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Orthodontic treatment in immature teeth: A contemporary review of endodontic, periodontal, and biomechanical aspects

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Abstract

Immature permanent teeth, characterised by open apices, thin dentinal walls, short or developing roots, and incomplete maturation of the pulp–periodontal tissues, require particular attention in orthodontic treatment planning. Since orthodontic therapy is most frequently applied during childhood and adolescence, clinicians often encounter vital teeth with incomplete root development, traumatised immature teeth, teeth treated with apexification, or necrotic immature teeth managed with regenerative endodontic therapy. Current literature indicates that controlled orthodontic forces in healthy, vital immature teeth do not invariably arrest root development, and in many cases root maturation continues within normal limits. Conversely, in the presence of trauma, pulp necrosis, apical periodontitis, root resorption, ankylosis, apexification, or regenerative endodontic therapy, the biological effects of orthodontic movement become more complex and less predictable. In particular, the long-term consequences of orthodontic forces applied following regenerative endodontic therapy remain insufficiently evidenced. The purpose of this review is to evaluate orthodontic treatment in immature teeth in relation to root development, pulp biology, periodontal response, root resorption, post-traumatic healing, apexification, and regenerative endodontic therapy in light of contemporary literature.

Keywords: Immature Tooth; Orthodontic Treatment; Root Development; Regenerative Endodontics; Apexification; Dental Trauma; Root Resorption

1. Introduction

Orthodontic treatment is frequently undertaken during periods of growth and development, and consequently some teeth subjected to therapy may not have completed root formation. Root development in permanent teeth commences following crown formation and continues for approximately two to three years after eruption. During this period, biological interactions between Hertwig's epithelial root sheath, the apical papilla, pulp tissue, periodontal ligament, and alveolar bone are decisive for root length, dentinal wall thickness, apical closure, and maturation of periodontal support tissues (1, 2). Thus, the impact of orthodontic forces on root development, pulpal circulation, and periodontal response in immature teeth constitutes a clinically significant area of debate.

Concerns regarding orthodontic treatment in immature teeth are grounded in two principal biological mechanisms. The first relates to whether the inflammatory–remodelling response induced in the periodontal ligament and alveolar bone by orthodontic forces affects developing root tissues. The second concerns whether apical tissues compromised by trauma or infection exhibit heightened sensitivity to orthodontic forces. In healthy, vital, developing teeth, there is no robust evidence that orthodontic forces completely arrest root development. On the contrary, some studies report that immature roots may continue to develop during treatment, achieving dimensions comparable to fully formed roots (3,

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4). In contrast, traumatised, necrotic, apexified, or regeneratively treated teeth present more complex clinical scenarios (5).

Contemporary endodontic approaches in immature teeth with pulp necrosis aim not only to establish an apical barrier but also to promote root development. Calcium hydroxide apexification and apical plug techniques using MTA or hydraulic calcium silicate cements demonstrate high success rates, yet in most cases they do not yield significant increases in root length or dentinal wall thickness (6). Regenerative endodontic therapy (RET), by contrast, is considered biologically advantageous in necrotic immature teeth due to its potential to support root maturation through stem cells derived from the apical papilla, biological scaffolds, and growth factors (7). Nevertheless, when such teeth subsequently undergo orthodontic treatment, the mechanical quality of newly formed tissue, pulpal–vascular stability, and risk of root resorption must be carefully considered (8).

2. Root Development and Biological Response to Orthodontic Forces in Immature Teeth

Immature permanent teeth undergo ongoing root development, guided by Hertwig's epithelial root sheath and supported by the apical papilla. Orthodontic forces induce controlled inflammatory responses within the periodontal ligament, facilitating bone resorption and apposition to enable tooth movement. Within physiological limits, pulpal and periodontal responses in vital teeth are generally reversible (9).

The influence of orthodontic forces on pulp is particularly associated with compression of the apical neurovascular bundle. Tipping, intrusion, and heavy continuous forces may transiently reduce pulpal blood flow. However, immature teeth with wide apical openings possess richer vascular supply, potentially conferring greater adaptability to controlled forces (10). This advantage may be diminished in cases where apical tissues have been compromised by trauma, infection, or surgical intervention.

Mavragani et al. reported that root elongation continued in some immature teeth during orthodontic treatment, suggesting that root development potential in young patients may partially offset the risk of resorption (3). Earlier clinical data similarly indicated that developing roots could reach their predetermined length under light, controlled orthodontic forces (4). More recent CBCT-based evaluations provide detailed insights. In a 2025 pilot study by Dodeja et al., immature premolars subjected to rapid maxillary expansion and fixed orthodontic therapy exhibited significant increases in root length and volume, with post-treatment dimensions comparable to controls with completed roots (1). These findings challenge the traditional concern that orthodontic treatment invariably halts root formation in vital immature teeth.

