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Orthodontically Induced Root Resorption

A Review

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ABSTRACT

Root resorption is the destructive process of the cementum and/or dentine layers of a tooth root due to clastic cell activity which leads to a subsequent loss root structure of a tooth. This process may be physiological or pathological. Physiological root resorption of deciduous teeth naturally occurs when the permanent teeth begin to erupt. It may also occur to a small degree in the permanent dentition associated with physiological tooth movement. Pathological root resorption has been related to orthodontic tooth movement, trauma, and ectopic eruption of adjacent teeth and in association with other pathology. Root resorption is an unpredictable, unavoidable pathologic consequence that occurs during orthodontic tooth movement. Fortunately in the majority of cases, root resorption is minimal. There are many possible causes to root resorption as a sequel of orthodontic treatment with fixed appliance. It is therefore essential for a clinician to be aware of these factors, to be able to estimate the risk of root resorption individually for each patient.

Keyword: - Root Resorption, Orthodontic Tooth Movement, Intrusion.

1. Introduction

Root resorption is the destructive process of the cementum and/or dentine layers of a tooth root due to clastic cell activity which leads to a subsequent loss root structure of a tooth. This process may be physiological or pathological. Physiological root resorption of deciduous teeth naturally occurs when the permanent teeth begin to erupt. It may also occur to a small degree in the permanent dentition associated with physiological tooth movement. [1] Pathological root resorption has been related to orthodontic tooth movement, trauma, and ectopic eruption of adjacent teeth and in association with other pathology.

Bates [2] was the first to describe root resorption of permanent teeth in 1856. The link between orthodontics and root resorption was identified in 1914 by Ottolengui. The term "Orthodontically induced inflammatory root resorption (OIIRR)" was introduced by Brezniak and Wasserstein to describe the type of root resorption experienced during orthodontic treatment. [3] It is a pathological surface or transient inflammatory root resorption that occurs due to the presence of an orthodontic force on a tooth. It is accepted that most individuals will experience some degree of root shortening after orthodontic treatment. Fortunately the presence of severe root shortening is relatively uncommon after orthodontic treatment. [4]

The exact aetiological factors of OIIRR are still unclear. These factors can be either patient biological related or treatment mechanics related. [5] Biological factors described in the literature include genetic factors, dental age, root morphology, bone density and a previous history of root resorption.

Treatment mechanic factors that have been suggested to cause an increase in root resorption are force magnitude, duration of treatment, the amount of tooth movement, direction of tooth movement, the type of bone.

2. Literature review

2.1 Orthodontic tooth movement and OIRR

Orthodontic tooth movement is made possible by remodelling changes that occur in the dental and paradental tissues including the dental pulp, periodontal ligament (PDL), alveolar bone and the gingiva. [6] Research by Sandstedt, Oppenheim [7] and Schwarz [8] has lead to the classic pressure- tension theory of orthodontic tooth movement. It occurs when forces applied to a tooth creates areas of compression and tension within the PDL [9] which alters the blood flow. A change in the PDL's vascularity results in local synthesis and release of key molecules such as inflammatory mediators.

This induces an acute inflammatory response which is necessary for tissue deposition on the tension side and resorption on the pressure side.

Bone resorption is crucial to orthodontic tooth movement by removing alveolar bone from the path of the moving tooth root. [6]

With light forces on a tooth and associated maintenance of vascular patency, clastic cells adjacent to the lamina dura start to remove bone in the process of direct (or frontal) resorption. Tooth movement begins soon after. [10]

Indirect (or undermining) resorption is associated with heavy forces which occlude the blood vessels and cut off blood supply to areas within the PDL. A sterile necrosis called the hyalinization zone develops. When this occurs, remodeling of bone bordering the necrotic area of the PDL must be performed by osteoclasts which attack the underside of the bone immediately adjacent to the necrotic tissues. Undermining resorption is associated with a delay in tooth movement as well as pain for the patient. [10], [11]

It is desirable to achieve orthodontic tooth movement with as much frontal resorption as possible as it is more efficient. However, in practice, even light forces have been associated with areas of hyalinisation and direct and indirect resorption appears concurrently. [12]

