Chapter 4

Multidisipliner Approach in Orthodontics and Endodontics

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Abstract

Orthodontics and endodontics are two significant and complementary fields of dentistry. Orthodontics focuses on the proper alignment of the teeth aesthetically and functionally, whereas endodontics deals with the health, pathology, and treatment of the dentin-pulp complex. The application of orthodontic forces causes inflammatory effects on the periodontal ligament and pulp. Therefore, the patient's oral tissues must be ensured to be completely healthy prior to orthodontic treatment. Close monitoring of pulp health during orthodontic treatment is crucial to maintain pulpal vitality, increase the mechanical resistance of the teeth, and ensure their long-term survival.

Furthermore, management of dental trauma should be a priority to preserve pulpal vitality. In such cases, appropriate orthodontic approaches and treatment plans should be developed. By offering a specialized treatment alternative for immature teeth, regenerative endodontics promotes pulpal and periodontal dental health. In orthodontic treatment planning, it is essential to precisely ascertain orthodontic force parameters while considering the patient's distinctive characteristics. In this process, a multidisciplinary approach is vital to achieve optimal results for patients, relatives of the patients, and physicians.

1. Introduction

Orthodontics and endodontics are two fields of dentistry that focus on different aspects of oral and maxillofacial health. Orthodontics is a field focused on enhancing the aesthetics and functionality of the teeth, jaws, and their interrelationship. Endodontics pertains to the biology, pathology, and

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regeneration of the dentin-pulp complex and periodontal tissues, aiming to preserve dental health through the diagnosis, prevention, and treatment of diseases and injuries affecting these tissues. This section of our book will analyze the intricate relationship between these two fields and highlight the significance of collaboration in multidisciplinary treatments.

1.1. Relationship between Orthodontic Force and Periodontium

Orthodontic tooth movement happens because of inflammation in the periodontal ligament (PDL) and alveolar bone when orthodontic forces are applied to the crown of the tooth using various attachments (Turner & Pavalko, 1998). According to Burstone, orthodontic tooth movement occurs in three phases:

1. Initial Phase: This phase, which starts with the compression of the PDL with the force applied to the tooth and the rapid movement of the tooth in the alveolar socket, occurs within 24 hours to 2 days. Cells and vessels sustain damage during this process, leading to the formation of hyalinized (cell-free, glassy) tissues.
2. Pausing Phase: In the second phase, the tooth movement is observed minimally or not at all.
3. Movement Phase: Tooth movement gradually increases. Hyalinization and indirect bone resorption occur in conjunction with each other (Smith & Burstone, 1984).

We expect orthodontic tooth movement to occur at optimum orthodontic force levels by stimulating cellular activity without interrupting the PDL blood supply(Burstone, 1989). However, depending on the type and intensity of orthodontic movement, the periodontium is subjected to different types of stress. In particular, forces that don't evenly compress the PDL may cause problems like tissue damage, root loss, or death of the tissue (Lin et al., 2023). Furthermore, if orthodontic forces cause compression of the blood vessels of the periodontium, this may result in a direct reduction in pulpal blood flow(Sabuncuoglu & Ersahan, 2014).

1.2. Relationship between Orthodontic Force and Dentin-Pulp Complex

The dental pulp is a specialized connective tissue surrounded by dentin with a rich vascular and nerve network (Goldberg et al., 2011). The four main functions of the pulp are nutrition, innervation, protection, and formation (Sloan & Smith, 2007). Although the pulp is richly vascularized,

its connection to the surrounding tissues is through the blood vessels of the periodontium passing through the apical foramen as it is surrounded by dentin. Thus, changes in periodontal blood flow or vascular tissue pressure affect the health status of the dental pulp (Hamilton & Gutmann, 1999).

Orthodontic pressures can induce changes on the pulp that vary from mild hyperemia to complete pulp necrosis (Reitan, 1960). This variation is caused by the variability of the intensity and duration of the applied orthodontic force, as well as the type, direction, and distribution of orthodontic movement (Krishnan & Davidovitch, 2006).

