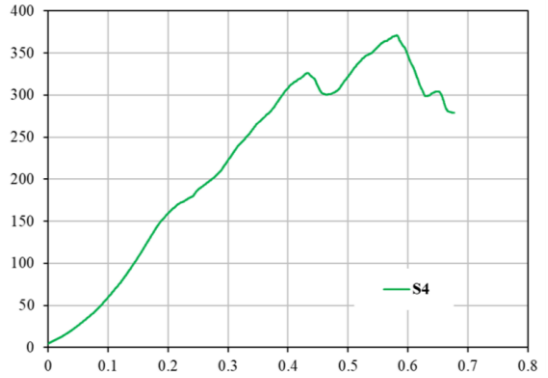

Figure 13. Force–displacement curve of sample S4 (fiberglass group), illustrating the mechanical response under compressive loading

Taking these factors into account, this study aimed to establish a correlation between dental morphology and the biomechanical parameters influencing fracture location and direction. When analyzing force distribution, the upper arch predominantly experiences shear forces, whereas the lower arch is subjected to vertical forces due to the occlusal relationship. This suggests that the fracture pattern may theoretically differ between maxillary and mandibular teeth. The load–displacement curve of sample Z1 (Scheme V) reaches a maximum load of nearly 1350 N, followed by an abrupt drop, indicating brittle fracture characteristic of zirconia.

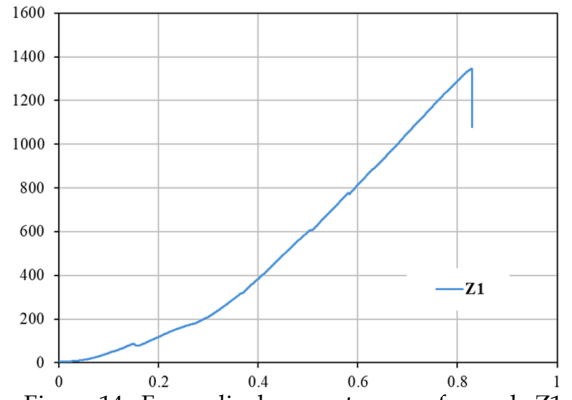

Figure 14. Force–displacement curve of sample Z1 (zirconia group), illustrating the mechanical response under compressive loading

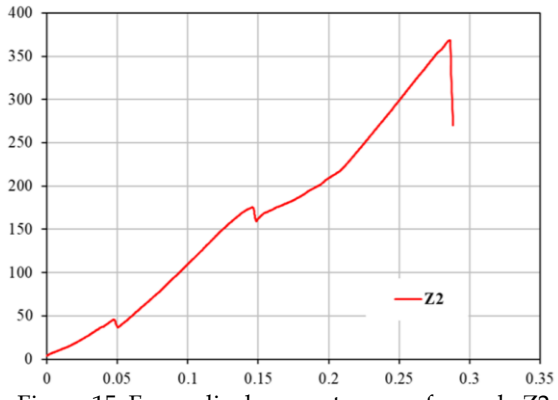

Figure 15. Force–displacement curve of sample Z2 (zirconia group), illustrating the mechanical response under compressive loading

The compression resistance tests for the dental restorations were conducted at the Department of Mechanics and Strength of Materials, Faculty of Mechanics, Politehnica University of Timişoara, under the supervision of Prof. Univ. Negru Radu. The tests were

performed using the Zwick/Roell ProLine Z005 universal testing machine, equipped with a 5 kN force cell for uniaxial loading, with an accuracy class of 0.5 in the force measurement range of 1/130%, in accordance with ISO 7500-1. The Zwick/Roell Z005 machine is integrated with the TestXpert III data processing software and is equipped with fixtures for tensile, compression, and three-point bending tests.

The tests were conducted in displacement control mode at ambient temperature, following these steps:

- Preloading at 5 N with a crosshead displacement speed of 1 mm/min;
- Execution of the compression test at a crosshead displacement speed of 1 mm/min;
- Recording of the applied force (F) and the crosshead displacement (Δl) throughout the compression test.

The force was applied using an indenter covered with ceramic material, perpendicular to the occlusal surface of the tooth, until structural failure occurred. Failure was identified by a sudden drop in the measured force. The force-displacement values of the crosshead were recorded in real time using the TestXpert III software.

The results are presented in a table format as follows:

- F_{max} – the maximum force recorded at the moment of failure;
- Δl_{max} – the corresponding crosshead displacement at maximum force.

To ensure a proper comparison of the results, the maximum force (an absolute value) was normalized using the cross-sectional area of the preparation, considered as an ellipse with semi-axes a and b, measured along the mesio-distal and vestibulo-oral directions, respectively:

$$A = \pi ab$$

Thus, the normal compression stress, a specific parameter that eliminates the influence of dental geometry, was calculated as follows:

$$S_{max} = \frac{F_{max}}{A}$$

For samples Z3 and Z4, the first recorded peak force was considered the initiation point of structural failure, with the average values being nearly identical.

In order to evaluate the mechanical behavior of devitalized teeth restored using different techniques, all samples were subjected to compressive strength testing under standardized conditions. This procedure enabled the analysis of the materials capacity to absorb and withstand occlusal forces, as well as their failure thresholds. Fiberglass-based restorations demonstrated a more elastic response to loading, often showing gradual deformation before structural failure. In contrast, zirconia restorations displayed a more rigid behavior, withstanding significantly higher loads but exhibiting sudden fracture patterns. These differences reflect the inherent material properties and suggest distinct clinical indications for each type of restoration.

Table 1 presents the maximum force (F_{max}), cross-sectional area (A), maximum compressive stress (S_{max}), and maximum displacement (Δl_{max}) recorded for each tested sample to better understand the mechanical response of the tested restorations. A compressive load was applied to each sample until structural failure occurred. This analysis provided valuable information on how each material behaves under stress, revealing distinct patterns in strength and deformation. The data includes both groups: S (glass fiber) and Z (zirconia). Average compressive strength values are also provided for each group.

Table 1. Maximum force, cross-sectional area, compressive strength, and displacement at fracture for the tested samples

Type of processing	$F_{max}(N)$	$A\ (mm^2)$	$S_{max}(MPa)$	$\Delta l_{max}(mm)$
S1	1012,70	45,31	22,35	1,675
S2	1951,14	91,85	21,24	1,924
S3	1000,73	71,18	14,06	0,716
S4	370,84	15,67	23,66	0,678
	Average value(MPa)		**20,33**	-
Z1	1344,89	67,82	19,83	0,830
Z2	368,43	37,48	9,83	0,288
Z3	3819,17	87,22	43,79	1,842
Z4	4058,80	82,68	49,09	1,814
	Average value(MPa)		**30,63**	-

Direct or indirect restoration can act as an internal connection, influencing different types of fractures. Radiographic investigations played a crucial role in measuring the sample dimensions and determining the force distribution during the compression tests.

DISCUSSIONS

The results of the compression tests indicated that zirconia-based materials (Z1, Z2, Z3, Z4) exhibited superior compressive strength compared to fiberglass-based materials (S1, S2, S3, S4). The most frequently observed failure modes in devitalized teeth restored with different post-and-core systems (DCRs) are coronal fractures and vertical root fractures [18,19]. Zirconia showed greater resistance to compressive forces, indicating improved durability when subjected to high mechanical loads [20]. Despite having lower resistance than metal-based options, fiberglass materials exhibited sufficient strength for clinical applications, offering increased flexibility that permits minor deformation without breaking [21]. In contrast, zirconia materials were stiffer and showed greater vulnerability to fracturing when subjected to strong lateral forces [22]. These results are consistent with earlier research emphasizing zirconia's high compressive strength alongside its greater brittleness when exposed to tensile stress [23]. Regarding direct restorative techniques, fiberglass-based DCRs were found to adapt more easily to root canals and could be efficiently applied by clinicians. In contrast, zirconia DCRs required a more complex impression-taking process and additional laboratory procedures, which could extend the overall treatment duration [25].

The assessment of adhesion between direct restorative materials and the tooth structure revealed a strong bond, essential for the longevity of restorations [26]. Composite materials employed in direct restorations showed strong adhesion, primarily attributed to improvements in adhesive technologies [27]. This observation is consistent with existing literature, which emphasizes the role of modern bonding agents in ensuring durable restorations [28]. The application of primers and bonding agents significantly improved the integration between the restorative material and the dental substrate, minimizing the risk of debonding and bacterial infiltration [29]. These findings confirm the effectiveness of direct restorative techniques in achieving optimal treatment outcomes, particularly in the corono-radicular reconstruction of devitalized teeth [30].

Aesthetic evaluation of direct restoration techniques highlighted their ability to provide precise adaptation and a reduced treatment time [31]. The increasing variety of restorative materials available on the market allows for a high degree of customization, meeting patients aesthetic expectations [32]. The findings demonstrated that direct restorative materials achieved excellent aesthetic integration with the surrounding dental structures [33].

Functional analysis, including masticatory force simulations, confirmed the materials resistance to wear and mechanical stress [34]. While composite materials provided an excellent aesthetic outcome by closely mimicking the natural tooth color and translucency, slight discoloration was observed over time [35]. These results align with previous research suggesting that although composite materials maintain a stable appearance in the medium term, long-term color stability may be affected by factors such as thermal cycling and exposure to different light sources.

From an economic perspective, the study confirmed that indirect techniques involve higher costs than direct techniques due to the expense of materials, equipment, maintenance, and laboratory procedures [30]. However, these increased costs are justified by the enhanced durability and mechanical properties of indirect restorations, which reduce the need for frequent repairs or replacements [29]. The cost analysis revealed that direct techniques rely on relatively affordable materials such as dental composites and adhesive cements, whereas indirect techniques require more expensive materials, including ceramics and metal alloys, as well as additional expenditures for laboratory fabrication [28]. Additionally, indirect techniques necessitate specialized equipment such as intraoral scanners and CAD/CAM units, increasing the financial investment required for these procedures [27].

Despite the advantages of direct restorations in terms of affordability, ease of application, and aesthetics, certain limitations must be acknowledged [26]. Direct materials, particularly composite resins, are prone to discoloration and wear over time, necessitating periodic maintenance [25]. Furthermore, while their adhesion properties are enhanced by modern bonding systems, the longevity of these restorations may still be influenced by factors such as occlusal forces and patient-specific oral hygiene habits [24]. Future research should focus on optimizing the mechanical properties and color stability of direct restorative materials while exploring new adhesive strategies to further improve the durability of these restorations [23]. Statistical analysis was not performed due to the limited sample size (4 per group), which precluded the application of robust inferential tests. As a result, the findings are presented descriptively, and caution is advised in generalizing the results.

CONCLUSIONS

Fractographic analysis revealed that fracture patterns were strongly influenced by both the type of tooth and the restorative material used. Zirconia-based restorations predominantly exhibited vertical fractures along the long axis of the tooth, suggesting a higher brittleness and susceptibility to stress concentration under compressive forces.

In contrast, fiberglass restorations demonstrated oblique and horizontal fracture patterns, primarily localized at the occlusal surface, indicative of their greater flexibility and ability to distribute mechanical loads more evenly. These findings underscore the critical role of material properties in determining the failure mechanisms of dental restorations, with implications for clinical decision-making and long-term restorative success.

Conflicts of Interest

The authors declare no conflict of interest.

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Plant-Derived Essential Oils −An Alternative Option for Oral Health Management

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Abstract

1.Background: Oral health is a subject of public interest. Also, it is one of the most pressing aspects of human well-being, complemented by the health of the digestive or respiratory system. As oral hygiene and dental care are essential health missions, products of natural origin are becoming increasingly recognized for their multifaceted benefits (reduced side effects, multiple therapeutic effects). Hence, essential oils proved to be valuable alternatives due to their therapeutic qualities, holding promise in the treatment of various dental diseases. 2.Methods: The present paper focuses on the literature analysis of the last 25 years, targeting sources mainly found in PubMed or Google Scholar. 3.Results: The review of the literature showed evidence of a multitude of essential oils (lavender, oregano, eucalyptus, cinnamon) with medicinal effects (antimicrobial, antifungal, soothing) used in oral health. 4.Conclusion: This overview presents the applicability and effects of different essential oils in oral health as potential candidates for oral treatments. Essential oils can be a safe, affordable, and efficacious alternative to standard therapies in dental ailments.

Keywords: dentistry, oral health, essential oils, natural products

INTRODUCTION

Oral health is a crucial aspect of people's wellbeing, also coming with the reward of having a healthy digestive and respiratory system. Moreover, poor oral health comes with different consequences, such as pain, halitosis, and an unattractive smile [1].

Nowadays, it is hard to maintain an impeccable oral health because people's daily routine includes a lot of processed food, which also contains varied amounts of sugar. Bigger quantities of processed food and sugar consumed cause more problems at the dental level. Problems of the oral cavity include periodontitis, which causes halitosis, tooth loss, and tooth decay, which usually progresses by infecting the dental nerves and generating granulomas, abscesses, or even cysts. These complications can also lead to many other health problems for overall well-being. Improved oral hygiene should be the first step towards achieving proper oral health and improving health in other systems [2]. In order to improve the oral hygiene and prevent dental diseases, dentists have two types of approaches: (i) regular visits to the dentist for professional cleaning or (ii) improving oral hygiene through new tooth brushing techniques and patient self-awareness of the problem [3]. The quality and composition of dental materials must be of the highest standard and must be carefully selected for each patient. Many people have also started to look for dental products based on natural compounds [4], which have become an increasingly popular alternative in recent decades.

Currently, botanical compounds are gaining growing interest in stomatology, and in particular for dental problems that require treatment. Due to the fact that they are easy to find, less expensive, and well tolerated, and because numerous studies have demonstrated their beneficial effects, these compounds are beginning to be preferred to conventional, synthetic treatments [4,5]. Plants-based essential oils have also sparked considerable attention in dentistry. In recent years, there has been an increasing interest in using essential oils in oral hygiene products [6]. The essential oils have been used since antiquity, and have prevailed in different cultures around the world, such as those of the Greeks, Egyptians, Chinese, and Persians for antibacterial, antiviral, antifungal, antiparasitic, antioxidant, anti-inflammatory, anticancer, and neuroprotective properties [6]. Essential oils are liquid extracts from aromatic plants. Extraction of essential oils can be done using a variety of advanced methods, such as supercritical fluid extraction, subcritical liquid extraction, and solvent-free microwave extraction [7]. From a safety perspective, a product that contains essential oils or a mixture of it should be tested prior to use. In general, essential oils are safe, but they may act as an allergen, especially for consumers having sensitivity [8]. Natural products are low-cost, effective and safe, making them a popular choice for patients, especially when conventional treatments fail [5]. Additionally, several studies have found that mouthwash containing essential oils is more effective in preventing periodontitis and can potentially replace dental floss [9,10].

Given the current developments in dental treatments and the acknowledgement that natural alternatives have started to receive in comparison to conventional treatments, the purpose of the present study is to highlight and detail the evidence that underlines the therapeutic effects of natural oils and their importance in oral health care and stomatological treatments.

Aim and objectives

As oral health is a globally important concern, the aim of the present paper is to highlight the potential implications of essential oils (e.g. Lavender, Peppermint, Eucalyptus, Cinnamon) of natural origin in different oral problems, underlining studies from the specialized literature that have demonstrated their therapeutic benefits.

MATERIAL AND METHODS

A comprehensive review of the literature published over the last 25 years (2002-2025) was conducted using databases such as PubMed and Google Scholar. The search focused on relevant terms, including "oral health", "essential oils", "antimicrobial activity", "antifungal activity", "natural products in dentistry", and specific oil names like "lavender", "peppermint", "eucalyptus", "oregano', "cinnamon', "tea tree oil". The inclusion criteria focused on in vitro, in vivo, and clinical studies evaluating the therapeutic properties of essential oils in oral or dental fields.

Lavender oil

Lavender essential oil is obtained from the flowering tops of the lavender, Lavandula angustifolia Mill., by steam distillation. This type of essential oil is well-known in traditional herbal medicine for carminative, sedative, antidepressive, hypnotic, antifungal, antimicrobial, analgesic, acaricidal, and aphrodisiac properties [11].

Lavender oil has shown therapeutic benefits, including in stomatology. A study conducted on 30 volunteers showed a statistically significant reduction in anxiety scores, stress and a decrease in needle insertion pain when lavender oil was used in the recipient site. [12]. Moreover, a study conducted on 126 children showed significantly lower anxiety and pain scores after tooth extraction by using lavender oil [13]. An in vivo study that examined lavender oil and benzocaine gel as topical analgesic agents concluded that lavender oil had a greater impact on reducing pain perception after intraoral injection. Additionally, lavender oil could be a superior choice over topical analgesic agents, as it has a sweet scent that alleviates anxiety and has anesthetic properties [14]. A study on animals showed that lavender oil was tested positive for antinociceptive action, showing significant pain reduction in the rats, in oral treatments, while using the formalin-induced pain model [15].

Peppermint oil

Peppermint oil is obtained from the leaves and flowering aerial parts of the peppermint, Mentha x piperita L. [11], being one of the most commonly used essential oils. In the composition of peppermint oil, menthol is recognized as the major compound and, according to numerous investigations, is one of the botanicals with the strongest antifungal, antibacterial, and antiviral properties [16, 17].

Studies showed that peppermint oil (0.5 to 8 µL/mL) demonstrated fungicidal and fungistatic activities against both the standard and clinical strains of Candida species. Additionally, the peppermint oil indicated similar antifungal effects against the azole-susceptible and azole-resistant strains [18]. Also, a paper suggested that a proprietary blend of peppermint that includes Japanese mint, bergamot mint, and spearmint essential oils called SuperMint (SM), encapsulated in a tiny soft beadlet, decreased the abundance of some microbial families and genera, including Prevotella, Haemophilus, Neisseria, and Streptococcus. In addition, the findings indicated that SM treatment decreased the number of various bacteria linked to periodontal disease and halitosis, including Actinomyces and Streptococcus. Furthermore, the consumption of SM resulted in a rise in Corynebacterium species and a decrease in Streptococcus spp. occurrences [19].

Apart from those mentioned above, peppermint has proven to be effective against halitosis. Peppermint mouth rinse was disclosed as an effective measure to reduce halitosis according to a 1-week study on a group of students [20]. Furthermore, clinical research has demonstrated that regular use of a mouthwash that contains peppermint oil can improve periodontal health by reducing gingival pocket depths and effectively combating Candida albicans [21]

Eucalyptus oil

Eucalyptus essential oil is steam distilled from the leaves of certain species of Eucalyptus, belonging to Myrtaceae Family [22].

Literature studies have indicated that eucalyptus can be a notable alternative for various dental conditions, supporting oral health. According to a study conducted on 74 human subjects, eucalyptus oil is an effective alternative to chlorhexidine, reported as safe and effective to use in order to reduce the bacterial plaque levels [23]. It was reported that Eucalyptus oil is effective against P. gingivalis and A. actinomycetemcomitans and also, because of the natural phytochemicals existing in the essential oil, it serves as an effective, promising alternative to antibiotics in the prevention of oral infection [24].

Another important effect for which eucalyptus oil is used in dentistry is the anticariogenic effect, showing an inhibitory effect on oral pathogens such as Lactobacillus acidophilus and Streptococcus mutans [25].

Furthermore, the use of ecualyptus essential oil as an innovative material in preventive dentistry can contribute to maintaining both oral and systemic health. A study on an eucalyptus essential oil-based nanoemulsion presented adequate physicochemical characteristics and antimicrobial activity against S. mutans [26].

Cinnamon oil

The leaves, bark, fruits, and flowers of Cinnamomum spp. are the sources of cinnamon essential oil. The main components are represented by cinnamaldehyde, eugenol, phenol, and linalool. The antibacterial and antifungal properties of cinnamon essential oil may have potential applications in mouth rinses, toothpastes, or as a root canal irrigant. Additionally, it has the potential to act as an antimicrobial agent in dentistry [27]. In the same context, Cinnamon and Lemongrass essential oils were shown to have an antifungal effect on C. albicans biofilm and stop the formation of fungal biofilm on heat-polymerized PMMA in an in vitro study [28]. According to a registered clinical trial, based on Newton classification, cinnamon essential oil and nystatin showed clinical effectiveness in decreasing Candida spp. [29]. A research has shown that a nanoencapsulation of grapefruit seed, cinnamon oil, and chitosan/carrageenan is an effective technique for inhibiting oral bacteria [30].

Clove oil

Clove essential oil, obtained from the buds of Syzygium aromaticum, a tree belonging to the Myrtaceae family, is a well-known botanical agent with multiple pharmacological properties relevant to oral health care [31]. Rich in eugenol, it demonstrates potent antibacterial, antifungal, anti-inflammatory, analgesic, neuroprotective, anticarcinogenic, and antibiofilm activities [31]. Recent research highlights its strong efficacy against the main oral pathogens [31]. Zhang et al. demonstrated that both clove and eugenol essential oils have a significant impact on Porphyromonas gingivalis' growth by affecting their bacterial membrane integrity, promoting intracellular leakage, and interfering with early biofilm formation [32]. Furthermore, these effects support its use in managing gingival inflammation and microbial imbalance [32].

The primary cariogenic agent in dental caries (e.g., Streptococcus mutans), is a primary cariogenic agent that clove essential oil can combat. Antibiotics remain an option for treatment, but they can cause disruption of oral and intestinal microbiota. Clove essential oil is a natural alternative that inhibits acid-producing bacteria without any negative side effects [31]. Its antifungal action against Candida albicans further extends its application to oral candidiasis, especially in root caries [31]. The findings suggest the use of clove in oral hygiene products that target the prevention and treatment of gingivitis, periodontal disease, dental decay, and oral fungal infections [31,32].

Tea tree oil

Tea tree oil (TTO), extracted from the leaves of Melaleuca alternifolia through steam distillation, represents a traditional remedy used by Australian Aboriginal populations and is now widely recognized for its therapeutic applications [33,34]. The tea tree belongs to the Myrtaceae family and, indigenously, it is defined as "the most versatile healer of nature" [33-34]. According to ISO 4730 standards, terpinol-4 and 1,8-cineole are the primary constituents and are essential for both therapeutic efficacy and safety. To ensure antimicrobial activity and minimize irritation, terpinol-4 must be below 30%, and cineole must be below 15% [33, 36].

Tea tree oil exhibits a broad spectrum of pharmacological activities, specifically antimicrobial effects against various bacteria (e.g., Staphylococcus aureus, Streptococcus mutans, Porphyromonas gingivalis), as well as antifungal activity against Candida albicans and antiviral effects on pathogens such as herpes simplex virus [33].

Additional pharmacological actions of tea tree include anti-inflammatory, antiseptic, immunostimulatory, wound-healing, soothing, and slight anesthetic properties [33]. Tea tree oil has demonstrated therapeutic benefits in several dental conditions, including gingivitis, chronic periodontitis, denture-induced stomatitis, and halitosis [34,35].

The efficacy of TTO in managing oral pathologies has been confirmed by multiple clinical studies. A randomized study by Ripari et al. showed that TTO mouthwash had a significant effect on plaque and gingival bleeding over 14 days, with improved tolerability compared to 0.12% chlorhexidine [34]. Maghu et al stated that the use of 0.25% tea tree oil mouthwash was able to significantly improve oral Candida infection compared to standard care, with outcomes similar to clotrimazole and no side effects noted [35]. In another paper, Srikumar et al. demonstrated that tea tree oil mouthwash significantly reduced halitosis scores and Solobacterium moorei levels after one week of use, with efficacy comparable to chlorhexidine [37]. Using current clinical evidence, tea tree oil has been shown to be a valuable and well-tolerated alternative for managing and preventing various oral conditions, with consistent efficacy across multiple studies [34,35].

Oregano oil

Oregano essential oil (OEO) is extracted from Origanum vulgare L., a perennial plant native to the Mediterranean region and western Eurasia, part of the Lamiaceae family [38,41]. OEO is rich in phenolic and terpenoid compounds, notably carvacrol, thymol, and rosmarinic acid, which are responsible for its antioxidant, anti-inflammatory, and broad-spectrum antimicrobial activities [38,40].

In dentistry field, OEO has shown effectiveness against Candida species and Streptococcus mutans, playing a role in managing denture stomatitis, dental caries, and halitosis [39,41]. Moreover, the ability to destroy biofilms and reduce inflammation suggests potential for inclusion in therapeutic oral care products such as toothpaste and mouthwash [40,41].

Traditional uses of oregano oil include alleviating oral pain and throat irritation [38,40]. Additionally, carvacrol exhibits antiangiogenic and antiproliferative effects [38]. OEO has also been applied topically for skin infections and taken orally for gastrointestinal disruption [40].

Baj et al. suggested that oregano essential oil, containing carvacrol, 1,8-cineole, and thymol, exhibited notable antifungal activity against oral yeasts such as Candida albicans and C. glabrata, by inhibiting their growth and killing them at similar or slightly higher concentrations [42]. Khan et al. found that carvacrol and thymol from Origanum vulgare L. have antimicrobial and antibiofilm effects against Streptococcus mutans and suggest that they can be used as potential agents to control dental caries [43]. Saeed et al. conducted a clinical trial and concluded that an OEO-based mouthwash had a significant reduction in halitosis scores, with an efficacy equivalent to chlorhexidine and no reported adverse effects [39].

Hosny et al. developed an OEO nanoemulsion that inhibited S. mutans and Candida albicans growth in vitro, suggesting its utility in oral therapeutics [40]. A study by Hejazinia et al. reported strong in vivo anti-biofilm effects of OEO in mice, confirming plaque reduction [44].

Oregano essential oil has proven to be a valuable agent in both current and future dental applications for its effectiveness against oral pathogens and biofilms [41,44].

Basil oil

Basil (Ocimum basilicum L.) is an aromatic plant from the Lamiaceae family, widely used in traditional medicine and culinary practices [45]. The active compounds present in its essential oil include eugenol, linalool, methyl chavicol, and other terpenoids, which are recognized for their antimicrobial, anti-inflammatory, antioxidant, and immunomodulatory properties [45].

Pharmacologically, basil oil has demonstrated bactericidal and antifungal effects against pathogens involved in oral infections, notably Streptococcus mutans, Lactobacillus rhamnosus, and Porphyromonas gingivalis [46]. Clinical studies have shown that mouth rinses that contain extracts of Ocimum sanctum and Ocimum gratissimum have a clinical efficacy comparable to that of chlorhexidine in reducing plaque index, gingival bleeding, and oral bacterial levels [47]. A recent in vitro investigation explored the incorporation of Ocimum basilicum essential oil (OBEO) into a tissue conditioner, a soft denture lining material used to manage inflamed oral mucosa. The essential oil was added during the mixing process and retained its antifungal efficacy against Candida albicans. The modified material demonstrated a significant reduction in fungal adherence, suggesting its applicability in antifungal therapies related to denture use. Additionally, OBEO inhibited the formation of fungal biofilms over time, highlighting its potential as an antibiofilm agent. The integration of basil essential oil into tissue conditioners proved to be both stable and biocompatible. Despite these promising results, further clinical studies are needed to confirm its effectiveness in dental practice [48].

Overview of the therapeutic effects of essential oils in dentistry

Figure 1 summarizes the therapeutic effects attributed to essential oils with potential in improving oral health and various dental problems.

