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Review Article

The maxillary expansion procedures, the types, and the root resorption analysis methods

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Abstract

Transversal constriction of the maxilla is a common problem and may occur due to many reasons. The maxillary expansion procedures can be classified as rapid maxillary expansion (RME), semi-rapid maxillary expansion (SRME), and slow maxillary expansion (SME). In orthodontic treatment procedure, it has been evaluated that it causes root resorption especially in the support teeth in many apparatus used for orthodontic treatment and in the expansion apparatus used in the treatment of transverse direction of maxilla. In this review, we aimed to evaluate maxiller expansion protocols, and the methods of examining resorption in support teeth.

Keywords: Maxillary expansion, root resorption, micro-CT

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Introduction

Although the transversal constriction of the maxilla is a problem that is frequently observed, it may arise because of various reasons (1). The maxillary expansion procedures have been implemented for treating the transversal constriction of the maxilla for a long time (2). In this review, it was aimed to provide information about the methods used for analyzing the resorption in the abutment teeth after the maxillary expansion procedure.

By making use of the factors such as activation frequency, age of the patient, the amplitude of force applied, and treatment time, the maxillary expansion procedures can be classified as rapid maxillary expansion (RME), semi-rapid maxillary expansion (SRME), and slow maxillary expansion (SME) (2).

In the maxillary expansion procedure, a force higher than needed for tooth movement is applied to the teeth and the adjacent alveolar bones supporting those teeth (3). In previous studies, the undesired adverse effects such as injuries in the temporomandibular joint, clefts in the mid-palatal sutura, the gingival recession, and the root resorptions were reported (2-4).

In some of the previous studies, it was examined if various apparatuses used for the orthodontic treatment and the expansion apparatus used for treating the posterior cross-bite caused root resorption in abutment teeth. In these examinations, the radiography, histological cross-sections, and scanning electron microscopes were used in general (5). However, since these methods degrade the data, which should be examined in 3D, into 2D, they cause insufficiencies in examining the root resorption volumes (8). In order to overcome this problem, the Micro-CTs enabling the 3D examination of resorption craters are used in recent years. With the use of micro-CTs offering advantage as an examination method, the dimensional analyses can be performed for the small areas such as root resorption craters and the 3D modeling can be performed (9). The 3D imaging procedures are accepted to be more reliable for the root resorption studies (10).

Posterior Cross-Bite

The posterior cross-bite, in which the maxilla has a transversal constriction, has been reported to be one of the most frequently observed types of skeletal anomalies in the craniofacial region (18).

The cross-bite occurs because of the malocclusions of maxilla in transversal plane and is defined as the alterations in proper occlusion between the buccal tubercles of maxillary molar and premolar teeth and the central fossa of mandibular molar and premolar teeth (20).

Indications of Maxillary Expansion

- Real maxillary constriction cases (in these cases, the maxillary bone is smaller than required when taking the facial bones and mandibular bone as reference, and the maxillary bone constriction incorporating the posterior group of teeth is observed) (1).
- Relative maxillary constriction cases (the cases arise from the maxillary bone with normal size for the skull base and the mandibular bone larger when compared to the skull base) (1, 2, 3).
- The patients with unilateral and bilateral posterior cross-bite because of the transversal constriction of maxilla or the large mandible (11, 21, 23, 27, 37).
- For the patients having cleft lip and palate, when the scar tissue of early period lift and palate surgery decreases the growth and development of maxillary bone and the lateral cross-bite occurs (19).
- For the patients having nasal obstruction, the spatial relationship of maxillary bone may be affected because of the mouth breathing and the maxillary constriction may be observed among these individuals; the maxillary expansion procedure can be applied for relieving this problem (1, 19).
- In sagittal discrepancies, which are severity Class II section I cases, the maxillary constriction may occur without posterior cross-bite, and the cross-bite may also be seen without the maxillary constriction in Class III malocclusion. In these cases, the maxillary expansion procedure should be implemented (21, 30, 42).
- For the individuals having dental arc length discrepancies, the enlargement can be achieved by implementing maxillary expansion without tooth extraction for the cases, in which the tooth extraction might negatively affect the soft tissue esthetic (48, 49).
- In the transversal insufficiencies of maxilla other than crowding and posterior cross-bite, the dark spots are seen at the edges of mouth while smiling (42). By eliminating the dark regions via expansion treatments, the smile can be made more esthetical and attractive (40).

Maxillary Expansion Procedures

The most widely discussed part of the maxillary expansion procedure has been the speed of expansion and many different methods were recommended for turning the screw in literature. In general, three screw activation protocols are implemented. The generally recommended method for the maxillary expansion performed by using different apparatuses is the rapid expansion by turning the screw 2 quarter cycles every morning and evening (26, 37, 38).