The primary effect on the pulp caused by orthodontic forces is a reduction in pulpal blood flow, leading to hypoxia and affecting the levels of inflammation-related enzymes and neuropeptides (Huokuna et al., 2023). Increased protein levels such as CGRF, SP, VEGF indicate that orthodontic force leads to mild inflammation in both the periodontium and the pulp (Caviedes-Bucheli et al., 2021). Another effect of orthodontic forces is that they can reduce tooth sensitivity because of a lack of oxygen in the nerve tissues of the pulp, which can result in altered responses during sensory tests like the electric pulp test(Butt & Harris, 2022; Huokuna et al., 2023). However, most of these reactions are acute reactions observed within the first few days to a week and are usually reversible (Consolaro & Consolaro, 2018).

Fibrotic tissue formation, pulp calculus formation, and reduction in pulpal volume are other histomorphologic changes that can be observed in the pulp with the implementation of orthodontic forces. (Lazzaretti et al., 2014).

2. Endodontic Factors in the Orthodontic Treatment Process

2.1. Endodontic Evaluation Before Orthodontic Treatment

Oral tissues should be completely healthy before orthodontic treatment. This condition requires a detailed anamnesis and examination process before orthodontic treatment, as in all branches of dentistry. In the clinical examination, the health of the pulp, dental anomalies, and the status of existing restorations should be examined; the presence of suspicious teeth and/or restorations should be evaluated; and basic health criteria such as periodontal pocket measurements, dental mobility, and the presence of gingival bleeding should be reviewed (Proffit et al., 2012). Thermal and electrical pulp tests should be performed to assess the health status of the pulp. Past dental traumas should be carefully evaluated for potential

damage such as missed root fractures, ankylosis, and root resorption, and care should be taken to obtain a detailed dental history from the patient/caregiver (Owtad et al., 2015). The current situation should be recorded with forms and intraoral and extraoral photographs (Lacombe et al., 2021). Radiographic examination should include periapical lesions, root resorption, dental fractures, and trauma history of hard tissues; dental caries (white spot lesions, enamel, and dentin caries); and the presence of healthy/unhealthy restored teeth and root structure (Bayram et al., 2011). Radiographs can also provide information about the health of the periodontal ligament, the presence and size of periodontal pockets, and the health status of the periodontium by monitoring lateral or apical lesions.

The prevalence of dental caries is decreasing globally, but the attachments used in orthodontic treatment are considered a strong risk factor for dental caries as they are considered a predisposing factor for plaque accumulation and demineralization (Cruz & Edelstein, 2016; Jin et al., 2016). During orthodontic treatment, the early diagnosis and treatment process may be interrupted as caries detection may become difficult (Tufekci et al., 2011). Therefore, prior to orthodontic treatment, the clinician should make patients aware of oral hygiene, plaque control, and elimination by performing preventive and invasive dental treatments.

Orthodontic force may generally lead to undesirable effects on the dentin-pulp complex, even temporarily. However, preserving pulp vitality increases mechanical resistance and long-term survival of teeth (Vitali et al., 2022). Therefore, pulp health must be closely monitored before, during, and after orthodontic treatment. The pulp vitality must be recorded before orthodontic treatment, dental symptoms, if any, should be reviewed, and appropriate treatments should be performed (Rathi & Rathi, 2023). The dental health during orthodontic treatment must be regularly monitored by radiographs taken from the patients.

It is known that exposure of endodontically treated healthy teeth to orthodontic forces does not increase the risk of root resorption, nor does orthodontic movement provide a protective effect against resorption and thus does not require a special orthodontic approach(Beck et al., 2013).

2.2. Management of Endodontic Emergencies During Orthodontic Treatment

Mechanical compression of the PDL induced by orthodontic pressures may lead to reduced pulpal blood flow and hypoxia. This condition causes mostly reversible effects on the pulp, but in the case of heavy forces or

trauma history, it may lead to irreversible pictures (Huokuna et al., 2023). Diagnosing endodontic treatment during the orthodontic treatment process brings some special circumstances. For example, it may be required to take radiographs of the suspicious tooth without superposition of the attachments or to remove the orthodontic attachments to perform pulp sensitivity tests without obtaining erroneous results due to the attachments. The same is also applicable for effective rubber dam isolation and proper cavity preparation, regardless of the endodontic treatment option (Beck et al., 2013).