During the resorption of bone process, clastic cells may also attack the outer cementum layers of the tooth root. If there was no difference between bone and cementum, orthodontic tooth movement would cause them to resorb equally. Although bone and cementum have many similarities, they behave very differently. Cementum is more resistant to resorption than bone which results in preferential bone resorption and orthodontic tooth movement. [13]

If the reparative capacity of cementum is exceeded by root resorption, it will present as the permanent loss of root structure. [14]

2.2 Classification of root resorption

Andreasen [15] defined three types of external root resorption:

1. Surface resorption – involves small outlining areas followed by spontaneous repair from adjacent intact parts of the periodontal ligament. This is a self limiting process.
2. Inflammatory resorption – initial root resorption has reached dentinal tubules of an infected necrotic pulpal tissue.
3. Replacement resorption - bone replaces the resorbed tooth material and then leads to ankylosis

Root resorption occurring from orthodontic treatment is either a surface resorption or transient inflammatory resorption. Replacement resorption is not normally seen after orthodontic treatment. [16]

Brezniak and Wasserstein [3] suggested the term orthodontically induced inflammatory root resorption (OIRR) to distinguish this type of resorption from others such as those caused by trauma, periapical lesions of periodontal disease. They then described three degrees of severity:

1. Cemental or surface resorption with remodeling – only the cemental layers are resorbed and then fully regenerated.
2. Dentinal resorption with repair – cemental and the outer layers of dentine are resorbed and usually repaired with cementum material. This process may alter the shape of the root from its original form.
3. Circumferential apical root resorption – full resorption of all hard tissues of the root apex occurs.

This leads to irreversible root shortening. External surface repair and remodeling of sharp edges occurs in the cemental layer.

2.3 Orthodontically induced root resorption

Root resorption is commonly seen on dental radiographs as the permanent shortening of the tooth root. Normally, the cementum layer of a tooth root does not undergo appreciable resorption. However, with orthodontic force application on a tooth, sometimes excessive resorption of root cementum and dentine is induced which will eventually lead to the irreversible shortening of a tooth root's length.

Root resorption in orthodontics has been referred to by many terms in the literature such as apical root resorption, external apical root resorption (EARR) or orthodontically induced inflammatory root resorption (OIIRR). It has long been recognised in the field of dentistry, especially in orthodontics.

Over a century ago in 1856, Bates [2] discussed root resorption in permanent teeth as a result of trauma. Ottolengui [17], in 1914 was able to relate root resorption specifically to orthodontic treatment. However, it was in 1927, when Ketcham [18] demonstrated root resorption with radiographic evidence after orthodontic treatment, that root resorption began to become a great concern.

At this time, the terms absorption and resorption were used interchangeably to describe the loss of apical root. This issue was put to rest by an article written by Becks and Marshall [19] in 1932.

Becks and Marshall [19] preferred the resorption over absorption as tissues constituting a tooth such as calcium or phosphorous are first absorbed by the blood from the food and then deposited as a tooth. Occasionally the calcium and phosphorous in a tooth are "absorbed again" from the root by the blood. The term "resorb" means, by its derivation, "absorb again" [20]. They initially defined root resorption as the destruction of formed tooth structure.

More recently, root resorption has been defined as the active removal of mineralised cementum and dentine. [21] To describe root resorption that specifically occurs in association with orthodontic treatment, Bresniak and Wasserstein suggested the term orthodontically induced inflammatory root resorption. [3] However, even when no radiographic signs of root resorption can be visible, it is accepted that most teeth undergoing orthodontic tooth movement will experience some degree of root resorption followed by repair. [22] The clinical significance of root resorption will depend on individual susceptibility and biological reaction to orthodontic treatment.