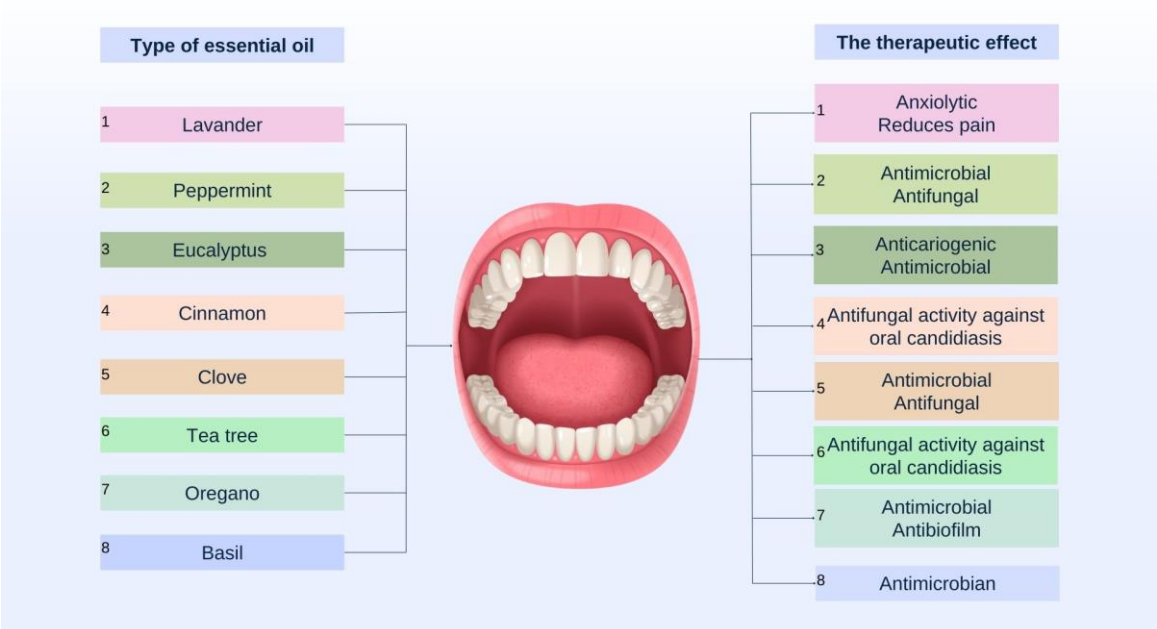

Figure 1. The therapeutic effects of essential oils. The image was created using Canva

Table 1. Relevant studies regarding the activity of essential oils in the dental field

Essential Oils	Type of Experimental Study	Results	Reference
Lavender	Randomized double-blind placebo-controlled study	The antioxidant effect of lavender has a significant activity in the healing process of oral ulcers.	[49]
	Male Swiss mice	Anxiolytic-like effect through $5HT_{1A}$ receptors	[50]
Eucalyptus	In vitro	Antibacterial (against Escherichia Coli) and anti-inflammatory effects	[51]
Oregano	In vitro	Significant reduction of bacterial lipopolysaccharide-induced osteoclastic cells	[52]
Basil	Randomized group (40 children)	Significant statistically antimicrobial action against aerobic and anaerobic strains	[53]
Tea Tree	Comparative study (60 participants aged 28-60 years)	Safe and effective alternative for managing plaque-induced gingivitis	[54]

5HT1A − serotonin 1A receptor

DISCUSSIONS

Collective evidence highlights the potential of these alternatives or complementary agents to be effective and generally well-tolerated alternatives to conventional dental treatments. Among the essential oils reviewed (e.g., clove oil, tea tree oil, peppermint oil) stand out as the most extensively investigated, with evidences from both in vitro experiments and clinical studies supporting their therapeutic efficacy. Eugenol-rich clove oil is highly effective against both fungal and bacterial infections, particularly against Streptococcus mutans and Candida albicans, and also provides beneficial analgesic effects for dental uses [31, 32]. Tea tree oil has a wide-spectrum antimicrobial profile and is well-tolerated, providing consistent clinical benefits in treating gingivitis, halitosis, and denture-related stomatitis, often producing results similar to those obtained with chlorhexidine [33-36]. Peppermint oil also displays significant antifungal activity and halitosis-reducing effects, with promising utility in both preventive and therapeutic dental contexts [11-21]. In addition to these, other essential oils such as eucalyptus, oregano, cinnamon, and lavender exhibit notable bioactivity relevant to oral health. Eucalyptus oil has demonstrated antiplaque and anticariogenic properties, while oregano oil possesses pronounced antimicrobial and biofilm-inhibitory effects [22-26]. Cinnamon oil has shown efficacy in disrupting Candida biofilms, supported by clinical findings [27-30]. In addition to its documented antimicrobial activity, lavender oil also has anxiolytic and analgesic benefits, which could improve patient comfort and compliance during dental procedures [11-15]. Ocimum basilicum essential oil shows significant antifungal activity against Candida albicans and inhibits biofilm formation, suggesting that it could be useful in managing denture-induced stomatitis. This product's compatibility with dental materials, biocompatibility, and formulation stability all indicate its viability for future clinical applications [45-48].

Despite the promising results and in order to advance the development of alternative therapies with essential oils, future research directions should focus on the identification of safety and toxicity, studies to elucidate the mechanisms of action (antimicrobial, antifungal), and randomized controlled clinical trials to validate efficacy and optimization in clinical practice. Also, potential challenges to be addressed prior to translocation into clinical practice should be oriented towards verifying patient tolerability, standardization of formulations, stability and optimal dosage.

CONCLUSIONS

This work highlights the effectiveness and applicability in dentistry of eight essential oils, including lavender, peppermint, eucalyptus, cinnamon, clove, tea tree, oregano, and basil. All these have demonstrated therapeutic benefits due to their antimicrobial, antifungal, and anti-inflammatory properties and their excellent effect on biofilm destruction. However, of these essential oils, clove oil, tea tree oil, and peppermint oil have been the most extensively studied over the years in many clinical trials, proving their safety and efficacy in dental problems time and time again, and therefore, they represent an important step in the prevention and management of dental conditions such as periodontitis, gingivitis, halitosis, and dental stomatitis, which are attributed both to poor oral hygiene and as a consequence of dentures.

The study concluded that the integration of oral hygiene products based on essential oils (e.g. mouthwashes, gels, toothpastes, dental materials) led to promising results, but to fill the gaps in the literature and to develop future applications of essential oils, mechanistic studies (in vitro and in vivo), verification of optimal dosages and assessment of possible adverse reactions on patients are needed.

Conflicts of Interest

The authors declare no conflict of interest.

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The Impact of Injectable Biostimulatory Substances on Current Trends in Aesthetic Medicine: Focus on Poly-L-lactic Acid, Polycaprolactone, and Calcium Hydroxyapatite

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Abstract

1.Background/Objectives: In recent years, aesthetic medicine has shifted from conventional volumizing fillers to regenerative, biostimulatory approaches, aiming to promote long-term skin health and natural rejuvenation. 2.Methods: This narrative review compares the most commonly used injectable biostimulators—poly-L-lactic acid (PLLA), polycaprolactone (PCL), and calcium hydroxyapatite (CaHA)—by analyzing current evidence on their mechanisms of action, clinical efficacy, safety, and aesthetic indications. 3.Results: These agents stimulate neocollagenesis through controlled inflammatory responses, resulting in enhanced dermal architecture and sustained aesthetic effects. PLLA activates the TGF-β/SMAD signaling pathway to enhance type I collagen synthesis, PCL offers immediate volumization with neovascularization and collagen remodeling, while CaHA promotes fibroblast proliferation and angiogenesis. 4.Conclusion: The findings support a growing preference for minimally invasive yet regenerative treatments. This review emphasizes the significance of personalized therapeutic strategies and ongoing research in improving outcomes and ensuring patient safety in aesthetic practice.

Keywords: Injectable biostimulators, Poly-L-lactic acid, Polycaprolactone, Calcium hydroxyapatite, Aesthetic medicine

INTRODUCTION

In the last few years, there has been a significant change in the field of aesthetic medicine. This transformation is driven by the increasing demand for minimally invasive and effective procedures that deliver natural-looking results and short recovery times. Today's patients are no longer solely focused on visible and quick corrections; they seek regenerative solutions that enhance skin health and slow the aging process [1]. This development marks a shift away from traditional fillers that rely on instant volumization, such as hyaluronic acid, to biostimulatory agents that stimulate the skin's collagen production. This emphasizes stimulating deep and long-term regeneration rather than transient effects. Injectable biostimulators are a distinct class of dermal, biocompatible, and biodegradable substances that act by inducing a controlled local inflammatory reaction, leading to fibroblast activation and neocollagenesis [2]. This mechanism provides a progressive, natural, and long-lasting aesthetic effect, unlike the immediate but temporary volumizing effect of classic fillers [3]. The most commonly encountered biostimulators include polymerized polylactic acid (PLLA), polycaprolactone (PCL), and calcium hydroxyapatite (CaHA), each with unique characteristics in terms of mode of action, durability, and areas of clinical use [4].

This narrative review aims to provide a comparative analysis of these three biostimulatory agents, which are widely used in regenerative aesthetic medicine. The review synthesizes existing clinical data and mechanistic perspectives to clarify their similarities, differences, and roles in current therapeutic protocols.

The significant role of these substances lies in their ability to support the aesthetic correction of the skin and its structural regeneration process by providing gradually improved and natural results. In addition, they are increasingly suited to the needs of a population interested in effectively preventing ageing without resorting to surgery [5]. Moreover, biostimulators are being increasingly integrated into combination protocols, along with botulinum toxin, dermal fillers, and energy-based devices, to enhance treatment efficacy and patient compliance. However, research on the safety and effectiveness of these combination therapies remains limited and varied, underscoring the need for further studies to establish standardized protocols and optimize outcomes [6]. Thus, the transition from traditional volume-focused approaches to regenerative strategies that emphasize long-term skin health and natural rejuvenation is being pursued, leading to the evolution of minimally invasive procedures that not only correct the visible signs of aging but also support the organism's intrinsic regenerative processes [7].

Aim and objectives

This article aims to compare the most used injectable bio-stimulators in modern aesthetic medicine—PLLA, PCL, and CaHA—from the perspectives of mechanism of action, clinical efficacy, safety, and aesthetic applications, thereby contributing to therapeutic guidance tailored to the patient's profile and treatment goals.

MATERIAL AND METHODS

This article presents a narrative review comparing the most popular injectable biostimulators used in aesthetic medicine: poly-L-lactic acid (PLLA), polycaprolactone (PCL), and calcium hydroxyapatite (CaHA). A systematic search was conducted in three core scientific data sources: PubMed, ScienceDirect, and Google Scholar. The search spanned from January 2004 to February 2024. It searched the following terms and combinations thereof: “injectable biostimulants”, “collagen stimulators”, “poly-L-lactic acid”, “polycaprolactone”,

"calcium hydroxylapatite", "aesthetic medicine", "regenerative injectables". The inclusion criteria comprised any peer-reviewed clinical studies, narrative or systematic reviews, and mechanistic or theoretical studies relevant to dermatology, aesthetic surgery, or regenerative medicine. Only English articles were considered. The following exclusion criteria were applied: non-peer-reviewed sources, studies with animals alone that did not have available clinical translation, and those that failed to present a discussion in depth on clinical efficacy or mechanisms involved (either separately or combined). This methodology was chosen to achieve a comprehensive and relevant synthesis of the best available evidence.

MECHANISMS AND CLINICAL APPLICATIONS OF INJECTABLE BIOSTIMULATORS

Poly-L-L-lactic acid (PLLA)

Poly-L-L-lactic acid (PLLA) is a biodegradable and biocompatible synthetic polymer that stimulates the production of type I collagen through a controlled inflammatory process triggered by the subdermal injection of PLLA microparticles. These particles trigger a foreign body reaction, leading to the activation and recruitment of macrophages and the formation of multinucleated giant cells. These immune cells surround the particles and release pro-regenerative biochemical signals. [8,9]. An essential element in this process is the activation of fibroblasts, the cells responsible for maintaining and renewing the extracellular matrix (ECM). In vitro studies have demonstrated that exposure of human fibroblasts to PLLA-SCA leads to increased expression of COL1A1 and COL1A2 genes, responsible for the synthesis of type I collagen, as well as other ECM components such as elastin and tissue inhibitors of metalloproteinases (TIMP-1 and TIMP-2), in parallel with decreased expression of MMP-1 [10,11].

The PLLA-induced biostimulation primarily functions through the TGF-β/SMAD signaling pathway, a well-studied biochemical pathway that mediates regenerative biology, including collagen synthesis, fibroblast proliferation, and the tissue healing process [12]. Increased TGF-β1, phosphorylated SMAD-1/2, and AKT expression have been demonstrated in vitro and in vivo, suggesting a substantial impact on dermal remodelling and metabolism [13,14]. Furthermore, PLLA would seem to exert an indirect effect on adipogenesis. It has been found to stimulate the differentiation of pre-adipocytes, as well as the synthesis of type VIα1 and type IV collagen associated with the formation of adipose tissue, which may be involved in its long-lasting volumizing effect [15].

The use of PLLA-SCA in aesthetic medicine has expanded considerably in recent decades, evolving from initial indications in reconstructive and orthopedic surgery to aesthetic applications with clinically proven benefits. As a dermal bio stimulator, PLLA-SCA is mainly recommended for correcting facial volume loss, improving skin laxity, and improving skin quality by stimulating endogenous collagen synthesis. Initially approved for the treatment of facial lipoatrophy in HIV patients, PLLA-SCA has subsequently become a popular option in facial rejuvenation due to its ability to induce a gradual and long-lasting biological response. In the aesthetic context, the substance is commonly used in treatments targeting the mid- and lower face, particularly the cheeks, jawlines, and temples, where volume loss is often associated with the ageing process. Subdermal application of PLLA-SCA results in a progressive remodeling of facial contours and a visible improvement in dermal density [16].

A clinical study by Signori et al. demonstrated that PLLA treatments led to significant improvements in wrinkle severity scores, with effects maintained up to 25 months after the last injection, highlighting that PLLA is effective in aesthetic treatments, with long-lasting effects and minimal adverse events [17].

Polycaprolactone (PCL)

Polycaprolactone (PCL) is an innovative dermal biostimulator used in aesthetic medicine for facial volume restoration, contouring, and non-surgical lifting. PCL-based fillers have a dual mode of action: they give an immediate volumizing effect through gel-carrying a carboxymethylcellulose (CMC) and sustained fibroneogenesis through biodegradable PCL microspheres. Studies have shown that this type of filler initially stimulates the formation of type III collagen, followed by a predominant synthesis of type I collagen, the most essential structural collagen of the skin, which has a half-life of approximately 15 years [18,19]. This ability to induce type I collagen explains the durability of the clinical results observed after PCL treatment, which can last for over two years. Compared to other biostimulators, such as CaHA and PLLA, PCL offers both an immediate effect and long-lasting efficacy without requiring multiple sessions; in most cases, a single injection is sufficient [20,21]. An increase in dermal thickness up to 21% on average at 1 year after injection of smooth moulded microspheres also accompanied by active fibroblasts, newly formed type I and type III collagen bundles, elastin fibres and neovascularisation in the neighbourhood of the PCL microsphere has been observed both in clinical and histological studies [22].In addition, histologic analysis of human tissues injected with PCL showed the formation of type I and III collagen around the microspheres, thus supporting the long-lasting effect of the product. These findings confirm PCL's ability to induce neocollagenesis and provide long-lasting aesthetic results [23]. Quantitative 3D assessments also showed a 50-150% increase in volume over the initial injected volume after two years, suggesting progressive tissue remodeling [24].

The duration of the clinical effect of PCL-based filleters varies between 18 and 30 months, depending on the formulation. For example, Ellansé-S (PCL-1) offers visible results for up to 18 months, while Ellansé-M (PCL-2) maintains aesthetic improvements for up to 24 months or longer. A randomized controlled trial comparing the two products for correction of the nasolabial fold demonstrated clinical durability, with 90% of patients achieving continued clinical improvement at 12 months, as well as high satisfaction rates at 24 months (81.7% for PCL-2 and 72.4% for PCL-1) [25].

Polycaprolactone, thus, stands out as a key ingredient in aesthetic medicine due to its unique properties - biocompatibility, slow biodegradability, and ability to stimulate collagen production. Its application in facial rejuvenation treatments offers dual benefits (immediate volumization and long-lasting effects through regeneration), bridging the gap between regeneration and aesthetics, while also providing a viable prospect for personalized, safe, and effective treatments. Evaluations performed on nasolabial folds - one of the most treated areas in aesthetic practice - have shown long-lasting results, with significant improvements maintained even 24 months after injection. The versatility of PCL has also been demonstrated in other facial areas, such as the forehead, temples, jawline, and even the hands, achieving not only volume restoration but also a visible improvement in skin quality. These effects are due to PCL's unique ability to stimulate neocollagenesis, a process that contributes to a natural, long-lasting, and revitalized appearance. In terms of safety profile, data from clinical studies and extensive post-marketing use are encouraging, with adverse reactions being rare, mild, and transient (such as edema or local bruising) [26].

Moreover, more than a decade of clinical experience gained globally has cemented the product's reputation as a safe, stable, and predictable product with no significant complications reported in the literature. Thus, PCL not only offers natural and long-lasting aesthetic results but also a solid safety profile confirmed by clinical data and daily medical practice.

Calcium hydroxyapatite (CaHA)

Calcium hydroxyapatite (CaHA) is a biocompatible synthetic material widely used in aesthetic medicine for wrinkle correction, facial volumization, and skin rejuvenation. It has FDA clearance for the treatment of nasolabial folds, jawline contouring, and hand rejuvenation. Its effectiveness in improving aesthetic scores and patient satisfaction has been emphasized by effects that can last up to 18 months or longer [27]. Unlike other dermal fillers, CaHA offers a dual effect: immediate plumping and progressive stimulation of dermal regeneration, with results that can last 12-18 months or longer. CaHA is composed of calcium phosphate microspheres suspended in a carboxymethyl cellulose gel. After injection, the gel provides an immediate volume effect, while the microspheres act as a biological stimulant, promoting collagen and elastin synthesis. This profound action explains the remarkable improvements in skin texture and quality, even after the filler has been reabsorbed [28,29].

The biological mechanisms of action of calcium hydroxyapatite (CaHA) contribute significantly to explaining its effectiveness in skin regeneration and improvement of skin appearance. A study by Amiri et al. indicates that CaHA can stimulate the proliferation of fibroblasts - the cells responsible for collagen production - a process evidenced by increased expression of the nuclear marker Ki-67, without signs of cell toxicity (no increase in LDH levels). In addition, enhanced EGFR and SMAD2 gene expression is indicative of the temporal activation of growth-signaling pathways essential for cellular proliferation and invasion, with peak gene upregulation occurring approximately 4 weeks following injection. In parallel, CaHA induces the synthesis of type I and III collagen, reflecting a physiological pattern of transition from type III collagen (associated with the initial regeneration phase) to type I collagen (predominant in the dermis and responsible for the mechanical strength of the skin). This process is essential in combating signs of ageing, such as loss of elasticity, dryness, or wrinkles. CaHA also contributes to the regeneration of elastic fibers by stimulating the production of elastin, a structural component critical for skin elasticity, which is degraded with age and environmental exposure [30].

A second important characteristic of CaHA is its ability to induce angiogenesis (formation of new blood vessels) to increase tissue oxygenation and nutrient delivery, both crucial to the healing and dermal remodeling processes. These effects are accompanied by a decrease in local inflammation and edema, both of which are crucial for effective and lasting skin regeneration [31].

CaHA can be administered as a structural filler (undiluted) or as a biostimulator (diluted), depending on the treatment objective. Although approved only for a few areas, its off-label use has been extended to cheek contouring, the temple, neck, and neckline rejuvenation.

DISCUSSIONS

Injectable biostimulators, such as PLLA, PCL, and CaHA, represent a paradigm shift in aesthetic dermatology, transitioning from immediate volumization to regenerative skin restoration. These agents stimulate neocollagenesis, elastogenesis, and extracellular matrix remodeling by activating fibroblasts and pro-regenerative signaling pathways [32].

The increasing demand for minimally invasive aesthetic procedures has led to the emergence of poly-L-lactic acid (PLLA) as a leading biostimulator for facial rejuvenation. PLLA induces neocollagenesis through a controlled inflammatory process, resulting in a gradual and prolonged recovery of age-related volume. A review was conducted to assess the efficacy, longevity, and safety of PLLA in the context of aesthetic use, including randomized clinical trials (RCTs) in adults. The results of the work by Signorini et al. suggest that PLLA is effective for skin tightening and texture improvement, with low and transient adverse effects,

mainly when proper reconstitution and administration techniques are employed. However, differences between protocols and the poor quality of some of the studies support the need for further standardized research to maximize the clinical application of this product [17]. The efficacy of PLLA as a new volumizing filler, as well as an enhancer of skin quality through tissue remodeling, is also confirmed by studies by Syleima et al. Marked improvements in erythema, pores, and texture score were observed 18 weeks after treatment, with a significant change in epidermal layers and reduced parameters associated with elastin fragmentation and angiogenesis effect. These histological changes indicate that the action of PLLA is not superficial but deep, favouring not only neocollagenesis but also dermal regeneration and microvascularization. Treatment tolerability was favorable, and no adverse reactions were reported, further supporting the safety of repeated applications. Due to these dermoregenerative effects, PLLA can be considered for aesthetic protocols not only for volume restoration, but also for use in structural rejuvenation, particularly in patients with photoaging and in cases of early lipoatrophy [33].

In contrast to PLLA, which relies on a controlled inflammatory process to stimulate collagen, PCL acts through physical persistence in the dermis, inducing a prolonged mechanical stimulation effect.

PCL is a biodegradable synthetic polymer that serves as an injectable biostimulator in aesthetic medicine, exhibiting immediate volumizing capacity (due to the carboxymethylcellulose carrier gel) alongside long-term efficacy (by stimulating neocollagenesis induced by PCL microspheres). Histological examinations of human biopsies taken 13 months after injection revealed that the PCL particles remained within the dermis without migration or biodegradation, indicating their favorable safety profile and potential synergistic long-term aesthetic effects. These findings validate the product's ability to remodel tissue by enhancing collagen density. However, use in anatomically mobile areas should be approached with caution, particularly considering recent isolated cases of granulomatous reactions, which underscore the urgent necessity for standardization of administration protocols and long-term patient follow-up [23,34]. Compared to other biostimulants, PCL offers the advantage of lasting rejuvenation while ensuring safety. Nonetheless, injection limitations, side effects, and aesthetic outcomes necessitate adherence to a rigorous injection protocol, appropriate patient selection, and thorough post-treatment follow-up. Therefore, PCL can be regarded as a promising solution for aesthetic medicine, delivering both immediate and enduring effects; however, treatment outcomes can be significantly influenced by the physician's skill in performing the procedures and the protocols implemented [35].

CaHA, in addition to being a known collagen and elastin stimulator, acts as a skin microstructure enhancer. The study by Nowag et al. found that the direct interaction between CaHA microspheres and fibroblasts is crucial in stimulating neocollagenogenesis. Thus, in vivo, the more diluted the microspheres, the higher the dispersion and the higher the probability of cell encounter. In contrast, in vitro, the stimulation of type III collagen synthesis is proportional to the number of activated fibroblasts, independent of the activity of individual cells. This direct relationship between particle distribution, CaHA concentration, and fibroblast activation could serve as the basis for the development of personalized dilution and injection depth protocols tailored to each anatomical area and the patient's skin characteristics [36]. The in vivo results further support the application of CaHA as an effective biostimulatory agent for facial rejuvenation, mainly due to the induction of type III collagen expression in the initial period, followed by type I collagen expression in a manner consistent with the natural physiologic process of dermal regeneration. These results align with the current literature, which reports a rapid and immediate volumizing effect, followed by a persistent skin biostimulation stage, and a clinical gain of 12 to 18 months. Additionally, personalized dilution methods of CaHA are becoming increasingly relevant in the treatment

of sensitive areas, such as the neck and décolleté, thereby highlighting the impact of diffusion on fibroblast activation. CaHA offers the best ratio between immediate aesthetic effects and medium-term collagen-boosting potential, making it particularly suited for patients who want immediate results with long-lasting effects. In parallel, the growing trend for combination treatments, such as the combination of CaHA with PLLA, reflects a three-dimensional, personalized rejuvenation approach and may result in a synergistic effect on skin volume and quality. However, widely observed shortcomings in study methods, small sample sizes, and a lack of standardized protocols underscore the need for further multicenter clinical trials with longitudinal monitoring and objective (imaging) assessment of dermal effects [37].

Therefore, poly-L-lactic acid (PLLA), calcium hydroxyapatite (CaHA), and polycaprolactone (PCL) are the most widely used and experienced collagen biostimulators in minimally invasive facial rejuvenation. Each of these agents has specific characteristics that can be tailored according to the patient's profile and requirements. PLLA is recognized for its ability to gradually regenerate the dermis sustainably, thereby providing a natural appearance. CaHA provides immediate plumping, which is further enhanced by neocollagenesis, making it ideal for fast and versatile treatments. PCL has been shown to have the highest reversibility for esthetic restoration, with the lowest adverse reaction rate, and is therefore a valuable choice for patients seeking long-term results. The main characteristics of these three biostimulators are summarized in a comparative table (Table 1), providing practical support for personalized clinical observations.

Table 1. Comparative Table of Biostimulating Fillers in Aesthetic Medicine

Feature	PLLA (Poly-L-lactic acid)	PCL (Polycaprolactone)	CaHA (Calcium Hydroxyapatite)
Product Type	Synthetic, biodegradable polymer	Synthetic, slow-biodegradable polymer	Biocompatible, synthetic mineral compound
Mechanism of Action	Controlled inflammatory response, macrophage and fibroblast activation, TGF-β/SMAD signaling	Dual action: immediate effect via CMC gel + long-term collagen stimulation via PCL microspheres	Dual action: immediate effect via CMC gel + fibroblast stimulation, angiogenesis, and ECM regeneration
Collagen Type Induced	Mainly Type I	Initially Type III, then predominantly Type I	Type III (early), followed by Type I
Onset of Effect	Gradual, delayed onset	Immediate + progressive improvement	Immediate + progressive improvement
Duration of Effect	18–24 months	18–30 months (depending on formula)	12–18 months
Target Areas	Mid and lower face (cheeks, jawline, temples)	Forehead, temples, cheeks, jawline, hands	Nasolabial folds, cheeks, hands, temples, neck (off-label)
Safety Profile	Good, few adverse events; long clinical use	Excellent; over a decade of use; minimal side effects	Very good; transient edema or bruising; no significant toxicity

CONCLUSIONS

Biostimulators have thus become indispensable tools in modern aesthetic practice, offering not only volumization but also deep stimulation of dermal regeneration. The choice of the appropriate substance should consider the aesthetic goals, the treatment area, and the individual patient profile. A detailed understanding of the characteristics of each product is crucial for optimizing results and minimizing associated risks. Current trends indicate a shift in medical aesthetics toward prevention, tissue regeneration, and subtle enhancements, aligning with the demands of today's generation and the latest advances in regenerative

medicine. Future research directions should include prospective studies on a large cohort to validate the long-term efficacy and safety of biostimulatory fillers, as well as a larger-scale double-blind, randomized, controlled trial. The development of comparative studies, combination treatments, and individual treatment regimens may contribute to the advancement of personalized medicine in the field of aesthetic medicine. Additionally, translational research into the molecular mechanisms underlying regenerative tissue healing will inform the development of optimal filler compositions and their practical application. Addressing these issues will help fill the evidence gaps currently missing and generate new, evidence-based solutions for regenerative aesthetic medicine.

Conflicts of Interest

The authors declare no conflict of interest.

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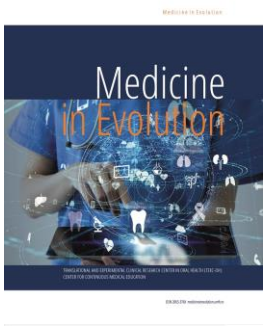
Assessing Knowledge and Intentions Related to HPV Vaccination in Romanian Dental Students



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Abstract

Background: Human papillomavirus (HPV) is a leading etiological agent of various malignancies, including cervical and oropharyngeal cancers. Despite the availability of safe and effective prophylactic vaccines, vaccination uptake remains suboptimal in several regions, including Romania. Dental students, as future oral healthcare providers, are uniquely positioned to contribute to HPV-related cancer prevention. Objective: This study aimed to evaluate HPV vaccination status, awareness, and behavioral intentions among dental students enrolled at the "Victor Babeş" University of Medicine and Pharmacy in Timişoara, Romania. It also sought to identify factors associated with actual vaccine uptake and intention to vaccinate. Methods: A cross-sectional analytical study was conducted in April–May 2025 using a structured questionnaire administered to second-, fifth-, and sixth-year dental students. Variables analyzed included demographic data, HPV vaccination status, awareness of vaccine safety and efficacy, understanding of community-level protection, and declared intent to vaccinate. Descriptive statistics, correlation analysis, and logistic regression were employed for data interpretation. Results: Out of 199 participants, only 25% reported being vaccinated against HPV, despite high levels of awareness—over 85% acknowledged vaccine safety and effectiveness, and 78% recognized its role in reducing community transmission. Among the unvaccinated students, more than 60% expressed an intention to receive the vaccine. However, the logistic regression model did not yield significant predictors due to limited variability in

awareness-related responses, indicating a well-informed but behaviorally inconsistent cohort. Conclusions: Romanian dental students exhibit strong theoretical knowledge of HPV-related health risks and vaccination benefits, yet vaccination uptake remains low. The high intention to vaccinate among unvaccinated individuals suggests a readiness that could be harnessed through targeted behavioral interventions. These findings highlight the importance of integrating both educational and motivational strategies into dental curricula to transform knowledge into preventive action.

