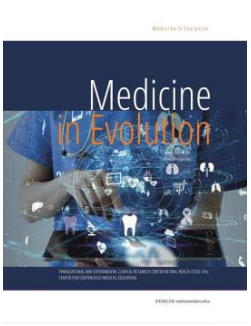
A Retrospective Analysis of Endodontic and Extraction Risk after Orthodontic Treatment



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Bratu Remus Christian[1], Sorana Maria Bucur[2*], George Popa[3*], Dana Cristina Bratu[3]

[1]*Faculty of Dental Medicine, "Victor Babes" University of Medicine and Pharmacy of Timisoara, 2 Eftimie Murgu Square, 300041 Timişoara, Romania*
[2]*Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureş, 3-5 Bodoni Sandor Street, 540545 Târgu Mureş, Romania*
[3]*Department of Orthodontics II, Orthodontic Research Centre, Faculty of Dental Medicine, "Victor Babes" University of Medicine and Pharmacy of Timisoara, 2 Eftimie Murgu Square, 300041 Timişoara, Romania*

Correspondence to:
Name: Sorana Maria Bucur
E-mail address: bucursoranamaria@gmail.com

Name: George Popa
E-mail address: popa.george@umft.ro

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Abstract

1.Background/Objectives*:** To evaluate the risk of root canal therapy and tooth extraction in anterior teeth following orthodontic treatment in adolescents. ***2. Methods: This retrospective study analyzed electronic dental records of 186 patients treated between 2021 and 2025. Permanent anterior teeth (maxillary #6–11, mandibular #22–27) were followed longitudinally. Adverse outcomes included endodontic treatment or tooth extraction. Kaplan–Meier survival analysis and Cox regression were used, with orthodontic treatment modeled as a time-dependent variable. ***3. Results:*** The mean age at treatment initiation was 12.93 ± 1.64 years. Root canal therapy occurred in 3.0% of anterior teeth and extractions in 0.1%. Maxillary central incisors showed the highest failure rate (12.2%) and the lowest 10-year survival (82.04%). Overall survival was 99.52% at 1 year, 97.59% at 5 years, and 95.20% at 10 years. Female patients had a lower risk of adverse outcomes (HR = 0.66, $p < 0.001$). Orthodontic treatment did not significantly increase overall risk, although a temporary increase in root canal therapy was observed 2–3 years after treatment initiation. ***4. Conclusions:*** Orthodontic treatment in adolescents does not significantly increase severe adverse outcomes in anterior teeth, supporting its generally favorable safety profile.

Keywords: Orthodontic treatment, Malocclusion, Root canal therapy, Tooth extraction, Anterior teeth Dental trauma, Tooth survival

INTRODUCTION

Malocclusion is one of the most prevalent oral health conditions worldwide, ranking after dental caries and periodontal disease [1]. It is commonly defined as an abnormal relationship between the maxillary and mandibular dentition when the jaws are closed. Moderate to severe forms affect approximately one-third of the population and often warrant treatment due to their impact on craniofacial growth, facial appearance, and oral function. Comprehensive orthodontic treatment is a well-established approach for correcting malocclusion, typically initiated after eruption of the permanent dentition unless significant skeletal discrepancies necessitate earlier intervention [2]. Orthodontic therapy relies on controlled mechanical forces applied to teeth and supporting structures to achieve alignment. These forces, however, are associated with potential adverse effects, including periodontal injury, pain, enamel damage, root resorption, caries, temporomandibular disorders, and possible pulpal complications [3]. Given the medicolegal importance of informed consent, clinicians must disclose not only the benefits of orthodontic treatment but also its risks and alternatives, including no treatment [1]. While several adverse outcomes are well documented, uncertainty remains regarding whether orthodontic forces can result in pulpal necrosis requiring endodontic treatment or tooth extraction [3]. Consequently, this study aimed to assess the likelihood of anterior teeth requiring root canal therapy or extraction following orthodontic treatment, as such outcomes may represent relevant risk factors for inclusion in informed consent discussions.