2.3.1 Mechanism of root resorption

Root resorption as a result of orthodontic tooth movement is associated with a local over compression of the periodontal ligament with the development of a sterile necrosis (hyalinised zone). Historically, Swartz [23] hypothesised that the ideal force to move a tooth would be those which just overcome capillary blood pressure (20-26 grams per square centimetre). If the force placed on a tooth exceeded the capillary blood pressure, the capillary would collapse, cut off blood circulation and lead to areas of tissue necrosis and thus root resorption. It is thought that when resorption processes exceed the reparative capacity of cementum, OIRR will ensure. [24] Much of what we know about the cellular processes involved is from mice and rat studies. Brudvik and Rygh [25] in a series of resorption studies found OIRR is part of the hyaline zone elimination process and follows a consistent pattern. OIRR starts in the circumference of the main necrotic hyalinised tissue and continues a few days later with the removal of the main hyalinised zone. [25] Two different cell populations are involved in the root resorption process. Cells involved in the initial phase of resorption (1-3 days) are not odontoclasts as they lack tartrate resistant acid phosphatase (TRAP) enzyme. They are macrophage-like cells whose role is to eliminate the necrotic tissues. During removal of the hyaline zone, the nearby cementoid layer can be damaged, exposing the underlying cementum. The cementoid layer acts as defence against resorption describing it as a resorption-resistant "coating". The presence of a cementoid or predentine layer on the root delays the resorption process. The initial phase of cells are followed by multinucleated (odontoclasts) as well as mononucleated TRAP positive cells which invade into the hyalinised tissue from the periodontal membrane as well as the adjacent alveolar bone. They attack the cementum and eventually dentine. The root surface under the main hyaline zone resorbs several days later. This resorption process continues at the same time repair processes in the periphery are taking place. It stops when no hyaline tissue is remaining and/or the force level decrease.

2.3.2 Repair processes

Repair of root resorption craters begins when the force applied is discontinued or reduced below a certain level. This has been recorded to begin as early as the first week of retention. [26] The reparative process increases with time [27], [28] and especially during the first 4 weeks of retention. [26] However, by the 5th and 6th weeks, repair seems to slow and reach a steady state. [29] The process of repair begins from the periphery in the resorbed lacunae where the PDL has been re-established while active resorption still occurs beneath the main, more centrally located over compressed hyalinised zone.

After 10 days of tooth movement multinucleated resorptive cells and collagen producing fibroblast-like cells occupy the same resorption lacuna. The fibroblasts invade the lacunae from the circumference indicating a transition of resorption to repair.

Approximately two weeks after force is removed, different phases of repair can be observed with the placement of new cementum or coverage of root dentine with fibrillar structures. By three weeks, mineralised cementum fills the resorption lacunae and PDL attachment is restored. In contrast, to this, Barber and Sims [27] found repair to proceed from the centre of the resorption cavity and moving outwards. Owman-Moll and Kurol [30] also found early repair initially began only on the bottom of the resorption cavities with occasional reparative cementum extending onto the lateral walls. No reparative cementum was found on the lateral walls alone. The repair process of root resorption was achieved mainly by deposition of cellular cementum with acellular cementum only at the initial phase of healing. Both repair patterns from the periphery and the centre were observed by Sismanidou and Lindskog [31] in adolescents. They also found that onset of reparative cementum appeared after 2 weeks of force discontinuation and initially only involved acellular cementum formation. Gradually this changed to cellular cementum at the more advance stages of healing.

2.4 Aetiology and risk factors associated with OIIR

Although many risk factors have been found, our predictive power in assessing the possibility of future resorption is still poor. Individual variation in biologic response to orthodontic forces and genetic predisposition may explain the variation in OIIR that occurs. Brezniak and Wasserstein in their review of the literature divided risk factors into biological and mechanical factors.

2.4.1 Biologic factors

2.4.1.1 GENETIC FACTORS

OIIR tends to have a strong genetic component. Although no definite genetic conclusion has been found, autosomal dominant, autosomal recessive and polygenic modes of inheritance are possible. OIIR of the maxillary central incisors have the highest heritability component and are usually the most severely affected. The possibility of genetic testing and screening for patient susceptibility to OIIR may become a reality in the future. However, presently, if a child has had previous orthodontic treatment, viewing of their post treatment radiographs may prove invaluable to the treatment of subsequent siblings.

2.4.1.2 RACE

Sameshima et al in their sample of 868 patients reported that Asian patients were found to experience significantly less root resorption than white or Hispanic patients. In contrast, Smale et al recruited patients from 3 different centres in 3 countries and found no differences in resorption among the subsamples. They reported that this justified their decision to combine all patients into one group for analysis.