Nevertheless, treatment outcomes are directly influenced by the magnitude, duration, direction, and type of orthodontic force applied. Intrusion, excessive torque, prolonged heavy forces, and extensive apical movements increase the risk of root resorption. Accordingly, treatment planning for immature teeth must consider root developmental stage, periodontal support, trauma history, occlusal loading, and radiographic findings.

3. Orthodontic Treatment in Vital Immature Teeth

In vital and healthy immature teeth, orthodontic treatment is generally considered safe. Root development may continue during therapy, allowing increases in root length to be observed throughout the treatment process. This does not imply, however, that developing teeth are entirely unaffected by orthodontic forces. In anchorage teeth such as premolars and molars, particularly during rapid maxillary expansion or fixed appliance therapy, resorptive changes may occur on buccal root surfaces (11).

The biological success of orthodontic treatment in vital immature teeth depends upon the application of light and controlled forces, avoidance of unnecessarily prolonged treatment durations, and limitation of high-risk movements. Pre-treatment periapical or panoramic radiographs should be used to determine the stage of root development, while CBCT should be reserved for cases where clinical necessity dictates. Early intervention may be required in situations such as increased overjet, anterior open bite, crossbite, or impacted teeth; however, the decision for early treatment should be based not solely on the presence of immature teeth but also on the potential progression of malocclusion, risk of trauma, and severity of functional disturbance (12-14).

Contemporary literature does not support the routine application of early orthodontic treatment in all children. Systematic reviews and clinical guidelines emphasise that early treatment is primarily indicated in cases of pronounced functional crossbite, Class III tendency, severe transverse constriction, increased overjet with trauma risk, psychosocial impact, and certain localised malocclusions (12, 13). Thus, treatment planning in vital immature teeth should aim both to preserve root development and to reduce the likelihood of more complex treatment requirements in the future.

4. Orthodontic Approach in Traumatised Immature Teeth

Dental trauma is common in children and adolescents, particularly affecting maxillary anterior teeth. Traumatic injuries may result in pulp necrosis, pulp canal obliteration, external inflammatory root resorption, replacement resorption, ankylosis, marginal bone loss, and arrested root development (15-17). Although the wide apical foramen of immature teeth may facilitate pulp healing, severe luxation, intrusion, or avulsion injuries can damage the apical papilla and Hertwig's epithelial root sheath, thereby impairing root development (15, 16).

Prior to orthodontic treatment, the pulpal and periodontal status of traumatised immature teeth must be clarified. Clinical evaluation should include assessment of discolouration, spontaneous pain, percussion sensitivity, mobility, sinus tract formation, periodontal pocket depth, and occlusal trauma. Radiographic examination should investigate periapical lesions, root resorption, irregularities in the periodontal ligament space, arrested root development, or signs of ankylosis (15, 18). Pulp sensibility tests may be misleading in the early post-trauma period; hence, a single negative response should not be considered sufficient for diagnosing pulp necrosis (16).

The timing of orthodontic force application following trauma depends upon the type of injury and the healing status. In mild trauma cases where vitality is preserved, controlled forces may be applied after an appropriate observation period. In contrast, severe injuries such as intrusion, avulsion, lateral luxation, or complicated crown–root fractures necessitate endodontic and periodontal stabilisation before orthodontic movement is attempted (17). Where ankylosis or replacement resorption is suspected, orthodontic success may be limited, requiring multidisciplinary decision-making involving orthodontists, endodontists, paediatric dentists, and surgeons (18).

Medeiros and Mucha evaluated immediate and delayed orthodontic extrusion in intruded traumatised teeth, noting that early orthodontic force may facilitate endodontic access and reduce ankylosis risk, but may also increase the likelihood of external root resorption and marginal bone loss (19). Consequently, orthodontic movement following trauma should be planned not merely to reposition the tooth within the arch but to preserve its long-term prognosis.

5. Orthodontic Treatment Following Apexification

In immature teeth with pulp necrosis, calcium hydroxide apexification was historically the standard treatment, later supplemented by apical barrier techniques using MTA and other hydraulic calcium silicate cements. These methods achieve periapical healing and apical barrier formation but generally fail to increase root length or dentinal wall thickness (5). As a result, teeth treated with apexification often remain mechanically fragile due to short roots, thin dentinal walls, and unfavourable crown–root ratios.

Prolonged calcium hydroxide use may adversely affect dentinal mechanical properties, increasing the risk of cervical root fracture (6). Although MTA apical plug techniques shorten treatment duration, they do not biologically promote continued root development, leaving structural weakness unresolved. Thus, orthodontic planning in apexified teeth must carefully consider root length, wall thickness, apical barrier integrity, and periodontal support.