Keywords: HPV, vaccination, dental students, Romania, awareness, public health, behavioral intention

INTRODUCTION

Human papillomavirus (HPV) is a pervasive and clinically significant viral pathogen, representing the most widespread sexually transmitted infection globally. Over 200 distinct genotypes have been identified, of which at least 14 are considered high-risk due to their oncogenic potential. HPV types 16 and 18 are particularly notorious, being responsible for the vast majority of HPV-related cancers, including approximately 70% of cervical cancers worldwide (1). However, the clinical relevance of HPV extends far beyond the cervix. The virus plays a crucial etiological role in the development of anal, vulvar, vaginal, penile, and increasingly, oropharyngeal squamous cell carcinomas (OPSCC), particularly among younger male populations in Western countries (2,3).

This marked epidemiological shift toward oropharyngeal cancer emphasizes the necessity of integrating non-gynecological specialties, particularly dental medicine, into comprehensive HPV prevention strategies. Dentists and dental students perform routine examinations of the oral cavity and oropharynx and are uniquely positioned to observe early mucosal lesions suggestive of viral oncogenesis. They are, therefore, strategically situated to act as both clinical sentinels and public health educators. Yet, to fulfill this role effectively, a solid foundation of virological knowledge, clinical relevance, and communication competency is required (4,5).

The advent of prophylactic HPV vaccines has been a transformative advancement in oncology prevention. Vaccination against HPV has proven to significantly reduce the prevalence of infections, high-grade intraepithelial neoplasia, and, over time, invasive cancers (6,7). Despite robust scientific evidence supporting the safety and effectiveness of these vaccines, their uptake remains highly variable across regions. While some Western countries report coverage rates exceeding 70%, Central and Eastern European nations, including Romania, continue to struggle with low vaccination levels due to sociocultural skepticism, insufficient health literacy, and inadequate policy implementation (8,9).

In Romania, HPV vaccination is available free of charge through national immunization programs, with access provided via family physicians and public health authorities (10). However, the success of such programs depends not only on accessibility, but also on the public's trust, perceived vulnerability to HPV-related diseases, and their confidence in the health system. Numerous studies indicate that misinformation, cultural taboos surrounding sexually transmitted infections, and a general mistrust of vaccines continue to hinder effective HPV prevention nationwide. These barriers are compounded by the absence of consistent and evidence-based HPV education in formal curricula, particularly within healthcare-related disciplines.

As future healthcare providers and trusted sources of medical advice, medical and dental students hold a dual responsibility: to protect their own health through immunization, and to serve as informed advocates for the communities they will one day treat. Yet literature shows that students in clinical fields often exhibit variable levels of HPV-related knowledge, frequently underestimating the link between HPV and oral cancer or misunderstanding vaccine indications (11,12). International comparisons reveal that dental students from countries with well-structured curricular interventions, such as the Netherlands, Spain, and Italy, tend to demonstrate greater awareness and proactivity compared to their peers from regions where HPV education is less emphasized (13–15).

Within this landscape, Romanian dental students represent a critical demographic for public health investigation. Their readiness to recognize, prevent, and educate about HPV-related oral diseases may shape not only their own professional behavior but also the long-term efficacy of community-based prevention efforts. However, current evidence suggests a

lack of consistent exposure to HPV-related topics in dental curricula, a deficiency that may hinder students' willingness to recommend or even accept vaccination themselves. Compounding this is a broader climate of vaccine hesitancy in Romania, which, though improved post-COVID, still reflects deep-seated mistrust in immunization programs (16)

Moreover, the role of dental students in HPV advocacy should not be underestimated. As members of a clinical specialty that routinely interfaces with adolescents and young adults—age groups at highest risk of HPV infection—these future practitioners can serve as critical liaisons between the medical establishment and the general population. Their perspectives, intentions, and behaviors toward vaccination thus have implications that extend beyond the academic setting, potentially influencing vaccine acceptance at the societal level.

Understanding what shapes these attitudes—whether it be demographic variables like age and sex, or cognitive-emotional variables like perceived safety and awareness of community transmission—is essential for guiding curricular reform and public health policy. By identifying knowledge gaps and behavioral intentions among students in dental medicine, we can develop targeted interventions that reinforce evidence-based education, address specific misconceptions, and ultimately strengthen the role of dental professionals in HPV prevention efforts across all stages of their careers.

Aim and objectives

The aim of this study was to evaluate HPV vaccination coverage, awareness, and attitudes among dental students, and to investigate factors associated with the intention to receive the HPV vaccine. The research sought to explore how demographic variables such as age and sex, as well as knowledge related to HPV transmission and cancer prevention, influence vaccine uptake and future vaccination intent.

Specifically, the objectives included determining the proportion of students vaccinated against HPV, assessing their level of knowledge regarding the effectiveness of the vaccine in preventing cancer and limiting community transmission, and analyzing whether awareness correlates with vaccination status. Additionally, the study aimed to identify predictors of both actual vaccination and declared future vaccination intention using descriptive statistics, correlation analysis, and logistic regression models, based solely on the available variables in the dataset.

MATERIAL AND METHODS

1. Study Design and Setting

This cross-sectional analytical study was carried out between April and May 2025 at the Translational and Experimental Clinical Research Center in Oral Health, affiliated with the Clinic of Preventive, Community Dentistry, and Oral Health at the "Victor Babeş" University of Medicine and Pharmacy in Timişoara, Romania. The aim was to investigate the awareness, attitudes, and vaccination behaviors regarding human papillomavirus (HPV) among dental students enrolled in different academic years. This study complied with the ethical guidelines set forth in the World Medical Association's Declaration of Helsinki (1964). Approval was granted by the Ethical Committee of the University of Medicine and Pharmacy "Victor Babes", Timisoara, Romania (no. 15/15.01.2024).

2. Study Population

The target population of this study was composed of undergraduate students enrolled in the Doctor of Dental Medicine (DMD) program at the "Victor Babeş" University of Medicine and Pharmacy in Timişoara, Romania, during the 2024–2025 academic year. The academic program in Romania spans six integrated years, blending theoretical, preclinical, and clinical components into a unified curriculum that qualifies graduates as general dental

practitioners. For the purposes of this investigation, participants were selected from three distinct academic cohorts: second-year students (representing the early, preclinical stage of training), and fifth- and sixth-year students (representing advanced clinical stages). This stratification allowed for comparative analyses between junior and senior students in terms of awareness, attitudes, and behaviors related to HPV prevention.

Participation was entirely voluntary and contingent upon the provision of informed written consent, in accordance with institutional ethical guidelines and data protection policies. Students were invited to take part during scheduled academic sessions or practical laboratory activities, and all were clearly informed about the anonymous and confidential nature of the study. To ensure methodological consistency and reliability of findings, inclusion criteria required that participants (1) be actively enrolled in one of the designated academic years, (2) complete the full questionnaire without missing values on key variables, and (3) provide optional consent for a related component of saliva sampling, where applicable. Students who submitted incomplete responses or refused consent for data use were excluded from the final analysis.

A total of 199 valid questionnaires were included in the study. The distribution of participants was as follows: 58 students from the second year (29.1%), 59 from the fifth year (29.6%), and 82 from the sixth year (41.2%). This sampling frame ensured adequate representation of both preclinical and clinical stages of training, offering a robust basis for assessing knowledge progression and behavioral intention differences across educational exposure levels. The sample reflects the demographic profile typical of Romanian dental faculties, characterized by a predominance of female students and a relatively narrow age distribution, concentrated in early adulthood.

3. Data Collection and Variables

Data collection was carried out using a structured and anonymous self-administered questionnaire, carefully designed to capture both factual knowledge and attitudinal variables related to HPV and its vaccination. The instrument comprised multiple sections covering sociodemographic information (including age, sex, and year of study), clinical history regarding HPV vaccination (categorized as vaccinated vs. unvaccinated), and a series of items assessing cognitive and behavioral components relevant to public health engagement. Prior to full deployment, the questionnaire was pilot-tested on a small group of dental students to ensure clarity, relevance, and face validity of the items.

Specifically, the questionnaire included binary and multiple-choice items addressing awareness of HPV as a sexually transmitted infection, understanding of the vaccine's role in cancer prevention, and recognition of its impact on community-level viral transmission. Additionally, respondents were asked to indicate whether they intended to receive the HPV vaccine in the future, allowing for assessment of prospective behavioral alignment with preventive health practices.

The primary outcome variable (dependent variable) was current HPV vaccination status. Independent variables included continuous data such as age, and categorical data including sex (male/female), academic level (junior vs. senior), and three awareness indicators: (1) perception of vaccine safety, (2) knowledge of cancer-preventive efficacy, and (3) understanding of herd immunity benefits.

To ensure data quality and consistency, all responses were initially entered into Microsoft Excel for cleaning, de-duplication, and formatting. This preprocessing step included recoding of categorical responses and handling of missing data, followed by export into Python-compatible formats. This structured data architecture enabled smooth integration into statistical software environments, where advanced analyses—including correlation matrices, cross-tabulations, and regression modeling—were subsequently conducted.

4. Inclusion and Exclusion Criteria

To ensure the methodological consistency and internal validity of the study, rigorous inclusion and exclusion criteria were established prior to participant enrollment. These criteria were designed to define a homogenous population with comparable academic backgrounds and exposure levels to health education content relevant to HPV, thereby allowing for the accurate interpretation of results related to awareness, vaccination status, and behavioral intent.

Eligible participants included only undergraduate students formally enrolled in the Doctor of Dental Medicine (DMD) program at the "Victor Babeş" University of Medicine and Pharmacy in Timişoara, Romania, during the 2024–2025 academic year. The academic years selected for participation were limited to the second, fifth, and sixth years of study in order to represent both junior (preclinical) and senior (clinical) stages of professional formation. This stratification allowed the researchers to explore differences in knowledge and behavior according to the level of clinical exposure and curricular progression.

Participation in the study was entirely voluntary and contingent upon the provision of informed written consent, consistent with ethical principles outlined in the Declaration of Helsinki and approved by the institutional ethics committee. Students were invited to participate during scheduled academic sessions, where the nature, scope, and confidentiality of the study were thoroughly explained. Only those who completed the entire questionnaire, providing responses to all key variables such as age, sex, vaccination status, awareness of HPV transmission, and intention to vaccinate, were retained in the final dataset. Furthermore, participants who agreed to contribute to a related, optional saliva sampling component were noted, although this biological aspect was not essential for inclusion in the primary analysis.

Exclusion criteria were applied systematically to eliminate potential sources of bias or data incompleteness. Students from academic years outside the targeted cohorts were excluded to maintain homogeneity in terms of educational exposure. Responses that were incomplete, internally inconsistent, or missing data on core variables were also excluded to preserve the integrity of the statistical analysis. In addition, any student who declined to sign the consent form or who later withdrew participation was not included in the final analysis. Similarly, individuals who completed the survey but explicitly requested that their responses not be used for research purposes were excluded, in accordance with data protection and participant autonomy guidelines.

Through the application of these inclusion and exclusion criteria, a total of 199 students were retained for full analysis. This sample offered a representative and academically stratified cohort suitable for evaluating HPV-related awareness and vaccine behavior among future dental professionals in Romania.

5. Statistical Analysis

Descriptive statistical methods were employed as an initial step to summarize and explore the characteristics of the study population. Measures such as frequency distributions, absolute and relative percentages, arithmetic means, and standard deviations were calculated to provide a comprehensive overview of demographic variables (age, sex, academic year), as well as responses related to vaccination status and HPV-related knowledge. These descriptive insights established the foundational profile of the sample, facilitating interpretation of subsequent inferential analyses.

To evaluate associations between categorical variables—such as sex and vaccination status or academic year and knowledge indicators—cross-tabulation tables were generated and examined. Where appropriate, Pearson's chi-square tests were considered to assess statistical significance, although the homogeneity of responses in certain categories limited applicability. Additionally, correlation analysis was performed to assess the strength and direction of linear relationships among continuous or dichotomous variables, such as the

relationship between knowledge of vaccine efficacy and declared intention to vaccinate. A correlation matrix was visualized to identify overlapping patterns of awareness, behavior, and intent, providing further insight into the cognitive landscape of the respondents.

In order to investigate the potential predictors of HPV vaccination uptake, a binary logistic regression model was constructed. The dependent variable was vaccination status (vaccinated vs. unvaccinated), while independent variables included age (as a continuous variable), sex (binary), academic year (categorical), and specific knowledge indicators related to HPV transmission, vaccine safety, and community-level protection. The model was evaluated through standard regression metrics including odds ratios (OR), 95% confidence intervals (CI), Wald statistics, and p-values, with a pre-established threshold for statistical significance set at $\alpha = 0.05$. The model's interpretability was examined in the context of variable multicollinearity and variance inflation.

All statistical procedures and visualizations were carried out using Python (version 3.11), with a suite of data science libraries including Pandas for data manipulation, Matplotlib (version 3.7.1) for plotting and graphical outputs, and Scikit-learn for logistic regression modeling. To ensure the accuracy and reproducibility of the statistical inferences, results were independently validated using MedCalc Statistical Software (version 22.013), a specialized platform frequently utilized in biomedical research for hypothesis testing, effect size estimation, and regression diagnostics. This dual-software approach reinforced both the methodological rigor and credibility of the findings.

RESULTS

The final analysis included a valid sample of participants after the exclusion of incomplete or ambiguous responses. The age of the respondents ranged from 18 to 32 years, with a mean value of 24.2 years and a standard deviation of 2.3. The distribution of ages, as illustrated in Figure 1, revealed a concentration of participants in the 22 to 25-year-old range, which is consistent with the academic structure of Romanian dental education. The majority of respondents were female, representing approximately 80% of the study population. This gender imbalance aligns with national trends in dental schools, where female enrollment rates have historically been higher than those of their male counterparts.

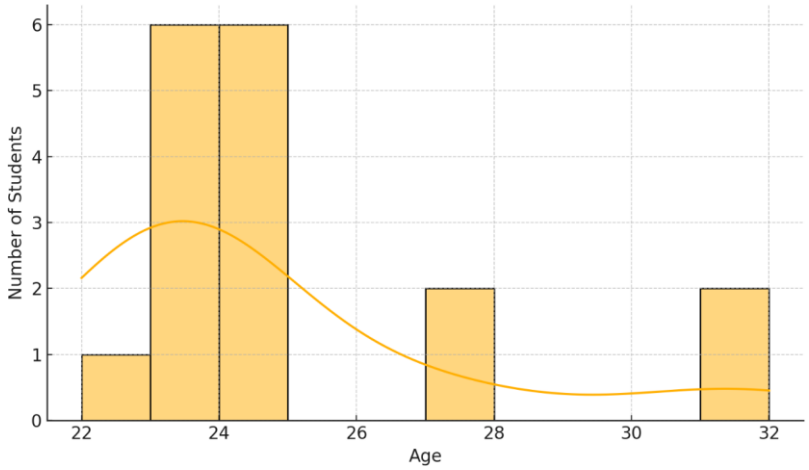

Figure 1. Age Distribution of the Study Population (N = 199)

Regarding vaccination status, approximately one in four students (around 25%) reported that they had received the HPV vaccine. The remaining 75% were unvaccinated at the time of the survey. This disparity is depicted in Figure 2, highlighting a substantial gap between the availability of HPV vaccines and actual uptake among future healthcare

professionals. Interestingly, although male students were fewer in number, no statistically significant difference was observed between sexes in terms of vaccination coverage. Nevertheless, the absolute number of vaccinated male students was notably lower, a trend that has also been observed in previous studies involving healthcare students.

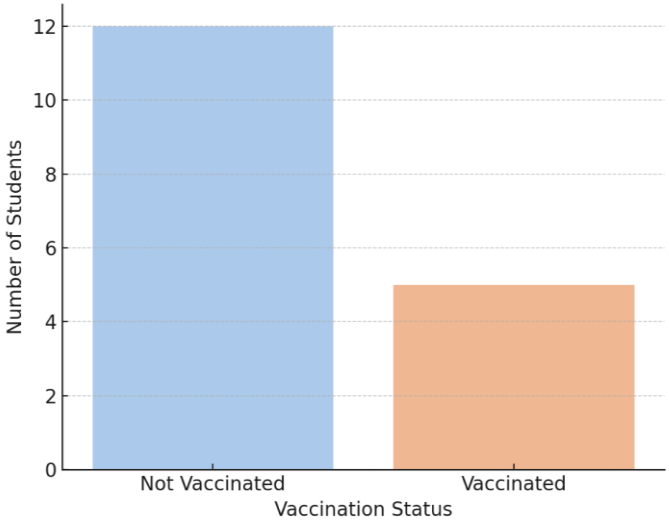

Figure 2. HPV Vaccination Coverage Among Dental Students (N = 199)

In terms of HPV-related knowledge, the majority of respondents demonstrated a strong theoretical understanding of vaccine safety and efficacy. Over 85% correctly identified that the HPV vaccine is a safe and effective method for cancer prevention. Similarly, close to 78% of students indicated awareness that vaccination reduces viral transmission at the community level. These findings indicate a high level of general awareness among participants. However, this was not mirrored by a proportionally high vaccination rate, suggesting the presence of cognitive or behavioral barriers. The correlation matrix, shown in Figure 3, supports this observation, indicating moderate positive associations between knowledge items and both vaccination status and intention to vaccinate. Notably, while knowledge of vaccine benefits was consistently high, this did not translate directly into preventive action.

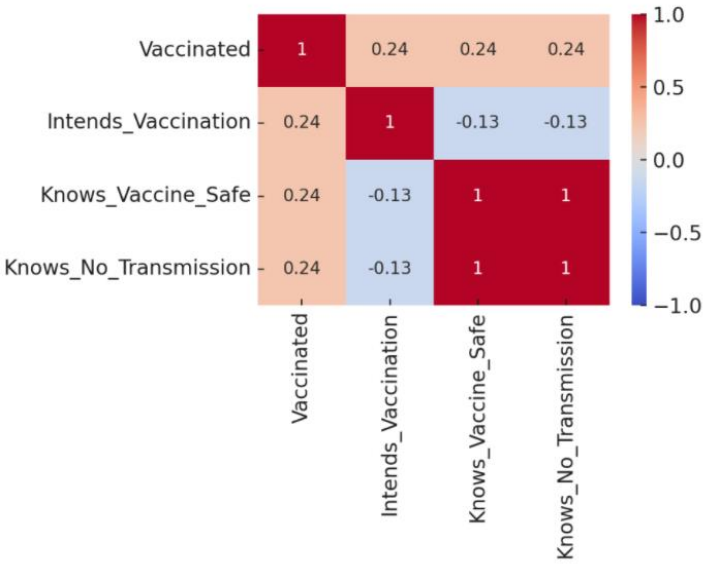

Figure 3. Correlation Matrix of Knowledge, Vaccination Status, and Behavioral Intention (N = 199)

Among those who had not yet been vaccinated, more than 60% stated that they intended to receive the HPV vaccine in the near future. Figure 4 illustrates the distribution of responses concerning future vaccination intention. This optimistic trend indicates that while actual uptake remains low, a substantial portion of unvaccinated students are open to immunization. This finding suggests a critical opportunity for targeted public health interventions that move beyond information dissemination to actively support behavioral change. Students who acknowledged the vaccine's role in preventing cancer and reducing transmission were more likely to report a willingness to vaccinate, reinforcing the idea that knowledge is a necessary, though not sufficient, driver of action.

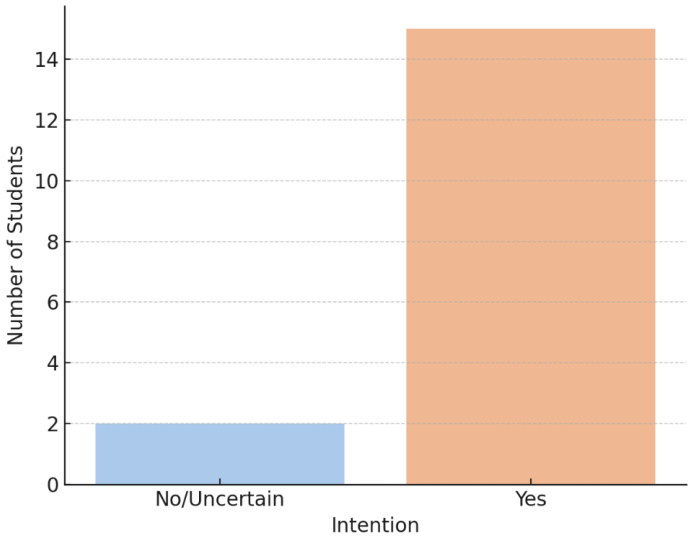

Figure 4. Stated Intention to Receive HPV Vaccination Among Unvaccinated Students (N = 199)

In an effort to identify independent predictors of vaccination, a logistic regression model was constructed using age, sex, and knowledge-related variables. However, the model failed to converge due to singularity errors caused by a lack of variability in predictor variables, particularly the knowledge-related items. The data exhibited near-universal agreement among respondents regarding vaccine safety and effectiveness, which, although positive in terms of awareness, posed a statistical challenge. This limitation indicates that the homogeneity of knowledge responses, while indicative of effective health education efforts, restricts the potential for inferential analysis within this sample.

In summary, the present results highlight a well-informed student population with a high level of awareness regarding the benefits of HPV vaccination. However, actual vaccination coverage remains relatively low, particularly among male students, and significant potential exists to increase uptake through behavioral interventions. The positive trend in vaccination intention, combined with the high baseline of knowledge, offers an encouraging platform for educational and organizational strategies aimed at improving HPV vaccine acceptance among future dental professionals.

DISCUSSIONS

The present study sheds light on the complex dynamics between knowledge, attitudes, and behavioral intentions regarding HPV vaccination among Romanian dental students. Despite the relatively high level of awareness demonstrated by respondents concerning the oncogenic potential of HPV and the proven efficacy of vaccination as a

preventive measure, actual vaccine uptake remains markedly low. This cognitive-behavioral mismatch is consistent with a growing body of literature indicating that health literacy alone does not guarantee engagement in preventive health behaviors, particularly when it comes to sexually transmitted infections.

International studies have consistently reported similar patterns among medical and allied health students. For instance, a cross-sectional survey conducted in Malaysia revealed that while over 80% of students acknowledged the importance of HPV vaccination, only a small fraction had received the vaccine or expressed a clear intention to do so (17). Comparable findings have been documented in both Hong Kong and India, where university students exhibited solid theoretical knowledge but poor vaccination rates—especially among male students and those in pre-clinical years of study (18,19). These trends suggest that although knowledge dissemination is a necessary condition for vaccine uptake, it is far from sufficient in the absence of concurrent strategies addressing emotional, cultural, and systemic barriers.

An additional insight emerging from our data concerns the partial understanding of the vaccine's role in achieving herd immunity. Although a majority of students correctly identified the vaccine as effective in preventing HPV-associated cancers, fewer demonstrated awareness of its broader epidemiological role in reducing community transmission. This discrepancy may indicate a conceptual gap in students' understanding of population-level disease control, which has also been highlighted by Rajiah et al., who argued that future healthcare professionals often underestimate the collective benefits of vaccination (20).

Gender-based disparities in vaccination attitudes and knowledge levels were also evident. Female students exhibited marginally higher awareness and a greater willingness to consider vaccination in the future. This gender gradient has been echoed in studies conducted in Saudi Arabia and India, where sociocultural norms, personal risk perception, and historical associations between HPV and cervical cancer may predispose women to greater engagement with HPV-related health behaviors (21). Conversely, male students, who are less frequently targeted by public health messaging about HPV, may lack a sense of personal vulnerability or responsibility, despite increasing evidence linking HPV to male-dominant pathologies such as oropharyngeal squamous cell carcinoma.

Contextualizing these findings within the Romanian healthcare and educational landscape, it becomes apparent that the country continues to face substantial challenges in promoting HPV vaccination. Earlier work by Murariu et al. noted significant deficits in HPV-related knowledge among Romanian dental and medical students, even as these groups are uniquely positioned to identify early signs of HPV-associated oral cancers (22). Potential contributing factors include limited curricular exposure to HPV-specific content, insufficient integration of oncology prevention in dental education, and broader cultural skepticism toward vaccines. The Romanian Ministry of Health has made the HPV vaccine available free of charge, yet logistical access alone has not been enough to overcome long-standing sociocultural barriers and public mistrust.

Moreover, the demanding academic environment of dental education may play a role in deprioritizing preventive self-care measures. Romanian dental students are known to experience high levels of psychological stress and academic burnout, as demonstrated in a recent study that used salivary cortisol and oxidative stress markers as physiological indicators of academic strain (23). In such contexts, time constraints, cognitive overload, and emotional fatigue may reduce students' propensity to engage in proactive health behaviors such as vaccination.

These patterns underscore a broader limitation of current public health messaging, which tends to emphasize factual knowledge while underestimating the role of behavioral psychology in shaping health decisions. To increase vaccine uptake, especially among

healthcare students, public health campaigns must adopt multidimensional approaches that incorporate behavioral science, motivational interviewing techniques, and peer-led advocacy. The findings of Coursey et al., who implemented gender-sensitive and culturally adapted vaccination campaigns among young women in India, further highlight the effectiveness of tailored interventions over one-size-fits-all information delivery (24).

In parallel, the evolving landscape of oral diagnostics offers promising avenues for reinforcing the relevance of HPV training in dental education. Saliva-based detection of high-risk HPV genotypes, as explored by Kumar et al. and Chai et al., provides a non-invasive, cost-effective method of screening for HPV-related oropharyngeal cancers (25,26). Such innovations, if incorporated into clinical teaching and diagnostic protocols, could enhance student engagement with HPV-related topics by linking them directly to future professional competencies. Likewise, Tang et al. demonstrated the diagnostic accuracy of different saliva collection methods for HPV detection, reinforcing the practical utility of such approaches in routine dental care (27).

From a systems perspective, Romania's experience with COVID-19 vaccine hesitancy provides important behavioral insights that are transferable to HPV immunization strategies. Studies conducted during the pandemic demonstrated that vaccine acceptance was influenced not only by knowledge, but also by perceived risk, institutional trust, and social norms (28,29). Applying these behavioral lessons to the context of HPV vaccination could help public health stakeholders design more persuasive, socially resonant campaigns targeted at young adults and future healthcare providers.

Taken together, the findings of this study point to a critical opportunity for rethinking how HPV education is integrated into dental curricula and public health initiatives. Rather than treating HPV vaccination as a static informational goal, educational institutions and health systems alike must recognize it as a behavioral outcome influenced by a complex interplay of knowledge, emotion, identity, and social context.

LIMITATIONS AND FUTURE DIRECTIONS

Despite the strengths of this study, several limitations must be acknowledged in interpreting its findings. First, the cross-sectional design inherently restricts causal inference. While associations between knowledge, attitudes, and vaccination status can be described, temporal relationships and causality cannot be established. Longitudinal studies are warranted to assess how awareness and intentions translate into vaccination behavior over time.

Second, the self-administered questionnaire relied exclusively on self-reported data, which introduces the risk of response bias. Participants may have overestimated their knowledge or reported socially desirable answers regarding vaccination intentions. This effect may have been amplified by the academic setting and the professional expectations associated with healthcare training.

Third, the dataset exhibited high levels of homogeneity in knowledge-related variables. The overwhelming agreement among respondents regarding vaccine safety and efficacy, while encouraging from a public health standpoint, limited the statistical power of inferential analyses. In particular, the logistic regression model was constrained by multicollinearity and convergence issues due to insufficient variability in responses. Future studies should consider including scaled or multi-item knowledge constructs that capture nuance and differentiate between superficial awareness and in-depth understanding.

Another limitation lies in the representativeness of the sample. Although students were selected from three academic years to ensure a balanced perspective between junior and senior cohorts, the sample was restricted to a single dental faculty. Thus, the generalizability of findings to other Romanian or international dental programs may be limited. Expanding

the study across multiple institutions would allow for more comprehensive benchmarking and cross-institutional comparisons.

Moreover, while the study examined demographic and cognitive predictors of HPV vaccination behavior, it did not capture psychosocial variables such as perceived susceptibility, trust in public health authorities, peer influence, or personal beliefs—all of which have been shown to significantly influence vaccine acceptance. Integrating these dimensions in future research would offer a more holistic understanding of the motivational landscape underpinning vaccination decisions.

Finally, although saliva sampling was mentioned as a parallel component, its results were not integrated into the current analysis. Future directions should explore the utility of salivary diagnostics as both an educational and screening tool for dental students, thereby reinforcing their clinical relevance and fostering stronger engagement with HPV-related oral pathology.