As it is known that the inflammatory process will resolve within 15 to 30 days after the endodontic treatment is completed, there is no harm in re-exposing these teeth to orthodontic force at the end of the process (Consolaro & Consolaro, 2013). Therefore, unless we observe external apical root resorption, endodontic treatment of teeth with undiagnosed periodontitis does not require a special approach (Chen et al., 2024). Conversely, teeth with inflammatory lesions requiring endodontic treatment require a meticulous approach to both endodontic and orthodontic treatment. It should be noted that orthodontic forces will affect unhealthy periodontal tissues even if they are within physiological limits(Bakkari, 2022). In this process, the timing and intensity of orthodontic forces to be applied to the tooth should be controlled following the effective treatment of the lesion by removing the relevant tooth from orthodontic treatment, and endodontic lesion follow-up should be performed more frequently compared to teeth without orthodontic treatment (Consolaro et al., 2020; Zhao et al., 2023).

In the event that periodontal lesions do not heal or progress, the tooth should be removed from orthodontic treatment; the presence of additional or accessory canals, crown anomalies such as dens invaginatus, and the possibility of extraradicular infection should be evaluated. This is because it has been reported that orthodontic forces do not affect the biology or virulence of the lesions, so orthodontic treatment can be continued following the inflammatory process after effective lesion treatment is provided (Consolaro et al., 2020).

2.3. The Effect of Orthodontic Movement on Root Resorption

External cervical root resorption is caused by the destruction of cementum tissue, leading to the interaction of clastic cells of the periodontium and dentin. Its etiology is not fully understood, but orthodontic treatment, history of dental trauma, and hypoxia are the most commonly associated factors. Pathogenesis consists of 3 phases: initial, resorptive, and reparative. In the initial phase, the pulp is vital and not yet affected. In this phase,

the patient is clinically and radiographically asymptomatic (Mavridou et al., 2017). In the later phases, the pulp cannot be protected from resorption, and a formation of vascular granulation tissue leads to the formation of an appearance called 'pink spot' in the crown, and cavitation in the root may be observed in the continuation of the clastic process (Heithersay, 2004). While the radiographic image appears as a radiolucent area during the resorption phase, radiopaque traces are attached to it with the onset of the reparative phase (Gunst et al., 2013). Although resorption is often irregular by its nature, there are well-marginated cases (Patel et al., 2022). Observing cavitation of the root makes it difficult to distinguish from internal root resorption (Patel et al., 2018). Therefore, the use of cone beam computed tomography is recommended by the European Society of Endodontics to facilitate the diagnosis of external root resorption (Patel et al., 2019).

External root resorption is regarded as one of the side effects of orthodontic treatment (Sondeijker et al., 2020). Mechanical risk factors for the formation of external root resorption include the magnitude, direction, and duration of orthodontic force, whereas biological risk factors include age, gender, history of traumatic injury, presence of periapical lesions, root morphology, previous root resorption, bone density, type of malocclusion, individual susceptibility, and genetic predispositions (YILDIRIM et al., 2025).

The relationship between the magnitude of orthodontic force and root resorption: As the magnitude of the applied force increases, the risk of periodontal tissue hyalinization and resorption increases (Wahab, 2017).

The relationship between the direction of orthodontic force and root resorption: Studies have indicated that strong forces, particularly when pushing teeth down or tilting them, create more pressure at the root tip and lead to more root resorption than other types of orthodontic forces (Bakkari, 2022; Chiqueto et al., 2008).

The relationship between duration of orthodontic force and root resorption: Long-term and continuous forces concentrated on the tooth increase the risk of root resorption, while short-term or intermittent forces lead to less resorption (Bakkari, 2022).

Demographic factors have significant effects on root resorption. Age is the main factor determining this relationship, whereas an increase in root volume is observed in young individuals, especially in immature teeth; the risk of root resorption is higher in adults. Root resorption rates in certain teeth (maxillary lateral, maxillary canine, and mandibular canine) are higher

in women than in men. According to reports, bite anomalies like open bite and deep bite increase the risk of root resorption (Lin et al., 2025).

