Comparative Effectiveness of Intraoral Scanners and Articulating Paper in Occlusal Contact Analysis

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Abstract

1.Background/Objectives: This study evaluates the accuracy of maximum intercuspation analysis using both conventional articulating paper and three digital intraoral scanners. The goal was to determine the reliability and equivalency of traditional and digital methods in recording occlusal contact points. 2. Methods: Ten subjects underwent occlusal contact point analysis using articulating paper, 3Shape® Trios 3, Omnicam Cerec®, and Medit i700® intra-oral scanners. Results were compared visually and statistically to evaluate method equivalence. 3.Results: Analysis revealed no statistically significant differences in the accuracy of occlusal contact points among the four methods tested, confirming the reliability of both traditional and digital approaches. 4.Conclusion: Articulating paper remains a reliable tool for occlusal analysis, even with the advent of advanced intraoral scanners. The findings support the feasibility of using any of the tested scanners for accurate occlusal contact analysis. This study underscores the potential for integrating both conventional and digital methods, depending on clinical needs and available technology, without compromising diagnostic accuracy.

Keywords: articulating paper, maximum intercuspation, CEREC®, MEDIT®, and 3Shape® Trios 3 intraoral scanning

INTRODUCTION

Reliable occlusal registration with appropriate occlusal contacts is critical in restorative procedures [1]. Accurate registration and effective transfer of this occlusal information to the dental technician are key components in prosthetic and restorative procedures [2,3]. A functional occlusal relationship is capital, as it will significantly impact the masticatory performance, the prevention of occlusal trauma and dysfunction, and the effectiveness of orthodontic treatments. Understanding these aspects is essential for maintaining oral health and achieving successful dental interventions.

Studies showed that increased chewing cycles power improved performance regardless of the occlusal patterns [4], dysfunctional syndromes of the stomatognathic system can arise from poor occlusal relationships, leading to pain and other complications [5]. The absence of proper occlusal contacts can result in occlusal trauma, which may manifest as joint and muscle pain, and periodontal issues, abnormal dental wear and abfractions, emphasizing the need for monitoring intermaxillary relations [6].

Occlusal trauma is closely linked to periodontitis, showing significant correlations with factors like amalgam restorations and pathogenic occlusion through logistic regression analysis (7). Although it does not initiate periodontitis, occlusal trauma can exacerbate connective tissue loss, especially when combined with plaque-induced periodontitis [7]. Patients with chronic periodontitis who experience high occlusal forces may exhibit deeper probing depths and increased bleeding on probing, suggesting a potential for enhanced periodontal destruction [8]. Diagnostically, confirming occlusal trauma is challenging as it relies on histological confirmation and is marked by a lack of consensus regarding its role in the onset and progression of periodontal diseases, further complicated by the unsupported link between abfraction and gingival recession [7]. Clinically, occlusal therapy plays a critical role in periodontal treatment by reducing tooth mobility, improving patient comfort, and enhancing masticatory function [9]. Comprehensive management strategies involving orthodontic and prosthodontic interventions are crucial for managing pathologic tooth migration linked to occlusal trauma, underscoring the importance of effective occlusal therapy in improving outcomes for periodontal patients [7-9].

Conventionally, occlusal contacts in patients and on plaster models have been assessed using articulating paper and shim stock (8-micron aluminum foil), with various thicknesses available. Research suggests that the tactile sensitivity of natural teeth can range from 8 to 10 µm, making 8 µm paper more suitable than thicker options such as 40 or 200 µm, thus often being regarded as the gold standard for accurately detecting interocclusal contacts [10-15]. Despite its widespread use, articulating paper has several limitations, such as: it requires patients to bite multiple times to capture full arch contacts, while results can be compromised by saliva, which may lead to false positives and negatives. Nevertheless, no method has yet been scientifically validated as the ideal technique for occlusal analysis [10].