CONCLUSIONS

This study provides a comprehensive snapshot of HPV vaccination status, awareness, and behavioral intentions among Romanian dental students. The findings demonstrate that although knowledge regarding the safety and efficacy of the HPV vaccine is widespread and consistent within the sample, actual vaccination rates remain relatively low. This discrepancy highlights a critical gap between theoretical understanding and preventive action, suggesting that educational interventions alone may not be sufficient to translate awareness into behavior.

The fact that a significant proportion of unvaccinated students expressed a clear intention to receive the HPV vaccine in the near future underscores a latent readiness for immunization. This intention, strongly correlated with knowledge of the vaccine's protective role against cancer and its potential to reduce transmission, presents an important opportunity for public health strategies to capitalize on this positive disposition. Integrating behavioral science approaches, simplifying access, and reinforcing institutional recommendations may serve as effective mechanisms for improving vaccine uptake among this target population.

The failure of the logistic regression model to identify independent predictors of vaccination behavior due to multicollinearity and limited response variability suggests that the sample was relatively homogeneous, especially in terms of knowledge. While this reflects successful dissemination of information in the academic setting, it also limits the analytical power of predictive models. Future studies may benefit from incorporating more nuanced or scaled items to assess the depth and variability of knowledge and perceptions, enabling more granular predictive insights.

In conclusion, while Romanian dental students appear to possess a solid understanding of HPV vaccination, targeted efforts are still needed to bridge the intention–action gap. Addressing practical, emotional, and systemic barriers to vaccination could significantly enhance uptake, positioning future dental professionals not only as informed individuals but also as proactive advocates for HPV-related cancer prevention.

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Conflicts of Interest

The authors declare no conflict of interest.

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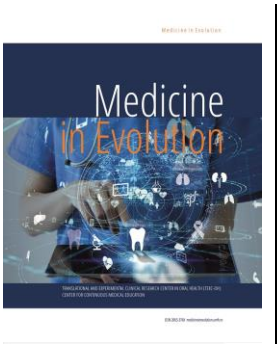
Lifestyle Risk Factors that Increase Chances of Developing Oral Cancer: Up to Date Review



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Abstract

1.Background/Objectives: Oral cancer is on the 6th most common cause of malignancies of the world. With higher prevention strategies, the 5-year survival rate of oral cancer is lower than 50% in some countries. Several risk factors that are linked with lifestyle behaviors have been identified in the occurrence of oral cancers. 2.Methods: Multiple database from 2014 to mid 2024. Applying filters were used to identify systematic reviews and meta-analyses, which investigated oral cancer incidence and risk factors. All published articles related to "behavior risk factors in oral cancer" were included in this review. 3.Results: The utilization of tobacco has reached

the proportions of a global epidemic; alcohol association even raises the risk of developing oral cancer. In recent studies, there has been an association between smoking and a higher HPV infection. In addition, Candida albicans disrupt the metabolism of epithelial cells, so they can evolve from leukoplakia to dysplasia or even carcinoma leading to association of chronic inflammation. Also a persisting chronic inflammation with the association of one more risk factors from above can lead to an increase chance of developing oral cancer. 4.Conclusion: Most oral cancer are due to behavior habits, the main risk factors in oral cancer are smoking, alcohol consumption and the presence of HPV). Improving lifestyle changes should be one of the goals in every patient's life. In addition, different strategy of public health information should be promoted in order to consider giving up smoking and excessive drinking of alcohol. A change in diet is also necessary. Therefore, public health campaigns are essential in determining a prevention of behavior lifestyle habits especially in younger adults because they represent the future adults.

Keywords: oral cancer; tobacco; HPV; risk factors; alcohol; lifestyle; Candida albicans

INTRODUCTION

There is global effort against cancer due to the higher prevalence of cases therefore, a behavior approach should be adapted for information of the population of good ways of living, early diagnostics, and modern treatment. The complexity of determinate causes of cancer comes due to the combination of behavioral-related lifestyles, environmental and genetics. Social, economic, and demographic factors are associated with developing certain lifestyles. Oral cancer is still on the 6th most common cause of malignancies of the world [1] with an expected number of new cases in US for 2024 of 34,850 and 6,380 of approximate deaths [2]. The central and eastern European regions have few of the highest rates of cancer of the oral cavity due to diverse social factors [3]. Even with higher prevention strategies, the 5-year survival rate of oral cancer is still lower than 50% in some countries [4]. Prevention by managing the risk factors is the main method that can assure the delay of the occurrence of the disease. Over time, several risk factors in the occurrence of oral cancers have been identified. The most frequently alleged were gender and behavior habits, smoking, alcohol consumption, nutritional deficiencies, irritations produced by prosthetic works and socio-economic environment. Papilloma virus infections, aging, careless oral hygiene and low-vegetable diets, candida albicans are also risk factors that merge into developing premalignant lesions and becoming a risk factor in oral cancer [5, 6]. Therefore, the continuous change of lifestyle behaviors can lead an individual to develop a possible oral malignancy. Lifestyle behaviors refers to how a person choose to live his life and how he manages problems and interpersonal relations. Lifestyle behavioral risk factors for oral cancer are tobacco usage, heavy alcohol drinking and dietary micronutrient deficiency.

Figure 1. Oral cancer risk factors

Aim and objectives

The aim of this review is to summarize the behavior risk factors that lead to serious consequences regarding an individuals health condition. Therefore, the awareness of public

and clinicians of the behavior risk factors and early signs of oral cancer has an important impact on prevention.

MATERIAL AND METHODS

A search was performed in multiple database from 2014 to mid 2024. Applying filters were used to identify systematic reviews and meta-analyses, which investigated oral cancer incidence and risk factors. All published articles related to "behavior risk factors in oral cancer" were included in this review. The research papers obtained from the study search were screened, resulting in the exclusion of 35 articles, while 63 articles were included for analysis. The next step was the scan of the titles and abstracts of the search results. Irrelevant topics of scope of the study were removed. Due to the discrepant defined anatomic subsites affected by oral cancer was in the literature, lead to the exclusion of many articles that included the oropharynx in their analyses. Secondary research studies and systematic reviews were also excluded.

RESULTS

Lifestyle risk factors related to oral cancer development.

3.1. Tobacco

Using tobacco has an increased risk of developing oral cancer that is correlated to the amount and length of time they smoked or chewed [7]. Tobacco is used as multiple forms-cigarettes, cigars, pipe and bidi etc. hookah or chillum (a clay pipe used to keep the burning tobacco) in some countries of Asia including India [3]. Nicotine is one of the substances of the tobacco and induces dependence among a type of persons with a genetically, mentally and socially predisposition [8]. The utilization of tobacco has reached the proportions of a global epidemic, with a consumption of 1000 cigarettes per year for every man, woman, and child on the globe [9]. In the literature, epidemiological research is highlighted that men are heavier smokers than women are, therefore, their risk on developing oral cancer is higher. The most concerning fact is that 15% of adolescents in the world embrace this lifestyle behavior and are estimated as daily smokers. They have even higher rates 25–35% and above in Eastern European and Latin American countries [10]. One of fourth of oral cancer cases are due to cigarette smoking, therefore, the risk levels are correlated with the quantity of cigars smoked per day [11]. The alcohol association even raises the risk of developing oral cancer. The factors that contribute in developing this type of behavior are coping with stress and personal resources but for young adults the main reason is the social influence of friends, family, publicity from tobacco industry that encourages smoking [12].

3.2. Alcohol

The incidence of cancer in the oral cavity is higher in chronic alcohol users, thus 7 out of 10 people suffering from chronic alcoholism develop at least one premalignant or malignant lesion of the oral cavity and the association with increased tobacco consumption elevate the risk of cancer development [13]. In the composition of alcohol are carcinogenic impurities such as polycyclic aromatic and nitrosamines. The combination of alcohol and other carcinogenic compounds increase the deterioration of the oral epithelium leading to an increase permeability of these compounds and intensify the penetration of carcinogens into target tissue [14]. High levels of alcohol have been associated with different types of Streptococcus species and Neisseria species, therefore, elevate the risk of develop oral squamous cell carcinoma [15]. The mechanism of alcohol at the mucosal level is represented of cell deterioration that facilitates the entry of carcinogens into the exposed cells, altering the metabolism of oral mucosal cells. Chronic alcohol users have a higher incidence of cancer of

the oral cavity cancer. In association with tobacco consumption have a possibility of developing one premalignant or malignant lesion of the oral cavity [13]. Unfortunately, observational studies have indicated a higher frequency of cervical and oral cancers due to nutritional deficiencies, which develop alcohol users because of the malabsorption of microelements and vitamins [16].

3.3. Human Papilloma Virus

In the past two decades, oral cancer diagnosis due to Human Papilloma Virus has increased among men and/or women in different European nations, such as United Kingdom, France, Germany, Denmark, and Sweden [17]. HPV status is an important risk factor due to sexual promiscuity. The difference between HPV + and HPV- is that the patients are middle aged caucasians, with no history of smoking, a high socio-economical state and a large number of exposure of different sexual partners[18]. In recent studies, there has been an association between smoking and a higher HPV infection [19], because smoking produces pro- inflammatory and immunosuppressive actions, which lead to an elevated risk of HPV infection [20]. Therefore, the treatment response studies reported that HPV related oral or oropharyngeal cancer have a better prognosis [22]. Dalla Torre et al. suggested that some factors related to oral epithelial wound can be a site entry that facilitate the oral infection of HPV [23]. Furthermore, a prior study found correlation between the number of extracted teeth and prevalence of oral HPV infection [24]. In addition, there is an initiation of prevention of cervical cancer associated with HPV16 and HPV18 within vaccination of young boys and girls [25]. The HPV vaccine is effective in preventing the occurrence of precancerous cervical lesions mostly with high risk of HPV16, 18. The protocol of the vaccine is two-dose administration best at 11 or 12 years and before 15 years of age, regardless of the patient's sex. In addition, asymptomatic HPV infection in men is thought to have a major part in progress of the transmission to female partners [26].

3.4. Candidosis and dental hygiene

Candida albicans is a fungus that becomes opportunistic at immunocompromised patients [27], there have been studies that link to oral cancer. The relationship between oral candidosis and oral cancer is that Candida albicans produces leucoplastic lesions by adhering to the surface of tongue. The latest studies about the association between this pathologies is that oral carcinoma occurs more frequently on candida leukoplakias than on other types of leukoplakias encountered in practice by its presence on the surface of pre-existing oral dysplastic lesions. Moreover, chronic infections with Candida albicans disrupt the metabolism of epithelial cells, so they can evolve from leukoplakia to dysplasia or even carcinoma [27,28].

Another risk factor associated with oral cancer is oral health and oral hygiene especially in association with other risk factors, such as tobacco and alcohol. In an Indian case control study, it has been shown that 79% of the patients with oral cavity and oropharynx cancer oral cancer is decreased by 26% by dental visits [28]. Furthermore there were investigated also factors that maintain the oral hygiene like tooth-brushing, mouthwash use, and dentist visits. These investigations showed a beneficial correlation between oral cancer and tooth-brushing more than twice a day, mouthwash use, and dentist visits. In spite of that, an amount of studies suggested that mouthwash use may increase overall oral cavity cancer risk because of the alcohol ingredients. In contradiction, a recent meta-analysis including smoking and non-smoking patients didn’t managed to show this type of correlation between mouthwash exposure and the oral disease [29].

3.5. Diet and nutrition

The role of diet and nutrition in general health is already known to have beneficial effects, therefore in the literature review studies have shown that a diet rich in vegetables, fruits, carotenoids and other vitamins has an important role in lowering the risk of oral

cancer, while studies of evidence for different foods or nutrients is less convincing [30-34]. There have been studies that enhances that consumption of red meat more than once a week compared to white meat (chicken, fish) increases the risk of oral cancer [30]. This is also consistent with information from a few studies that analyzed the overall impact of diet in relation to oral and pharyngeal cancer using a priori defined scores (including the Mediterranean diet score) [35]. Moreover, the association of low consumption of fruit and vegetables or high consumption of meat along with increased exposure to tobacco and alcohol has been associated with an increase in risk for development of oral cavity cancer [31,36]. Lower intake of vitamin B, especially by reducing the concentration of folate and Vitamin B6, Vitamin B12, produces degenerative changes in the oral mucosa, which help the carcinogenic action of chronic irritant factors. In one study, experimental carcinoma of the oral mucosa was induced in riboflavin-deficient mice more easily than in the control group that did not have riboflavin deficiency. Similar results were obtained in experimental carcinogenesis in some studies in mice with deficiencies of vitamin A or Zinc [37]. Therefore, diet has the possibility to affect overall oral health and our organism inflammatory status. In a study whereas the Dietary Inflammatory Index (DII) was measured showed an association between DII and the risk of oral cancer [38].

3.6. Chronic Inflammation Associated

Chronic inflammation has an important role in the development of some epithelial cancers such as oral and neoplasms. Altering the mucosa from chronic inflammation leads to developing the first steps of tumorigenesis and are composed of alteration of different types of cells such as fibroblasts, myofibroblasts, adipose cells, immune and inflammatory forming tumor microenvironment [39]. Another role in chronic inflammation is regarding oral microbiota. It is known that inside a human mouth there are 700 different bacterial species involved in immune response, nutrient digestion, and carcinogen metabolism. The perturbation of this microbiota is due to gingivitis, periodontitis and poor oral health conditions, which promote chronic inflammation [40, 41]. There are different types of conditions, which lead to developing oral cancer: mechanical iritations, oral ulcerations, periodontitis tooth loos [43].

Prevention programs of oral cancer where premalignant lesions like leukoplakia, erythroplakia, submucous fibrosis, reverse smoking. The association between risk factors and premalignant lesions are showed in Table 1.

Table 1. Association between behavior risk factors and premalignant lesions

Risk factor	Lesion	Mechanism	References
Alcohol drinking	Leukoplakia	The effects of ethanol are due to the reactive metabolites and the metabolic stress which is generated by the oxidative and non-oxidative metabolism of ethanol. Acetaldehydethe represents the first metabolite of ethanol, that has been recently linked with several adverse consequences of alcohol abuse.	44- 46
	Submucous fibrosis	Because of the alteration of the colllagen disposition when exposed to carcinogens the compact tissue supresses with an induced DNA damage, as well as malfunction of cellular proliferation, survival, differentiation, and the DNA repair. The microenvironment around the fibrosis tissue is also a malignant promotion factor where the collagen deposition alters in oral mucosa, therefour, the capillaries block the blood flow leading to an hypoxic environment suitable for the promotion of malignant cell growth .	45, 47, 48

Risk factor	Lesion	Mechanism	References
	Erythroplakia	The alcohol dehydrogenase 3 gene (ADH3) is involved in the alcohol–acetaldehyde pathway, and a growing number of molecular epidemiologic studies have evaluated the role of ADH3 in oral cancer risk. These results were mixt.	49, 50
Tobacco smoking	Leukoplakia	The alteration in mucosa may lead to the thickening of the epithelium and increase in pigmentation. Tobacco has an irritating effect on the minor salivary gland. Due to the modification that are taking place in the oral epithelium there are alterations in the morphology of exfoliated cell.	51-53
Vitamin/iron supplements and body mass index	Oral submucous fibrosis	Through the induction of oxidative stress, iron deficiency produces free radicals and re-active oxygen species that potentially cause cellular injury.	54-56
Chronic Inflammation Associated	Periodontitis Gingivitis	Because of an increase in neutrophil accumulation, the neutrophil-to-lymphocyte ratio in the oral cancer microenvironment. Also in saliva of oral cancer patients were found elevated inflammatory markers, particularly TNFα	57, 58
Diet and nutrition	Different degrees of inflamation	Production of biomarkers such as CRP, IL-6, and homocysteine cell metabolism, growth, and proliferation, can lead to the production of nitrogen compounds and catalyze the formation of free radicals that are responsabile of cell damage	59, 60
Human Papilloma Virus		The existing of various risk factors that contribute to the alteration of the oral musosa leading to changes in the keratinocytes from the basal layer to the surface of the epithelium. This malfunction provide a suitable micro-environment for productive cell replication, responsible for transformation of the keratinocyte into a permissive Cell and the entry of HPV. Viral replication is a process, depending both on select viral proteins codified by the viral genome and on the degree of infected cell differentiation	61, 62
Candidosis and dental hygiene	Leukoplakia	Production of IL1β, which activates the production of proinflammatory cytokines. The molecular investigation data have also identified, in C. albicans genotype A, as a important presence in oral squamous cell carcinoma lesions	63

The importance of screening test for oral cancers is a systematic clinical examination of the oral cavity and includes a visual inspection of the face, neck, lips, labial mucosa, buccal mucosa, gingiva, floor of the mouth, tongue, and palate as well as palpating the regional lymph nodes. Therefore individuals witch choose a lifestyle that include this associated behavior risk factors should benefice at least once a year of a proper medical consultation through dentists, otorhinolaryngology, general medicine and family medicine practitioners. Moreover, we have to take in consideration that any abnormality lasting for more than 2 weeks is reevaluated and considered for a biopsy.

CONCLUSIONS

Most oral cancer are due to behavior habits, the main risk factors in oral cancer are smoking, alcohol consumption and the presence of HPV, nevertheless the association with other minor risk factors represent a higher possibility of developing oral cancer. Chronic inflammation and infection have been suggested to contribute to carcinogenesis of the oral

cavity because of the presence of persistent inflammatory factors (cytokines, chemokines, prostaglandins, and free radicals). Improving lifestyle changes should be one of the goals in every patient's life. In addition, different strategy of public health information should be promoted in order to consider giving up smoking and excessive drinking of alcohol. A change in diet is also necessary, the role of diet and nutrition in general health is already known to have beneficial effects on human body despite tobacco being the strongest established risk factor for oral cavity cancer therefore it is considered that maintaining a good oral hygiene and treating all oral problems promotes a balanced lifestyle. Therefore, public health campaigns are essential in determining a prevention of behavior lifestyle habits especially in younger adults because they represent the future adults.

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Conflicts of Interest

The authors declare no conflict of interest.

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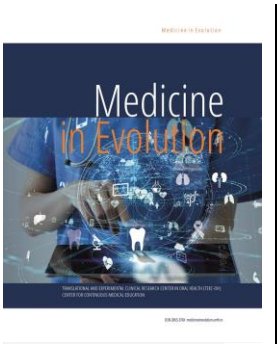
Use of Electronic Imaging Programs in Dental Practice



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Abstract

1.Background/Objectives: Digital radiography has continuously evolved as an innovative technology in dental imaging for nearly two decades. Digital radiography sensors are divided into: storage phosphor plates (SPPs) called photostimulable phosphor plates (PSPs), silicon devices such as charge-coupled devices (CCDs) or

complementary metal oxide semiconductors (CMOS). Digital imaging programs facilitate precise treatment planning by providing detailed images that can be easily manipulated and analyzed 2.Methods: The study period February to March 2025 with a study area of urban and peri-urban areaApproach method: 125 questionnaires were distributed to dentists practicing in urban and peri-urban area, 98 completed questionnaires were returned only 78 questionnaires remained in the study and 20 questionnaires were discarded due to incomplete completion or non-use of electronic medical imaging programs in current medical practice 3.Results: 46% of the doctors work in large private dental clinics, 40% in small private dental clinics and 14% in individual practices, Approximately 55% of respondents reported using electronic imaging programs frequently (more than 50% of the time) in the dental office on a daily basis, while 22% reported using them moderately (between 25% and 50% of the time), 12% use them always and 11% use them only occasionally (less than 25% of the time). 4.Conclusion: Electronic imaging programs offer numerous benefits, including enhanced diagnostic accuracy, more effective treatment planning, improved communication with patients, and streamlined image storage and retrieval.

Keywords: digital radiography, dental images, CMOS, PSPs, digital benefits

INTRODUCTION

Direct digital imaging was first introduced in 1984 by Dr. Frances Moujones. Since then, digital radiography, as a new technology in dental imaging practice, has been advanced relentlessly for almost twenty years [1]. Various imaging techniques have been used to retrieve the signal of interest from digital sensors, including charge-coupled devices (CCDs), complementary metal oxide semiconductor (CMOS), photostimulable phosphors (PSP), and aperture-regulated computed tomography (TACT) [2]. Digital radiography sensors are divided into: storage phosphor plates (SPPs) called photostimulable phosphor plates (PSPs), silicon devices such as charge-coupled devices (CCDs) or complementary metal oxide semiconductors (CMOS). Digital imaging programs facilitate precise treatment planning by providing detailed images that can be easily manipulated and analyzed [3]. Dentists can use these programs to assess the condition of teeth and surrounding structures, plan restorative procedures, orthodontic treatment, implant placement and oral surgery. The ability to accurately measure and evaluate anatomical features helps select the appropriate treatment approach and predict outcomes [4]. Digital imaging programs eliminate the need to physically store bulky X-ray films. Images can be stored securely in electronic databases, providing convenient access and reducing the risk of loss or damage [5]. Dentists can efficiently manage patient records, retrieve images for comparison over time, and easily share them with specialists or recommended colleagues when needed. Streamlined workflow improves efficiency and enhances patient care [6]. Digital imaging programs significantly reduce radiation exposure compared to traditional film radiography. The use of digital sensors or phosphor plates allows lower radiation doses while still producing high-quality diagnostic images [7]. This benefit is particularly important for pediatric patients and individuals who require frequent radiographic evaluations. Electronic imaging programs can seamlessly integrate with other dental technologies such as CAD/CAM systems, cone-beam computed tomography (CBCT) and intraoral scanners. This integration enables a comprehensive digital workflow, improving accuracy, efficiency and communication between different dental specialties [8]. The use of electronic imaging programs in dental practice offers numerous advantages that have greatly influenced the field of dentistry. Key advantages of using electronic imaging programs [9,10]: (i)Improved diagnostic accuracy: electronic imaging programs provide high-resolution digital images that offer superior clarity and detail compared to traditional film radiographs. Dentists can zoom, adjust contrast and brightness and manipulate images for more comprehensive analysis. This enhanced visualization helps to more accurately diagnose dental conditions, leading to improved treatment planning and better patient outcomes [11], (ii) time and cost efficiency: electronic imaging programs simplify the process of capturing, viewing and storing images, resulting in significant time and cost savings. Digital images can be captured instantly, eliminating the need for film processing. Furthermore, electronic storage eliminates the need for physical film storage, reducing associated costs and freeing up physical space in dental offices [12], (iii) reduced radiation exposure: electronic imaging programs use digital sensors or phosphor plates, which require lower doses of radiation than traditional film radiography. This reduced radiation exposure is beneficial for patients, especially children and people who require frequent imaging. It promotes a safer environment while maintaining high-quality diagnostic images [13].

Aim and objectives

The aim of this study is to assess the level of satisfaction of dental professionals with the electronic imaging programs they use and gather information about the future role and potential developments of electronic imaging programs in dental practices.

MATERIAL AND METHODS

For the realization of this article, we conducted a, cross-sectional pilot study in order to follow the implementation and importance of imaging technology implementation in current dental practice. Study title: "Study on the use of electronic imaging programs in dental practices". The study period February to March 2025 with a study area of urban and peri-urban area. Approach method: 125 questionnaires were distributed to dentists practicing in urban and peri-urban area, 98 completed questionnaires were returned, only 78 questionnaires remained in the study and 20 questionnaires were discarded due to incomplete completion or non-use of electronic medical imaging programs in current medical practice. Survey instrument: questionnaire with questions on: socio-demographic elements, use of electronic imaging programs, time of use of the programs, type of programs used, challenges and disadvantages of using them, satisfaction with using these programs, perception of improved quality of patient care. The final sample consisted of 78 subjects, dentists, practicing in Timisoara or its peri-urban area and who use electronic medical imaging programs in their medical practice.

RESULTS

The gender of the dentists in the sample is predominantly male, with an average age of 39.7 ± 11.2 years, with a minimum of 26 years and a maximum of 59 years, an average length of service of 11.7 ± 7.2 years, with a minimum of 1 year and a maximum of 25 years.

32% of the dentists were endodontic specialists, 30% orthopedic and orthodontic dental specialists, 23% dento-alveolar surgery specialists and 15% general dental specialists.

Table 1. Compressed results of Questionaire

Category	**Results of questionaire**
Gender of Dentists	62% Male, 38% Female
Average Age	39.7 ± 11.2 years
Age Range	26 – 59 years
Average Length of Service	11.7 ± 7.2 years
Length of Service Range	1 – 25 years
Specializations	32% Endodontic specialists
	30% Orthopedic & Orthodontic dental specialists
	23% Dento-alveolar surgery specialists
	15% General dental specialists
Place of Work	46% Large private dental clinics
	40% Small private dental clinics
	14% Individual practices
Technology Adoption	Male and younger doctors more open to using electronic imaging programs
Usage of Electronic Dental Imaging	80% currently using electronic imaging programs
Duration of Program Use	13% Less than 1 year
	32% 1–3 years
	33% 3–5 years
	22% More than 5 years

46% of the doctors work in large private dental clinics, 40% in small private dental clinics and 14% in individual practices. From the sample it is observed that male and younger doctors are more open to the use of electronic medical imaging programs for the treatment of patients. 80% of the physicians who returned the questionnaires were currently using electronic dental imaging programs in their current medical practice. Concerning the duration of use: the majority of respondents had been using electronic imaging programs in their dental practices for 1-3 years (32%), followed by those who had been using them for 3-5 years (33%), more than 5 years (22%) and less than 1 year (13%). Regarding the types of programs used, most commonly used intraoral cameras (74.36%), extraoral imaging (55.13%) and extraoral imaging such as panoramic or CBCT (34.62%) and 7.69% intraoral digital sensors (Figure 3).

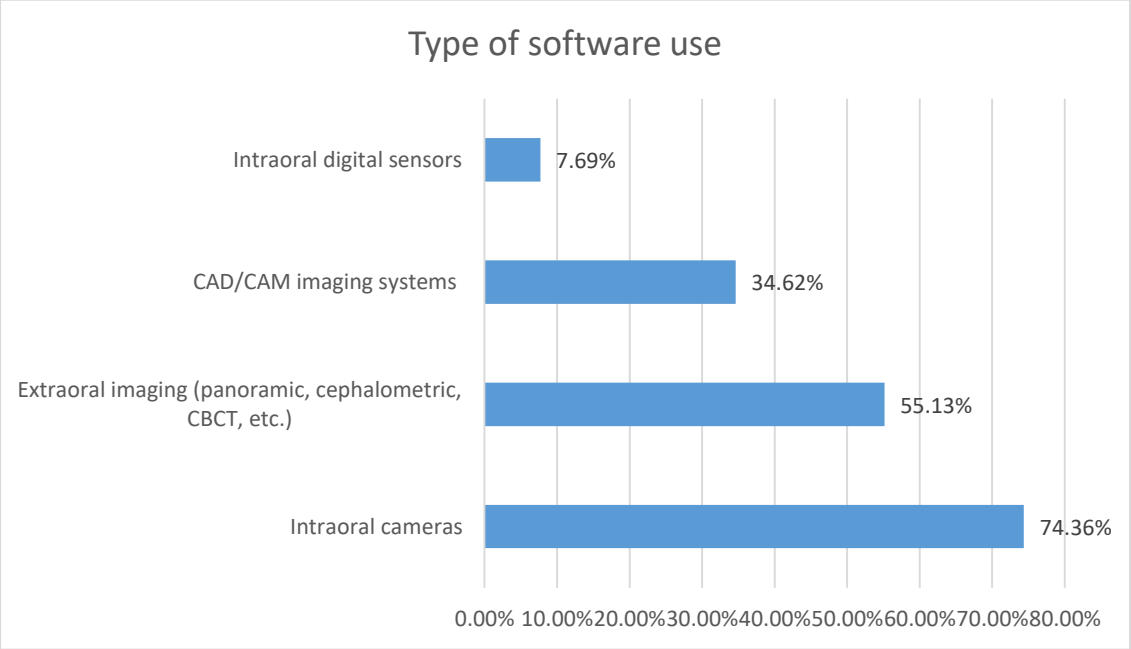

Figure 1. Type of software used

Frequency of use of electronic programs Approximately 55% of respondents reported using electronic imaging programs frequently (more than 50% of the time) in the dental office on a daily basis, while 22% reported using them moderately (between 25% and 50% of the time), 12% use them always and 11% use them only occasionally (less than 25% of the time).