When root resorption arises during orthodontic treatment, the clinician must carefully evaluate whether to continue treatment, taking into account the risk of resorption progression. Continuation, modification, or termination of treatment are among the clinician's options (Sondeijker et al., 2020). In making this decision, existing occlusal problems (deep bite, occlusal trauma) and the patient's aesthetic concerns should be considered. For example, if there are long-term negative effects of occlusal trauma, it may be more appropriate to continue treatment or to remove the orthodontic force on the affected teeth (Danz et al., 2014). In case of generalized severe root resorption, orthodontic treatment should be terminated. However, if treatment is planned to continue, it has been recommended that it be interrupted for at least 3 months to allow the resorptive lacunae to heal (Mehta et al., 2017).

It is recommended during the follow-up period that radiographic evaluation should be performed 6 months after the treatment is restarted, passive retention appliances should be used after the treatment, and these appliances should not create any force on the tooth. In teeth with root resorption of 2 mm or more, the remaining root length and mobility level should be carefully monitored, periodontal examinations should be performed regularly, and the patient should be informed about oral hygiene (Sondeijker et al., 2020).

Although root resorption is often asymptomatic, endodontic evaluation may be required when pulpal pain or pulpitis symptoms are observed (Ahangari et al., 2015). Therefore, the multidisciplinary approach of the orthodontist and endodontist together has a critical role in the survey of the teeth to protect the teeth at risk.

3. Endodontic-Orthodontic Multidisciplinary Approach in Dental Trauma

Traumatic dental injuries (TDI) mainly occur in children and young adults and account for 5% of all traumas. Up to 25% of school-age children experience a dental injury. In adults, it occurs in 33% of the population, most of whom are younger than 19 years of age. While luxations are the most frequent dental injuries in deciduous dentition, crown fractures are more common in permanent teeth. Correct diagnosis, treatment planning, and follow-up are crucial for a favorable healing process. It should be considered that teeth with a history of dental trauma will be affected more

than healthy teeth in terms of pulpal and periodontal complications during the diagnosis phase. Therefore, pulp sensitivity tests should be applied to evaluate the vitality of the tooth, and a comprehensive clinical examination should be performed in line with the type and severity of the trauma (Levin et al., 2020). Periapical radiographs should be taken in a parallel technique for teeth with a history of trauma before, during, and after orthodontic treatment. Additionally, the clinicians might use more advanced imaging methods like cone beam computed tomography (CBCT) if they think there is external root resorption (Sandler et al., 2021).

Preservation of pulpal vitality and periodontal health should be a top priority in acute trauma cases. The patient and the patient's relatives should be informed about the treatment procedure, possible complications, home care, and follow-up process, and informed verbal and written consent should be obtained prior to treatment. It is necessary to refer to the guidelines developed by the International Association of Dental Trauma (IADT) on emergency management and possible treatment options (Levin et al., 2020).

Prior to orthodontic treatment of traumatized teeth, the patient/parent should be apprised of the potential risks of root resorption, pulp necrosis, and infection. The clinician should generally take care to move with light forces during the treatment process of traumatized teeth. Thermal nickel-titanium archwires should be preferred, especially at the beginning of the treatment process or when aligning newly traumatized teeth. Additionally, radiographic evaluation and pulp sensitivity tests should be performed at frequent and regular intervals during the treatment (Sandler et al., 2021).

Orthodontic management of traumatized teeth depends on the type of trauma. According to the orthodontic management of traumatized teeth classification guide, minor periodontal damage (concussion and subluxation), moderate-severe periodontal damage (lateral-extrusive-intrusive luxation and avulsion), crown and crown/root fracture, root fractures, root canal-treated teeth due to trauma, and endodontic difficulties (pulp obliteration, root resorption, ankylosis, autotransplantation, and regenerative endodontic treatment) (Sandler et al., 2021) (Table 1).

Table 1. Orthodontic management of traumatized teeth depends on the type of trauma