2.4.1.3 SYSTEMIC FACTORS

Systemic factors such as the inflammatory mediators produced outside of the PDL may act to enhance cellular interactions involved in root resorption. Owman-moll and Kurol in 2000 analysed factors that might be associated with OIIR by examining extracted maxillary premolars of 96 adolescents after buccal movement. A preliminary screening of possible risk factors such as root morphology, allergy, nail biting, medication etc was performed.

Interestingly, only those subjects with allergies showed an increase risk of root resorption, however, this result was not statistically significant.

2.4.1.4 DENTAL AGE

Orthodontic treatment does not stop root development. The stage of root formation at the onset of treatment has been discussed in terms of lessening the severity of OIIR. Brezniak and Wasserstein⁵ reported in their review of the literature that orthodontic treatment should begin as early as possible since there is less root resorption in developing roots and young patients show better muscular adaptation to occlusal changes.

2.4.1.5 CHRONOLOGICAL AGE

With increasing age, the periodontal membrane becomes less vascular, aplastic, and narrow, the bone more dense, avascular, and aplastic, and the cementum wider.

2.4.2 Habits

Nail biting and tongue thrust habits have been implicated in causing more severe root resorption.

2.4.2.1 ROOT MORPHOLOGY

Teeth with abnormally shaped roots have a greater risk of OIIR than teeth with normally shaped roots. Long roots, narrow roots and deviated root shape are significant risk factors.

2.4.2.2 PREVIOUS TRAUMA AND ENDODONTICALLY TREATED TEETH

Dental trauma and orthodontic treatment after dental trauma is generally considered a predisposing factor for OIIR. The correlation between endodontic treatment and OIIR is not yet conclusive. This may be due to some bias in the study design which has included teeth that have a history of trauma.

2.4.2.3 TYPE OF MALOCCLUSION

Many believe that the presence of an overjet is a strong predictor for OIIR due to large distances the anterior teeth have to move for overjet correction. Increased overjet but not overbite has been significantly associated with greater root resorption.

2.4.2.4 BONE DENSITY

Historically, the use of areas of increased bone density such as the labial or palatal cortical plate were thought to be good for increasing anchorage during treatment mechanics. The approximation of root to palatal cortical plate during retraction of incisors influences the amount of root resorption. Narrowing of alveolar bone width also influences apical root resorption.

2.4.2.5 SPECIFIC TOOTH VULNERABILITY TO ROOT RESORPTION

OIIR can present as localised to particular teeth or as a generalised shortening of all the teeth. Regardless of genetic or mechanical related factors, it is generally agreed that maxillary incisors seem to be affected by OIIR more frequently and to a greater extent than the rest of the dentition. A possible reason is that the maxillary incisor is most often moved the greatest distance through bone and subjected to longer active force duration than any other tooth. Maxillary central incisors are usually quoted as more affected than the maxillary lateral incisors. Other teeth vulnerable to OIIR are the mandibular incisors, distal root of the mandibular first molars, mandibular second premolars, and maxillary second premolars. Peg shaped laterals have not been associated with an increased risk of OIIR. The presence of root resorption on teeth prior to orthodontic tooth movement significantly increases the risk of further resorption during orthodontic treatment.

2.4.3 Mechanical factors

Mechanical risk factors associated with OIIRR are those related to the type of orthodontic treatment mechanics used to move teeth. Many treatment related risk factors have been studied such as force characteristics, type and direction of tooth movements, treatment duration and orthodontic appliance factors. As these factors are under the clinician's control, knowledge in this area may allow for minimization of OIIRR.

2.4.3.1 FORCE CHARACTERISTICS

Mechanical risk factors which may possibly be preventable such as the magnitude of force used or the duration of force have been investigated. Continuous, interrupted continuous and discontinuous forces have been compared. It has been hypothesised that periods of rest may allow for secondary cementum to repair resorption cavities. The duration of force was more crucial than magnitude in regards to root resorption. It is generally thought that increasing force magnitude would be associated with an increase in root resorption as it would lead to more areas of hyalinisation. It is also believed that higher forces cause more extensive root resorption because the rate of lacuna development is more rapid and the tissue repair process is compromised.

2.4.3.2 TYPE OF ORTHODONTIC MOVEMENT

All types of orthodontic tooth movement induced some form of root resorption. Tipping, torque and bodily movement of teeth have been implicated as mechanical risk factors. Intrusion of teeth seems to be the most detrimental movement in terms of root resorption as this movement concentrates pressure at the tooth apex. Expansion with RME has also been identified to cause root resorption.