The increasing integration of digital technology in dentistry is enhancing the way occlusal contacts are recorded. Intraoral scans are notably more time-efficient than traditional methods, improving workflow significantly when clinicians are adequately trained [13,16–18]. This technological advancement not only enhances patient comfort but also streamlines data processing and storage [19,20]. Additionally, digital scans used for individual restorations and some bridge elements yield more accurate and meaningful data compared to traditional physical casts [13]. However, for long-span restorations, conventional impressions remain the preferred method [21]. Thus, further refinements in software accuracy are required to improve the reliability of these digital measurements [22].

In addition, the development of digital occlusion technologies has had a major impact on dental practice by improving diagnostic capabilities and treatment planning. Systems such as T-scan® (Tekscan, Boston, MA, USA), Zebris® (Amman Girrbach, Germany) and Modjaw® (Villeurbanne, France) have been at the leading edge of these advances, providing sophisticated tools for both static and dynamic occlusal analysis. While all three systems improve clinical outcomes, their efficacy and limitations warrant further investigation [11,13,14].

When comparing these systems, studies often evaluate the accuracy and consistency of the data they provide. Furthermore, further analysis is required to fully understand the capabilities of these systems in different clinical scenarios, although the predictive values and accuracy of these systems, such as those reported for Accura, confirm their potential [24].

Methodological approaches to occlusal assessment, including conventional, photographic and computerized techniques, have shown varying degrees of correlation. This variability highlights the need for critical evaluation of these methods, as no single approach has emerged as the definitive standard. While conventional methods are currently adequate for many clinical settings, the integration of advanced systems such as T-scan, Zebris and Modjaw could potentially provide more accurate and reliable measurements, provided their methodologies are continually refined and validated through research [24-25].

Over the past decade, the use of chairside intraoral scanners to take digital impressions has become more widespread. These scanners use digital maxillary and mandibular models in Standard Triangle Language (STL) format. To accurately position the maxillary and mandibular files, a third file capturing the buccal view of the intermaxillary articulation is generated using reference points analyzed by a mathematical algorithm [11,13,14]. This process allows accurate simulation of a patient's occlusal contacts and allows virtual models to be placed in the desired intercuspal position, typically maximum intercuspal position or centric occlusion. This technique bypasses the need for an interocclusal record using elastomers and scanning, overcoming concerns about the dimensional stability of traditional interocclusal record materials and simplifying the overall process [2]. The benefits of Computer-Aided Impression (CAI) include reducing time-consuming clinical steps, improving patient comfort, streamlining data storage, eliminating time spent casting and pinning models in the laboratory, reducing inaccuracies in manual trimming, and eliminating the need for mechanical articulators and facebows [14].

Aim and objectives

The primary aim of this observational study is to determine whether the analysis of occlusal contact points using the software of intraoral scanners (CEREC®, MEDIT®, and 3-SHAPE®) is equivalent to the traditional method of marking occlusion using articulating paper. This aim seeks to assess whether modern digital methods can provide the same accuracy and reliability as the conventional approach, which has been a longstanding method in dental practice.

The secondary aim of the study is to evaluate whether there are any notable disparities in the occlusal analysis capabilities among the three specified intraoral scanners: CEREC®, MEDIT®, and 3-SHAPE®. This part of the study looks to identify if one scanner shows superior performance over the others or if all scanners operate with comparable effectiveness in a clinical setting.

The primary null hypothesis states that there is no difference between the occlusal contact point analysis obtained using the software of intraoral scanners (CEREC®, MEDIT®, and 3-SHAPE®) and the traditional occlusion marking method with articulating paper. The secondary null hypothesis asserts that there are no significant disparities in occlusal analysis among the three intraoral scanners (CEREC®, MEDIT®, and 3-SHAPE®).

MATERIAL AND METHODS

Study design and participants

This prospective study was approved by the Ethical Committee of the "Iuliu Hatieganu" University of Medicine and Pharmacy, Cluj Napoca, Romania (no.15/21.05.2024). The research was performed in accordance with the Declaration of Helsinki from 1975 and subsequent revisions and written informed consent were obtained from every subject before collecting data.