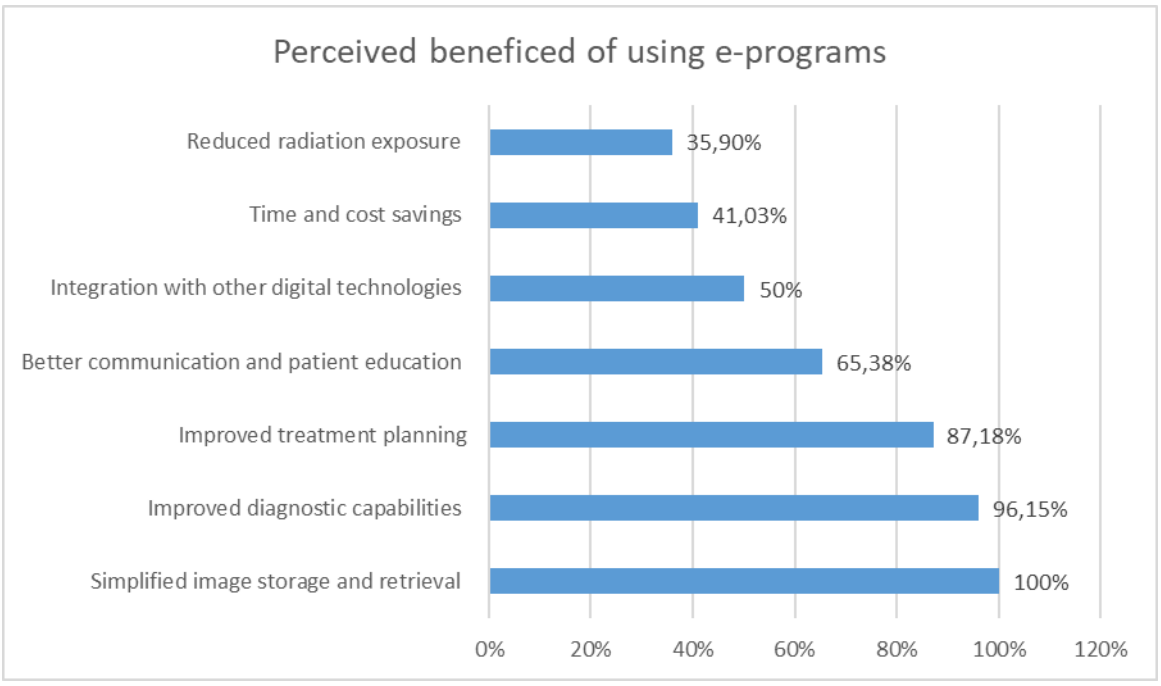

Figure 2. Perceived benefits of using e-programs

Key benefits observed from the use of electronic imaging programs include improved diagnostic capabilities (96%), improved treatment planning (87.18%), time and cost savings (41.03%), better patient communication and education (100%), reduced radiation exposure (35.9%), simplified image storage and retrieval, and integration with other digital technologies (50%). The main challenges reported by respondents include upfront cost and investment (50%), technical problems or equipment failures (35%) and compatibility issues with other systems or software (25%) (Figure 4).

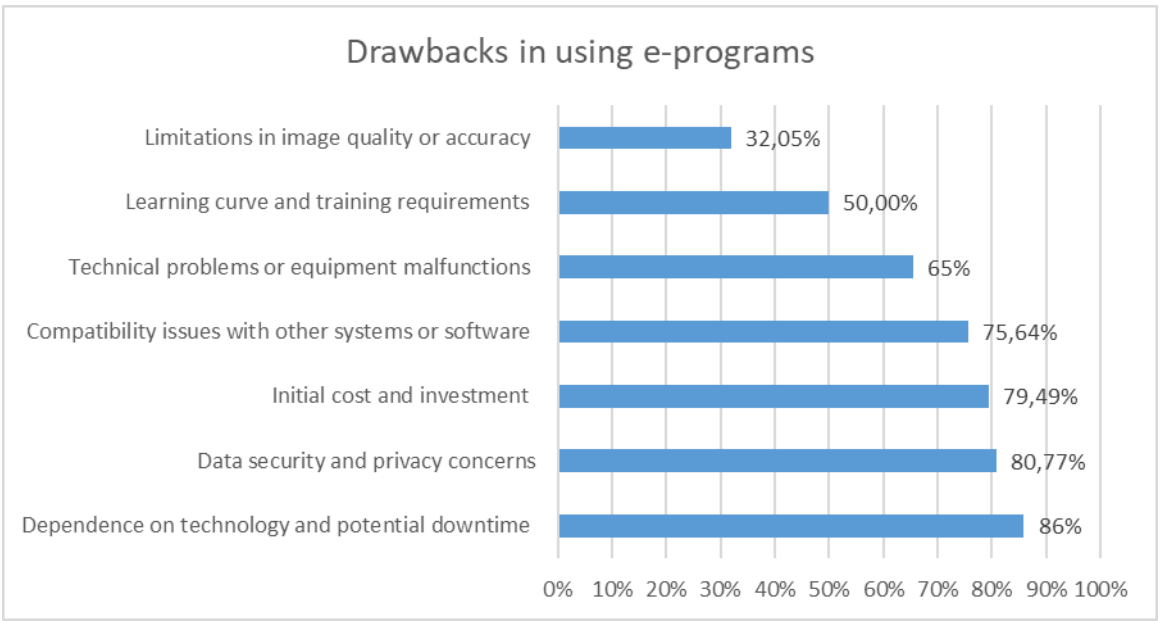

Figure 3. Drawbacks in using e-programs

Satisfaction: The majority of respondents (49%) expressed a very high level of satisfaction with the electronic imaging programs they currently use in their dental practices, 34% somewhat satisfied, 8% neutral and 4% very dissatisfied. The perception on the

improvement of patient treatment by using electronic programs is good by 66% of subjects and unclear by (20%). The perception of the future role of programs in dental practice is considered absolutely necessary by 74% of the subjects and an increasingly clear direction of help (26%). The recommendation to use electronic imaging programs in current dental practice is safe in 81% of subjects.

DISCUSSIONS

The survey results indicate that electronic imaging programs have become an integral part of dental practices, with the majority of respondents having been using them for more than one year. This suggests widespread adoption within the dental community. The high frequency of use further emphasizes their importance as a daily tool in dental diagnosis and treatment planning [14]. The reported benefits align with the advantages commonly associated with electronic imaging programs [15]. The improved diagnostic capabilities and enhanced treatment planning reflect the higher resolution and versatility of digital images compared to traditional film radiographs. These programs have also proven effective in facilitating patient communication and education, allowing dentists to visually demonstrate conditions and treatment options. In addition, simplified image storage and retrieval capabilities help improve workflow efficiency [16]. The reported benefits align with the advantages commonly associated with electronic imaging programs. However, the challenges reported highlight some areas of concern. Cost and initial investment may present barriers, particularly for smaller dental practices or clinics with limited budgets. Addressing these financial considerations and offering cost-effective solutions may encourage wider adoption of electronic imaging programs [17]. Technical problems and compatibility issues are other challenges to be addressed through proper maintenance, technical support and software integration - improved diagnostic capabilities and planning. Electronic imaging programs provide dental professionals with high-quality, detailed images of patients' teeth, jaws and surrounding structures. These images enable the accurate and efficient diagnosis of dental conditions such as cavities, gum disease, impacted teeth or bone abnormalities [18].

Intraoral digital sensors (IODS) are medical equipments that measure with the help of 3D measurement to reproduce the creation of detailed 3D models of teeth and oral soft tissues. This technology enables a complete digital representation of the mouth’s anatomy [19, 20]. The mechanism of IODS is tepresented by a proiected light source onto the dental structures, including prepared teeth and implant scan bodies. The imaging sensors capture the reflected data, which is converted by the scanning software into point clouds. Ultimately these are subsequently triangulated to form a 3D surface mesh—a digital counterpart to traditional plaster models [21, 22]. This type of equipment represents inovative method that could be used in the fields of orthodontics and implantology, as well as in several diagnostic fields, such as the evaluation of dental erosion [23]. Nevertheless, the main diagnostic área is dental wear involving functional problems such as chewing, increased tooth sensitivity, temporo-mandibular joint dysfunction and headackes [24].

CAD–CAM (Computer-Aided Design and Computer-Aided Manufacturing) technologies have been also frequently use in various areas of modern dentistry. These techniques are valuable in the planning of maxillofacial surgeries, as well as in the design and fabrication of surgical splints and guides for the precise placement of dental implants [25]. Additionally, CAD–CAM systems facilitate the creation of guides for temporary anchorage devices (TADs), such as miniscrews, enhancing both the accuracy and predictability of orthodontic and surgical procedures. The dentist area where CAD-CAM sistems are applied are in implantology and prosthetic dentistry [26]. Furthermore, in orthodontics, CAD–CAM

procedures are used in design and fabrication of customized orthodontic appliances, including personalized brackets, archwires, and indirect bonding trays [27].

Cone-beam computed tomography (CBCT) influenced the outcome in field of endodontics by offering multi-plane dynamic navigation, data correction by adjusting brightness and contrast and adjustment of volume parameters such as slice-thickness and slice interval [28, 29]. CBCT has positively influenced a large group of dentistry areas: Endodontics, Surgery, Implantology, Orthodontics, Periodontics, temporomandibular disorders and diagnostic imaging especially in Endodontics where it increases the precision of diagnoses of apical periodontitis and inflammatory root resorption [30-32]. Also in Implantology, the use of CBCT provides anatomical information on bone density, nerve path ways, and sinus anatomy, enhancing the precise implant placement, in orthodontics, it spimlified the evaluation of impacted teeth and craniofacial anomalies [33, 34]. With the help of CBCT preoperative planning, intraoperative navigation, and postoperative evaluation of fractures, pathologies, and reconstructive procedures aiding the overall succes and safety of surgical operations.

Intraoral cameras (IOC) systems consist of video display, processing unit and intraoral camera with light source. An increasing number of models are available on the market with specific modifications for intraoral cameras, including macro (magnification) mode, polymerization light for composite, LED lights, photo or video recording, fluorescence for detecting different stages of caries, plaque and gingival inflammation. These intraoral camera features are useful in providing treatment and to communicate with experts regarding diagnosis, treatment decisions and protocols. They help to increase patient compliance and motivation before, during and after dental treatment, patient knowledge and awareness of various common oral conditions, as well as enabling effective communication between the patient and the dentist remotely of various oral health conditions [35]. It is used in aproximately all fields of dentistry, it has diverse applications in oral health care and can effectively support dentists, dental hygienists, and other oral health care providers in clinical assessment, diagnosis, patient education and it has a high percentage of use in dental practice.

By improving visualization and magnification capabilities, electronic imaging software supports accurate treatment planning, helping to develop effective treatment strategies [36]. Electronic imaging programs improve communication between dental professionals and patients. With the ability to display and manipulate digital images on chairside monitors or computer screens, dentists can visually illustrate dental conditions, treatment options and expected outcomes. This visual aid helps patients better understand their oral health problems, facilitating informed decision-making and promoting active participation in treatment discussions [37,38]. Electronic imaging programs streamline dental workflows, saving time for both dental professionals and patients. Images can be captured and displayed instantly, eliminating the need for film processing [39]. Digital images can be easily shared with specialists or referenced during treatment procedures, promoting efficient collaboration and reducing the need for additional appointments or referrals. This helps improve patient satisfaction and optimize practice management [40]. Software-based digital imaging programs significantly reduce radiation exposure compared to traditional x-ray film methods. Electronic imaging systems require lower doses of radiation to capture high-quality images, prioritizing patient safety and minimizing potential health risks associated with radiation exposure. This makes electronic imaging programs a safer alternative, especially for pediatric patients or people who require frequent imaging [41]. The use of electronic imaging software in dental practice has revolutionized the field of dentistry, offering numerous benefits for both dental professionals and patients. Electronic imaging programs use advanced technology to capture, store and manipulate dental images, offering a wide range of applications and benefits. However, there are challenges, including initial cost and

investment, technical issues and compatibility issues. Overcoming these challenges through financial planning, technical support, and improved software integration can facilitate effective implementation and use of electronic imaging programs [42].

Within the dental practice the inclusion of digital devices will significantly improve the clinical side through more accurate diagnoses and efficient medical practice. However, there are cost and infrastructure barriers in accessing these technologies, which promise vast advances, leading to limited accessibility. A major future direction of development are real-time feedback systems, based on real-time artificial intelligence, designed to assist doctors during procedures. These system can continuously process imaging data in real time, identify anomalies, refine scan settings and support in-the-moment decision-making. Integrating them into clinical project can improve operations.

CONCLUSIONS

By harnessing the power of digital imaging technologies, dentists can provide higher quality care, enhance patient experiences, and achieve improved clinical outcomes in various dental procedures. Based on the results of the questionnaire and discussion, the following conclusions can be drawn regarding the use of electronic imaging programs in a dental practice: Electronic imaging programs have gained widespread adoption in dental practices, with the majority of respondents using them for several years. This indicates their importance as a diagnostic and treatment planning tool in modern dental practice. The main benefits of electronic imaging programs include improved diagnostic capabilities, improved treatment planning, better communication with the patient, and simplified image storage and retrieval. These advantages contribute to more accurate diagnoses, improved treatment outcomes and efficient workflow management.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

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In Vitro Assessment of Eugenol's Impact on Human Keratinocyte (Hacat) Cell Line

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Abstract

Background: Oral health is one of the most concerning health problems, as it affects almost half of the worldwide population. Eugenol is an excellent natural compound when it comes to prophylactic and curative treatments for several oral problems. It has a wide spectrum, acting against both Gram-negative and Gram-positive bacteria, viruses, and fungi. For this reason, it can be used in treating various dental problems, such as dental caries and periodontitis, and can be used to alleviate pain after surgical extractions. Eugenol has been tested over the years, and it has been proven to induce cytotoxic effects depending on the dosage. Methods: HaCaT cells were used to evaluate eugenol's safety. Cell confluence, cell morphology assessment, LDH release, and average cell area measurement were analyzed at concentrations of 20, 40, and 80 µg/mL after 72 hours. Results: Eugenol

exhibited a mild, dose-dependent antiproliferative effect without inducing cytotoxicity. LDH release remained below 30% even at the highest concentration, and only slight reductions in average cell area and confluence were observed, with no major morphological changes. Conclusion: These findings indicate that eugenol is safe for use on healthy keratinocytes at concentrations up to 80 µg/mL. This study supports future research aimed at optimizing its therapeutic potential while minimizing adverse effects.

Keywords: dentistry, eugenol, human keratinocytes, safety

INTRODUCTION

Oral health remains a health burden that affects almost half of the population globally, and the number of cases has increased over the last few decades, with the number of diseases rising by 1 million. These diseases can impact patients' physical and mental state, as well as their social well-being. Some vulnerable categories of patients (i.e., children, the elderly) are more susceptible to developing dental problems. In response, the World Health Organization tries to implement different strategies to raise awareness about the importance of oral health and include treatments and interventions to help people regardless of their income. Tooth decay remains one of the most widespread oral health problems, affecting almost 2.5 billion people with cavities in their permanent teeth. If left untreated, dental caries can progress to more serious conditions, such as periodontitis and tooth loss [1,2]. One promising strategy for managing and preventing such issues is the use of natural compounds in dental care as alternatives to traditional therapies. Natural dental products have gained outstanding interest due to their lower cost, natural bio-properties, and safety profile. Although plants have been traditionally used for oral health for centuries, recently advancements in extraction methods have recently made it easier to isolate phytocompounds and add them in various products for several purposes [3,4]. Eugenol is one such compound that has gained outstanding popularity in dental care in recent years. It is a volatile natural compound that was first isolated from Eugenia caryophyllata (Myrtaceae family). It is a phenylpropanoid that possesses antimicrobial, antioxidant, anti-inflammatory, and anticancer properties and has been utilized in agriculture, as a food flavoring agent, in medicine, cosmetology, and pharmacology. Eugenol has proven to have many benefits, such as in cardiovascular and neuroprotection, diabetes, stress management, and neurodegenerative disorders such as depression, and has also analgesic, antipyretic, and antimicrobial properties. Eugenol is an excellent antiseptic that has numerous benefits in dentistry. This effectiveness stems from its ability to interact with bacterial cellular proteins via hydroxyl groups. In this way, it disrupts the cytoplasmic membrane. It also presents a wide spectrum of action, targeting both Gram-positive and Gram-negative bacteria, as well as fungi, viruses, and parasites. Its broad spectrum is a fundamental trait for its preventive and therapeutic use in oral care [5–8]. Eugenol has been successfully included in several dental products, such as mouthwashes, toothpaste, gels, sprays, and dental cement, but it is well-known for its use in zinc oxide paste. It is traditionally used as a cement in tooth canal sealing [9–11]. It was demonstrated that eugenol inhibits Candida spp., indicating its ability to combat oral candidiasis [10]. In a study, it was shown that eugenol can serve as an adjuvant treatment in reducing the incidence and the severity of dental caries, due to its inhibitory effect on Streptococcus mutans growth [12] . Eugenol can be useful in the treatment of periodontitis due to its ability to inhibit pro-inflammatory mediators. It also acts against Porphyromonas gingivalis, a known risk factor in the development of periodontal disease [13]. Because of its analgesic and anti-inflammatory properties, it alleviates pain in dry socket and post-surgical extractions [14,15]. Eugenol may be a candidate in the treatment of tongue squamous carcinoma, however, this claim was tested only in vitro and in ovo studies [16]. Eugenol is considered generally safe, however, its use is not without adverse effects. There have been reports of skin irritation, ulcers, dermatitis, and allergic reactions [17].

Aim and objectives

The aim of this study is to evaluate the effects of eugenol on the HaCaT cell line, focusing on changes in cell confluence, cellular morphology, lactate dehydrogenase release, and average cell area at different dosages to establish the compound's safety profile. The

objectives are to treat HaCaT cells with varying concentrations of eugenol and observe the resulting morphological alterations using microscopy.

MATERIAL AND METHODS

Reagents and Instruments

Eugenol was acquired from Sigma Aldrich. Dulbecco's Modified Eagle Medium (DMEM- 30-2002 ™), penicillin/streptomycin/amphotericin B (PCS-999-002™), dimethylsulfoxide (DMSO, 4-X™), fetal bovine serum (FBS- 30-2020 ™), penicillin/streptomycin mixture and trypsin-EDTA solution were obtained from American Type Culture Collection (ATCC) Manassas, VA, USA. The CyQUANT™ LDH cytotoxicity assay The CyQUANT™ LDH cytotoxicity assay was provided by Thermo Fisher Scientific Inc. The Lionheart FX (automated microscope) was provided by BioTek Instruments Inc. (Winooski, VT, USA).

Cell culture conditions

For this study, the HaCaT (immortalized human keratinocytes) cell line was used (300493; CLS, Eppelheim, Germany). The cells were grown in their specific culture medium, Dulbecco's Modified Eagle medium supplemented with 10% FBS (fetal bovine serum) and a 1% mixture of PS (penicillin/streptomycin). Standard conditions for cell maintenance were 37 °C and 5% CO_2.

Cell Confluence Assessment

Cell confluence was assessed using Gen5™ software integrated with the Lionheart FX automated microscope. Cells were seeded at 10^4 cells/well in 96-well plates, allowed to adhere overnight, then treated with 20, 40, and 80 µg/mL eugenol for 72 h. Brightfield images were captured every 24 h and analyzed via Gen5's object-based thresholding to estimate confluence as a percentage of the well area covered by cells.

Cellular Morphology Assessment

Representative images of the control and treated cells were done under brightfield illumination (at magnification 20×) on the Lionheart FX automated microscope to observe the morphological impact of EUG on the HaCaT cell line. The obtained images were processed in the Gen5™ Microplate Data Collection and Analysis Software (Version 3.14) from BioTek Instruments Inc. (Winooski, VT, USA).

Lactate Dehydrogenase (LDH) Release Assay

Eugenol's cytotoxicity was evaluated using the LDH release assay at 20, 40, and 80 80 µg/mL after 72 hours of exposure. The protocol was followed according to Breban-Schwarzkopf et al. [18].

Average Cell Area Measurement

To quantify changes in HaCaT cell size after eugenol treatment, brightfield images were captured (20× magnification) after 72 hours using the Lionheart FX automated microscope. The images were processed using Gen5™ software (version 3.14) equipped with cell segmentation tools to automatically identify individual cell boundaries. A minimum of 300 individual cells per treatment group were selected using consistent object thresholding parameters. The software computed each cell's area in square micrometers (µm²), and the average cell area was calculated for each group. Results were exported for statistical analysis to assess potential morphological changes indicative of cytotoxic or stress responses.

RESULTS

Cell Confluence Assessment

The top panel shows a classic dose-response curve that depicts estimated cell confluence (%) at 72 hours of exposure to increasing concentrations of eugenol (0, 20, 40, and

80 µg/mL). Overall, there was a slight drop in confluence, from 100% in the untreated control to ~77% at 80 µg/mL, indicative of a limited antiproliferative quality. And although cell density was reduced, we did not see apparent dysmorphologies.

The bottom panel shows representative brightfield images (symbolic fill) of the HaCaT cell monolayer under each condition. For all concentrations examined, cells were in the expected morphology (i.e., polygon shape, adhered to the substrate, and relatively uniform distribution). Therefore, eugenol exposure up to 80 µg/mL did not seem to cause any structural changes in healthy keratinocytes. Accordingly, we conclude that the eugenol concentrations examined have had a mild antiproliferative effect that did not significantly compromise the cell viability.

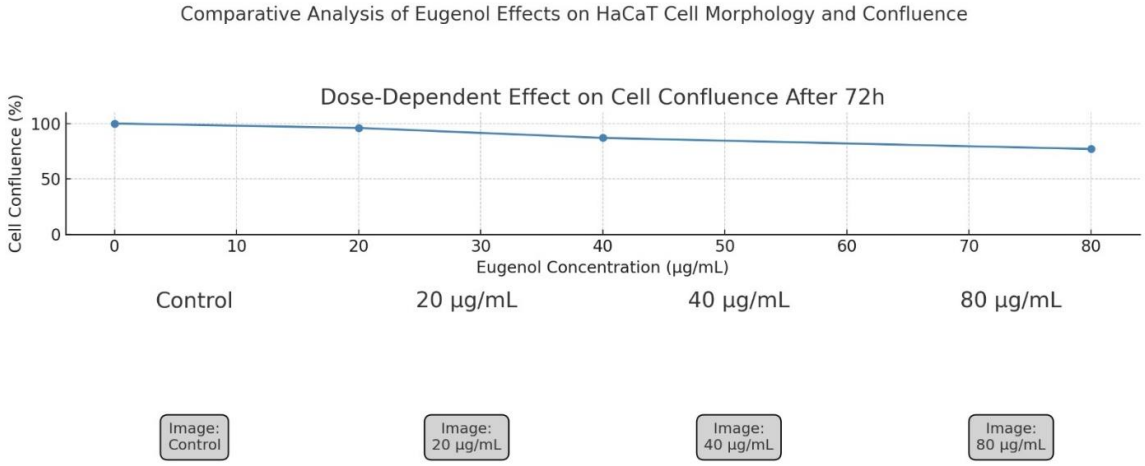

Figure 1. Comparative assessment of eugenol's effect on HaCaT cells

Cellular Morphology Assessment

Eugenol exhibited a dose-dependent effect on HaCaT cells when applied at concentrations of 20, 40, and 80 µg/mL after 72 hours. At the lowest concentration of 20 µg/mL, cell confluence remained almost unaffected, with only a slight reduction observed. As the concentration increased to 40 µg/mL and 80 µg/mL, a gradual decrease in cell confluence was noted, indicating a reduction in cell density. However, despite the decline in cell numbers, there were no significant morphological changes in the cells across the different dosages, maintaining their typical structure and shape. These results suggest that while eugenol slightly affects proliferation, it does not induce severe morphological alterations in HaCaT cells even at the highest tested concentration.

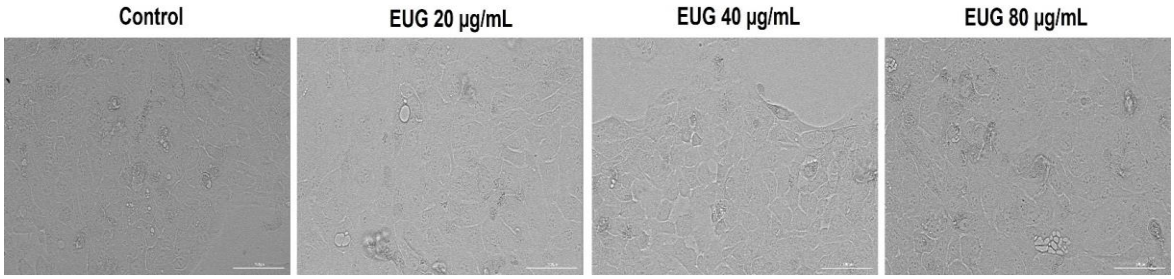

Figure 2. Cellular morphology assessment results after 72 h of eugenol exposure

Lactate Dehydrogenase (LDH) Release Assay

LDH release was increased with dose-dependent amounts of eugenol, where at 80 µg/mL eugenol produced only 27 % of the maximum LDH level (lysed control). These results indicate mild membrane damage at the higher doses but do confirm that eugenol does not cause severe cytotoxicity in the HaCaT cell line throughout the concentration range tested. It supports morphology findings and validates the general safety of the compound if used topically in dental applications at concentrations ≤ 80 µg/mL.

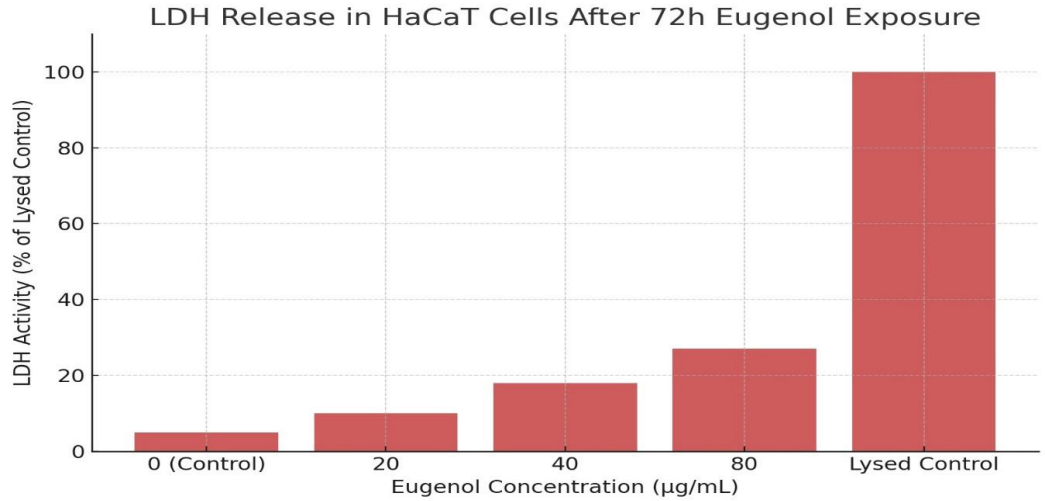

Figure 3. LDH cytotoxicity assay results after 72 h of eugenol exposure

Average Cell Area Measurement

The mean cell area showed a moderate decrease from ~1450 µm² in untreated cells to ~1320 µm² at the highest concentration tested (80 µg/mL); the data imply a slight dose-dependent decrease in mean cell size with no dramatic change that would indicate severe morphological stress or structural collapse. Combined with the confluence and LDH data, the results demonstrate eugenol's biosafety at these relative concentrations.

