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Review of current medical literature on root resorption in orthodontics.

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LITERATURE REVIEW

Abstract

Root resorption is a common iatrogenic consequence of orthodontic treatment, although it can also be seen in the absence of orthodontic treatment. It may occur at any time during orthodontic treatment and compromise prognosis of the tooth involved and also the stability of treatment results. Orthodontics is the only branch which actually uses the inflammatory process as a tool for solving esthetic and functional problems. Therefore, every orthodontist should know the risk factors of root resorption involved in the process and plan treatment with an aim to reduce its possibility. The severity and degree of root resorption related with orthodontic treatment are multifactorial, involving environmental factors and host factors. A proper medical history, an assessment of predisposing factors, radiographic evaluation of alterations in root morphology and careful planning and execution of orthodontic mechanics may reduce the incidence of root resorption. The current review is aimed at providing clinicians and academics with an insight into the mechanical and biological aspects in the process of root resorption, the methods of identification during its early stages and intervention at the right time to reduce its severity.

Keywords: *Heavy Orthodontic Forces, Orthodontics, Root Resorption.*

Revisão da literatura médica atual sobre reabsorção radicular em Ortodontia.

Resumo

A reabsorção radicular é uma consequência iatrogênica comum do tratamento ortodôntico, embora também possa ser observada na ausência de tratamento ortodôntico. Pode ocorrer a qualquer momento durante o tratamento ortodôntico e comprometer o prognóstico do dente envolvido e também a estabilidade dos resultados do tratamento. A Ortodontia é o único ramo que realmente utiliza o processo inflamatório como ferramenta para a solução de problemas estéticos e funcionais. Portanto, todo ortodontista deve conhecer os fatores de risco da reabsorção radicular envolvidos no processo e planejar o tratamento com o objetivo de reduzir sua possibilidade. A gravidade e o grau de reabsorção radicular relacionada ao tratamento ortodôntico são multifatoriais, envolvendo fatores ambientais e fatores do hospedeiro. A história clínica adequada, a avaliação dos fatores predisponentes, a avaliação radiográfica das alterações na morfologia radicular e o planejamento e execução cuidadosos da mecânica ortodôntica podem reduzir a incidência de reabsorção radicular. A presente revisão tem como objetivo fornecer aos médicos e acadêmicos uma visão dos aspectos mecânicos e biológicos no processo de reabsorção radicular, os métodos de identificação durante seus estágios iniciais e a intervenção no momento certo para reduzir sua gravidade.

Palavras Chave: Forças ortodônticas pesadas, Ortodontia, Reabsorção radicular.

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INTRODUCTION

Root resorption is the undesirable but common sequelae of orthodontic mechanotherapeutics. It has been a concern to clinicians and patients since 1914, when it was first reported by Ottolengui. [1] The problem was investigated comprehensively by Ketcham, who published landmark articles in 1927. [2, 3] In 1929, Ketcham [4] demonstrated with radiographic evidence, the differences between root shape before and after orthodontic treatment. This was followed by a wide range of histological, clinical and physiologic research on root resorption and orthodontic treatment.

It has been shown that root resorption can appear during or after orthodontic treatment and compromise the stability of the treatment results and longevity of the tooth. Recent research has focused more on a cause and effect relationship as well as possible preventive treatment options for this unwelcome event. Furthermore, research has highlighted the genetic as well as molecular aspects of the process and helped clinicians determine who might be susceptible.

The most common type of root resorption occurring due to orthodontic treatment is external apical root resorption [EARR] that results in permanent loss of tooth structure from root apex. The literature shows that patients undergoing orthodontic treatment are more prone to have severe EARR. [5-8] However, this is not the only factor responsible for EARR but the effect of orthodontic treatment can be a major factor. [6, 9] Hence, it is important to understand the role of orthodontics in the occurrence of EARR. Major knowledge derived from high-quality research will help reduce these adverse effects.