Malocclusion classification originated with Angle's molar-based system in 1899, later expanded by Ackerman and Proffit to incorporate dental relationships across multiple planes and facial profile analysis [4]. While Angle's classification remains foundational, contemporary indices such as the Index of Orthodontic Treatment Need provide a more comprehensive assessment by evaluating abnormalities, including missing teeth, overjet, crossbite, contact point displacement, and overbite [5]. Orthodontic treatment is indicated not only for functional correction but also for prevention of dental trauma, normalization of facial growth, and mitigation of psychosocial effects associated with malocclusion [6]. Children with untreated Class II malocclusions, particularly those with protrusive maxillary incisors, face a significantly increased risk of dental trauma, with studies reporting pulpal devitalization or fracture in approximately one-third of affected cases [7]. Additionally, facial disharmony has been shown to negatively influence social perception and psychological well-being, further supporting orthodontic intervention when appropriate [8]. Malocclusions often develop between ages 6 and 12, with treatment timing determined by severity and etiology [9]. Phase I treatment is initiated during the primary or mixed dentition to guide skeletal and dental development, particularly in cases involving crossbites, open bites, or skeletal Class III relationships. Phase II treatment, or comprehensive orthodontics, is typically undertaken once permanent dentition is established and generally lasts 12 to 36 months [10].

Comprehensive treatment progresses through stages of alignment, correction of occlusal relationships, space closure, and final detailing [1]. Tooth movement occurs through biologic remodeling of alveolar bone and periodontal tissues, mediated by osteoclast and osteoblast activity in response to sustained mechanical forces [11]. Orthodontic therapy carries recognized risks, including periodontal damage, root resorption, pulpal alterations, and enamel defects [3]. Ethical practice requires clinicians to clearly communicate these risks to patients before treatment initiation [12]. Root resorption is defined as the pathological loss of dental hard tissues unrelated to caries or trauma [13]. External apical root resorption is the most frequently associated form in orthodontic patients and results from a combination of biological susceptibility and treatment-related factors [14]. Excessive or prolonged forces,

particularly involving rapid tooth movement, are strongly linked to apical cementum loss [13,14].

While severe root resorption is relatively uncommon, occurring in approximately 1–5% of cases, it disproportionately affects maxillary incisors [15]. Histologic studies indicate that minor resorption occurs in over 90% of orthodontically treated teeth, suggesting that radiographs may underestimate its prevalence [15,16]. Severity is commonly classified using the Levander and Malmgren system, ranging from minor apical irregularities to extensive loss exceeding one-third of the root length [17]. The long-term prognosis of teeth affected by resorption remains unclear. Invasive cervical resorption represents a less common but clinically significant condition linked to orthodontic treatment, trauma, bleaching, and idiopathic causes [18]. Orthodontic therapy has been identified as a predisposing factor in nearly one-quarter of affected cases, predominantly involving maxillary anterior teeth [15]. Advanced lesions may necessitate endodontic therapy or extraction. Dental pulp is highly susceptible to ischemic injury due to its confined environment, and inflammatory pressure increases may compromise vascular supply, leading to necrosis. Orthodontic forces have been shown to induce transient molecular and vascular changes within the pulp-dentin complex. Histologic studies report varying degrees of pulpal inflammation, circulatory disturbances, and cellular degeneration following orthodontic force application [19].

Some evidence suggests an association between orthodontic movement, particularly in impacted teeth, and reduced pulp vitality or increased need for root canal treatment [19,20]. However, other investigations demonstrate reversible pulpal changes, with blood flow returning to baseline within days of force application and no detectable long-term structural damage [20]. Pulpal complications appear more likely when preexisting irritation from trauma, caries, or restorations is present [19,20].

Aim and objectives

This study aimed to evaluate the incidence and risk of root canal therapy and tooth extraction in anterior teeth following comprehensive orthodontic treatment, and to determine whether orthodontic therapy constitutes a clinically relevant risk factor for pulpal complications that should be addressed during informed consent.

MATERIAL AND METHODS

This retrospective observational study was conducted at the two University Clinics, using institutional electronic dental records collected between 2021 and 2025. This was a retrospective observational study without a non-orthodontic control group. Therefore, causal relationships between orthodontic treatment and adverse outcomes cannot be established.