The participants were recruited from students at the Faculty of Dental Medicine, "Iuliu Hatieganu" University of Medicine and Pharmacy, Cluj Napoca, Romania.

Subjects were considered eligible according to the following inclusion criteria: full permanent dentition, except for the third molar; age between 20 and 25 years, with no restrictions regarding the sex or ethnicity; normal mouth opening; presence or absence of direct dental restorations using composite resins or glass ionomer materials; presence or absence of single-unit indirect restorations (crowns, inlays, onlays, or overlays).

The exclusion criteria were. as follows – anterior or posterior open-bite, temporomandibular joint disorders, missing teeth, or previous orthodontic extractions.

According to the aforementioned criteria, 10 subjects were enrolled in the study group. For each participant, photographs of articulating paper marks and digital scans were collected and analyzed by two operators (B.D. and P.O).

The study analyzed maximum intercuspation in the participants using four different occlusal relationship assessment methods, starting conventionally with marking with 200 µm calibrated articulating paper and digitally using three different intra-oral scanners: Cerec Omnicam® (Dentsply Sirona, North Carolina, USA), 3Shape® Trios 3 (3Shape, Denmark), and Medit® i700 (Medit corp., South Coreea).

The data collected underwent both descriptive and comparative analysis. Each participant was subject to a clinical examination along with an occlusal assessment. The clinical occlusal analysis was conducted, and maximum intercuspation (IM) was recorded using Bausch® articulating paper. Subsequently, on the same day, intraoral scans were performed using three distinct scanners, mentioned above. For the same subject, all activities were carried out during the same day at the Department of Prosthodontics, Faculty of Dental Medicine, Cluj-Napoca.

Protocol for occlusal examination

The protocol for dental occlusion examination consisted of four different analyses: using articulating paper, and three different types of intraoral scanners. The occlusal contacts were recorded using a 200 µm blue articulating paper (200 µm Arti-Fol; Dr. Jean BauschGmbH & Co KG, Köln, Germany). The equipment and materials used during the study were: (1) dental examination kit (including a No. 6 probe, a dental mirror, and surgical tweezers); (2) OptraGate® (Ivoclar Vivadent, Schaan, Liechtenstein) buccal retractors in regular and small sizes; (3) translucent blue plastic cheek retractors; (4) salivary cotton rolls; (5) 200µm Bausch® blue articulating paper; (6) Apple® iPhone Xr camera; (7) dental photography mirrors; (8) Cerec Omnicam® (Dentsply Sirona, North Carolina, USA) intraoral scanner; (9) 3Shape® Trios 3 (3Shape, Denmark) intraoral scanner; (10) Medit® i700 (Medit corp., South Coreea) intraoral scanner.

Each subject was seated in an upright position and instructed to close his/her mouth in a natural occlusion, repeating the movement until the operator was sure that the patient was able to reproduce a correct intercuspation. The analysis of occlusion in maximum intercuspation using articulating paper (figure 2) was performed according to the following protocol: (1) the patient was instructed on how to close their mouth in maximum intercuspation - the patient was asked to repeat the movement several times to ensure they were in the correct position; (2) occlusal surfaces of the teeth were dried using an air spray; (3) blue 200 µm articulating paper was placed between the left and right side in the same moment so that the patient does not deviate and closing/opening movements were performed several times. -this step was performed 3 times to be sure that the same contact points were marked; (4) occlusal markings on the surfaces were checked for accuracy; (5) an image of the maxillary and then mandibular arch was captured using an occlusal dental photography mirror with an Apple® iPhone Xr camera and a Smile lite® (Smile Line, Switzerland) device; the markings were removed using cotton rolls for the patient's aesthetic comfort following their participation.