Keinan et al. conducted a retrospective study on traumatised immature anterior teeth treated with apexification, assessing the impact of subsequent orthodontic therapy. Over a minimum five-year follow-up, apexification success rates were high, with orthodontically treated teeth exhibiting minor root resorption averaging 0.3 mm, while untreated teeth demonstrated minimal root elongation (20). Although statistically significant, these findings suggest that orthodontic movement in apexified teeth is generally safe (20).

Nevertheless, orthodontic forces in such teeth should be applied as lightly as possible, avoiding excessive torque and intrusion. Continuous periapical monitoring is essential, and treatment plans must be reconsidered if resorption or pathology emerges. In aesthetically critical regions, the therapeutic objective should extend beyond ideal alignment to ensuring long-term tooth retention.

6. Orthodontic Movement Following Regenerative Endodontic Therapy

Regenerative endodontic therapy (RET) represents a biologically based approach designed to support root development in necrotic immature teeth. The principal stages of treatment include canal disinfection, induction of bleeding from apical tissues, establishment of a biological scaffold within the canal, and provision of coronal sealing (7). Clinical outcomes following RET may include apical closure, increases in root length, dentinal wall thickening, periapical healing, and in some cases positive responses to sensibility testing (21).

Nevertheless, histological studies demonstrate that tissue formed within the canal after RET is not invariably a true pulp–dentine complex. Instead, the newly generated tissue may frequently exhibit characteristics of cementum-like, bone-like, or periodontal-derived fibrous tissue (22). Consequently, radiographic evidence of root development or apical closure does not necessarily equate to biomechanical equivalence with a physiologically mature root.

Evidence regarding orthodontic treatment following RET remains limited. Bucchi et al., in a systematic review, noted that available studies were largely case reports, with low-quality evidence and a non-negligible incidence of adverse effects (8). Reported complications included sinus tract formation, root resorption, symptomatology, apical periodontitis, and intracanal tissue necrosis, although overall tooth survival was reported at 87.5% (8). In contrast, Yoshpea et al. (2025) reported that orthodontic treatment did not negatively affect root development in traumatised immature teeth treated with RET (23). Their study found no detrimental impact during treatment or retention phases, with root area increases attributed primarily to age-related factors [8]. Case reports similarly suggest that RET-treated immature teeth can be successfully moved orthodontically under careful monitoring and with light forces (24).

These apparently conflicting findings highlight the necessity of individualised clinical decision-making. When planning orthodontic movement in RET-treated teeth, clinicians must consider trauma type, stage of root development, time elapsed since RET, periapical healing status, dentinal wall thickness, presence of intracanal calcification or pathology, and the magnitude and direction of planned movement. RET-treated teeth should not be regarded as equivalent to normal vital teeth, yet they should not automatically be excluded from orthodontic movement in suitable cases.

7. Biomechanical Considerations in RET-Treated Immature Teeth

The biomechanical quality of root development following RET depends upon the nature of the newly formed hard tissue. Dentine, with its regular tubular structure and mechanical resilience, distributes orthodontic forces more evenly along the root. In contrast, cementum-like or bone-like tissues may exhibit irregular structural properties, potentially compromising stress distribution compared with physiological dentine (25).

Finite element analyses by Bucchi et al. compared stress distribution in immature maxillary incisors reinforced with dentine-like versus cementum-like tissue following revitalisation. Their 2019 study demonstrated that simulated hard tissue apposition reduced mechanical stress in immature teeth, with dentine-like tissue providing more balanced stress distribution than cementum-like tissue (26). A subsequent 2022 study found that RET-treated teeth reinforced with dentine or cementum exhibited more favourable periodontal ligament stress distribution compared with untreated immature teeth with weak roots (25). These findings suggest that orthodontic loading may be theoretically feasible in RET-treated teeth with partial root maturation, though clinical decisions must be supported by in vivo data and individual risk assessment.

Biomechanically high-risk scenarios include short roots, thin dentinal walls, unfavourable crown–root ratios, wide apical openings, prior resorption, and susceptibility to new trauma. Maxillary incisors are particularly vulnerable due to increased overjet, inadequate lip coverage, and sports-related trauma risk. Accordingly, orthodontic treatment in RET- or apexification-treated anterior immature teeth should be planned to minimise trauma risk and avoid excessive force application.

8. Risk of Root Resorption and Radiographic Monitoring

Apical root resorption associated with orthodontic treatment is a multifactorial complication influenced by genetic predisposition, root morphology, prior trauma, prolonged treatment duration, heavy forces, intrusion, excessive torque, extensive apical movement, and pre-existing resorption (27). While ongoing root development in immature teeth may confer some protective advantage, teeth with histories of trauma or necrosis require particularly cautious evaluation (17).