Patients who initiated orthodontic treatment during adolescence were identified from the department's clinical database. A total of 186 patients met the inclusion criteria and were included in the analysis. Orthodontic treatment initiation was defined as the first documented placement of a fixed or interceptive orthodontic appliance, recorded using internal institutional procedure identifiers (ORTH-A for comprehensive treatment and ORTH-B for interceptive treatment).

All permanent anterior teeth were evaluated, including maxillary teeth #6–11 and mandibular teeth #22–27. Teeth were followed from baseline until the occurrence of an adverse dental outcome or the end of the observation period. Adverse outcomes were defined as either endodontic intervention (pulp therapy) or tooth removal, as documented in the patient record. Teeth without recorded adverse outcomes were considered event-free. For statistic al purposes, contralateral teeth were grouped, and teeth were further categorized as maxillary or mandibular anterior teeth.

Because multiple teeth from the same patient were included, the teeth were not statistically independent. No adjustment for intra-patient clustering was performed, and hazard ratios should therefore be interpreted cautiously. Baseline tooth status (previous trauma, vitality testing, restorations, or caries) was not systematically documented in the electronic records and was therefore assumed based on the absence of recorded treatment. This may introduce misclassification bias. Descriptive statistics were calculated for patient demographics, treatment type, and outcome frequency. Survival analysis was performed using Kaplan–Meier estimates, with survival time defined as the interval from baseline assessment to the first recorded adverse event. Because Kaplan–Meier methods account for censoring, survival probabilities beyond the observed follow-up period represent statistical projections rather than actual observed long-term outcomes. The proportional hazards assumption was not formally tested and represents a limitation of the study. Cox proportional hazards regression models were applied to assess associations between orthodontic treatment timing, tooth location, gender, and failure risk. Statistical significance was set at $p < 0.05$. All analyses were performed using SAS version 9.4.

Hazard ratios were reported as point estimates derived from Cox proportional hazards models. Confidence intervals were not available in the original institutional dataset because survival outputs were exported as aggregated summary statistics. Consequently, the precision of the hazard ratio estimates cannot be formally quantified, and results should be interpreted with caution. Orthodontic treatment exposure was modelled as a time-dependent covariate, with teeth contributing person-time to the non-exposed period before appliance placement and to the exposed period thereafter.

RESULTS

The study included 186 patients, with a mean age at orthodontic treatment initiation of 12.93 ± 1.64 years. The majority of patients (89.4%) began treatment between 10 and 15 years of age. Comprehensive orthodontic therapy (ORTH-A) accounted for 95.5% of treatments, while interceptive therapy (ORTH-B) represented 4.5% (Table 1).

Table 1. Patient Characteristics and Orthodontic Treatment Type

Variable	Total (n = 186)
Age at treatment initiation (years)	
Mean ± SD	12.93 ± 1.64
Median (Range)	12.8 (10–20)
Age group	
10–<11	11.5%
11–<12	19.3%
12–<13	24.9%
13–<14	21.8%
14–<15	11.9%
≥15	10.6%
Treatment type	
ORTH-A (comprehensive)	95.5%
ORTH-B (interceptive)	4.5%

A total of 2,232 anterior teeth were evaluated across all patients. Among these, 69 teeth experienced adverse outcomes, including 67 teeth requiring root canal therapy (3.0%) and 2 teeth extracted (0.1%). Endodontic treatment accounted for 3.0% of teeth, whereas extractions accounted for 0.1%. The highest frequency of adverse outcomes occurred in the maxillary central incisors (#8 and #9), which represented 12.2% of all failures. Teeth #7 and #10 accounted for 3.6%, while #6 and #11 showed a failure rate of 0.5%. Mandibular anterior teeth demonstrated substantially lower failure rates, ranging from 0.1% to 1.6% (Table 2).

Table 2. Distribution of Adverse Events by Tooth Group

Tooth Group	Failure (%)	Endodontic (%)	Extraction (%)
#6 / 11	0.5	0.4	0.1
#7 / 10	3.6	3.4	0.1
#8 / 9	12.2	12.0	0.2
#22 / 27	0.1	0.1	0.0
#23 / 26	0.5	0.5	0.0
#24 / 25	1.6	1.6	0.0

Overall tooth survival remained high throughout the observation period. Kaplan–Meier estimates showed survival probabilities of 99.52% at 1 year, 98.67% at 3 years, 97.59% at 5 years, and 95.20% at 10 years (Table 3).

