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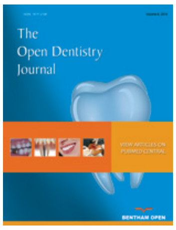

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REVIEW ARTICLE

Root Resorption of Maxillary Posterior Teeth after Rapid Maxillary Expansion: A Comprehensive Review of the Current Evidence from *in-vitro* and *in-vivo* Studies

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Abstract:

Background:

The application of heavy forces to the dentition, as those produced during a Rapid Maxillary Expansion (RME), has been associated in the literature with the development of root resorption of maxillary posterior teeth.

Objective:

The aim of the present manuscript was to report the available data from *in-vitro* and *in-vivo* studies that can elucidate the biological processes of resorption and repair of radicular cementum after RME.

Methods:

Studies evaluating the occurrence of root resorption after RME by means of histological and radiographic methodology were included. We detailed the changes of the radicular anatomy after RME and provided a synthesis of the most valuable scientific evidence showing the biological processes behind the potential modifications of radicular anatomy. Results. Loss of cementum material and reduction of radicular volumes were seen after rapid maxillary expansion. A small radicular volumetric recovery of anchored teeth occurred after the retention period; this reparative phenomenon was caused by cementum deposition without the reattachment of periodontal fibers, supporting the detrimental effects associated with RR.

Conclusion:

Retention period and the timing of radiographic examination could influence the extension of radicular resorption detected after RME since root resorption and cementum repair may occur at the same time at this stage.

Keywords: Rapid maxillary expansion, Maxillary expansion, Orthodontic treatment, Root resorption, Dental root, External root resorption.

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1. INTRODUCTION

Root Resorption (RR) is defined as the dissolution of cementum and dentin of dental roots, in the form of both a physiologic or pathologic condition [1]. RR is also an inevitable sequela of the orthodontic treatment, being dependent on patients' predisposition and orthodontic mechanics used as etiological factors [2]. Nevertheless, when orthodontic treatment causes RR, it generally does not interfere with the physiologic function of the involved teeth, despite that definitive conclusion cannot be drawn [3].

Among different orthodontic therapies, Rapid Maxillary Expansion (RME) is the treatment of choice for the correction of transversal maxillary deficiency and associated crossbite [4, 5] in growing subjects. During RME, heavy forces are transmitted to the maxilla by the anchored teeth. Those forces cause the hyalinization of the periodontal ligament, preventing dental movement and favoring skeletal expansion [6]. However, skeletal expansion is reached before orthopedic forces are completely dissipated and, consequently, the residual

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forces stored in the appliance start to move the anchored teeth. At this stage, the side effects related to the orthodontic movement and the sequelae of periodontal ligament hyalinization may occur, namely, buccal bone plate reduction and RR [7 - 9]. Considering the high prevalence of crossbite among children and youngsters [10], clinicians must be deeply aware of the potential side-effects of RME protocol on the dento-alveolar complex and of the underlying biological phenomena.

In the present paper, we describe in detail the changes in the radicular anatomy that can occur after the RME protocol. In particular, the aim of the present study was to provide a synthesis of the most valuable scientific evidence explaining the biological processes behind the occurrence of resorption and repair phenomena of radicular cementum after RME.

2. LITERATURE REVIEW

The information as well as the data discussed in the present review were obtained from the most relevant studies addressing the evaluation of root resorption from clinical assessment, histological materials and radiographic investigation (Cone-beam computed tomography). Table **1** shows the most relevant studies assessing the occurrence of Root resorption (RR) after Rapid Maxillary Expansion (RME).

2.1. Clinical Assessment of Root Resorption

The clinical assessment of RR is difficult to achieve due to the lack of clinical pathognomonic symptoms referred by patients. For instance, clinicians generally notice signs of RR through routine examinations such as panoramic or periapical radiographs [11]. However, conventional 2-D radiography shows large inaccuracies in detecting RR, especially when it is located at the buccal or lingual root surface [12], as it may occur after RME. In this respect, literature provides reliable data of root resorption after RME obtained from *in-vitro* studies using histological material or from *in-vivo* studies using CBCT-derived volumetric data of dental root [13 - 26].