Root resorption is often asymptomatic and detected radiographically (27). Baseline radiographic records are therefore essential prior to treatment in immature, traumatised, or endodontically treated teeth. During therapy, high-risk teeth should be monitored at regular intervals, with orthodontic forces reduced or temporarily discontinued if resorption is detected. CBCT offers valuable three-dimensional assessment of resorption and periapical pathology, though its use in children and adolescents should be restricted to clinically necessary situations due to radiation exposure (9).

Trauma-related injuries such as lateral luxation may lead to pulp canal obliteration, pulp necrosis, inflammatory resorption, or surface resorption (17). Consequently, thorough evaluation and ongoing pulp–periapical monitoring are indispensable in traumatised immature teeth undergoing orthodontic treatment. Diagnostic reliance solely on sensibility testing is inappropriate, as responses may fluctuate during orthodontic therapy.

9. Timing of Early Orthodontic Treatment and Preservation of Immature Teeth

Immature teeth are typically present during the mixed dentition stage, making the timing of early orthodontic intervention closely relevant. The primary objectives of early treatment are to intercept developing malocclusion, correct functional shifts, reduce trauma risk, harness growth potential, and mitigate the severity of future comprehensive treatment (12, 28).

Systematic reviews indicate, however, that early treatment does not confer long-term superiority across all malocclusions, and unnecessary two-phase treatments may prolong overall treatment duration (13). Stronger indications for early intervention include posterior crossbite, functional mandibular shift, certain Class III cases, pronounced transverse maxillary constriction, increased overjet with trauma risk, and psychosocial impact (29). In children with increased overjet, early reduction is particularly important to protect immature maxillary incisors from trauma (28). In patients with traumatised or endodontically treated anterior teeth, such interventions must be carefully planned with controlled forces.

Rapid maxillary expansion is frequently employed during mixed dentition, yet current debate emphasises that routine expansion in all preadolescent patients is inappropriate. Indications should be based on transverse deficiency, crossbite, arch constriction, and functional findings (30). In Class II treatment, the effectiveness of functional appliances depends upon growth stage, mandibular morphology, and patient response (31). Thus, decisions regarding early orthodontic intervention in immature dentition should be based not solely on chronological age but on biological development stage and individual risk profile.

10. Clinical Recommendations

Orthodontic treatment planning in immature teeth must begin with assessment of vitality, trauma history, and endodontic treatment status. Controlled orthodontic therapy is generally safe in healthy, vital immature teeth, whereas traumatised, necrotic, apexified, or RET-treated teeth require categorisation as higher risk.

Pre-treatment evaluation should include root developmental stage, apical opening, root length, dentinal wall thickness, periodontal ligament space, periapical status, and potential resorption. Orthodontic forces should not be applied to traumatised teeth until pulp necrosis or ankylosis has been excluded. In apexified teeth, heavy forces, excessive torque, and intrusion should be avoided due to structural fragility. In RET-treated teeth, periapical healing, stability of root development, and asymptomatic clinical status must be confirmed before orthodontic movement is initiated.

During treatment, light and intermittent forces should be preferred, with activation intervals carefully controlled in high-risk teeth. If resorption or periapical pathology emerges, forces should be reduced or treatment temporarily suspended. Communication between orthodontists and endodontists must be maintained throughout treatment and retention phases. Long-term follow-up is essential, particularly in traumatised immature anterior teeth (18, 23).

11. Conclusion

Orthodontic treatment in immature teeth can be safely undertaken with appropriate indications and careful biological planning. Current evidence suggests that controlled orthodontic forces in healthy, vital immature teeth generally do not arrest root development, and many teeth achieve normal root dimensions during therapy. However, trauma, pulp necrosis, apexification, regenerative endodontic therapy, root resorption, and ankylosis increase treatment risk. While orthodontic movement in apexified teeth is feasible, structural fragility persists. In RET-treated teeth, promising clinical findings exist, though the level of evidence remains limited.

Treatment planning in immature teeth must therefore be individualised, multidisciplinary, and follow-up oriented. Objectives should extend beyond achieving ideal occlusion to include long-term functional and aesthetic preservation of developing or biologically compromised teeth. Future research should focus on prospective long-term studies of orthodontic treatment in RET- or apexified immature teeth, CBCT-based root volume analyses, patient-centred outcome measures, and standardised monitoring protocols to strengthen the evidence base.

Compliance with ethical standards

Disclosure of conflict of interest

The author declares no conflict of interest.

Author contribution

İdris Onur YALÇIN and Cemre ÇELİK YALÇIN contributed to conceptualization, literature evaluation, manuscript drafting, critical revision, and final approval of the manuscript. Both authors have read and approved the final version of the manuscript.

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