Table 3. Survival Probabilities for All Anterior Teeth

Time Point	Survival Probability (%)
1 year	99.52
3 years	98.67
5 years	97.59
10 years	95.20

Female patients exhibited consistently higher survival rates than male patients. Cox regression analysis demonstrated a 34% reduction in failure risk among females compared to males (HR = 0.66, $p < 0.001$). Confidence intervals were not available for hazard ratio estimates. Tooth-specific analysis revealed significantly lower survival in maxillary central incisors (#8/9) than in all other anterior teeth. Their survival probabilities declined to 82.04% at 10 years. Mandibular anterior teeth demonstrated a 87–99% lower hazard of failure than maxillary central incisors, while teeth #7 and #10 showed a 72% lower hazard. Overall, mandibular anterior teeth had a markedly lower failure risk than maxillary anterior teeth (HR = 0.13). When comparing periods before and after orthodontic treatment initiation, no statistically significant difference in overall failure risk was observed (HR = 1.11, $p = 0.122$). However, a significant increase in adverse events occurred during years 2–3 following treatment initiation (HR = 1.38, $p = 0.015$). This association remained significant when considering endodontic treatment alone (HR = 1.33, $p = 0.031$). Confidence intervals were not available for these estimates.

When extractions were analyzed separately, orthodontic treatment was associated with a significantly increased hazard at all post-treatment time intervals, with hazard ratios ranging from 4.50 to 7.20. Because only two extraction events occurred, these estimates are unstable and should be interpreted cautiously.

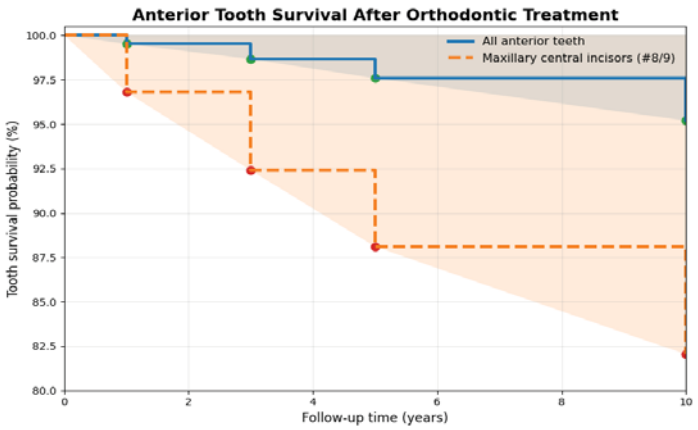

Figure 1. Kaplan–Meier survival curves for anterior teeth following orthodontic treatment. Overall, anterior tooth survival remained high throughout follow-up, while maxillary central incisors (#8/9) demonstrated a markedly lower long-term survival probability, consistent with their increased susceptibility to trauma and biologic risk factors

DISCUSSIONS

This study evaluated the occurrence of serious adverse dental outcomes—root canal therapy and tooth extraction—following orthodontic treatment of the anterior dentition in adolescent patients treated between 2021 and 2025. The findings indicate that orthodontic therapy is a generally safe treatment modality, with a low overall incidence of severe complications affecting anterior teeth. Orthodontic tooth movement is achieved through biologic remodeling of the periodontal ligament and alveolar bone in response to sustained mechanical forces [11]. Although these forces are necessary for occlusal correction, they have been associated with several potential adverse effects, including root resorption and transient pulpal changes [3]. Whether such biologic responses translate into irreversible pulpal damage requiring endodontic treatment or extraction remains clinically relevant, particularly for informed consent discussions. In the present cohort, orthodontic treatment did not result in a statistically significant increase in overall adverse outcomes when comparing periods before and after treatment initiation (HR = 1.11, p = 0.122). Root canal therapy accounted for 3.0% of evaluated teeth, while extractions were rare (0.1%), supporting previous reports that severe pulpal or structural complications following orthodontic therapy are uncommon [19,20]. These findings reinforce the notion that orthodontic forces alone do not typically compromise long-term tooth vitality.