Figure 1. The maxillary and mandibular arches, marked using blue 200 µm articulating paper in maximum intercuspation

The analysis of occlusion in maximum intercuspation using Omnicam Cerec® (Dentsply Sirona, North Carolina, USA) intra-oral scanner was performed according to the following protocol, following the manufacturer's recommendations: (1) before scanning, ensuring the scanner is calibrated, and the tip was cleaned - the subject's teeth were dried thoroughly to reduce glare and improve scanning accuracy; (2) starting with the upper arch, scanning from one posterior molar across the occlusal surfaces to the opposite side, capturing the buccal and palatal/lingual surfaces; the lower arch was examined afterwards, following the same sequence; finally, the buccal surfaces were scanned with the two arches in maximal intercuspation; (3) during scanning, the scanner was held 5–15 mm from the tooth surface and maintain steady, smooth movements, using the live feedback on the software to verify that all surfaces are captured; (4) to record the occlusal relationship, the patient was asked to close their mouth in maximal intercuspation and instructed to keep their teeth in contact but without clenching: then, four digital recordings were taken – at the level of the left first molars, left canines, right canines, and right first molars – starting from the occlusal surface and moving the intraoral scanner head first cranially and then caudally, until the upper and lower scans were recognized by the software and properly matched after scanning, the 3D model was checked in the software for any missing areas, and rescanning was performed only where necessary.

The analysis of occlusion in maximum intercuspation using Medit i700® (Medit corp., South Coreea) intra-oral scanner was performed by the same operator, following the manufacturer's recommendations: (1) before scanning, the scanner was calibrated, and the tip was cleaned and properly attached; the patient's teeth were dried thoroughly to improve scanning accuracy and minimize reflections, removing any debris or saliva from the surfaces; (2) starting with the upper arch, from one posterior molar and moving systematically across the occlusal surfaces to the opposite side, ensuring the capture of buccal and palatal/lingual surfaces; the same process was repeated for the lower arch, and the buccal surfaces were scanned afterwards with the patient in occlusion to record the bite; (3) the scanner was held at a consistent distance of 10–15 mm from the tooth surface, maintaining smooth and steady movements, following the live scan feedback on the software to ensure complete coverage of all areas; (4) after completing the scan, the 3D model was reviewed for missing regions and perform rescanning only where necessary; (5) the patient was instructed on how to close their mouth for the occlusion impression; the patient was asked to close their mouth in a normal occlusal position, avoiding an edge-to-edge bite; (6) the occlusion impression was performed by vestibular scanning with the mouth closed in maximum intercuspation.

The analysis of occlusion in maximum intercuspation using 3Shape® Trios 3 (3Shape, Denmark) software was performed following the manufacturer's recommendations: (1) dental surfaces were dried using an air spray; (2) the maxillary impression was taken, starting posteriorly from the second quadrant; a "zig-zag" scanning motion was performed (buccal → occlusal → lingual) until reaching the posterior end of the first quadrant; (3) non-recorded areas were corrected with a new impression; (4) the mandibular impression was taken, starting posteriorly from the third quadrant; a "zig-zag" scanning motion was performed (buccal → occlusal → lingual) until reaching the posterior end of the fourth quadrant ; (5) non-recorded areas were corrected with a new impression; (6) the scanner was held at a consistent distance of 10–15 mm from the tooth surface, maintaining smooth and steady movements, following the live scan feedback on the software to ensure complete coverage of all areas; (6) the patient was instructed on how to close their mouth for the occlusion impression; the patient was asked to close their mouth in a normal occlusal position, avoiding an edge-to-edge bite; (7) the occlusion impression was performed by vestibular scanning with the mouth closed in maximum intercuspation.

After performing each of the digital scanning, the operator evaluated the occlusal contacts through a specific function of each intraoral scanner software, where the contacts are shown as a colored map depicting the intensity of the contact (the color codes are variable, depending on the software used for evaluation) (figures 2-7).