For the semi-rapid maxillary expansion, Kılıç (50) and İşeri and Özsoy (40) applied the program consisting of 2 quarter cycles activation per day until the sutura opened and then 3 quarter cycles (1 quarter every 2 days) per week after the opening of sutura.

It is emphasized that the mild and continuous forces are transferred to the adjacent tissues when the quad helix apparatus used in the slow maxillary expansion procedures is expanded to the buccolingual size of molar teeth or 1 cycle of screw activation (0.2-0.25mm) every two days is applied (31).

Rapid Maxillary Expansion

In the rapid maxillary expansion, a force exceeding beyond the orthodontic tooth movement limits is applied to the teeth and maxillary alveolar structures (3, 38). If the force is at the level not exceeding beyond the elasticity limits of the periodontal ligaments, then it would cause the tooth movement. It might be possible to create the skeletal effect by hindering the lateral movement of teeth by applying heavy forces (118). Isaacson and Ingram (3) measured the single activation of a screw to be approx. 3-10 pounds (1.5- 4.5 kg). Developed by Isaacson and Ingram (3), the hypothesis that the amplitude of these forces accumulating in the maxillary structures would increase the resistance of the facial skeletal structure to the expansion was supported by Zimring and Isaacson (12).

When the forces applied during the expansion influence the teeth, then the periodontal ligaments constrict and the force are transferred to the alveolar bone. As a result, both the midpalatal sutura opens and the teeth flex towards the vestibule (11).

Semi-Rapid Maxillary Expansion

İşeri et al. (39) examined the resistance of adjacent tissues during the rapid maxillary expansion by using finite elements method on 3D human skull, and they reported that high levels of forces are observed in various regions of craniofacial complex and different levels of resistance occurred depending on the direction and center of the forces. The authors reported lower levels of resistance when slower maxillary expansion procedure was applied and they described the semi-rapid maxillary expansion. Accordingly, the rapid maxillary expansion is applied until the sutura opens and then the slow maxillary expansion is applied.

While describing the semi-rapid maxillary expansion, an expansion by 1-1.5mm per week, which corresponds to slightly more than 1/8 cycle per day, was recommended and a turning program slightly more than 1/8 cycle per day was offered (46). Mew (32) termed his study, where he achieved 1mm expansion per week, the procedure as semi-rapid or -slow maxillary expansion.

Slow Maxillary Expansion

The slow maxillary expansion procedure is applied for 2-6 months by using various mechanics implementing force ranging between 450g and 900g (29). It is argued that the slow movement occurring in 2-6 months during the slow expansion creates less tissue resistance and better bone formation in intermaxillary sutura and these two factors minimalize the relapse after the expansion (27).

In slow maxillary expansion procedure, the orthodontic movement is at high levels and the orthopedic movement is low since the resistance of sutural tissues is broken (27, 29). Besides that, in the radiography, the orthopedic separation of the maxillary segments, especially in the youth group in deciduous and/or mixed dentition period, was shown to be the effect of slow maxillary expansion in both animal (13, 31, 34, 35) and human (33, 35, 36) studies.

Tooth Movement and Root Resorption

The bioelectric and pressure stress mechanisms occurring in periodontal ligament are discussed in order to explain the tooth movements in orthodontic treatments. The pressures applied cause flexion in alveolar bones and emergence of bioelectric signals, which are named “piezoelectric” within seconds. The blood vessels would constrict in the constriction areas of periodontal ligaments and dilate in the stress zones. The tooth movement occurs via the remodeling of bone by the osteoblast and osteoclast cells related with the bone structure’s construction and destruction as a result of the cellular activities (22).

The construction and destruction in the alveolar bone that is needed for the tooth movement cause alterations also in root surface. It was reported that the later resorption of cement, which is similar to the bone structure, when compared to the bone was related with the resistance mechanisms causing the resorption of cement. Especially in the external layers, the cementine contains more fluoride than the bone does. Moreover, the construction-destruction events continuing at high levels in the bone structures that have closer contact with the periodontal ligament than with the cement hinder the establishment of mature collagen structure in this region. The older and mature collagens surrounding the cement increase this tissue’s resistance to the chemical changes. The non-mineralized cementoid layer surrounds the cement and acts as an important layer for the resistance to resorption (53).

The resorption process continues until the force applied is decreased or the hyalinized region is completely removed. The resorption lacunas spreading around the root surface would indirectly cause a decrease in pressure until the new forces are applied. Thus, the resorption process would revert and it would enable the cement restoration (54).