Pathophysiology

The process of root resorption is closely associated with the injury and necrosis of PDL. During the movement of a tooth, areas of compression (where osteoclasts are in action inducing bone resorption) and areas of tension (where osteoblasts are active inducing bone deposition) are formed. Hence, a tooth moves in the direction of bone resorption. It is considered that the heavy forces of orthodontic treatment and hyalinization of periodontal tissues induced by increased activity of the cementoclasts and osteoclasts result in the occurrence of root resorption. When heavy orthodontic forces are applied, a hyaline zone is formed around the tooth root because of the resulting imbalance between the process of bone resorption and deposition and thus, tooth movement stops. This hyaline zone is removed by mononucleus cells and multinuclei giant cells along with regeneration of periodontal ligament and the tooth starts to move again. While removal of the hyaline zone, an outer tooth root surface consisting of layer of cementoblasts may be damaged which leads to the loss of protective characteristics of cementum contributing to cementoclasts/osteoclasts resorbing the areas of root and thus exposing the underlying dense mineralized cementum. [10-12] Hence, it is possible that a force occurring during orthodontic treatment may damage outer root surface. The tooth root surface under the hyaline zone resorbs after a few days, when the repair process is already occurring in the periphery. In the literature data, it is stated that the resorption process is completed just after removal of the hyaline zone and when the orthodontic force decreases. [10, 13]

Radiographically, resorption is mostly observed in apical region of the root because the apical root third is covered with cellular cementum, which relies on active cells and supporting vasculature, the loss of which renders the area vulnerable to trauma and cell injury-related reactions.[14] It is reported that blood vessels occupy 47% of the PDL space in the apical region, compared with 4% at the cervical end of theroot. [15] In addition, there is a decrease in the hardness and elastic modulus of the cementum, from the cervical to the apical region, making the apical areas prone to resorption. [16] Furthermore, the fulcrum of tooth movement (centre of rotation) is occlusal to the apical half of the root during tipping movements. This, along with the differences in the direction of the periodontal fibres likely results in increased trauma to the apical and middle thirds of the root. [17]

Classification

3.1. According to Shafer, Hine and Levy

According to Shafer, Hine and Levy resorption of root occurs in many circumstances other than the normal process associated with shedding of deciduous teeth.[18] Resorption of root may occur either on the external surface or internal surface of the root, thus classified as:

(1)External root resorption.
(2)Internal root resorption.

3.2. Andreasen

Andreasen gave a modified system classification which provides a more detailed description of the differing presentations of root resorption. [19] Root resorption has been broadly classified as:-

(1)External root resorption-

(a)External surface resorption,
(b)External inflammatory resorption,
(c)External cervical resorption

(2)Internal root resorption-

(a)Internal surface resorption
(b)Internal inflammatory resorption
(c)Internal replacement resorption

3.3. According to Proffit

According to Proffit shortening of roots after orthodontic treatment occurs in three distinct forms. [20] These forms must be distinguished when the etiology of resorption is considered:

(1)Moderate Generalized Root Resorption
(2)Severe Generalized Root Resorption
(3)Severe Localized Root Resorption

3.4. Fuss Z, Tsesis I and Lin S

Fuss Z, Tsesis I and Lin S said that the classical classification of root resorption following traumatic injuries i.e. replacement and inflammatory resorption are related to completely different aetiologies. So it is essential to develop a new, clinically related classification and the various types of root resorption should be identified according to the stimulating factors, which can be as follows [21]:

(1)Pulpal infection root resorption.
(2)Periodontal infection root resorption.
(3)Orthodontic pressure root resorption.
(4)Impacted tooth or tumour pressure root resorption.
(5)Ankylotic root resorption.

Grading of Apical Root Resorption

4.1. Robert W. De Shields (1969)

Robert W. De Shields (1969) using intraoral periapical Xrays has described the following grading system for apical root resorption [22]:

Grade 1-Possible resorption.
Grade 2- Definite resorption- The apical outline was definitely irregular but the root was not shortened or blunted.
Grade 3-Mild apical blunting- The reduction in root length was less than 3mm.
Grade 4- Moderate apical blunting- Resorption more than 3mm but less than 1/3rd the root length.
Grade 5- Severe blunting- More than 1/3rd of the original root length was lost.

4.2. Malmgren O et al (1982)

Malmgren O et al (1982) described root resorption index for quantitative assessment of root resorption [23] (Figure 1)

Grade 1-Normal root length only displaying irregular root contour- Mild resorption
Grade 2- Root resorption apically, amounting to less than 2 mm- Moderate resorption.
Grade 3- Root resorption apically, from 2 mm to one third of the original root length- Severe resorption.
Grade 4- Root resorption exceeding one third of the original root length-Extreme resorption.

Later, Zero degree was added to this index, as proposed by Levander et al, [24] in order to point out unaltered teeth in the root apex.