A transient increase in adverse events was observed during years two to three after treatment initiation, with a significant rise in root canal therapy (HR = 1.33, p = 0.031). This period coincides with the average duration of comprehensive orthodontic treatment, which commonly lasts approximately two years [10]. One possible interpretation is that orthodontic correction of increased overjet may reduce post-treatment trauma risk, while pulpal sequelae from pre-existing injuries become clinically evident during or shortly after treatment completion. Maxillary central incisors (#8 and #9) demonstrated the lowest survival rates, with a 10-year survival probability of 82.04%, and accounted for the highest proportion of adverse outcomes (12.2%). This distribution mirrors the well-established vulnerability of these teeth to traumatic dental injuries and orthodontically induced root resorption [7,15]. Children between 7 and 12 years of age experience the highest incidence of dental trauma, with maxillary central incisors most frequently affected [5,7]. Previous studies have also shown that untreated Class II malocclusions with increased overjet substantially elevate the risk of incisor trauma, pulpal devitalization, and fracture [7,16].

Gender-related differences observed in this study further support a trauma-associated explanation. Female patients exhibited a 34% lower hazard of adverse outcomes compared to males (HR = 0.66, p < 0.001), consistent with earlier reports demonstrating higher trauma prevalence among boys [7]. These findings suggest that patient-specific risk factors, rather than orthodontic mechanics alone, significantly influence pulpal outcomes. Biological mechanisms may also contribute to the observed pattern. Severe external apical root resorption occurs in approximately 1–5% of orthodontic patients and is most frequently reported in maxillary incisors [15,17]. Excessive or prolonged orthodontic forces can disrupt cementum integrity and alter pulpal blood flow, particularly in teeth with pre-existing inflammation or trauma [13,14,19]. Although many pulpal changes induced by orthodontic forces appear reversible, compromised teeth may progress to necrosis, necessitating endodontic intervention [19,20].

Invasive cervical resorption represents another potential pathway linking orthodontic treatment and adverse outcomes. Orthodontics has been identified as a predisposing factor in a substantial proportion of cases, predominantly involving maxillary anterior teeth [18]. Advanced lesions may ultimately require root canal therapy or extraction, further explaining the higher failure rates observed in this region.

Several limitations must be acknowledged. The study population was derived from a single academic institution, which may limit generalizability. The retrospective design did not allow control over confounding factors such as oral hygiene, caries history, or undocumented dental trauma. Additionally, it was assumed that all evaluated anterior teeth were present and untreated at baseline and that orthodontic therapy had not been initiated before age 10. The absence of a non-orthodontic control group limits causal inference. Observed associations may reflect underlying patient risk factors rather than treatment effects. The analysis treated teeth as independent observations despite clustering within patients, which may have led to underestimated standard errors and overestimated statistical significance. Reported survival estimates up to 10 years reflect statistical projections derived from Kaplan–Meier modeling rather than direct observation, as the study follow-up period extended from 2021 to 2025.

Additionally, confidence intervals for hazard ratios were not available due to the aggregated nature of the exported survival data, limiting assessment of the estimate's precision. In summary, orthodontic therapy did not significantly increase the overall risk of root canal therapy or extraction in this adolescent population. Maxillary central incisors and male patients demonstrated higher susceptibility to adverse outcomes, likely reflecting the combined effects of trauma exposure, biologic vulnerability, and pre-existing conditions rather than orthodontic forces alone. Given the low overall incidence of severe complications, orthodontic treatment remains a safe and effective modality for managing malocclusion in children and adolescents. Given the retrospective observational design and potential residual confounding, these findings should be interpreted as associative rather than causal.

CONCLUSIONS

Orthodontic treatment was not associated with a sustained increase in overall risk of root canal therapy or tooth extraction, although a transient increase in adverse events was observed during years 2–3 after treatment initiation. Maxillary central incisors and male patients exhibited a higher susceptibility to adverse outcomes, likely reflecting trauma-related and biologic factors rather than orthodontic forces alone. Overall, the low incidence of severe complications supports orthodontic therapy as a safe treatment modality in children and adolescents.

Conflicts of Interest

The authors declare no conflict of interest.

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