The restoration of orthodontic root resorption can be achieved via tissues such as nerves within the periodontal ligament, Malassez epithelial cell rests, and blood vessels (52). In many studies, it was shown that the resorption defects were restored via accumulating new cement and remodeling the periodontal tissues (5, 6, 55). The restoration process might start around or at the center of resorption craters or in all the directions.

The Methods Used in Identifying and Measuring the Root Resorption

- ### Radiography

Besides the diagnostic purposes, the radiographic methods are also frequently used for diagnosing the root resorption in dentistry. It is very difficult to achieve standard radiography, in which the same tooth can be examined at different time. The root sizes, which are observed in radiography to shrink after the torque and tipping movements in orthodontic treatment, make it difficult to evaluate the amount of root resorptions. Since the radiographic methods used in evaluating the resorption provide 2D image, they remain insufficient in evaluating the possible resorptions in buccal and lingual root regions (51).

Despite many advantages such as low level of radiation and shorter time for obtaining, the radiographic methods raise difficulties in detecting the root resorption especially in the region of incisor teeth since the panoramic radiography cause magnification (24).

The errors such as distortion rate and superpose are seen much less frequently in periapical radiography when compared to the panoramic radiography. Especially the periapical radiograph obtained by using parallel method provides better information for the root resorption than panoramic radiography and lateral cephalometry (24, 51).

The use of radiographic methods as a diagnostic instrument in detecting the root resorption decreased since they remain insufficient in calculating the resorption (8).

- **Histological Examination Method**

The changes of resorptions at molecular, cellular, tissue levels as a result of the orthodontic forces can be histologically analyzed (53). The morphological image of the existing root resorptions can be detected by using histological methods and the resorption cavities in buccal, palatinal, mesial, and distal regions can be more easily detected (17).

By using the histological examination method, it is possible to evaluate the detection of root resorption lacunas, which have been reported to occur at buccal to the abutment teeth in rapid maxillary expansions, in these regions and to evaluate their different stages from cellular aspect (45).

- **Immunological Biochemical Measurement Method**

It was reported that the organic matrix proteins are secreted in the first stage of root resorption process and then the amount of these proteins within the gingival crevicular fluid changes depending on the amount of root resorption. It was stated that the biochemical measurement can be used in assessing the root resorption (16).

- **Electron Microscope**

There are studies carried out in using an electron microscope in assessing the root resorption craters (5, 15, 25, 47).

The scanning electron microscope (SEM) method makes it possible to examine the root resorption and increases the visuality. Achieving the wrong numerical data from the measurements performed by considering the curved root surface to be a flat surface is a disadvantage (8). In a study carried out by using scanning electron microscope in examining the resorption craters in abutment during the rapid maxillary expansion, the images obtained during the retaining period after the expansion can provide information about the mineralization of craters. The resorptions, which are clearly observed at the buccal to the abutment teeth in SEM images, are not observed in periapical radiography (5).

- **Computed Tomography**

2D and 3D images of the examined region can be achieved by using computed tomography. The 3D volumetric images can be moved and rotated in any direction. By magnifying the images, the more detailed examination and measurement can be performed (57).

In the previous studies, it can be seen that the computed tomography was widely used in airway measurements, examining the root resorptions arising from the orthodontic treatment, examining the implant procedures performed in jaw, detecting the impacted teeth, detecting especially the localization of maxillary canine teeth, and evaluating the temporomandibular joint (57,58,59).

Since the volume of root resorption is 3D, the aforementioned methods offering 2D examination cannot meet the necessary accuracy in determining the amount of resorption crater. In this case, the computed tomography method providing 3D imaging is accepted to be more realistic. The image can be achieved in a short time. However, the high level of radiation is a disadvantage in this method (9).

- **Micro Computed Tomography (Micro-CT)**

Micro-CTs, which are a type of computed tomography, are capable of imaging the small structural contents of scanned material without damage by performing high dimensional analyses. Ensuring the immobility of the material during the scanning procedure, the long time needed for obtaining the image, the long time spent for 3D structuring, and the use in in vitro studies are the disadvantages of this method (41).

The Micro-CT method makes it possible to perform a 3D analysis in very small areas such as root resorption. The images obtained from Micro-CTs are converted to the spatial data by making use of computer software. The amount of volumetric changes occurring on the root surfaces as a result of the resorption can be determined. The usability in this field since they work at a high accuracy level and they are repeatable is accepted to be an advantage. However, this method can be applied only to the extracted teeth (9).

- ### Cone-Beam Computed Tomography (CBCT)

This method, which started to be used in orthodontics in the recent period, is also used for detecting the root resorptions (9). Low level of radiation, shorter time needed for obtaining the image, absence of the problem of decrease in image quality as a result of patient's movement, and fewer artifacts arising from the orthodontic devices when compared to conventional CT are the advantages of CBCT (56). Moreover, thanks to their lower radiation levels, CBCTs allow the examination of orthodontically induced root resorptions on the patient in the clinic environment (14).