4.3. David N. Remington et al (1989)

David N. Remington et al (1989) described the following grading scale for apical root resorption as [25]:

Grade 0- Normal apical contour, same length as pretreatment.
Grade 1- Apical irregularity, same length as pre-treatment.
Grade 2- Apical root resorption of less than 2mm.
Grade 3- Apical root resorption more than 2mm, less than one third of original root length.
Grade 4- Apical root resorption more than one third of original root length

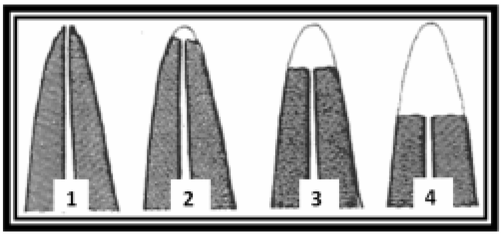

Figure 1. Grading scale for apical root resorption according to Malmgren O et al.

Risk Factors for Root Resorption

Naphtali Brezniak, Atalia Wasserstein (1993) have described the following factors responsible for Root Resorption: [1, 26]

(1)Biologic Factors:

1) Genetics
2) Systemic factors
3) Nutrition
4) Chronologic Age
5) Dental age
6) Gender
7) The presence of root resorption before orthodontic treatment
8) Habits
9) Tooth structure
10) Previously traumatized teeth
11) Endodontically treated teeth
12) Alveolar bone density
13) Types of malocclusion
14) Specific tooth vulnerability to root resorption

(2)Mechanical Factors

1) Orthodontic Appliances

a) Fixed versus removable
b) Begg versus edgewise
c) Magnets
d) Inter-maxillary elastics

2) Extraction versus non-extraction

3) Serial extractions

4) Other appliances

5) Types of orthodontic tooth movement

6) Orthodontic force

7) Continuous versus intermittent force

8) Jiggling and occlusal trauma

9) The extent of tooth movement

(3)Biologic and Mechanical Factors:-

1) Treatment duration
2) Relapse
3) Root resorption after appliance removal

(4)Other Considerations:

1) Teeth vitality
2) Loss of crestal bone and tooth stability

Table 1. Influence of Orthodontic Force on Root Resorption as Studied by Different Authors

FACTOR	AUTHOR	RESULT
Discontinuous vs continuous force	Acar et al [27] (1999)	Teeth experiencing orthodontic movement had significantly more RR that control teeth. Continuous force produced significantly more RR than discontinuous force application.
Removable thermoplastic appliance vs fixed light and heavy force	Barbagallo et al [28] (2008)	Heavy force (225 g) produced significantly more RR (9 times greater than the control) than light force (25 g) (5 times greater than the control) or TA force (6 times greater than the control) application.
Light vs heavy continuous forces	Chan & Darendelier [29] (2004)	Heavy forces produced significantly more RR than light forces or controls.
Intrusive vs extrusive forces	Han et al [30] (2005)	RR from extrusive force was not significantly different from the control group. Intrusive force significantly increased the percentage of resorbed root area (4 fold).
Straight wire vs standard edgewise	Reukers et al [31] (1998)	Results showed no statistically significant differences in the amount of tooth root loss or prevalence of RR between the groups.
Archwire sequence	Mandall et al [32] (2006)	There was no statistically significant difference between the proportion of patients with and without RR between archwire sequence groups.
Trauma vs no trauma	Mandall et al [32] (2006) Levander et al [33] (1994)	No evidence of incisor trauma and RR. No statistically significant correlations between RR and trauma history.
Two-phase vs 1-phase Class II treatment	Brin et al [34] (2003)	The results showed that children treated in 2- phases with a bionator followed by fixed appliances had the fewest incisors with moderate to severe OIIRR, whereas children treated in 1 phase with fixed appliances had the most resorption. However, the difference was not statistically significant. As treatment time increased, the odds of OIIRR also increased.

Diagnosis

Progressive intra-oral periapical radiographs (IOPAR) still form the major investigative method used to identify mid-treatment root resorption. Multiple grading systems and scoring criteria exist for assessing the resorptive process. [22-25] Severe ARR is defined as a shortening that is more than 4 mm or one-third of the root length and is observed in 1% - 5% of teeth. [36] Histological research indicates an extremely high (more than