Immature traumatized teeth	Observe whether there is evidence of continued root growth on radiographs. Perform clinical and radiographic evaluation six months, one year, and two years after trauma.
Minor damage to the periodontium (Concussion and Subluxation)	(A concussion is an injury to the periodontal structure of the tooth without mobility or displacement. The tooth is usually sensitive to percussion, and there are no other symptoms.) (Subluxation is an injury that causes abnormal mobility of the periodontal structure of the tooth. The tooth is not displaced and is sensitive to percussion, with sulcular bleeding from the gingiva.) A three-month observation period is recommended to eliminate inflammatory root resorption.
Moderate/severe damage to the periodontium (Extrusion, Lateral Luxation, Intrusion, Avulsion)	(Extrusion: The tooth appears longer than its neighbor due to outward displacement, and it exhibits mobility. Reports indicate a significant loss of tooth vitality following this type of TDI. Lateral Luxation: The tooth is displaced in the palatal or lingual direction. The tooth may give a high metallic sound to mobility and percussion. Intrusion: A type of traumatic dental injury that displaces the tooth deep into the alveolar bone socket. It has reduced mobility and produces a high metallic sound on percussion. Avulsion: The tooth is completely displaced out of the socket. Such teeth may be replanted and splinted.) A one-year observation period is necessary to eliminate ankylosis. Orthodontic tooth movement can start only after the completion of periodontal healing, taking at least six months. If teeth are moved orthodontically between 6 and 12 months, a strong suspicion of ankylosis is considered, especially when tooth movement is not as expected.
Crown and crown/root fractures without pulpal involvement	A crown fracture is defined as a fracture involving enamel, dentin, and possibly pulp. A crown-root fracture is defined as a fracture involving enamel, dentin, cementum, and possibly pulp (complicated or uncomplicated fractures). An observation period of three months is recommended to eliminate inflammatory resorption.
Crown and crown/root fractures with pulpal involvement	Once radiographic evidence of vital pulp treatment and the hard tissue barrier is evident (approximately three months), orthodontic movement can begin.
Root fractures	A recommended observation time is one to two years, with a shorter duration advised for asymptomatic cases. Upon the completion of connective tissue healing, the coronal segment must be managed as if it were a short-rooted tooth, and the tooth should remain immobile until effective endodontic treatment and connective tissue healing of the coronal segment have occurred.

Teeth in need of endodontic treatment due to caries	In the absence of periapical pathosis, immediate orthodontic movement is recommended. Definitive obturation with gutta-percha is recommended instead of using calcium hydroxide in the root canal.
Teeth in need of endodontic treatment due to trauma	In mature teeth, following the initial calcium hydroxide dressing, a definitive obturation with gutta-percha should be placed. This conflicts with advice previously given by others. The observation period prior to orthodontic treatment should be one year to monitor healing and ankylosis. Routine radiographic monitoring every six months thereafter is recommended.
Pulp canal obliteration	This is not an indication for endodontic treatment as the tooth is still alive. Radiographic monitoring is recommended. We recommend light, short-acting forces if necessary. Whenever possible, it is useful to partially or completely exclude such teeth from orthodontic forces.
Resorption due to infection	Orthodontic treatment is started only when the infection is under control. A multidisciplinary team is recommended.
Teeth requiring endodontic treatment due to inflammatory resorption	Radiographic evidence of healing with an observation period of at least one year should be awaited before initiating orthodontic tooth movement; teeth with signs of root resorption are considered to be more susceptible during orthodontic treatment.
Replacement resorption	We recommend a multidisciplinary team for potential auto-transplantation or decoronation needs. Treatment goals should be limited. Pulp and root health records should be kept at baseline and during treatment. Forced luxation followed by orthodontic extrusion should be considered for final position alignment. The tooth should be left outside the archwire or used for anchorage.
Autotransplanted teeth	(Autotransplantation is a traditional method used in dentistry to reconstruct a functional tooth substitute and can provide an often overlooked treatment option in cases of hypodontia requiring orthodontic treatment) Orthodontic treatment can be started three to nine months after periodontal healing (approximately eight weeks) and before complete bone repair. Extrusion can be started earlier than rotational or bodily tooth movements. Ankylosis should be excluded when the tooth does not move as expected.
Regenerative endodontics/ revitalization techniques	Orthodontic treatment should be postponed until the results have stabilized with an observation period of at least two years.
Teeth with apical resection	Periapical lesions should demonstrate significant radiographic healing one year post-apicoectomy prior to the initiation of orthodontic therapy.