The most reliable one among the current root resorption analysis methods is accepted to be the Micro-CT method since it enables imaging the resorption craters' volume in 3D and making the volumetric calculations. However, this method can be used only on the extracted teeth. The CBCTs can be used in the analysis for the cases, in which no extraction will be performed.

Maxillary Expansion and Root Resorption

In their study on examining examined the first maxillary premolar teeth, which are the abutment teeth, from the aspect of restoration after 14-53 weeks of retaining following the rapid maxillary expansion, Langford and Sims (6) reported by using light and scanning electron microscope that the root resorption was located especially at the buccal to the abutment teeth. They observed that the restored defects were largely filled with cellular cement. It was shown in the histological cross-sections that the periodontal fibers directly bonded to the increasing cellular cement tissue as the retaining period prolonged.

Barber and Sims (5) examined the abutment teeth and non-abutment teeth right after the rapid expansion procedure they performed and after different retaining periods from the aspect of root resorption. These researchers, who have used SEM in their analyses, reported that there was resorption especially on the buccal root surfaces of all the abutment teeth but not on the non-abutment teeth. The researchers determined that, although the restoration is the dominant process in the retaining periods, the active resorption continues even in retaining periods up to 9 months.

Langford (44) analyzed the buccal surfaces of first maxillary premolar teeth of 13-16-year-old patients by using SEM method after the rapid maxillary expansion procedure and then applied 3-month retaining period. The author stated that the relapse forces having effect for up to 3 months caused root resorption, the restoration process started after 3 months, and the restoration process is completed at the end of 1-year period.

It was reported that the resorption craters were at the buccal to the abutment teeth and enlarged to the lateral after the retaining period following the expansion and that the defects were generally restored with cellular cement (44, 45).

In their study on comparing the root resorption effects of Haas and Hyrax apparatuses used in the rapid maxillary expansion of 10-13 year-old patients, Odenrick et al. (7) reported that, although the resorption was observed at apical to the maxillary premolar teeth, the dominant resorption areas were located at the buccal to the root in both groups. There was resorption at the palatinal to two premolar teeth only in Haas group. They reported that the active surface resorption was observed on the teeth extracted right after the expansion. When the retaining periods varying between 3 and 267 days were compared, it was determined that the sizes of resorption lacunas decreased as the retaining period prolonged. When compared to the Haas group, the dimensions of cavities located at buccal to the root in Hyrax group were larger. In most of the maxillary premolar teeth that were examined, the distance between the buccal resorption areas and the junction between cement and enamel was 1.2mm. This finding suggests that the teeth did not move completely parallel to each other during the expansion treatment and they slightly inclined towards the buccal side.

It was reported that none of the maxillary expansion methods caused resorption in maxillary incisor teeth (43). However, the histological cross-sections used in an animal study on 14 cats undergone RME (9) and not (4) suggest the resorption after the maxillary incisor teeth after the expansion procedure (25). The researchers, who observed a higher level of root resorption in the treatment group, especially in maxillary incisor teeth when compared to the untreated group, reported that it is very difficult to detect these resorptions by using the radiography.

The root resorption of the first maxillary premolar and first maxillary molar teeth, which were the abutment teeth, and that of the second molar teeth, which were the non-abutment teeth, were examined in 3D by using CBCT records after the rapid expansion procedure. The CBCT records taken before and after the treatment were converted to the volumetric data by using computer software. The measurements showed that the root resorptions in the abutment teeth and the non-abutment second maxillary premolar teeth were statistically significant. Although the highest level of volumetric loss was observed in the mesiobuccal root of the first maxillary molar teeth, there was no statistically significant difference between the examined teeth from the aspect of loss when calculated in percentage (28). Topal Kaya et al. examined the root resorption in abutment teeth after the rapid maxillary expansion, semi-rapid maxillary expansion, and slow maxillary expansion by using Micro-CT method. They determined that the total root resorption volume was at the highest level in RME group, followed by SRME, and SME groups. It was observed that the root resorption craters concentrated on the buccal surfaces of the abutment teeth in all three groups (60).

Conclusion

Among the maxillary expansion methods applied in the orthodontic practice, the most widely preferred protocols in the clinical practice are the banded maxillary expansion apparatus in RME method, bonded expansion apparatus in SRME, and quad helix apparatus in SME. It was determined by using various methods that the resorption occurred in the abutment teeth after the expansion procedure. However, the number of studies carried out by using computed tomography methods, which are considered to be a more reliable and modern method, is not enough and further studies are needed.

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