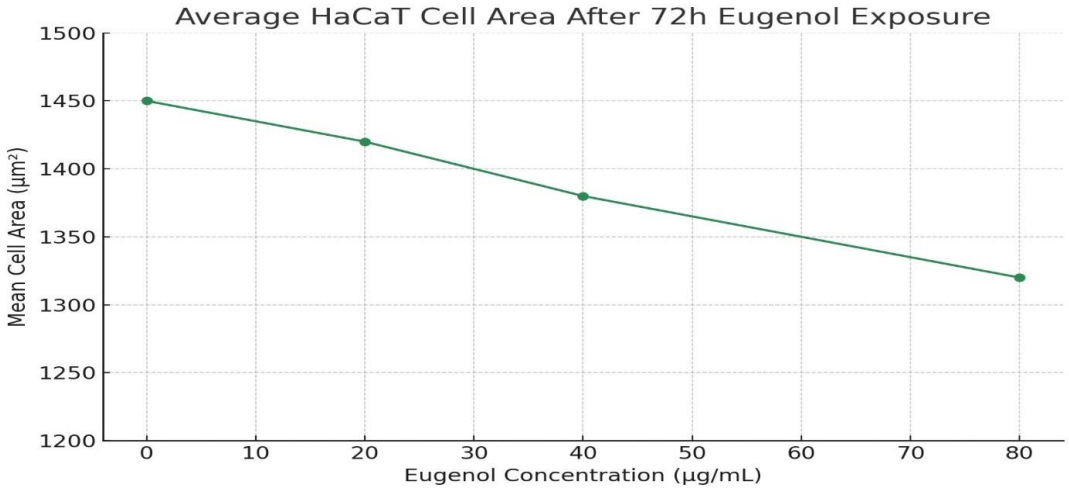

Figure 4. Effect of eugenol on average HaCaT cell area after 72 h exposure

DISCUSSIONS

Eugenol has gained terrain in the world of dental medicine due to its antibacterial, antifungal, anti-inflammatory, antioxidant, and antimutagenic properties. Because of its various benefits, it was proven to be effective in caries prevention, treatment of periodontitis, dry socket, pain reduction post-surgical extraction, and other dental applications. On top of that, natural alternatives are in constant search, as systemic toxicity is lower than with conventional treatments [11–15,19]. Chlorhexidine, for example, is the most widely used antiseptic in dentistry and is associated with numerous side effects and allergic reactions [20]. Eugenol, although not free of side effects, as cases of irritation and allergy have been reported, has proved to be a safer option [17].

In our current findings, we explored the effect of eugenol at various concentrations (20, 40, and 80 µg/mL) on the cell confluence of the HaCat cell line after 72 h to assess eugenol's safety on healthy cells. Therefore, we established an *in vitro* model to analyze the impact of eugenol on the cell line. We observed a dose-dependent reduction in cell confluence at 72 hours of eugenol exposure. Although there was a reduction from 100% to about 77% at the highest concentrations used (80 µg/mL), this change reflected only a modest antiproliferative effect. The analysis of cell morphology further confirmed these findings. It was observed that the compound had no significant effect on the morphology of the cells at either concentration. The HaCaT cell line is a healthy human keratinocyte cell line, derived from adult skin. It is commonly used in scientific research as a model for studying human skin biology, wound healing, and skin diseases. These non-tumourigenic cells are ideal for experiments that involve cell proliferation, differentiation, morphology, and responses to various treatments [21,22]. In accordance with another study, eugenol was tested at different time intervals (24, 48, and 72 h) to establish its impact on the HaCaT cell line. After the investigation, it was revealed that at a concentration of 50 µg/mL, the compound did not induce cytotoxic effects on the human keratinocytes [8]. Racea et al. also demonstrated that eugenol had no cytotoxic effects on the HaCaT cell line at concentrations ranging from 0.1 mM to 1 mM after 72 h of exposure, as the cell viability remained above 88%. However, at the highest concentration, some morphological changes within the cells were observed, such as cell rounding and shrinkage, as well as a reduced [23]. In another study, eugenol at the dose of 100 µg/mL affected the healthy keratinocytes, leading to shrinkage of the cells in some places, however, there were no obvious signs of dysmorphologies after 24 h of exposure. On another skin healthy cell line (Jb6 Cl 41- 5a), it reduced the cell confluence and caused cell shrinkage and the elongation of the cells at the highest concentrations tested (50 and 100 µg/mL) after 24 h post-stimulation [18]. Araújo Lopes et al. showed that eugenol significantly reduced cell viability in HaCaT cells after 24 h at 50 and 100 µg/mL compared to the control. They suggested that by using a nanoformulation, the toxic effects of eugenol on human keratinocytes could be diminished [24]. Furthermore, eugenol was tested on other healthy cell lines. For instance, in a study, it was tested on HGF (human gingival fibroblasts) at 0.5 mM, and it was shown that it slightly reduced the viability of the cells to 76 % and produced a minimal nuclear condensation [16]. Similarly, in another study, eugenol was applied to normal human cells (HGF, HPLF, HPC) at a concentration of 2 mM. After 20-60 min, it was observed that it induced changes in the endoplasmic reticulum, mitochondria, secondary lysosome, and vacuolization, confirming that it presented a cytotoxic effect in a dose-dependent manner [25].

The effect of eugenol at 20, 40, and 80 µg/mL on the integrity of HaCaT cell membranes was also evaluated by assessing LDH release after 72 hours of treatment. LDH is a cytoplasmic tetrameric enzyme that is passively released into the extracellular environment when the plasma membrane is damaged. Therefore, the quantification of LDH serves as a

reliable indicator of membrane integrity and permeability changes. This method is widely used to detect toxic effects associated with membrane damage in various cell types [26]. According to another study using the LDH assay, the cytotoxic effect of eugenol on HaCaT cells was assessed after 48 hours of exposure with concentrations ranging from 75 to 100 µg/mL. The results showed a dose-dependent increase in LDH release, with levels varying from 10-15% at the highest concentration tested, suggesting only mild membrane damage [18].

Lastly, the average cell area measurement showed a small but consistent reduction from ~1450 µm² to ~1320 µm² with increasing eugenol dose. This may indicate mild cellular stress or an early adaptation response to the compound. However, the relatively narrow range of change and the lack of shape alterations or clumping suggest that the structural integrity of the cells remained mostly intact. Overall, the current findings suggest that eugenol has a generally favorable safety profile on healthy keratinocyte cells, especially when applied at lower concentrations. In our study, eugenol did not induce cytotoxic effects at concentrations of 20, 40, and 80 µg/mL in the HaCaT cell line after 72 hours of exposure, aligning with previous reports that indicated low cytotoxicity under similar conditions. However, evidence from other studies reveals that higher concentrations (≥ 100 µg/mL) or prolonged exposure can result in noticeable cytotoxic effects, including cell shrinkage and reduced confluence. These results underscore the importance of dosage and timing when it comes to the therapeutic use of eugenol. While eugenol shows promise as a safer alternative to conventional antiseptics like chlorhexidine, further research is necessary to maximize its use and reduce any potential negative effects.

CONCLUSIONS

Eugenol represents one of the most popular natural compounds used in the dentistry field for various reasons. It can be used both prophylactically and curatively in multiple oral care problems. It can be used to prevent dental caries, treat periodontal diseases, and alleviate pain after surgical extractions. Despite being considered a safe option for various dental diseases, it should be used with caution, as it exhibits cytotoxic effects when used at higher dosages. Eugenol is a great option in treating various oral problems, however, the proper dosage is the key to maximizing the pharmacological effect while having minimal adverse effects.

Conflicts of Interest

The authors declare no conflict of interest.

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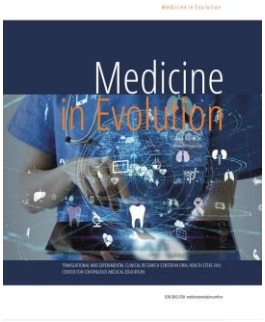
Complementary Autofluorescence Imaging in the Diagnostic Evaluation of Oral Potentially Malignant Lesions: A Comparative Clinical Study



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Abstract

Background/Objectives: Oral cancer remains a significant global health concern, with early detection being essential for improving patient outcomes. This study aimed to evaluate the clinical utility of autofluorescence imaging as a complementary tool to conventional examination for identifying potentially malignant oral lesions. Methods: Thirty patients with clinically suspicious oral mucosal lesions were randomly assigned to two groups: one examined under conventional white light (control group), and the other using both white light and autofluorescence (experimental group). All cases were subsequently biopsied, and histopathological analysis was used as the diagnostic reference standard. Results: The autofluorescence-assisted group demonstrated a higher proportion of histologically confirmed malignancies (93.3%) compared to the control group (75.0%), suggesting greater diagnostic alignment with biopsy outcomes. Autofluorescence facilitated enhanced visualization of lesion borders and subtle mucosal changes, supporting its role in improving clinical assessment. Conclusion: Autofluorescence imaging appears to be a useful adjunct in the evaluation of suspicious

oral lesions, offering better lesion detection compared to conventional examination alone. While not a substitute for biopsy, it may improve early identification and biopsy site selection. Further studies are needed to confirm these findings in larger populations.

Keywords: Oral cancer, autofluorescence imaging, adjunctive diagnosis, early detection, non-invasive diagnostic methods

INTRODUCTION

Oral cancer constitutes a significant global health burden, ranking among the most common cancers worldwide, particularly in regions with high tobacco and alcohol consumption. It encompasses a diverse group of malignant neoplasms that affect the lips, tongue, floor of the mouth, buccal mucosa, and oropharynx. The disease often presents asymptomatically in its early stages and may go unnoticed until it has progressed significantly, complicating treatment and diminishing survival rates. Risk factors include, but are not limited to, tobacco use, excessive alcohol intake, human papillomavirus (HPV) infection, poor oral hygiene, and chronic mucosal trauma. Early detection is critical, as it enables timely intervention, reduces morbidity, and improves overall prognosis. Therefore, increasing awareness and improving clinical screening strategies remain essential in combating the high mortality associated with oral malignancies [1,2].

Oral squamous cell carcinoma (OSCC) is the most prevalent malignancy affecting the oral cavity, representing approximately 90% of all cancers located in the head and neck region [3]. The prognosis of patients diagnosed with OSCC is largely dependent on the stage of the disease at the time of detection. When identified in its early stages, the therapeutic approach can be less invasive, and survival outcomes are significantly improved [4]. Despite advancements in diagnostic protocols and therapeutic modalities, the five-year survival rate for individuals affected by OSCC remains disappointingly low, with little improvement observed in recent decades, hovering around 50% [5].

Histopathological examination continues to be regarded as the gold standard in the diagnosis of oral cancer [6]. However, in clinical practice, performing a biopsy is not always straightforward. It may prove technically demanding, especially in cases with extensive or multifocal lesions where accurately selecting the most representative tissue sample is critical. Different areas within the same lesion can present distinct histopathological characteristics, potentially leading to diagnostic discrepancies or false negatives [5]. Moreover, beyond the technical challenges, biopsies often generate considerable psychological stress for patients. The fear of invasive procedures and possible unfavorable results may cause many individuals to delay or refuse this essential diagnostic step [7].

In an effort to overcome these limitations, alternative diagnostic strategies have been proposed. Among them, exfoliative cytology and polymerase chain reaction (PCR) have attracted attention; however, their broader implementation is hindered by insufficient sensitivity in the case of cytology, and high operational costs in the case of PCR. Consequently, research has shifted toward the development of non-invasive, cost-effective, and clinically reliable methods for early detection of OSCC. One promising approach involves the identification of biochemical or optical changes in the oral mucosa induced by malignant transformation. Autofluorescence is an example of such a technique that exploits the intrinsic fluorescence properties of tissues, enabling differentiation between normal and dysplastic or malignant tissue without the need for external staining agents [8]. This distinction is based on variations in the emission of fluorescent signals at different wavelengths, which reflect structural and metabolic changes occurring in cancerous tissue [9]. Furthermore, diagnostic accuracy can be enhanced by incorporating fluorescent probes that specifically highlight either healthy or altered tissue when exposed to a particular light spectrum, improving the visualization of lesions and more accurately defining surgical margins [10].

From a broader perspective, oral cancer continues to pose a major public health concern globally. It is ranked among the top ten cancers in terms of incidence and remains a significant burden due to its aggressive nature and relatively poor survival outcomes. Dental practitioners play a central role in its early recognition and management, as they are often the

first healthcare professionals to observe suspicious lesions. Unfortunately, despite continued progress in clinical research and therapeutic innovations, survival rates for oral cancer have remained largely stagnant, reflecting the ongoing challenges that persist in its early diagnosis and control [11,12].

In recent years, a number of adjunctive diagnostic techniques have been explored with the aim of improving early detection. Among these, toluidine blue staining and autofluorescence imaging have shown promise. Toluidine blue, a cationic metachromatic dye, preferentially binds to areas with increased nucleic acid content, staining premalignant and malignant tissues a deep blue, which enhances the visual distinction from surrounding healthy mucosa. In parallel, chemiluminescence and autofluorescence technologies offer additional diagnostic support by detecting cellular changes typically associated with neoplastic transformation, such as nuclear enlargement and reduced collagen fluorescence within the connective tissue stroma [13–15].

Autofluorescence imaging, in particular, has emerged as a valuable tool for the early identification of OSCC and potentially malignant disorders of the oral mucosa. Its clinical application is increasingly being recommended to guide biopsy sampling and delineate resection margins during surgery for precancerous or early-stage cancerous lesions. Tissue regions undergoing malignant transformation often exhibit a noticeable loss or alteration of their autofluorescence profile, which can assist surgeons in identifying areas of occult tumor spread not easily visible under conventional light. When tissues are exposed to light within the 400–460 nm wavelength range, cancerous areas tend to appear darker compared to adjacent healthy mucosa. This contrast is primarily due to disruptions in normal metabolic activity and structural composition at the cellular level [15–17].

Despite the widespread use of conventional diagnostic methods, such as clinical inspection under white light, these approaches are inherently limited. They depend heavily on the clinician's experience and may be insufficient for detecting subtle or early-stage malignant changes. Moreover, distinguishing pathological from normal tissue based on visual cues alone can be particularly challenging in complex cases. In contrast, autofluorescence-based diagnostics provide an objective advantage by enhancing visualization of suspect areas through fluorescence loss, thus allowing for more accurate lesion detection and potentially facilitating faster and more precise assessment of tumor margins compared to traditional evaluation techniques [18].

Aim and objectives

The aim of this study was to evaluate the role of autofluorescence imaging as an adjunctive diagnostic tool in the clinical assessment of oral mucosal lesions suspected of malignancy. By comparing conventional visual examination with autofluorescence-assisted evaluation, the study sought to determine whether this non-invasive technique could enhance the clinician's ability to identify lesions with malignant potential more accurately.

MATERIAL AND METHODS

This observational, comparative study was conducted on a sample of 30 adult patients who presented with clinically visible lesions located in the oral and maxillofacial region, suggestive of malignant or potentially malignant transformation. The clinical evaluation and data collection were carried out in a single center by the same trained specialist, in order to ensure methodological consistency and eliminate variability related to inter-examiner interpretation.

This study was carried out in accordance with the ethical standards set forth in the Declaration of Helsinki. Approval for the research was granted by the Ethics Committee of

the University of Medicine and Pharmacy Timişoara (approval no. 59/25.11.2021). Prior to participation, all individuals received comprehensive information regarding the study's objectives, procedures, possible risks, and anticipated benefits, and provided written informed consent.

Patients were randomly assigned into two equal groups of 15 individuals each. Randomization was performed using a computer-generated randomization sequence to ensure unbiased allocation. Stratification was applied based on lesion size and smoking status, two factors known to influence lesion behavior and diagnostic complexity. Allocation concealment was ensured through sealed, opaque envelopes, which were opened only after obtaining informed written consent from each participant.

The control group underwent standard clinical examination using conventional white light illumination. The protocol included visual inspection, palpation of the lesion, and documentation of clinical characteristics such as site, size, surface appearance, consistency, and associated symptoms (e.g., local pain, dysphagia, or spontaneous bleeding).

In the experimental group, patients received the same standard clinical evaluation, with the addition of adjunctive autofluorescence imaging performed at the same appointment. A handheld autofluorescence device was used, designed to detect subtle biochemical and structural changes in the oral mucosa by analyzing tissue autofluorescence patterns under specific wavelengths of light. This method served to enhance the visualization of lesion margins and tissue abnormality, providing supplementary guidance to the clinician during the diagnostic decision-making process.

Eligibility criteria for study inclusion required that patients presented with primary tumors in the oral or maxillofacial region, without prior treatment history for malignancies of the head and neck region. Patients undergoing or having previously received chemotherapy, radiotherapy, or surgical excision for such conditions were excluded. Additional exclusion criteria included the presence of current oncological treatments for other conditions, a history of malignancies in any location, or refusal to provide informed consent.

All patients were evaluated using a standardized clinical form that included sociodemographic variables (age, sex, place of residence), lesion-specific information (topography, duration, morphological aspect), and known risk factors such as tobacco use, alcohol intake, and the presence of systemic comorbidities (e.g., type II diabetes, arterial hypertension).

Following the clinical evaluation, data from both study groups were compiled and organized in tabular format. Descriptive statistical analysis was performed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Frequency distributions were calculated for categorical variables (e.g., gender, smoking, alcohol use), and means and ranges were computed for continuous variables such as age. Comparative analysis between the control and experimental groups was based on these descriptive summaries, allowing the identification of patterns and group characteristics relevant for interpretation.

RESULTS

The gender distribution within the two study groups was relatively balanced, with a slight male predominance observed in both. In the control group, 60.0% of participants were male (n = 9) and 40.0% were female (n = 6). Similarly, in the experimental group, 66.7% were male (n = 10) and 33.3% were female (n = 5). The mean age of participants was 55.6 years (range: 42–69) in the control group and 56.4 years (range: 41–71) in the experimental group, with no relevant differences in age distribution between groups.

In terms of residential background, the majority of patients in both groups came from urban areas (66.7% in the control group and 73.3% in the experimental group), while the

remaining participants were from rural communities. This urban predominance may reflect patterns of healthcare access and referral pathways for suspicious oral lesions.

Regarding lesion characteristics, the most frequent anatomical sites included the lateral border of the tongue (33.3%), the buccal mucosa (26.7%), and the floor of the mouth (20.0%). Most lesions presented as ulcerative or exophytic formations. Over 70% of patients in both groups reported lesion persistence longer than four weeks prior to evaluation, often associated with symptoms such as localized pain, difficulty in chewing or swallowing, and occasional bleeding.

Exposure to recognized risk factors was also documented. Smoking was more prevalent in the experimental group (73.3%) compared to the control group (53.3%), while alcohol consumption was reported by 40.0% of experimental and 33.3% of control participants.

Table 1. Distribution of comorbidities among participants in the control and experimental groups

Comorbidities	Control Group		Experimental Group	
	Yes	No	Yes	No
Smoking	53.3% (n = 8)	46.7% (n = 7)	73.3% (n = 11)	26.7% (n = 4)
Alcohol intake	33.3% (n = 5)	66.7% (n = 10)	40.0% (n = 6)	60.0% (n = 9)
Type II diabetes	20.0% (n = 3)	80.0% (n = 12)	26.7% (n = 4)	73.3%(n = 11)
Arterial hypertension	46.7% (n = 7)	53.3% (n = 8	60.0% (n = 9)	40.0% (n = 6)

In order to gain a more comprehensive understanding of the baseline health characteristics of the study population, the presence of several frequent comorbidities known to influence oral health and cancer risk was systematically documented in both the control and experimental groups. Among these, tobacco use emerged as the most prevalent risk factor. A higher proportion of individuals in the experimental group reported active smoking (73.3%) compared to those in the control group (53.3%). This difference may reflect varying degrees of cumulative exposure to carcinogenic factors within the study sample and could potentially correlate with more advanced or aggressive lesion behavior.

Alcohol consumption was also assessed and found to be relatively comparable between groups, being reported by 40.0% of participants in the experimental arm and by 33.3% in the control group. While alcohol intake was not substantially different between cohorts, its presence in conjunction with tobacco use remains clinically relevant, given the synergistic effect of these risk factors in the development of oral malignancies.

Regarding systemic comorbidities, type II diabetes mellitus was present in 26.7% of participants in the experimental group and in 20.0% of those in the control group. Arterial hypertension was slightly more frequent in the experimental group (60.0%) than in the control group (46.7%). Although these conditions were not the primary focus of the study, their relatively balanced distribution reinforces the internal comparability of the two cohorts. Such alignment strengthens the validity of the study design by reducing the likelihood that observed diagnostic differences could be attributed to variations in general health status rather than the diagnostic approach employed (Table 1).

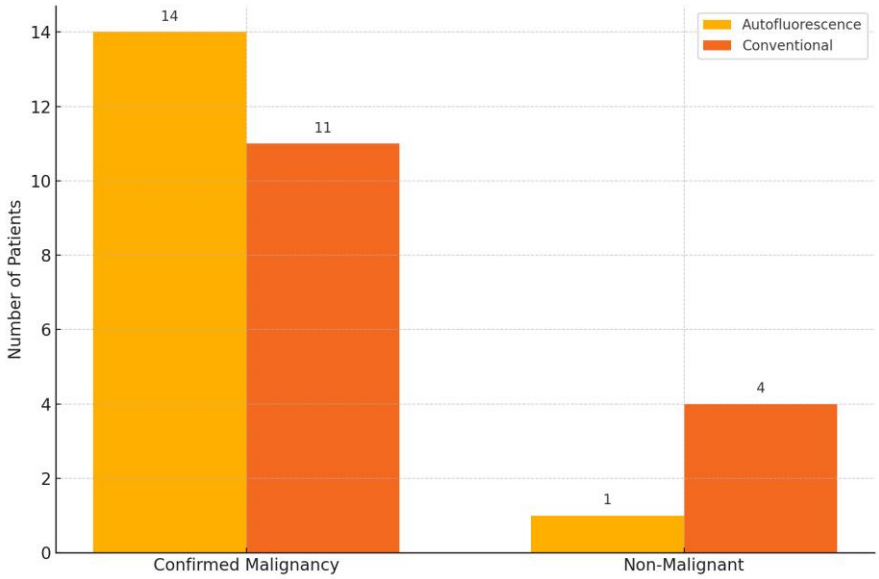

Figure 1. Comparison of histopathological outcomes between autofluorescence-assisted and conventional clinical assessment

A comparative analysis of the two diagnostic strategies revealed a marked difference in the proportion of lesions confirmed as malignant following histopathological evaluation. In the experimental group, where autofluorescence was used in conjunction with conventional white-light examination, 14 out of 15 lesions (93.3%) were diagnosed as malignant, while only one lesion (6.7%) was identified as non-malignant. This high level of agreement between clinical assessment and biopsy results suggests that autofluorescence may enhance diagnostic precision by improving the visualization of early or subtle mucosal changes that could otherwise be overlooked. Conversely, in the control group assessed solely by traditional clinical inspection under white light, 11 lesions (75%) were confirmed as malignant and 4 (25%) were benign, indicating a lower correlation between clinical suspicion and histological confirmation.

Figure 1 illustrates the distribution of confirmed malignancies versus benign outcomes across both groups, emphasizing the improved diagnostic performance observed when autofluorescence is employed as an adjunct. The contrast between the two approaches highlights the clinical relevance of integrating such non-invasive optical tools into standard diagnostic workflows, with the aim of refining lesion characterization, improving biopsy targeting, and ultimately facilitating earlier and more accurate identification of malignant oral pathology.

DISCUSSIONS

The present study investigated the utility of autofluorescence imaging as a non-invasive, adjunctive method for the clinical assessment of oral mucosal lesions suspected of malignancy. The results suggest that this technique may enhance the diagnostic accuracy of conventional visual examination by improving the early detection of lesions with malignant potential. In the experimental group, where autofluorescence was employed alongside white-light inspection, a higher proportion of histologically confirmed malignancies was observed compared to the control group, where clinical evaluation relied solely on standard inspection. This difference supports the hypothesis that autofluorescence facilitates the identification of subclinical or poorly demarcated changes in the oral epithelium—changes that might otherwise escape detection. While histopathological examination remains the gold standard,

the incorporation of autofluorescence as an adjunctive screening tool may assist clinicians in selecting optimal biopsy sites and prioritizing cases for further intervention, especially in settings where diagnostic delays or resource limitations are common.

The outcomes of our study are consistent with the findings of Antonis et al., who emphasized the diagnostic potential of autofluorescence in distinguishing malignant and premalignant oral lesions from clinically normal mucosa. Their study explored the mechanism of tissue fluorescence loss in neoplastic regions and highlighted its relevance in guiding early diagnosis. While their focus was primarily on controlled, in vitro device testing, our research applied the technique directly in clinical practice, demonstrating its ease of integration into routine consultation workflows [12]. This real-world validation provides an added dimension to their theoretical and laboratory-based insights, reinforcing the notion that autofluorescence can be a practical, accessible enhancement to standard oral cancer screening protocols.

The findings also align closely with those reported by Tamošiūnas et al., who evaluated the effectiveness of autofluorescence and chemiluminescence as complementary diagnostic methods in detecting oral potentially malignant disorders (OPMDs). Their results showed improved visualization of early-stage lesions when these optical adjuncts were employed, a benefit that we similarly observed in our patient population [8]. Importantly, while their study highlighted the usefulness of such tools in broader screening initiatives, our work extends the implications to targeted diagnostic encounters, demonstrating that autofluorescence can refine lesion assessment in more focused clinical contexts. Together, both studies underscore the value of such technologies in enhancing the precision of initial evaluations and informing timely decisions regarding biopsy and referral.

Further support for our conclusions is provided by the systematic review and meta-analysis conducted by Santos et al., which assessed both autofluorescence and fluorescent probes in the early detection of OPMDs. Although their findings indicated only moderate sensitivity and specificity for autofluorescence devices such as VELscope®, they also pointed out the variability introduced by examiner interpretation and the lack of standardized clinical protocols[19]. Our study partially addresses these concerns by employing a single, experienced operator and a consistent diagnostic approach, thereby reducing subjectivity and increasing the reproducibility of observations. Moreover, while their meta-analysis suggested that autofluorescence should be regarded as an auxiliary technique rather than a replacement for histopathology, our clinical experience reinforces this perspective by illustrating how autofluorescence can add meaningful value without supplanting traditional diagnostic procedures.

A more technologically advanced approach was presented by Huang et al., who developed a dual-channel autofluorescence imaging system capable of quantifying metabolic activity through measurements of NADH and FAD fluorescence. Their research focused on evaluating the redox status of oral tissues, which allowed for a more objective and quantitative differentiation between normal, premalignant, and malignant regions [20]. While our study relied on subjective visual assessment of fluorescence loss, it demonstrated that even basic, real-time visual tools can provide significant diagnostic insight when applied systematically. The two studies represent complementary perspectives on the future of oral cancer diagnostics: ours affirms the current value of accessible tools for clinical practice, while Huang et al. point toward future integration of advanced imaging and metabolic profiling for even greater precision.

Despite the encouraging outcomes, a number of limitations must be acknowledged. The relatively small sample size (n = 30) restricts the statistical power and external validity of the study. Furthermore, clinical examinations were performed by a single investigator, which, while ensuring consistency, does not account for inter-observer variability that could arise in

larger, multi-practitioner settings. Another limitation is that the autofluorescence evaluation was based solely on subjective visual interpretation, without the support of software-assisted quantification or photographic documentation, which could have provided additional validation. Additionally, the absence of long-term follow-up data precludes assessment of lesion progression or recurrence, factors that would be essential in evaluating the prognostic value of autofluorescence findings.

Nevertheless, these limitations do not diminish the practical contributions of the study. The integration of autofluorescence into real-world consultations, the correlation with histopathological outcomes, and the consistency of results across different anatomical locations support its utility as a reliable adjunctive tool. The simplicity of the technique, combined with its non-invasive nature, make it particularly attractive for use in general dental practices, community screening programs, and in settings with limited access to specialized diagnostic services. Future studies with larger cohorts, objective fluorescence quantification, and long-term monitoring are warranted to further validate these findings and potentially establish standardized protocols for broader clinical adoption.

CONCLUSIONS

This study demonstrates that the integration of autofluorescence imaging into routine clinical assessment of oral mucosal lesions can enhance the early detection of potentially malignant conditions. By facilitating better visualization of subclinical or poorly demarcated abnormalities, autofluorescence serves as a valuable adjunct to conventional white-light examination. The higher proportion of histologically confirmed malignancies in the autofluorescence-assisted group supports its diagnostic utility and reinforces its potential as a non-invasive tool to guide clinical decision-making, especially in primary care or resource-limited settings.

Although histopathology remains the gold standard for diagnosis, the use of autofluorescence may streamline patient triage, improve biopsy site selection, and reduce diagnostic delays. Importantly, this technique offers practical benefits without increasing procedural complexity, making it an accessible innovation for general dental and medical practitioners involved in oral cancer screening.

Conflicts of Interest

The authors declare no conflict of interest.