2.2. Data of Root Resorption after RME from Histological Material

Barber and Sims [13] examined the roots of extracted premolars, used as anchorage units during RME, by Scanning Electron Microscope (SEM) and found that all specimens Exhibited External Root Resorption (ERR). Most root resorption occurs on the buccal surface of the roots [14 - 16] in the form of small irregularly shaped lacunae. This can be attributed to the direction of the heavy forces generated by RME protocol that is orientated towards the buccal side of the dentoalveolar arch, thus causing the compression of the periodontal ligament and, consequently, hyalinization on the buccal side of the roots [7, 17]. The area of resorption is mostly located at the buccal radicular surface but to some extent on the mesial, distal, and apical portions of the roots. Similarly, Odenrick *et al*. [16] reported large areas of resorption on the premolars extracted soon after the end of expansion, as assessed by light microscopy. In both studies [13, 16], the histological data disagreed with radiographic examinations that revealed no signs of ERR on the same premolars. Despite that the reliability of histological evaluation of ERR has been questioned [18] due to the destruction and loss of material during preparation [19], this discordance between histological and radiographic findings suggested that ERR likely was partially undetected or underestimated in the 2D radiographic studies [9].

Previous histologic evidences [13, 16] have suggested that the formation of resorption lacunae is not permanent and that the resorption cavities can be filled by subsequent deposition of hard tissue. However, these studies failed to identify the reattachment of periodontal fibers in the areas of reparative cementum deposition. Accordingly, Langford and Sims [8] showed that the cellular cementum obtained by repair deposition was constituted of scarce and inconsistent Sharpey's fibres and, thus, it was different from that of normal cellular cementum. These findings would suggest that the cementum repair of a root defect could not be associated with the reattachment of principal periodontal fibers, supporting the detrimental effects associated with RR.

Table 1. Most relevant studies assessing the occurrence of Root Resorption (RR) after Rapid Maxillary Expansion (RME).

Study	Design	Study Sample	Maxillary Expander	Radiographic Assessment of RR	Histological Assessment of RR
Barber and Sims 1981	Clinical Trial	9 subjects		No RR assessed via periapical radiograph	Extended RR assessed via SEM
Odenrick *et al*. 1991	Clinical Trial	9 subjects	Haas and Hyrax expander	No RR assessed via periapical radiograph	Extended RR assessed via LM
Langford and Sims 1982	Clinical Trial	18 subjects	Hyrax expander	-	Extended RR assessed via SEM and subsequent repair deposition of cementum without Sharpey's fibres and periodontal fibers reattachment
Baysal *et al*. 2012	Retrospective	25 subjects	Hyrax expander	Reduced radicular volume after RME assessed via CBCT. No significant differences in the percentage of volume loss	-

(Table 1) contd.....

Study	Design	Study Sample	Maxillary Expander	Radiographic Assessment of RR	Histological Assessment of RR
Dindaroğlu and Doğan 2016	Clinical Trial	33 subjects	Haas and Hyrax expander	Significant root volume loss was observed in both the Hyrax and the Haas appliances, assessed via CBCT. The repair was observed in resorption cavities after 6 months of retention	-

SEM = Scanning Electron Microscope; LM = Light Microscopy; CBCT = Cone-beam Computed Tomography

2.3. Data of Root Resorption after RME from CBCT Studies

In the last decade, the usage of Cone-Beam Computed Tomography (CBCT) has been widespread in dentistry [20 - 22]. In this regard, CBCT scans provide 3-D images of dentoalveolar structures without projection errors, also showing less artifacts compared to conventional CT [21]. Concerning the development of radicular resorption cavities, CBCT has shown greater accuracy in detecting *in-vitro* simulated RR compared to conventional periapical radiographs [11]. Besides, CBCT allows for the detection of radicular volume changes which is of great relevance for recording RR, since this phenomenon can provoke dental volume loss and be underestimated if assessed *via* bidimensional analysis of root length [23].

Previous CBCT studies have compared the radicular volumes before and after RME and have suggested that skeletal maxillary expansion induces radicular volume loss of posterior teeth [14, 24, 25]. In these studies, maxillary first molars were the teeth most affected by radicular resorption ranging from 83.12 mm^3 to 37.4 mm^3. First premolars and second premolars were affected by radicular volume loss ranging from 40.86 mm^3 to 13.12 mm^3 from 37.64 mm^3 to 13.93 $mm^{3,}$ respectively. According to the findings of Baysal [24] and Dindaroğlu [25], maxillary first molars loosed up to 6.87% of total volume [25] or from 10.50% to 13.70% of the volume for each root [24]. Also, first and second premolars showed a total volume reduction respectively from 5.58% to 7.21% and from 5.77% to 6.47% [24, 25]. Such volumetric loss was found immediately after the active treatment phase [24 - 26]and after almost five months of retention [14].