2.4.3.3 CORRECTION OF IMPACTED MAXILLARY CANINES

Impacted maxillary canine treatment has been identified as a risk factor for apical root resorption of incisor teeth. This is not just confined to the root of the adjacent lateral incisor and cannot be fully explained by the ectopic eruption path of the canine. The extrusive of the canine would cause a reciprocal intrusive force on the incisors. Intrusion of maxillary incisor teeth has been associated with considerably more apical root resorption in orthodontic patients.

2.4.3.4 TWO PHASE CLASS II TREATMENT

Early growth modification to reduce the severity of an overjet plays a role in decreasing the incidence of OIIRR in class II malocclusion patients. The use of herbst functional appliance for treatment of class II malocclusion may deliver unphysiologic forces to the immediate anchor teeth thereby exposing them to a high risk of root resorption.

2.4.3.5 SELF LIGATION

With the introduction of self ligating brackets, many claims have been made about the increased efficiency of tooth alignment compared to conventional brackets. This is most likely due to lower friction levels reported with the use of self ligating brackets. The use of elastics such as in the case of class II correction may be a risk factor for the teeth that support the elastics. It is due to the jiggling movements that occur on these anchor teeth.

2.4.3.6 EXTRACTION TREATMENT

The literature is inconclusive regarding the effect of extraction treatment on OIIRR. Patients who have extraction treatment with the correction of open bite may be more prone to OIIRR. This may be due to the amount of overjet correction and retraction of central incisor apices. Extraction space closure using 2-step sliding mechanics (canine retraction first then incisor retraction) and en masse space closure has been investigated in 52 patients by Huang et al. It was postulated that since two step space closure takes longer to close an extraction space than an en masse procedure, it may be associated with more frequent and serious OIIRR. Their study, however found no significant difference in root resorption between two step and en masse space closure procedures. Early Serial extraction

followed by mechanotherapy has previously been hypothesised to cause less OIIR due to the procedure needing less mechanotherapy since crowding of incisors would be relieved.

2.4.3.7 TREATMENT DURATION

Most studies have found a positive correlation between increased treatment duration and the amount of root resorption experienced by a patient. Since more en-masse anterior retraction is needed with miniscrew anchorage cases, treatment time increases which might increase the risk of OIIR.

3. Management of OIIR

Patients must be informed of the risk of root resorption prior to starting orthodontic treatment as part of informed consent. In most cases, clinically significant shortening of a tooth root is rare. However, each patient must be made aware that, at present, we cannot predict which individuals will be susceptible to severe root resorption. Significant loss of tooth root structure can lead to an unfavourable crown to root ratio. Many clinicians fear that the potential consequence is an adverse effect on the long term prognosis of the affected tooth. Current literature, however, suggests that even extensive root resorption does not usually affect the functional capacity or greatly compromise the longevity of the teeth. The reason for this may be in the initial stages of root resorption and crestal bone loss, 3mm of root resorption is approximately equivalent to 1mm of crestal bone loss. Following more than 2mm of loss, the ratio is closer to 2mm of root resorption equalling 1mm of crestal bone loss.

Various methods are there to minimise OIIR. These include the use of light intermittent forces, reduction of treatment duration, habit control and prior assessment of family and medical history. Minimizing the use of intermaxillary elastics and high risk tooth movements such as intrusion and root torquing have also been recommended.

4. CONCLUSIONS

Full radiographic records should be taken prior to commencement of treatment to aid in diagnosis and assess the preoperative root structures. Progress radiographs taken six to twelve months after the commencement of orthodontic treatment to detect early signs of OIIR.

If severe loss of root structure is detected, treatment objectives for the patient should be reassessed and a decision made on whether treatment should be stopped early or to reach an occlusal compromise. Active treatment should cease for 2 to 3 months with passive arch wires to decrease further root resorption and allow for reparative processes to occur. Alternative treatment options should be sought to decrease the time in fixed appliances such as prosthetic replacements to close space, and stripping teeth instead of extracting. After active orthodontic treatment has been completed, further shortening of root structure will normally cease. This is to be expected as OIIR is a tissue-pressure response.

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