90%) occurrence of root resorption that is caused by orthodontic forces. However, radiological incidence is lower than histological incidence. [37] In a study by Marques et al, [38] the incidence of severe ARR of the incisors after orthodontic treatment was found to be 14.5%. The most commonly used diagnostic techniques are panoramic or periapical radiography. Results show that ARR after orthodontic treatment is underestimated when evaluated with panoramic radiography. Contemporary digital imaging tools such as cone beam computed tomography (CBCT) with reduced radiation dose and high accuracy, have been critical for the purpose of identification. [39] In a recent study by Dudic et al. [40] which compared panoramic radiography with cone beam computed tomography (CBCT), significant differences were found between the two methods: 56.5% and 31% of the teeth displayed no resorption in panoramic radiography and CBCT, respectively. Duracket al. [41] compared IOPAR and CBCT for the detection of resorption craters and concluded that IOPAR carries inherent limitations and shortcomings. A detailed study by Sherrard et al [42] concluded that IOPAR evaluation could lead to an underestimation of root length by an average of 2.6 mm while a CBCT discrepancy is of the order of 0.3 mm, making it the assessment tool of choice. The main problems of CBCT usage are the associated increased radiation dose, cost and ethical issues. Estrela C et al [43] explored the presence of dentine sialoprotein (DSP), dentinephosphoprotein (DPP) & dentine matrix protein1(DMP-1) in the GCF and it was concluded that the use of DSP and DPP as biomarkers was a suitable alternative for monitoring root resorption during orthodontic tooth movement.

Repair of Root Resorption

Active orthodontic forces are believed to have an important role in the continuity of root resorption; therefore, the repair process begins after the cessation of orthodontic force or decrease in the magnitude of the force at a certain level. The repair is first observed around the resorption lacunae. This process shows similarity to the early cementogenesis during the development of the teeth.[44]

Resorption lacunae are recovered with the accumulation of new cementum and formation of a new periodontal ligamentum. [45] Owmann-Moll et al[46] stated that the possible repair level in resorption cavities that can be histologically observed can be summarized as follows:

(1)Partial Repair: Part of the surface of the resorption cavity is covered with reparative cementum (cellular or acellular cementum).

(2)Functional Repair: The total surface of the resorption cavity is covered with reparative cementum without the re-establishment of the original root contour (cellular cementum).

(3)Anatomic Repair: The total surface of the resorption cavity is covered with reparative cementum to an extent such that the original root contour is reestablished.

Cheng et al. [47, 48] reported that it takes at least 8 weeks of rest for anatomic repair to occur while the partial and functional repair processes predominate during the first 4-6 weeks. The resorption continued for 4 weeks after the stop of orthodontic force. After 4-week light force application followed by 4-week retention, there was continuous and regular repair. It was concluded that a minimum of 4 weeks rest is essential for the initiation of the repair process.

Adjunctive Approaches for the Repair Process

Many approaches have been demonstrated to reduce the rate of root resorption during orthodontic treatment which includes drugs, hormones, application of low intensity pulsed ultrasound, etc. The drugs which have been administered as potent bone resorption inhibitors include bisphosphonates. The anti-inflammatory properties of tetracycline and NSAIDs have also been noted to reduce root resorption. Studies have been published describing anti-inflammatory properties of tetracycline (and their chemically modified analogues) unrelated to their antimicrobial effect. A significant reduction in the number of mononucleated cells on the root surface was observed. Such cells have been related to EARR. [49] Thus, the administration of anti-inflammatory drugs might suppress root resorption induced by orthodontic therapy. Hormones which have a positive effect on resorption include L-thyroxine and corticosteroids due to its dual activation of parathormone and bone remodelling resulting in less stress on the root apex. Among them, L-thyroxine has been shown to have an inhibitory effect and clinical application has been attempted. [50] Similar effects have been shown for prednisolone in rats, in which low doses of corticosteroids during orthodontic treatment decrease root resorption. [51] Most of these research data are obtained from either animal experiments or by incidental observation of patients consuming these drugs. This creates uncertainty related to the clinical applicability of pharmacological programmes solely for the purpose of suppressing the root resorptive process. Considering the unfavourable effects that pharmacology might have in other systems, a rest period of at least 8 weeks is considered the best option, if mid-treatment root resorption is diagnosed.

Conclusion

Apical root resorption is a common sequel of orthodontic treatment. A proper medical history, an assessment of predisposing factors, a radiographic evaluation for alterations in root morphology and careful planning and execution of orthodontic mechanics may reduce the incidence of root resorption to an extent. A mid-treatment radiographic evaluation can identify teeth at risk and can indicate the need for an adequate rest period so that functional or anatomic repair might be promoted. Root resorption may compromise the continued existence and functional capacity of the affected tooth, depending on its magnitude. However, the process of root resorption during orthodontic treatment is usually smooth and stops when the force is removed.

THE AUTHORS DECLARE NO CONFLICTS OF INTEREST

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