3. DISCUSSION

Given the above-mentioned findings, it can be assumed that root development is disrupted by the application of heavy forces, as those produced by rapid maxillary expansion. However, the retention period and the timing of radiographic examination can influence the extension of radicular resorption detected after RME. Histological findings revealed that RR is sustained long after termination of the active phase of RME and suggested that the cumulated forces stored in the appliance may support the radicular resorption even during the retention period [3, 15, 27, 28]. According to Barber and Sims [13], it could be possible that even the relapse forces extending later into treatment (up to 9 months) may additionally contribute to forces on the dentition with the expansion devices operating as retainers.

While a direct correlation between the total area of resorption and the timing retention period was not found, data from histological materials [8, 13, 16] showed an increase in cementum repair with longer periods of retention. In this respect, Cheng [29] postulated that the cementum reparative process could start when the orthodontic forces are below a certain level. Accordingly, Dindaroğlu *et al*. [25] found, in their CBCT study, a small radicular volumetric recovery of anchored teeth after the retention period of RME protocol. The values of volumetric gain found in this study ranged from 4.43 mm^3 for first premolars to 25.14 mm^3 for first molars and reflected the amount of reparative cementum that occurred at this stage. Thus, it can be assumed that both RR and cementum repair may occur at the same time during the retention period, with the former process prevailing to an amount that is influenced by several variables such as age, skeletal maturity, biological response and type of maxillary expansion. Therefore, sequential radiographic monitoring should be required to detect the maximum extension of RR. However, this is not possible considering the ethical limitation related to the patients' radiation exposure [30 - 32]. For the same reason, CBCT examination taken at 6 months of retention may be insufficient to appreciate the full extension of radicular volumetric recovery, which suggests tissue repair. In this regard, volumetric assessment of radicular hard tissue could not provide an accurate appraisal of functional surface area with periodontal fibers attachment [9, 33 - 36]. Despite the fact that the radicular volumetric recovery (repair process) obtained during retention can mitigate the total volumetric damage occurred after RME, the alternation between resorption and later reparative processes could significantly and irremediably affect the periodontal ligament support in the interested areas, according to the histological findings available.

Further investigation is warranted both from a histological and an *in vivo* 3D radiographic approach. More studies involving the 3D evaluation of root resorption comparing various appliance designs and retention periods are also required in order to further elucidate the aspects related to the RR after RME [37].

3.1. The Alternative Treatment Approach to Reduce the Risk of Root Resorption after RME

Skeletal anchorage has been proposed to increase the skeletal effect of RME, limiting dentoalveolar issues and the associated side-effects [38 - 40]. Recent comparative findings suggest that bone-borne RME induces greater opening of the mid-palatal suture reducing the excessive load caused by conventional appliances onto the buccal periodontal ligament of teeth to which they are anchored [41 - 43]. With this notion in mind, it has been speculated that skeletal anchorage could potentially alleviate the development of side-effects caused by RME on premolars and molars used as anchorage with conventional tooth-borne expander [43]. As a consequence, miniscrew-supported palatal expander may be a possible treatment alternative to reduce the risk of root resorption of maxillary posterior teeth. However, the management of RME supported by skeletal anchorage could be more arduous than conventional system (toot-borne) since miniscrews could undergo fracture under excessive load or when smaller diameters are used [44, 45]; additionally, infections of the insertion site is another complication that can occur with the usage of miniscrews [46].

Considering the prevalence of transverse maxillary deficiency among children and adolescents [10], the awareness of the risks associated with the use of a tooth-borne and a bone-borne RME appears clinically relevant and future studies including subjects treated with tooth-borne and bone-borne maxillary expander are required to compare the risk of root resorption between the two groups.

CONCLUSION

The present review focused on the adaptive phenomena occurring in the radicular portion of maxillary posterior teeth after the application of heavy forces as those produced by RME protocol. Previous evidence suggests that both root resorption and cementum repair are involved in RME. However, the retention period and the timing of radiographic examination can influence the extension of radicular resorption detected after RME, since root resorption and cementum repair may occur at the same time at this stage. A sequential radiographic monitoring should be required to detect the maximum extension of RR. However, this is not possible considering the ethical limitation related to the patients' radiation exposure.

CONSENT FOR PUBLICATION

Not applicable.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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