There are many factors involved in the etiology of traumatic dental injuries (TDI). Dentists need to advise patients and/or their parents about the risk factors associated with certain malocclusions. The vast majority of TDIs occur in children and in the maxillary anterior teeth. Increased overjet and upper lip insufficiency are the two main factors that increase the risk of such injuries (Wig et al., 2022). Consideration of these predisposing factors raises the issue of whether orthodontic intervention can help prevent dental trauma in individuals with malocclusion. The use of various functional fixed or removable orthodontic attachments at an early age may help the teeth and jaws to be more appropriately positioned and less susceptible to dental trauma. A Cochrane study concluded that providing early orthodontic treatment to children with prominent upper anterior teeth is more effective in reducing the incidence of incisal trauma than providing orthodontic treatment in adolescence (Batista et al., 2018). Another study found that starting orthodontic treatment early or using a two-step plan for children with prominent upper front teeth is better at preventing injuries to those teeth than waiting until adolescence to start treatment(Veitz-Keenan & Liu, 2019). Cobourne et al. concluded that while early treatment does not lead to improved overall outcomes compared to later treatment, early initiation of orthodontic treatment may prevent psychological trauma, even if it does not affect physical trauma, when the risk of dental trauma is actually increased or when a child is bullied because of his or her aesthetic appearance (Cobourne et al., 2022). Therefore, approaches that favor early orthodontic intervention to reduce the likelihood of physical and/or psychological trauma seem rational for now.

4. Relationship between Regenerative Endodontics and Orthodontic Treatment

Immature permanent teeth can lose their vitality for many reasons, including caries and dentoalveolar trauma (Banchs & Trope, 2004). The ideal outcomes in the treatment of immature teeth diagnosed with pulpal necrosis are to treat and/or prevent the recurrence of apical periodontitis, to promote the continuation of root growth interrupted by necrosis, and to restore the biofunctional competence of pulpal tissue (Hargreaves et al., 2008). REP with a biologically based perspective is not a fanciful approach but a successful alternative to traditional apexification procedures that aims to produce pulp-like tissue in the root canal cavity, provide revascularization, and relieve pain and inflammation by stimulating the migration of viable inflammation- and destruction-resistant stem cells in the periapical region, thus eliminating the need for foreign stem cell transfer(Diogenes et al., 2013; Dissanayaka & Zhang, 2020; Sonoyama et al., 2007).

In root canals filled with blood clots upon induction of periapical hemorrhage, blood-derived growth factors such as platelet-derived growth factor (PDGF), transforming growth factor (TGF), vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF), and fibroblast growth factor (FGF) may facilitate angiogenesis by signaling to endothelial precursor cells and perivascular progenitor cells in periradicular tissues, and thus new vessel formation may occur in the root canal cavity along with other growing tissues (Civinini et al., 2011; Jung et al., 2019). Another advantage of periapical hemorrhage induction is the migration of SCAPs from the apical foramen into the root canal space. This eliminates the need for foreign stem cell transfer. Many studies have indicated that the use of a blood clot as a scaffold in REP is practical and successful (Flake et al., 2014; Nagy et al., 2014; Petrino et al., 2010). Nevertheless, the induction of periapical hemorrhage does not always result in a sufficient quantity of hemorrhage, which may lead to a scaffold matrix that is incomplete in terms of the content of blood clot signaling molecules, growth factors, and stem cells(Nosrat et al., 2021). In many histological studies in the literature, it has been observed that the induction of apical hemorrhage alone does not provide selective migration of apical papilla stem cells and consequently fails to regenerate the dentin-pulp complex, and contrary to expectations, the hard tissues formed in the root canals are organized as cementum or bone instead of dentin, and the soft tissue is organized as fibrous connective tissue or periodontal ligament instead of pulp (Arslan et al., 2019; Nicoloso et al., 2019; Torabinejad et al., 2017).

The need for directed regenerative endodontic procedures emerged from the goal of creating a dentin-pulp complex rather than repair (Galler et al., 2014). Tissue engineering in regenerative endodontic procedures is based on the use of the triple concept of stem cells, biomimetic scaffolds, and growth factors to treat pulp inflamed by infection, trauma, or developmental anomalies (Nakashima & Akamine, 2005).

Clinical practice's revitalization procedures, known as CF-REP, don't fully align with the modern tissue engineering concept of pulp regeneration. This procedure is a long-standing approach in medicine and dentistry (Lin et al., 2021). The current tissue engineering trio can be converted into resident stem cells, customized scaffolds, and endogenous growth factors for cell-free tissue engineering (Nakashima & Akamine, 2005).