Figure 2. Screen capture of maxillary and mandibular scans using Omnicam Cerec® (Dentsply Sirona, North Carolina, USA) (in the contact point analysis mode)

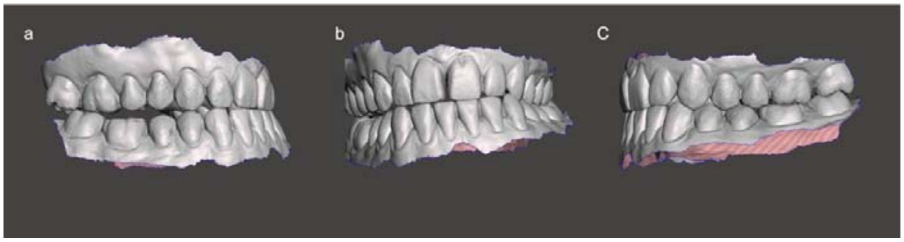

Figure 3. Screen capture of STL file created with Omnicam Cerec® (Dentsply Sirona, North Carolina, USA) (a) right view (b) front view (c) left view

Figure 4. Screen capture of maxillary and mandibular scans with Medit i700® (Medit corp., South Coreea) (in the contact point analysis mode)

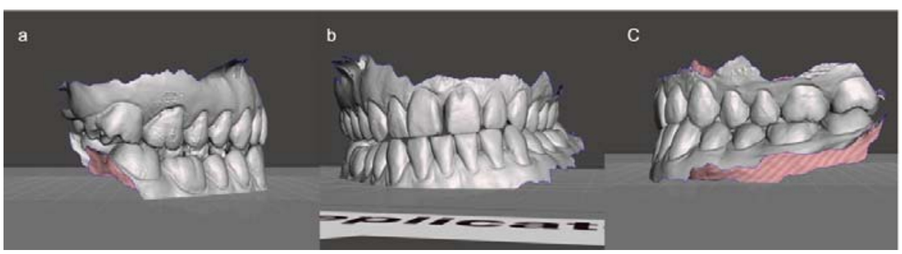

Figure 5. Screen capture of STL file created with Medit i700® (Medit corp., South Coreea) (a) right view (b) front view (c) left view

Figure 6. Screen capture of maxillary and mandibular scans with 3Shape® Trios 3 (3Shape, Denmark) (in the contact point analysis mode)

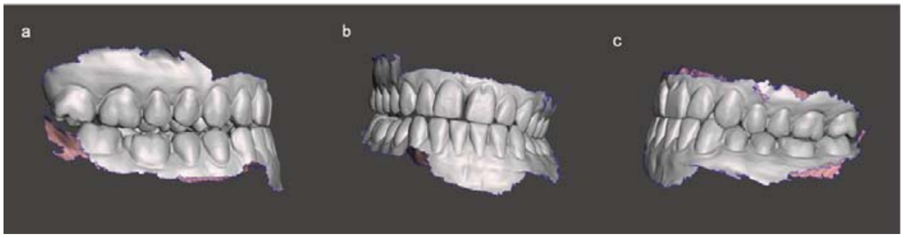

Figure 7. Screen capture of STL file created with 3Shape® Trios 3 (3Shape, Denmark) (a) right view (b) front view (c) left view

Data collection

All records - articulating paper examination photographic records and intraoral scans STL images - were reviewed by two experienced operators to verify the accuracy of the occlusal contact points. Any discrepancies or unclear recordings required a re-assessment to confirm the findings. The data from the articulating paper and each of the scanners were then digitally processed to create a comprehensive occlusal map for the patient, highlighting contact points and their intensity.

Upon completion of all four examinations for each enrolled subject, the number of contact points marked on each tooth was recorded and entered into an Excel file to facilitate statistical analysis and comparison of contact points between different occlusal analysis methods. This organized data collection allowed for efficient aggregation, sorting and visual presentation. This helped to identify patterns, discrepancies and the overall effectiveness of each method used in the study.

Statistical analysis

After collecting the data, a statistical analysis was performed to test the null hypothesis that there is no difference in the evaluation of the occlusal contacts detected using articulating papers and intraoral scanner, as well as differences between different types of intraoral scanners. Descriptive statistics for the count of occlusal contacts evaluated from digital scan and photographs of articulating paper marks were calculated. The t-test was performed to evaluate the presence of differences between the number of occlusal contacts evaluated via the four methods.