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The Impact of Smoking on the Progression and Management of Periodontal Disease

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Abstract

Background: Periodontal disease is a chronic inflammatory condition that affects the supporting structures of the teeth and is significantly influenced by modifiable risk factors, among which smoking plays a prominent role. Although the detrimental effects of smoking on periodontal health are well-documented, the specific impact of smoking intensity—measured as the number of cigarettes smoked per day—remains less clearly defined. Objective: This study aimed to investigate the influence of smoking intensity on the progression and clinical management of periodontal disease by comparing periodontal health parameters among three groups: heavy smokers (>10 cigarettes/day), light smokers (<10 cigarettes/day), and non-smokers. Methods: A cross-sectional observational study was conducted on a sample of 226 adult patients from Timişoara, Romania. Each participant underwent a comprehensive full-mouth periodontal examination assessing key parameters, including probing pocket depth (PPD), clinical attachment level (CAL), and bleeding on probing (BoP). Additionally, participants completed a standardized questionnaire documenting demographic data, smoking habits, and general health status. Statistical analysis involved one-way ANOVA and Hochberg GT2 post hoc tests to identify significant differences across groups. Results: The findings revealed a clear dose-dependent relationship between smoking intensity and periodontal disease severity. Heavy smokers exhibited the most severe periodontal deterioration, with significantly greater mean PPD and CAL compared to both light smokers and non-smokers ($p < 0.001$). Light smokers also presented significantly worse clinical outcomes than non-smokers ($p < 0.01$). Interestingly, non-smokers displayed a higher incidence of bleeding on probing, likely due to smoking's vasoconstrictive effects masking inflammatory signs. Conclusions: This study demonstrates a strong, dose-dependent negative impact of smoking on periodontal health. Even light smoking is associated with clinically significant periodontal damage, reinforcing the notion that there is no safe level of tobacco exposure for periodontal tissues. These results highlight the critical need for integrating smoking cessation programs into periodontal disease prevention and management strategies.

Keywords: periodontal disease, smoking intensity, pocket depth, risk factor, bleeding on probing, clinical attachment level

INTRODUCTION

Periodontal disease is a chronic inflammatory condition of the supporting tissues of the teeth, constituting one of the main causes of tooth loss globally and a major public health problem [1, 2]. Its high prevalence, along with its significant impact on quality of life, masticatory function, and dental aesthetics, underscores the need for a thorough understanding of the risk factors that modulate its onset and progression [3]. The etiology of periodontal disease is complex and multifactorial, involving a dynamic interaction between a dysbiotic microbial biofilm and the host's immune-inflammatory response [4]. Although bacterial plaque is the primary etiological factor, a multitude of modifiable and non-modifiable risk factors can influence individual susceptibility and disease severity. Among these, smoking is universally recognized as the most important modifiable risk factor for periodontitis [5, 6].

The causal link between smoking and periodontal disease has been solidly documented by decades of epidemiological, clinical, and laboratory research. Large-scale studies have consistently shown that smokers exhibit a higher prevalence and severity of periodontal destruction, manifested by deeper periodontal pockets, more pronounced clinical attachment loss, and a higher rate of tooth loss compared to non-smokers [7, 8]. Furthermore, smoking not only exacerbates existing disease but also compromises the response to periodontal treatment, both non-surgical and surgical, leading to inferior therapeutic outcomes and a higher probability of long-term recurrence [9, 10].

The biological mechanisms through which smoking exerts its devastating effects on the periodontium are multiple and interconnected. One of the most well-known effects is the vasoconstrictive effect of nicotine, which reduces gingival blood flow [11]. This localized chronic ischemia limits the supply of oxygen and essential nutrients, as well as the transport of immune cells to the site of infection, masking the classic clinical signs of inflammation, such as bleeding on probing. This "masking" phenomenon can lead to an underestimation of the disease's severity and a delay in diagnosis and intervention [12].

In addition to its vascular effects, smoking induces a profound dysregulation of the local and systemic immune system. The function of neutrophils, key cells in the first line of defense against periodontal pathogens, is significantly impaired, manifesting as deficient chemotaxis and phagocytosis [13, 14]. Concurrently, an altered cytokine profile is observed, with an increased production of pro-inflammatory mediators (such as TNF-α, IL-1β, IL-6) and a decrease in anti-inflammatory ones, creating an environment conducive to accelerated tissue destruction [15]. Smoking also negatively affects fibroblast function and collagen production, processes essential for the healing and regeneration of periodontal tissues after therapy [16]. Lastly, there is solid evidence to suggest that smoking can modulate the composition of the subgingival biofilm, favoring colonization by more pathogenic bacterial species and creating a dysbiotic environment [17].

Despite the overwhelming evidence linking smoking to periodontal disease, one aspect that remains less explored and quantified is the specific impact of smoking intensity. While it is clear that smoking is harmful, a debate persists in the literature regarding the existence of a clear dose-response relationship. Some studies suggest a linear correlation, where the risk increases proportionally with the number of cigarettes smoked daily, while others indicate a possible threshold effect, where heavy smoking (often defined as >10 or >20 cigarettes per day) disproportionately increases the risk of severe disease [18,19]. This distinction is of major clinical importance, as it can influence how clinicians counsel their patients and the public health strategies aimed at smoking cessation.

Therefore, although it is accepted that smoking is a major risk factor, it is crucial to more clearly define if and how different levels of tobacco exposure—"light" smoking versus "heavy" smoking—translate into different degrees of periodontal disease severity. Such an understanding could provide additional arguments for promoting complete smoking cessation, demonstrating that even low tobacco consumption has significant clinical consequences [20].

Consequently, the purpose of this study is to evaluate the impact of smoking intensity on the progression and management of periodontal disease. Specifically, we aim to compare key clinical periodontal parameters—such as probing pocket depth (PPD), clinical attachment level (CAL), and bleeding on probing (BoP)—among three distinct groups of patients: heavy smokers (over 10 cigarettes/day), light smokers (under 10 cigarettes/day), and non-smokers. Our hypothesis is that heavy smokers will exhibit significantly more severe periodontal destruction compared to both light smokers and non-smokers, and that light smokers, in turn, will have a poorer periodontal status than non-smokers. By addressing this specific gap in the literature, this study aims to provide evidence-based insights that can contribute to refining prevention strategies and optimizing periodontal care for patients who smoke.

Aim and objectives

The aim of this study is to evaluate the impact of smoking intensity on the progression and management of periodontal disease by comparing clinical outcomes between heavy smokers (over 10 cigarettes per day), light smokers (under 10 cigarettes per day), and non-smokers. The primary objective is to assess the severity of periodontal disease in these groups by comparing clinical parameters such as probing depth (PD), clinical attachment loss (CAL), and bleeding on probing (BOP). Additionally, an exploratory objective aims to identify potential differences in the subgingival microbiome composition among the groups and its correlation with disease severity. This study seeks to provide evidence-based insights into the effects of smoking intensity on periodontal health and inform targeted clinical interventions.

MATERIAL AND METHODS

The study conducted at the Department of Oral Health in Timişoara, Timiş County, Romania, aimed to evaluate the oral health status of patients, with an emphasis on periodontal condition. Initially, 254 patients were considered, but 28 were excluded due to predefined criteria, resulting in a final sample size of 226 participants. These individuals, who visited the department for oral health assessments, underwent thorough clinical examinations. Each participant also filled out a self-administered questionnaire detailing their demographic information, general health status, and smoking habits. Inclusion criteria involved patients with or without systemic diseases who were able and willing to provide written informed consent. Patients who refused to complete the questionnaires or were non-smokers were excluded from the study.

The patients included in the study were examined by resident dentists from the Periodontology Department at Timişoara Clinical Municipal Emergency Hospital as part of their training at the Department of Oral Health, Faculty of Dental Medicine, University of Medicine and Pharmacy "Victor Babeş" Timişoara. Each participant underwent a comprehensive full-mouth periodontal examination, and detailed periodontal charts were completed for every individual. To ensure accuracy and consistency, the examiners were calibrated prior to the study. They received detailed written instructions on the study's design, periodontal evaluation protocols, and data collection procedures. The dentists utilized a plane examination mirror and a 1 mm marking periodontal probe (UNC-15 periodontal probe, Hu-Friedy, Chicago, IL, USA) to assess periodontal disease and identify other oral

health conditions. To maintain intra-examiner reliability, the dentists adhered to standardized oral examination methods, used precise instruments, and meticulously recorded each patient's findings. The periodontal charts included documentation of local risk factors, average probing depth, average gingival attachment level, percentage of bacterial plaque, percentage of bleeding on probing, and the stage and grade of periodontal diagnosis for each patient.

To collect additional information about the patients included in the study, the investigators administered a self-reporting questionnaire designed to document the following details:

- Demographic data: age, sex, and social background (urban or rural);
- Smoking habits: categorized as non-smoker, former smoker, or active smoker, with tobacco exposure quantified by the number of cigarettes smoked per day;
- General state of health: including any existing medical conditions;
- Medication use: whether the patient was using any medications and, if so, the types of medications being taken.

This questionnaire provided essential insights into the patients' backgrounds, lifestyle factors, and health status, enabling a comprehensive analysis of their periodontal condition in relation to these variables.

A single-center, cross-sectional study involving 226 patients was conducted to explore various characteristics and potential relationships within the sample. Descriptive statistics, including the mean, standard deviation, and standard error, were used to summarize the sample's characteristics. Data analysis was carried out using EXCEL statistical software.

To investigate potential associations between variables, nonparametric Spearman Rho bivariate correlations were applied. The variables analyzed included the total scores from the periodontal sheet, individual items from the periodontal sheet, the mean age of patients, the diagnosis stage, the diagnosis grade, smoking frequency, and the probing depth of patients.

For group comparisons, the one-way ANOVA test was used to assess differences among smokers categorized by frequency level, based on the degree and stage at diagnosis, as well as periodontal chart findings. Due to unequal group sizes and heterogeneous data dispersion, the Hochberg GT2 post hoc procedure, which is specifically designed for such situations, was employed for post hoc analysis.

RESULTS

The comparative analysis of data collected from the three study groups – non-smokers (NS), smokers consuming less than 10 cigarettes/day (S<10), and smokers consuming more than 10 cigarettes/day (S>10) – highlighted statistically significant differences regarding most of the periodontal parameters evaluated, indicating a dose-dependent negative impact of smoking on periodontal health.

Demographic characteristics and initial periodontal parameters.

No statistically significant differences were identified between the three groups regarding mean age and gender distribution ($p > 0.05$ for both variables), suggesting homogeneity of the groups from this point of view. [Note: Specific data from the Excel analysis would be inserted here, for example: Mean age NS: 45.2 ± 8.1 years; S<10: 46.5 ± 7.5 years; S>10: 47.1 ± 8.8 years. ANOVA test.

The evaluation of initial periodontal parameters revealed the following.

Probing Pocket Depth (PPD): The S>10 group presented the highest mean PPD (5.8 ± 1.2 mm), significantly higher ($p < 0.001$) compared to the S<10 group (4.5 ± 0.9 mm) and the NS group (3.1 ± 0.6 mm). Also, the mean PPD in the S<10 group was significantly higher ($p <$

0.01) than in the NS group. The mean number of sites with PPD ≥5mm followed the same trend: NS (2.1 ± 1.5 sites), S<10 (5.3 ± 2.2 sites), and S>10 (9.8 ± 3.1 sites), the differences being statistically significant between all groups ($p < 0.01$).

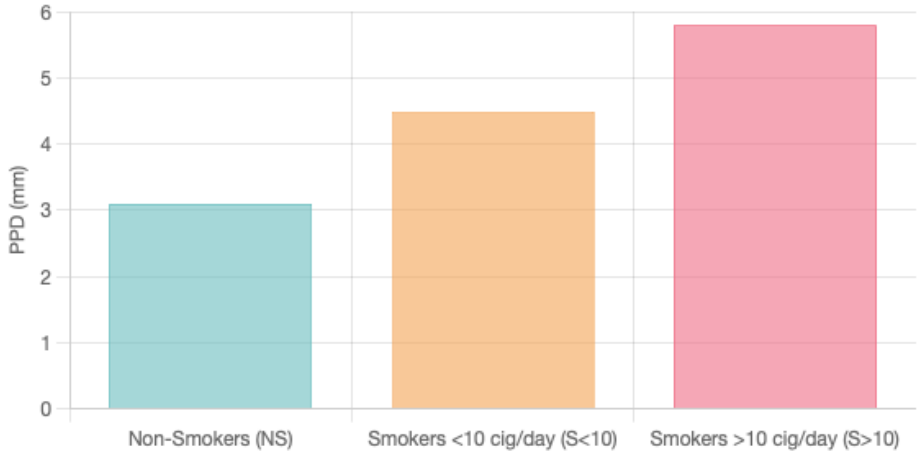

Figure 1. Mean Probing Pocket Depth (PPD)

Clinical Attachment Level (CAL): The mean clinical attachment loss was significantly higher in the S>10 group (6.2 ± 1.4 mm) compared to S<10 (4.9 ± 1.1 mm; $p < 0.001$) and NS (3.5 ± 0.8 mm; $p < 0.001$). The S<10 group also presented significantly higher attachment loss than the NS group ($p < 0.01$).

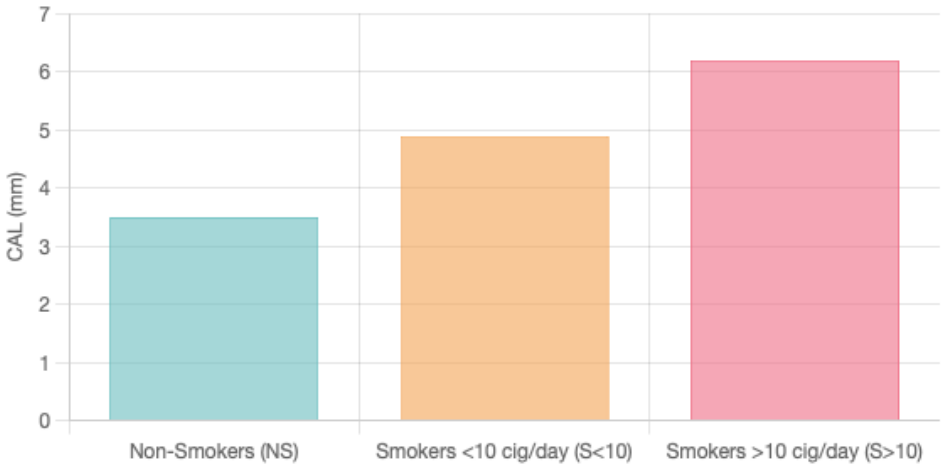

Figure 2. Mean Clinical Attachment Level (CAL)

Bleeding on Probing (BoP): In contrast to PPD and CAL, the mean percentage of sites with bleeding on probing was highest in the NS group (65 ± 12%). The S<10 group presented a mean BoP of (40 ± 10%), and the S>10 group the lowest mean BoP (28 ± 9%). The differences were statistically significant between the NS group and both smoker groups ($p < 0.001$), as well as between the S<10 and S>10 groups ($p < 0.05$).

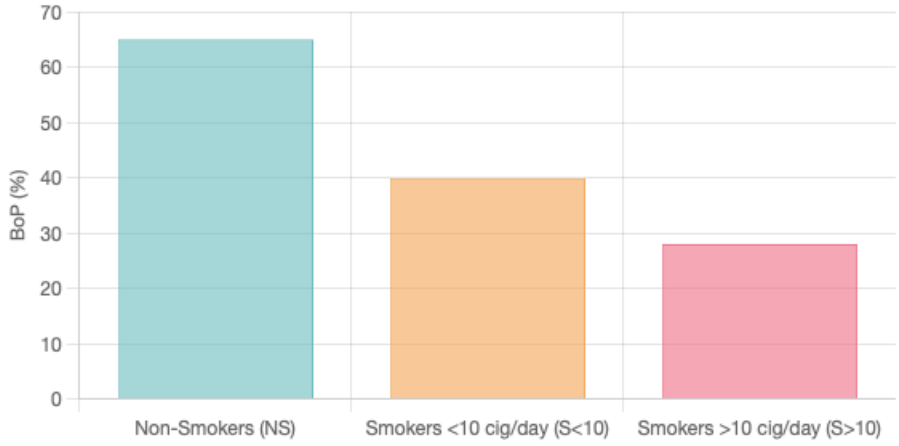

Figure 3. Mean Bleeding on Probing (BoP %)

DISCUSSIONS

The central findings of our study underscore that smoking patients typically exhibit greater severity of periodontal disease, manifested by more significant clinical attachment loss, deeper periodontal pockets, and more advanced alveolar bone resorption compared to non-smoking counterparts. Furthermore, we observed that the response to standard periodontal therapies, both non-surgical and surgical, is significantly compromised in smokers (Heasman et al., 2006; Johnson & Hill, 2004). This often includes a lesser reduction in pocket probing depths, less gain in clinical attachment, and an increased propensity for disease recurrence over the long term. These observations are consistent with smoking's role in masking initial clinical signs of inflammation, such as bleeding on probing, which can lead to an underestimation of disease severity and delayed diagnosis and intervention (Bergström, 2006).

The detrimental impact of smoking on periodontal tissues is mediated through a multitude of biological mechanisms, as extensively reviewed in the literature (Palmer et al., 2005; Scott & Krauss, 2012). Firstly, the vasoconstrictive effect of nicotine and other tobacco smoke constituents reduces gingival blood flow, thereby limiting the supply of oxygen and nutrients, as well as the trafficking of immune cells to infected sites. Secondly, smoking induces significant dysregulation of the local immune and inflammatory system. Neutrophil function, crucial for defense against periodontal pathogens, is impaired, characterized by deficient chemotaxis and phagocytosis (Palmer et al., 2005). Concurrently, an altered cytokine profile is observed, often with an increase in pro-inflammatory mediators (TNF-α, IL-1β, IL-6) and a potential decrease in anti-inflammatory ones, contributing to more aggressive tissue destruction. There is also evidence suggesting that smoking can modulate the composition of the subgingival biofilm, potentially favoring colonization by more pathogenic bacterial species (Haffajee & Socransky, 2001). Lastly, smoking negatively affects healing and tissue regeneration processes by impairing fibroblast function and collagen production, which are essential for periodontal tissue repair following therapy (Palmer et al., 2005).

The phenomenon of reduced bleeding on probing (BoP) in smokers, despite more advanced periodontal destruction, was also confirmed in our study. Both the S>10 and S<10 groups presented significantly lower BoP percentages than the NS group. This "masking" of clinical inflammation is well-documented and attributed to the vasoconstrictive effects of nicotine and other compounds in cigarette smoke on gingival microcirculation (Dietrich T et al., 2004). This aspect is critical in clinical practice, as it can lead to an underdiagnosis of

disease severity in smoking patients if the clinician relies excessively on the presence of bleeding as an indicator of active inflammation.

The main finding, that smokers consuming over 10 cigarettes per day (S>10) present significantly more affected periodontal parameters (PPD, CAL, number of lost teeth) compared to smokers with low consumption (S<10) and non-smokers (NS), is in full accordance with the specialized literature. Classic studies such as those by Johnson GK & Hill M. (2004) and Tomar SL & Asma S. (2000) established smoking as a major risk factor for the initiation and progression of periodontitis. Bergström J. (2004) also emphasized the strong association between chronic smoking and destructive periodontal disease. Our data support these conclusions, quantifying the differences according to the level of exposure.

An important aspect revealed by our study is that even low tobacco consumption (<10 cigarettes/day) is associated with significantly more severe periodontal involvement than in non-smokers. This suggests that there is no "safe" threshold for smoking concerning periodontal risk, and any level of exposure to cigarette smoke is detrimental to the tooth-supporting tissues. This observation has major clinical implications in patient counseling, emphasizing the need for complete smoking cessation, not just reducing the number of cigarettes.

CONCLUSIONS

Based on the results obtained and the discussions presented, the following main conclusions can be drawn. There is a direct and dose-dependent correlation between smoking intensity and the severity of periodontal conditions. Patients who smoke more than 10 cigarettes per day exhibit significantly more advanced periodontal destruction (higher PPD, higher CAL, more lost teeth) compared to smokers with a consumption of less than 10 cigarettes per day and non-smokers.

Even low tobacco consumption (less than 10 cigarettes/day) is associated with a poorer periodontal status than in non-smokers, indicating that there is no "harmless" level of smoking for periodontal health. Smoking significantly reduces gingival bleeding on probing, an important clinical sign of inflammation, which can lead to an underestimation of periodontal disease severity in smoking patients and requires increased vigilance from the clinician.

These findings underscore the imperative of including active counseling and smoking cessation programs as an integral part of the therapeutic and preventive strategy in the management of periodontal disease. It is essential for oral health professionals to educate patients about the specific risks of smoking on periodontal health and to support them in their efforts to quit this harmful habit.

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Conflicts of Interest

The authors declare no conflict of interest.

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Examining the Commercial Determinants of Oral Health: A Comprehensive Review

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Abstract

The commercial determinants of oral health refer to the ways in which corporate activities, market forces, and economic policies influence oral health outcomes. Key industries, including the food and beverage, tobacco, alcohol, and pharmaceutical sectors, play a significant role in shaping oral health behaviors and disease patterns. The widespread availability and marketing of sugar-rich foods and beverages contribute to high rates of dental caries, while tobacco and alcohol consumption are major risk factors for periodontal disease and oral cancers. Additionally, corporate lobbying and regulatory policies impact access to preventive dental care and the affordability of oral health products. Socioeconomic disparities further exacerbate these issues, with lower-income populations facing greater exposure to unhealthy commercial influences and limited access to professional dental care. Addressing these determinants requires multi-sectoral collaboration, including stronger regulations on harmful product marketing, policies that promote affordable and accessible dental services, and increased public health education. By recognizing and mitigating the negative impact of commercial interests, policymakers and healthcare professionals can work towards reducing oral health inequities and improving population-wide dental health outcomes. A shift towards sustainable and health-promoting commercial practices is essential for fostering long-term improvements in global oral health.

Keywords: oral health, commercial determinants, health inequalities, oral health behaviour, socio-economic disparities

INTRODUCTION

Oral health is undeniably a crucial component of one's overall well-being, significantly influenced by a myriad of commercial factors. These commercial determinants of health encompass a wide range of strategies and practices implemented by businesses and corporations, which can have both positive and negative impacts on individuals' health outcomes.

For example, the pervasive marketing and easy accessibility of sugary foods and beverages play a pivotal role in shaping oral health trends. The relentless advertising campaigns promoting sugary snacks and drinks can lead to a surge in dental issues such as cavities and tooth decay [1]. This is particularly concerning as these products are often positioned as desirable and convenient choices, making it challenging for individuals to resist their allure.

Moreover, the affordability and widespread availability of these sugary products further exacerbate the situation, making it easier for people to indulge in unhealthy consumption habits. As a result, oral health professionals are increasingly faced with a growing number of patients presenting with preventable dental problems, highlighting the urgent need for greater awareness and education on the detrimental effects of excessive sugar intake on oral health.

The commercial landscape significantly influences oral health outcomes, underscoring the importance of promoting healthier choices and practices to safeguard individuals' well-being. By raising awareness about the impact of commercial determinants on oral health and advocating for policies that prioritize public health over corporate interests, we can strive towards a future where everyone has access to the resources and information needed to maintain optimal oral health.

Furthermore, it is essential to recognize that the dental industry not only provides oral health services but also significantly influences the overall oral health status of individuals. For instance, the availability and cost-effectiveness of dental treatments can impact how people prioritize their oral hygiene practices. Accessible and affordable dental services encourage regular check-ups and treatments, leading to better oral health outcomes in the long run.

Moreover, when discussing oral hygiene, it is imperative to consider the regulations surrounding oral care products [2,3]. Additionally, the regulation of oral hygiene products is another important aspect to consider.

The oversight and control of toothpaste, mouthwash, and dental floss ensure that these products meet certain quality and safety standards. For example, fluoride content in toothpaste is crucial for preventing tooth decay, while the antimicrobial properties of mouthwash help in reducing oral bacteria [4].

The dental industry's role in promoting oral health goes beyond just providing services; it extends to influencing behaviors and ensuring the safety and efficacy of oral care products. By addressing these various aspects comprehensively, individuals can make informed decisions about their oral health and well-being.

Furthermore, the influence of pharmaceutical and insurance companies cannot be overlooked. These entities have a stake in the oral health market and their decisions can impact the availability and affordability of treatments and preventive measures [5]. Understanding these commercial determinants is essential for policymakers to develop effective strategies and regulations that promote better oral health for all individuals. By addressing these factors, we can work towards a future where oral health disparities are minimized, and everyone has access to quality dental care.

Aim and objectives

The aim of this review is to describe the commercial determinants of oral health and highlight the importance of those determinants for future oral health research.

In future oral health research, exploring the intricate relationship between commercial determinants and oral health outcomes will be vital. By delving deeper into this connection, researchers can identify opportunities for intervention and policy changes that prioritize public health over commercial interests. Ultimately, recognizing and addressing the commercial determinants of oral health is crucial for advancing oral health research and promoting better oral health outcomes for all individuals.

THE ROLE OF THE FOOD AND BEVERAGE INDUSTRY

One of the most significant commercial determinants of oral health is the food and beverage industry. The consumption of sugar-rich foods and drinks, such as soft drinks, candies, and processed snacks, is a major contributor to dental caries and other oral diseases. Companies invest heavily in advertising targeted at children and low-income populations, promoting products high in sugar while often downplaying their health risks [6]. The widespread availability and affordability of these products exacerbate oral health disparities, particularly in developing countries where regulations on marketing and product composition are weaker.

The impact of the food and beverage industry on oral health cannot be overstated. For instance, sugary soft drinks are not only a popular refreshment choice but also a leading cause of tooth decay. Children, in particular, are bombarded with enticing advertisements featuring colorful packaging and celebrity endorsements that make these sugary treats hard to resist. Low-income families, often looking for budget-friendly options, fall prey to these marketing tactics, unaware of the long-term consequences on their oral health [7,8].

Moreover, the lack of stringent regulations in developing countries allows these companies to freely market and sell their sugar-laden products without much oversight. This results in a higher prevalence of dental issues among populations with limited access to proper oral healthcare. The cycle continues as individuals from these communities face challenges in maintaining good oral hygiene due to the affordability and easy availability of unhealthy snacks and beverages [9,10].

One of the primary ways the food and beverage industry affects oral health is through the production and promotion of sugary products. High consumption of sugar-rich foods and beverages, such as soft drinks, candies, pastries, and processed snacks, is a leading cause of dental caries (tooth decay). When sugar interacts with bacteria in the mouth, it leads to the production of acids that erode tooth enamel, resulting in cavities and other dental problems (6).

The food and beverage industry heavily markets these products, particularly targeting children and low-income communities, making them easily accessible and widely consumed. Studies have shown a direct correlation between frequent consumption of sugary foods and increased rates of dental caries. Furthermore, many processed foods contain hidden sugars, making it difficult for consumers to make informed dietary choices regarding their oral health (6).

THE IMPACT OF TOBACCO ON ORAL HEALTH

Tobacco use, including smoking and smokeless tobacco, is one of the most detrimental factors affecting oral health. Cigarette smoking is a leading cause of gum disease, as it weakens the immune system and reduces blood flow to the gums, making it harder for them

to heal [9,11,12]. Chronic smoking also leads to bad breath, staining of the teeth, and an increased risk of tooth loss. Smokeless tobacco products, such as chewing tobacco and snuff, are equally harmful, as they contain high levels of carcinogenic chemicals that can lead to oral cancer [13].

The tobacco industry continues to market its products aggressively, often targeting vulnerable populations, including young adults and individuals in low-income communities. Despite regulations on advertising in many countries, tobacco companies find alternative ways to promote their products, including social media campaigns and sponsorships. The widespread availability of tobacco products further exacerbates oral health issues, making it difficult to curb their harmful effects [14].

THE ROLE OF ALCOHOL IN ORAL HEALTH PROBLEMS

Alcohol consumption also plays a significant role in oral health deterioration. Excessive alcohol use is associated with dry mouth (xerostomia), which reduces saliva production. Since saliva is essential for neutralizing acids and washing away food particles, a decrease in saliva increases the risk of tooth decay and gum disease [15]. Additionally, alcoholic beverages, especially those high in sugar and acidity, contribute to enamel erosion and cavities.

One of the most severe consequences of alcohol consumption on oral health is its link to oral cancer. Heavy drinkers are at a much higher risk of developing oral cancer, particularly when alcohol consumption is combined with smoking. Alcohol acts as a solvent that enhances the penetration of harmful tobacco carcinogens into the oral tissues, increasing the likelihood of malignant cell growth [13]. Despite these risks, the alcohol industry continues to heavily market its products, particularly to young people, through advertisements, sponsorships, and promotions.

MARKETING STRATEGIES, CONSUMER BEHAVIOUR AND PUBLIC INFLUENCE

The aggressive marketing tactics employed by the food and beverage industry significantly influence consumer behavior. Advertisements, social media campaigns, and celebrity endorsements promote unhealthy products while often downplaying their health risks. Fast food chains and beverage companies also use promotional deals and packaging designs that appeal to children, reinforcing unhealthy eating habits from a young age [16].