Vessels in pulp tissue play a critical role in the supply of nutrition and oxygen, act as a conduit for the transport of metabolic waste, and regulate inflammation. Due to the unique anatomy of the tooth structure,

the pulp, surrounded by a dense dentin, receives a limited blood supply from the apical foramen (Dissanayaka & Zhang, 2017). Nerve fibers contribute to the extravasation of immune cells to regulate inflammation, pulp homeostasis, angiogenesis, and pulp defense mechanisms. So, creating the right environment that helps with new blood vessel growth and nerve growth is important for regenerating dental pulp (Lambrichts et al., 2017). In this regard, nerve fibers contribute to pulp homeostasis, angiogenesis, and pulp defense mechanisms.

SB-REP is a method that relies on the use of biomaterials to create a structural foundation that supports cells in the process of tissue formation. SB-REP is versatile in that the strong mechanical properties of the scaffolds and the deconstruction process provide the time needed for the regeneration of tissues, as well as the inclusion of growth factors (Dissanayaka & Zhang, 2020). Growth factors and signaling molecules are polypeptide/protein structures that functionalize cells by binding to surface receptors of cells targeted for migration, adhesion, proliferation, and differentiation in stem cells (Lind, 1996; Schmalz et al., 2017). These molecules, which are also critical in the process of dental pulp regeneration, play a role in angiogenesis, neurogenesis, and dentinogenesis. In general, these molecules can be obtained in protein form from commercial preparations, endogenously derived from resident tissues and peripheral blood, or from transplanted cells. In REP, they can be sourced from leftover pulp or gum tissue, by using chelation on hidden dentin, from blood clots that come from the area around the tooth root, or by transplanting platelet concentrates (autologous biomimetic scaffolds) from peripheral blood into the root canal space (Schmalz et al., 2017).

These advances in REP allow the organization of hard and soft tissues developing in the root canal space to be more controllable and the nature of the regenerated tissues to be anticipated. However, a finite element analysis revealed that PDL and tooth structures formed with dentin and cement showed similar biomechanical performance under various scenarios, even when the newly formed tissues lacked odontoblast-like cells and were rich in reparative tissues such as cementum. The study emphasizes that teeth treated with regenerative endodontics may perform similarly to physiologically developed teeth with minimal differences in orthodontic processes, especially under balanced and low forces, but these should be confirmed under in vivo conditions (Bucchi et al., 2022).

Root resorption is one of the most common complications of orthodontic tooth movement in both endodontically treated and vital teeth. Regardless of

the orthodontic treatment method or type of orthodontic appliance applied after REP, it has been observed that periapical remodeling occurs while the periapical infection resolves, and the teeth are asymptomatic during active and retentive orthodontic treatment periods (Chaniotis, 2018; Jawad et al., 2018; Natera & Mukherjee, 2018; Yoshpe et al., 2025).

When treating REP-treated teeth with orthodontics, it should be focused on the general treatment plan, orthodontic appliance selection and force parameters. If necessary, the option of partial or complete exclusion of REP-treated teeth from orthodontic forces should be considered, and light and short-acting forces should be applied. Furthermore, strict endodontic follow-up should be performed before, during, and after orthodontic treatment as long as root development continues (Jawad et al., 2018). When to apply orthodontic forces to teeth with REP depends on how long it has been since the tooth died, how symptoms have progressed after REP, the development phase of the tooth's root, and the orthodontic treatment plan selection (Bucchi et al., 2024). Therefore, cooperation and interaction between both disciplines is important and necessary to improve the management of the patient in need of REP requiring orthodontic treatment and the patient's compliance with the treatment process.

Conclusion

We should not ignore the fact that the forces applied during orthodontic treatment can cause inflammatory and vascular changes in the periodontal ligament and pulp. In particular, maintenance of pulp health and management of the inflammatory process are key factors that increase treatment success. Regenerative endodontic approaches support root development in immature teeth, and multidisciplinary clinical applications, where cases in the common age group are widely addressed, are promising. However, early and accurate planning of orthodontic and endodontic treatments is of great importance in preventing possible complications, maintaining the patient's long-term oral health, and increasing patient compliance with treatment. Therefore, continuous communication and collaboration between specialists will provide patients with the most appropriate and effective treatment approaches. In the future, the integration of pulpal tissue engineering and innovative approaches will lead to more successful and advanced treatment options in both orthodontics and endodontics.

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