RESULTS

All contact points were recorded for each subject. The results follow a normal distribution (Table 1). The average contact points obtained for the 10 subjects of the study using each method were calculated (Table 2).

Table 1. Total number of contact points observed in 10 subjects with each method

Subject no.	No. of contacts 3Shape® Trios 3	No. of contacts Omnicam Cerec®	No. of contacts Medit i700®	Articulating paper
1	36	41	35	41
2	59	69	58	68
3	44	63	48	56
4	67	65	54	55
5	57	58	49	62

6	46	43	40	53
7	56	54	46	52
8	47	50	35	45
9	27	66	67	52
10	38	55	51	44
Total contacts	477	564	483	528

Table 2. Average number of contact points obtained on both opposing arches for each method

3Shape® Trios 3	Omnicam Cerec®	Medit i700®	Articulating paper
47,7	56,4	48,3	51,8

Considering that not all dental offices are equipped with intraoral scanners, we consider the paper to be the gold standard for analyzing occlusal contact points. We decided to assign a 100% contact point analysis rate with the articulating paper. This way, it can observe the variations between each scanner and between the scanners and the articulating paper (Table 3).

Table 3. Percentage of contact points obtained with intraoral scanners compared to articulating paper

3Shape® Trios 3	Omnicam Cerec®	Medit i700®	Articulating paper
92,08%	108,90%	93,24%	100%

By performing a statistical test (t-test) we determined whether there is a statistically significant difference between each scanner and the paper, as well as between the scanners themselves (Table 4 and Table 5).

Table 4. t-test results comparing intraoral scanners to paper

t-test	Significance level (p)
3Shape® Trios 3 vs articulating paper	0,285826
Omnicam Cerec® vs articulating paper	0,380973
Medit i700® vs articulating paper	0,905812

Table 5. t-test results comparing intraoral scanners to each other

t-test	Significance level (p)
3Shape® Trios 3 vs Omnicam Cerec®	0,094248
3Shape® Trios 3 vs Medit i700	0,905769
Medit i700 vs Omnicam Cerec®	0,082672

For each p-value < 0.05 from a t-test, a significant difference is considered. The results based on gathering the data from 10 subjects demonstrated that there was no statistically significant difference between any of the methods employed.

DISCUSSIONS

The findings of our study confirmed both null hypotheses, indicating that there were no statistically significant differences between the occlusal contact point analyses obtained through the use of intraoral scanner software (CEREC®, MEDIT®, and 3-SHAPE®) and the traditional method using articulating paper. Additionally, our results showed no significant disparities in the occlusal analysis capabilities among the three tested intraoral scanners. This study explored the comparative effectiveness of articulating paper and intraoral scanners for occlusal contact analysis, revealing no significant differences in accuracy among the tested methods. These findings align with the current discourse in dental diagnostics, where traditional methods continue to hold relevance alongside advancing digital technologies.

Recent literature supports our observation that while intraoral scanners offer rapid data collection and enhanced patient comfort, their accuracy in occlusal analysis can be variable. Mangano et al. (2017) highlighted that subjective interpretation using traditional methods like articulating paper often fails to differentiate between high and low occlusal forces effectively, suggesting a shift towards more quantitative, measurement-based methods might be beneficial [26].

Furthermore, studies have shown that factors such as paper thickness, operator experience, and the patient's biting force significantly influence the outcomes of traditional occlusal contact assessments [27]. This variability underscores the need for standardized procedures in occlusal analysis, regardless of the method employed.

Digital methods, particularly those involving complete-arch intraoral scans, have demonstrated varying levels of precision. For instance, the Trios 3 system was noted for its superior accuracy in full arch scans, suggesting that the choice of scanner could critically impact clinical outcomes [28]. However, discrepancies in scanner performance, as evidenced by the underestimation of occlusal contacts by the Medit i500 compared to more accurate systems like the Trios 3, indicate that not all digital solutions provide equivalent results [28,29].