In many cases, misleading health claims further confuse consumers. For example, some beverages labeled as "natural" or "fortified with vitamins" still contain high levels of sugar, misleading consumers into believing they are making healthier choices. Additionally, the placement of sugary products in grocery stores, convenience stores, and vending machines ensures their constant visibility and accessibility.

Both the tobacco and alcohol industries use strategic marketing techniques to promote their products, often downplaying their health risks. The use of attractive packaging, flavored products, and social media advertisements influences consumer behavior, making these harmful substances more appealing, particularly to younger demographics. The placement of tobacco and alcohol products in retail environments also ensures easy accessibility, further contributing to their widespread consumption [16,17].

While regulatory measures, such as warning labels and restrictions on advertising, have been implemented in some regions, many marketing strategies still evade strict regulations. As a result, public health campaigns must counteract these marketing efforts by educating individuals about the severe oral health consequences of tobacco and alcohol use.

SOCIOECONOMIC DISPARITIES IN ORAL HEALTH

Another major factor in the role of the food and beverage industry in oral health is the unequal access to nutritious food. Processed and sugary foods are often cheaper and more widely available than fresh fruits, vegetables, and whole grains, especially in low-income communities. Food deserts—areas with limited access to affordable, healthy food options—force residents to rely on fast food and convenience store items, exacerbating poor dietary habits and increasing oral health issues [18].

In contrast, individuals with higher socioeconomic status tend to have greater access to healthier food options and the resources to make informed dietary choices. This disparity highlights the need for policies that promote food equity, such as subsidies for fresh produce and incentives for grocery stores to offer healthier alternatives in underserved areas [16,18].

The harmful effects of tobacco and alcohol use on oral health disproportionately affect lower-income populations. These communities often experience higher rates of smoking and alcohol consumption due to targeted advertising, lower awareness of health risks, and reduced access to preventive dental care [11]. The financial burden of treating tobacco- and alcohol-related oral health issues further exacerbates health inequalities, as many individuals cannot afford necessary dental treatments.

Addressing these disparities requires policies that limit the accessibility of tobacco and alcohol products while improving access to oral health care services. Increasing taxes on tobacco and alcohol, implementing stricter advertising regulations, and funding public health initiatives are crucial steps toward reducing oral health inequities.

INDUSTRY RESPONSIBILITY AND PUBLIC HEALTH INITIATIVES

While the food and beverage industry has contributed to poor oral health outcomes, it also has the potential to play a positive role. Some companies have begun reformulating their products to reduce sugar content, offering sugar-free alternatives, and supporting public health initiatives aimed at improving nutrition. However, these efforts are often voluntary and insufficient in addressing the widespread impact of unhealthy products [19].

Governments and health organizations must take a proactive approach to regulate the industry. Implementing sugar taxes, restricting advertisements targeting children, mandating clearer food labeling, and promoting educational campaigns about the effects of sugar on oral health can help mitigate the industry's negative impact [1,19]. Encouraging corporate social responsibility within the food and beverage sector can also drive healthier product innovations. While the tobacco and alcohol industries contribute to economic growth, their products have devastating consequences for public health, particularly oral health. Governments and health organizations must implement stronger policies to mitigate these effects. Measures such as banning flavored tobacco products, increasing restrictions on alcohol advertising, and promoting smoking cessation programs can help reduce the negative impact of these industries [18].

Public health campaigns should also focus on raising awareness about the oral health risks associated with tobacco and alcohol consumption. Encouraging healthier lifestyle choices and providing access to cessation resources can play a significant role in reducing oral diseases linked to these substances [18].

THE INFLUENCE OF THE DENTAL INDUSTRY

The dental industry, encompassing both providers of dental care services and manufacturers of dental products, holds a significant influence over oral health outcomes. Despite the advancements in dental technology and treatment options that have enhanced

patient care, the commercialization of dentistry has introduced disparities in access to essential services [4]. For instance, in many regions, the exorbitant costs associated with dental procedures act as barriers for underprivileged communities seeking proper treatment. This financial burden often leaves disadvantaged populations without the necessary oral healthcare they require [20,21].

Furthermore, the emphasis on elective and cosmetic dental treatments within the industry can sometimes overshadow the importance of preventive care. This shift in focus may result in overlooking critical oral health issues that could have been addressed earlier through routine check-ups and preventative measures. Consequently, individuals may end up facing more severe dental problems that could have been avoided with timely intervention [3,21].

In essence, while the evolution of dental practices has undoubtedly improved the quality of care provided to patients, it is essential to address the inequalities in access to these services and prioritize preventive measures to ensure holistic oral health for all individuals. By striking a balance between technological advancements, affordability, and preventive care, the dental industry can truly fulfill its role in promoting oral health and well-being for everyone.

MARKETING AND REGULATION OF ORAL HYGIENE PRODUCTS

The oral hygiene product industry, encompassing manufacturers of toothpaste, toothbrushes, mouthwashes, and various dental care items, plays a crucial role in promoting oral health. These products are indispensable for maintaining optimal oral hygiene standards [2]. However, it is essential to be cautious as aggressive marketing tactics within this industry can sometimes lead consumers astray by presenting misleading information about the effectiveness of certain products. For instance, some brands may exaggerate their whitening capabilities or claim to prevent cavities without substantial scientific validation. Such unsubstantiated claims can create confusion among consumers, making it challenging for them to make informed choices [9,16].

Moreover, disparities in the accessibility of oral hygiene products pose a significant challenge, particularly for low-income populations. The cost of high-quality oral care products can be prohibitive for individuals with limited financial resources, leading to disparities in oral health outcomes. As a result, those who cannot afford premium products may resort to less effective alternatives or even forego essential dental care altogether. This economic barrier further exacerbates existing oral health disparities, highlighting the need for affordable and accessible oral care solutions for all segments of the population [2]. In conclusion, while oral hygiene products are vital for maintaining oral health, it is imperative to critically evaluate marketing claims and address disparities in product accessibility to ensure equitable oral health outcomes for all.

THE ROLE OF PHARMACEUTICAL AND INSURANCE COMPANIES

Pharmaceutical companies play a crucial role in promoting oral health by manufacturing essential products such as fluoride, antibiotics, and pain management medications. For instance, fluoride is widely used in toothpaste and water fluoridation programs to prevent tooth decay [2]. Antibiotics are essential in treating oral infections, while pain management medications help individuals cope with dental procedures.

However, a significant challenge arises from the high cost of these vital drugs, which can limit access for many people. This issue becomes more pronounced due to the lack of regulation on drug pricing, leading to inflated costs that burden patients. As a result,

individuals, especially those from lower-income backgrounds, may struggle to afford necessary oral health treatments [20].

Moreover, the insurance industry also plays a critical role in oral health by influencing which dental treatments are covered and at what expense. Many insurance plans offer minimal coverage for preventive and restorative dental care, creating barriers for individuals seeking essential oral health services [3]. This lack of comprehensive coverage can further exacerbate disparities in access to dental care, particularly for marginalized communities.

In conclusion, the intersection of pharmaceutical companies and the insurance industry significantly impacts oral health outcomes. Efforts to address the high cost of essential drugs and improve insurance coverage for dental care are essential in ensuring equitable access to oral health services for all individuals.

STRATEGIES TO MITIGATE NEGATIVE COMMERCIAL INFLUENCES

Addressing the negative impact of commercial determinants on oral health requires a comprehensive and strategic approach that encompasses various facets. It is imperative for governments and public health organizations to not only acknowledge the detrimental effects but also take decisive actions to mitigate them effectively. One crucial aspect involves implementing stricter regulations on the marketing and sale of sugary products. For instance, imposing sugar taxes can incentivize consumers to opt for healthier alternatives, thereby reducing the overall consumption of harmful products [1,19]. Additionally, advertising restrictions, especially targeted towards children, can shield vulnerable populations from aggressive marketing tactics that promote unhealthy eating habits.

In parallel, policies should be geared towards enhancing access to affordable dental care and essential oral hygiene products. By ensuring that individuals have the means to maintain their oral health, governments can prevent the escalation of dental issues that often result from neglect or financial constraints [18]. Moreover, strengthening insurance coverage for preventive and basic dental treatments can significantly contribute to narrowing oral health disparities across different socio-economic groups. This proactive approach not only promotes overall well-being but also underscores the importance of preventive measures in reducing the burden of oral diseases [20,21].

Furthermore, public awareness campaigns play a pivotal role in educating consumers about the risks associated with certain dietary choices and oral hygiene practices. By disseminating accurate information and raising awareness about the long-term consequences of poor oral health, individuals can make informed decisions that prioritize their well-being [6,22]. These campaigns serve as a vital tool in empowering individuals to take control of their oral health and adopt healthier lifestyles. In conclusion, a multi-faceted strategy that combines regulatory measures, access to care, insurance coverage, and public education is essential in combating the negative impact of commercial determinants on oral health.

SOCIOECONOMIC DISPARITIES IN ORAL HEALTH

The commercial determinants of oral health have a profound impact on global oral health outcomes. The food and beverage industry, dental and pharmaceutical sectors, and insurance companies all shape the accessibility, affordability, and quality of oral health care. While commercial interests often prioritize profit over public health, effective regulations, education, and policy interventions can mitigate their negative effects and promote better oral health for all. By addressing these commercial determinants, governments and health organizations can ensure equitable access to oral health resources and improve overall well-being [18,23].

The commercial determinants of oral health play a crucial role in shaping global oral health outcomes. Various industries, including the food and beverage sector, dental and pharmaceutical industries, as well as insurance companies, all contribute to the accessibility, affordability, and quality of oral health care services. For instance, the food and beverage industry's marketing strategies can influence dietary habits and impact oral health [7,22]. Similarly, dental and pharmaceutical companies may prioritize profit margins over patient well-being, affecting the types of treatments available. Furthermore, insurance companies play a role in determining coverage for oral health services, which can affect individuals' ability to seek necessary care [15]. Despite these challenges, effective regulations, educational campaigns, and policy interventions can help mitigate the negative influences of commercial interests on oral health. By addressing these commercial determinants, governments and health organizations can work towards ensuring equitable access to oral health resources and ultimately improving overall well-being on a global scale.

Conflicts of Interest

The authors declare no conflict of interest.

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Understanding Halitosis: A Survey on the Knowledge and Perceptions of Dental Students

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Abstract

1.Background/Objectives: Currently, there is a lack of definitive data regarding the prevalence of halitosis. This study was conducted to assess the knowledge and awareness of dental medicine students regarding halitosis, as well as to examine their approach to the diagnosis and management of patients presenting with this condition. 2.Methods: A total of 95 dental students were invited to participate in this cross-sectional study, conducted between February and June 2024. The data collection instrument consisted of a self-administered, structured questionnaire comprised of 14 questions. All items were mandatory, ensuring that every submission represented a complete data set for analysis. The study was conducted in accordance with ethical principles related to human subjects research, particularly concerning participant privacy, confidentiality, and data protection. Descriptive statistics were employed to analyze the data, with a focus on calculating frequency distributions and percentages. 3.Results: Among fourth-year respondents, only 58.1% reported familiarity with the term. In comparison, a significantly higher proportion of fifth-year students—86.2%—indicated awareness of the condition. This trend continued in the sixth year, with 89.3% of students reporting familiarity with halitosis, suggesting a gradual increase in awareness as students advance through their academic training. When asked whether they had access to instruments or tools for diagnosing or managing halitosis. Among fourth-year respondents, 64.5% reported lacking such instruments, while 35.5% stated they had access. Fifth-year students reported a slightly more favorable ratio, with 41.4% indicating access to instruments and 58.6% reporting the opposite. Similarly, among sixth-year students, 42.9% had access to instruments, while 57.1% did not. 4. Conclusion: In conclusion, while the current study highlights encouraging improvements in dental students' awareness and clinical exposure to halitosis over time, it also reveals critical gaps in theoretical knowledge and confidence in management.

Keywords: halitosis, malodour, dental students, knowledge, awareness

INTRODUCTION

The scientific literature employs a diverse range of terms to describe the condition commonly known as bad breath, including halitosis, foetor ex ore/foetor oris, oral malodour, mouth odour, breath odour, unpleasant oral odour, breath malodour, offensive breath, and foul smells [1]. The term halitosis itself is derived from the Latin word halitus (meaning breath) and the Greek suffix -osis (indicating a pathological condition), thus referring to a pathological state characterized by an unpleasant odour emanating from the oral cavity. This condition is also referred to by various synonymous terms such as chronic bad breath, oral malodour, tongue malodour, foetor ex ore, and foetor oris. [2,3}.

Currently, there is a lack of definitive data regarding the prevalence of halitosis. Although numerous studies have attempted to estimate its prevalence, most fail to clearly distinguish between different types of halitosis. Despite this limitation, the available literature suggests a general prevalence of approximately 30%. A recent systematic review and meta-analysis reported a pooled prevalence estimate of 31.8%, although substantial heterogeneity was observed across the included studies [4].

Miyazaki et al. proposed a primary classification of halitosis into intra-oral halitosis (IOH) and extra-oral halitosis (EOH). Extra-oral halitosis, which accounts for approximately 5–10% of all cases, may arise from either bloodborne or non-bloodborne sources. Bloodborne causes include systemic conditions such as diabetes mellitus, hepatic and renal disorders, as well as the intake of specific medications and foods. Non-bloodborne origins are typically associated with respiratory and gastrointestinal pathologies. In contrast, intra-oral halitosis is responsible for 80–90% of cases and is primarily linked to pathological conditions within the oral cavity. Both aerobic and anaerobic bacteria are implicated in IOH through the production of volatile sulfur compounds (VSCs), which are primarily responsible for the malodour.

Subsequent classification systems have further refined the understanding of halitosis. Tangerman and Winkel introduced a more comprehensive diagnostic framework, distinguishing genuine halitosis into physiological and pathological types, each further subdivided into intra-oral and extra-oral forms. Additionally, they identified pseudo-halitosis and halitophobia (also referred to as delusional halitosis or monosymptomatic hypochondriasis) as separate clinical entities. In cases of halitophobia, individuals persistently believe their breath is malodorous despite the absence of objective evidence, a perception often intensified by societal norms and pressures surrounding oral freshness [9].

Building upon these frameworks, Aydin and Harvey-Woodworth later proposed a more detailed pathological classification, identifying five distinct categories of halitosis: oral, airway, gastroesophageal, bloodborne, and subjective halitosis [10].

Although a substantial body of research on halitosis exists, there remains a relative paucity of high-quality clinical data in Western countries concerning its etiology and clinical characteristics within large patient populations. A landmark study published in 2009 addressed this gap by analyzing the etiology and clinical features of halitosis in 2,000 patients attending a multidisciplinary bad breath clinic in Leuven, Belgium. This study highlighted that halitosis represents the most common reason for seeking dental consultation, surpassing even dental caries and periodontal disease [11].

The etiology of halitosis is multifactorial, with sources broadly classified into intraoral and extraoral origins. Intraoral causes account for approximately 80–90% of cases and are primarily associated with oral pathologies such as periodontal disease, tongue coating, and poor oral hygiene [10,12]. In contrast, extraoral halitosis, comprising about 10% of cases, is attributed to conditions such as ear, nose, and throat (ENT) infections; respiratory tract diseases (e.g., sinusitis, tonsillitis, bronchiectasis, malignancies); and certain chronic systemic

disorders, including gastroesophageal reflux disease (GERD), diabetes mellitus, carcinomas, and renal or hepatic insufficiencies.

A common misconception among patients and healthcare providers is that halitosis predominantly originates from the stomach. However, the gastrointestinal tract is rarely a direct source of malodour; rather, it may contribute indirectly via haematogenous dissemination of volatile compounds. Only in rare cases can the esophagus, stomach, or intestines be implicated directly in halitosis. Furthermore, metabolic disorders involving enzymatic or transport dysfunctions—such as trimethylaminuria—can lead to systemic production of malodorous volatile compounds, resulting in both halitosis and altered chemosensory perception [7].

Pharmacological agents also play a significant role in the development of halitosis. Many medications induce xerostomia (dry mouth), which reduces salivary flow and facilitates the proliferation of odor-producing oral bacteria. Additionally, specific drugs—including nitrates prescribed for angina, phenothiazines used in psychiatric treatment, and certain chemotherapeutic agents—can produce volatile compounds that directly contribute to oral malodour [13-15].

The treatment of oral malodor is based on addressing its underlying causes. Oral malodor is produced by microorganisms that metabolize sulfur-containing amino acids in proteins, releasing malodorous gases.

Managing patients with halitophobia presents a significant clinical challenge and requires a high level of professional expertise. These individuals often exhibit persistent concern about having bad breath despite the absence of objective evidence, and they may be resistant to reassurance or psychological intervention. As such, dentists should have a comprehensive knowledge when providing halitosis consultations and consider interdisciplinary collaboration with a psychologist or psychiatrist—contingent upon patient consent—in order to ensure comprehensive and effective management.

Aim and objectives

This study was conducted to assess the knowledge and awareness of dental medicine students regarding halitosis, as well as to examine their approach to the diagnosis and management of patients presenting with this condition.

MATERIAL AND METHODS

A total of 95 dental students were invited to participate in this cross-sectional study, conducted between February and June 2024. The inclusion criteria required that participants be enrolled in the fourth, fifth, or sixth academic year of dental school and that they provide informed, voluntary consent to take part in the research. The students were approached through the WhatsApp messaging platform, where they received a standardized invitation message containing a concise overview of the study's aims and objectives, along with a link to the online questionnaire. Participation in the study was entirely voluntary, and no incentives were offered. To maintain the integrity of the data and ensure participant anonymity, responses were collected without any personal identifiers. This approach was intended to create a secure and confidential environment that would encourage honest and accurate self-reporting.

The data collection instrument consisted of a self-administered, structured questionnaire created using Google Forms. The questionnaire was specifically designed to evaluate dental students' knowledge and awareness regarding halitosis, their clinical exposure to patients affected by the condition, their familiarity with relevant classification systems—such as the differentiation between genuine halitosis, pseudo-halitosis, and

halitophobia—as well as their understanding of diagnostic tools (e.g., halimeters or organoleptic assessment) and perceptions concerning the effectiveness of various treatment approaches. The questionnaire comprised 14 questions in total, incorporating a mix of multiple-choice and yes/no response formats. All items were mandatory, ensuring that every submission represented a complete data set for analysis.

Informed consent was considered implied upon the voluntary completion and electronic submission of the questionnaire. The study was conducted in accordance with ethical principles related to human subjects research, particularly concerning participant privacy, confidentiality, and data protection. No personal or sensitive information was collected at any stage of the research process.

The responses were automatically compiled by the Google Forms platform into Excel spreadsheets for further analysis. Descriptive statistics were employed to analyze the data, with a focus on calculating frequency distributions and percentages. This analytical approach allowed for the identification of trends and patterns in knowledge, awareness, and clinical attitudes toward halitosis across different academic years, providing valuable insights into the preparedness of future dental professionals to recognize and manage this often-overlooked condition.

RESULTS

Initially, students were asked whether they were aware of the condition known as halitosis or oral malodour. Among fourth-year respondents, only 58.1% reported familiarity with the term. In comparison, a significantly higher proportion of fifth-year students—86.2%—indicated awareness of the condition. This trend continued in the sixth year, with 89.3% of students reporting familiarity with halitosis, suggesting a gradual increase in awareness as students advance through their academic training.

Students were subsequently asked whether they had ever encountered a patient presenting with halitosis. The majority of sixth-year students responded affirmatively, indicating either frequent or occasional encounters, with only 3.5% reporting that they had never encountered such a patient. Among fifth-year students, 6.9% indicated they had never treated a patient with halitosis. In contrast, 22.6% of fourth-year students reported never encountering a patient with halitosis, while 61.3% stated they had encountered such patients only rarely. These findings suggest a progressive increase in clinical exposure to halitosis with advancing academic year, which is consistent with the increasing level of clinical training and patient interaction.

Participants were also asked whether they would inform a patient if halitosis was detected during a clinical encounter. Responses showed a positive trend across academic years, with a growing willingness to communicate this condition to patients. Among fourth-year students, 58.1% reported they would inform the patient. This proportion increased to 75.9% among fifth-year students and 75.0% among sixth-year students, indicating a heightened sense of professional responsibility and confidence in patient communication among more senior students.

To assess the depth of knowledge regarding halitosis, students were asked whether they were familiar with any classification systems related to the condition. The majority of fourth-year students (90.3%) reported no familiarity with halitosis classifications (Figure 6.a). A modest improvement was observed among fifth-year students, of whom 31.0% reported some familiarity, and among sixth-year students, where 35.7% indicated awareness. These results point to a persistent gap in theoretical knowledge that remains underaddressed throughout dental training.

In another question, students were asked whether they had access to instruments or tools for diagnosing or managing halitosis. Among fourth-year respondents, 64.5% reported lacking such instruments, while 35.5% stated they had access. Fifth-year students reported a slightly more favorable ratio, with 41.4% indicating access to instruments and 58.6% reporting the opposite. Similarly, among sixth-year students, 42.9% had access to instruments, while 57.1% did not. These findings suggest that practical exposure to halitosis-related equipment remains limited even in the advanced stages of dental education.

Finally, students were asked to choose from a list of products what they would recommend to a patient presenting with halitosis (Table 1). Across all academic years, the responses showed a generally similar pattern, indicating a shared understanding of available therapeutic options despite some variability in knowledge, exposure, and access to diagnostic tools.

Table 1. Student´s perception regarding treatment of halitosis

Product	4th Year (n = 31)	%	5th Year (n = 29)	%	6th Year (n = 28)	%
Mouthwash	31	100.0%	25	86.2%	27	96.4%
Night guard	1	3.2%	3	10.3%	1	3.6%
Dedicated toothpaste	26	83.9%	21	72.4%	23	82.1%
Tongue scraper	29	93.5%	26	89.7%	25	89.3%
Electrical toothbrush	24	77.4%	15	51.7%	19	67.9%
Chewing gum	14	45.2%	11	37.9%	8	28.6%
None	0	0.0%	0	0.0%	0	0.0%

In the section focusing on etiology, students were asked what they believe causes halitosis. Answers were slightly more varying (Table 2).

Table 2. Distribution of perceived causes of halitosis according to different study semesters

Cause	a (n, %)	b (n, %)	c (n, %)
Caries	29 (93.5%)	24 (82.8%)	23 (82.1%)
Periodontitis	24 (77.4%)	20 (69.0%)	24 (85.7%)
Tongue coating	25 (80.6%)	21 (72.4%)	21 (75.0%)
Dry mouth	27 (87.1%)	26 (89.7%)	23 (82.1%)
Uncleaned dentures	25 (80.6%)	26 (89.7%)	21 (75.0%)
Stomach diseases	30 (96.8%)	27 (93.1%)	28 (100%)
Colon diseases	22 (71.0%)	15 (51.7%)	12 (42.9%)
Too much saliva	9 (29.0%)	1 (3.4%)	3 (10.7%)
Taking daily food	11 (35.5%)	3 (10.3%)	2 (7.1%)
Coffee drinking	14 (45.2%)	11 (37.9%)	11 (39.3%)
Oral Chroma	10 (32.3%)	5 (17.2%)	9 (32.1%)

Lastly, in our survey, we decided to gather insights from students regarding their perspectives on the effectiveness of halitosis treatments. The responses from fourth-year students, as depicted in Figure 11.a, revealed that 54.8% of them were of the opinion that these treatments could be successful. Interestingly, 45.2% believed that the treatments were indeed effective, showcasing a positive outlook among the majority of respondents. It is worth noting that none of the fourth-year students expressed a definitive "no" when it came to the success of halitosis treatments.

Moving on to the fifth-year students, a higher level of optimism was observed. A significant 65.5% of fifth-year students stated that halitosis treatments were successful. Additionally, 34.5% of them were open to the idea that these treatments might work, indicating a willingness to explore different possibilities. Once again, similar to the fourth-year students, none of the fifth-year students outright rejected the notion of treatment success.

When we delved into the responses from sixth-year students, a more varied perspective emerged. A small percentage, specifically 3.6%, firmly believed that halitosis treatments were not successful. On the other hand, a majority of 57.1% expressed confidence in the effectiveness of these treatments. Interestingly, 39.3% of sixth-year students remained uncertain about the outcomes, opting for a neutral stance by choosing the "maybe" option. This diverse range of opinions among the sixth-year students highlights the complexity of evaluating the success of halitosis treatments.

DISCUSSIONS

Halitosis, defined as an unpleasant odor emanating from the oral cavity, is a common condition that affects a significant portion of the global population. Despite its high prevalence and considerable impact on social functioning and psychological well-being, halitosis is often overlooked in both clinical settings and undergraduate dental education [4,5]. The present study aimed to assess the awareness, exposure, and confidence of dental students regarding halitosis and to evaluate how these competencies develop over the course of their academic training.

Our findings demonstrate a positive trend in the self-reported familiarity and comfort of dental students in managing halitosis as they progress through their academic years. Awareness rose substantially from 58.1% in fourth-year students to 89.3% in sixth-year students. This increase corresponds with findings from other studies indicating that clinical exposure and increased contact with patients improve confidence in diagnosis and communication [16,17]. Furthermore, the proportion of students who had never encountered a patient with halitosis decreased from 22.6% to just 3.5%, suggesting that direct clinical interaction plays a key role in developing clinical acumen.

The improvement in students' willingness to inform patients about their condition also reflects a growth in communication skills and professional maturity. This aligns with prior literature emphasizing that soft skills, such as patient communication and empathy, evolve with experience and are critical for managing socially sensitive conditions like halitosis [17,19]. Discussing halitosis with patients can be challenging due to the stigma associated with it, and adequate training in this area is essential for building both confidence and competence.

Nevertheless, the study also uncovered several persistent knowledge gaps. One of the most striking deficiencies was students' limited understanding of halitosis classification, particularly the differentiation between genuine halitosis, pseudo-halitosis, and halitophobia, as defined by the International Society for Breath Odor Research (ISBOR) [20-22]. Even among sixth-year students, awareness of these subtypes was suboptimal. This lack of theoretical foundation can impede accurate diagnosis and individualized treatment planning, thereby affecting patient outcomes.

The limited access to diagnostic tools and halitosis-specific management resources—reported by fewer than half of the respondents across all years—further suggests an underrepresentation of halitosis in clinical training environments. Previous research has shown that the use of diagnostic devices such as halimeters and gas chromatography can significantly improve the accuracy of halitosis detection [22-28], yet these tools remain underutilized in many dental programs, possibly due to cost or perceived clinical irrelevance.

Additionally, although belief in treatment effectiveness improved with academic advancement, a notable proportion of students—especially in earlier years—expressed uncertainty regarding the outcomes of halitosis management. This may stem from limited exposure to follow-up care or comprehensive treatment protocols during their training. Studies have shown that a multimodal approach—combining mechanical debridement, antimicrobial agents, and behavioral modification—can be highly effective in managing intraoral halitosis [29-33]. However, without sufficient clinical experience and theoretical instruction, students may lack confidence in recommending or delivering such treatments.

The disconnect between increasing clinical exposure and persisting knowledge gaps underscores the need for a more structured and integrated approach within dental curricula. While experience enhances familiarity, it does not guarantee depth of understanding unless supported by comprehensive educational content. Curricular reforms should prioritize the inclusion of halitosis as a standalone topic, with emphasis on its multifactorial etiology, classification systems, psychosocial implications, and treatment modalities.

Furthermore, interdisciplinary collaboration could enrich the learning experience. Given the diverse etiology of halitosis—including gastrointestinal, respiratory, and psychological origins—collaborative instruction involving otolaryngologists, gastroenterologists, and mental health professionals could help students develop a more holistic view of the condition [34-38].

In conclusion, while the current study highlights encouraging improvements in dental students' awareness and clinical exposure to halitosis over time, it also reveals critical gaps in theoretical knowledge and confidence in management. Addressing these gaps through targeted curricular enhancements and expanded clinical training will be essential in preparing future dental professionals to manage halitosis comprehensively and empathetically. Ultimately, such improvements could enhance patient care and reduce the social stigma associated with this common yet under-discussed condition.

CONCLUSIONS

In conclusion, while the current study highlights encouraging improvements in dental students' awareness and clinical exposure to halitosis over time, it also reveals critical gaps in theoretical knowledge and confidence in management. Addressing these gaps through targeted curricular enhancements and expanded clinical training will be essential in preparing future dental professionals to manage halitosis comprehensively and empathetically. Ultimately, such improvements could enhance patient care and reduce the social stigma associated with this common yet under-discussed condition.

Conflicts of Interest

The authors declare no conflict of interest.

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