The integration of digital technologies in dental practice, as discussed by Alghazzawi (2016), provides significant advancements in the diagnostic and design capabilities of prosthodontic care [30]. Nevertheless, the potential for inaccuracies, particularly in the context of whole arch scans, remains a concern that necessitates further refinement of these technologies [31].

The research, while comprehensive, has several limitations that must be acknowledged:

1. Sample size: the study was conducted with a limited number of participants (10 subjects). This small sample size may not provide a representative cross-section of the population, which could affect the generalizability of the findings.
2. Operator dependency: the results could potentially be influenced by the operators' proficiency and technique. Although efforts were made to standardize the examination process, individual differences in handling the intraoral scanners and articulating paper could introduce variability in the data.
3. Technology-specific limitations: each scanner has its own set of technological nuances and limitations, which might have affected the accuracy and efficiency of occlusal contact recordings. These device-specific factors were not controlled for, which could skew comparisons between devices.
4. Lack of longitudinal data: the study was conducted in a single session per participant, which does not account for potential changes in occlusal contact over time. Longitudinal studies could provide a more detailed understanding of the stability and reliability of occlusal recordings.

5. Exclusion of complex cases: the exclusion criteria removed individuals with certain dental conditions that could have provided additional insights into the performance of the occlusal recording methods under varied clinical circumstances.

However, our research has several strengths, such as the use of a comprehensive methodology, comparing traditional occlusal contact analysis using articulating paper with three different digital intraoral scanners. All occlusal examinations were performed under standardized conditions, which minimizes variability due to procedural differences. By incorporating three different intraoral scanners (3Shape® Trios 3, Omnicam Cerec®, Medit i700®), the study offers a broad evaluation of current digital technologies. The operators performing the scans and analyses were well-trained, which reduces the risk of operator-induced discrepancies and enhances the reliability of the findings.

Futures perspectives

Given these limitations, future research directions could include increasing participant diversity to improve robustness and applicability across populations, and longitudinal studies to track changes in occlusal contacts over time. Further research could also explore the use of advanced technology, such as the latest intraoral scanners and digital occlusal analysis tools, possibly incorporating machine learning to help interpret the data. Furthermore, implementation in restorative or orthodontic clinical trials could provide valuable insights into clinical efficacy. A detailed comparison of each scanner's technological capabilities and limitations could provide clearer guidance on their optimal clinical use, ensuring more targeted and effective dental solutions.

The clinical implications of this research underscore the usefulness of both traditional and digital methods of occlusal contact analysis. It shows that articulating paper and intraoral scanners provide comparable results, allowing clinicians to choose based on availability, cost and preference without sacrificing accuracy. This allows practices to make confident choices to improve workflow and patient satisfaction. It also highlights the need for continued training and calibration in using these technologies to maintain high standards of care. As digital dental technologies continue to evolve, ongoing research and adaptation in clinical practice is essential to ensure that the benefits of these tools are fully realized and that patient outcomes are improved through precise occlusal adjustments and well-fitting prosthetic solutions.

CONCLUSIONS

The analysis of occlusal contact points in the maximal intercuspation position shows equivalent results with these four methods of analysis. Indeed, no statistically significant difference is observed between the use of articulating paper and the three intra-oral scanners.

The use of articulating paper remains reliable despite the introduction of intraoral scanners. However, these four analysis methods are empirical, and it would be interesting to incorporate the use of other digital occlusal examination (e.g. T-scan® - Tekscan, Boston, MA, USA) in order to visualize the intensity of the contact points.

This study demonstrates that it is entirely feasible for a practitioner equipped with any of these three scanners to perform an analysis of occlusal contact points with the software. For the diagnosis and treatment of occlusal equilibration, it is preferable to correlate the conventional occlusal analysis method with the digital method if the software provides distorted values.

The advantages of these methods of analysis come from exploiting the benefits of each method and using them in combination for a complete occlusal diagnosis.

Conflicts of Interest

The authors declare no conflict of interest.

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