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ORIGINAL ARTICLE

Apical Resorption of Upper Incisors and Canines During Orthodontic Treatment in Class III Orthognathic Surgery Patients – a Longitudinal Cone Beam Computer Tomography Study

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Summary
Introduction. Although severe root resorption is rare, it is a side effect of orthodontic treatment which affects tooth prognosis. Patients with severe dentofacial deformity, for whom orthodontic treatment and orthognathic surgery was done at the age of 18 and later, had long duration orthodontic treatment and orthognathic surgery, and are at a high risk of root resorption. The impact of orthognathic surgery on root resorption has not been sufficiently studied, and therefore is an interesting topic to research.
Aim of the Study. To identify the risk factors for apical root resorption of maxillary incisors and canines as a result of orthodontic and surgical treatment of Class III malocclusion involving LeFort I osteotomy.
Material and methods. The root lengths of upper incisors and canines were measured on cone beam computer tomography (CBCT) scans obtained from a database of orthognathic surgery patients. As a criteria for root resorption was chosen the difference in root lengths between different time points. The measurements were performed using the scans taken before orthodontic treatment (T1), before surgery (T2), and after post surgery orthodontic treatment (T3), of 28 subjects, aged 20.5 ± 3.81 years, with the mean pre-surgery treatment time of 19.9 ± 8.8 months, and post-surgery time of 7.1 ± 3.1 months. Changes in root lengths during different time spans were correlated with treatment duration, the initial crown/root ratio, and the severity of dentofacial deformity (Wits appraisal, ANB angle, and overjet).
Results. During T1 - T2 the roots of the lateral incisors shortened by a maximum of 0.78 ± 0.83 mm ($p < 0.001$), at a rate of 0.04 mm per month. During T2 - T3 the lengths of the central incisor roots decreased most by 0.49 ± 0.52 ($p < 0.001$) at a rate of 0.07 mm per month. The resorption speed for canines increased from 0.03 mm to 0.1 mm per month before and after surgery. There were statistically significant correlations between the crown-root ratio and the incisor root length ($r = 0.319$ for lateral and r = 303 for central, both p<0,05) and for canines (r = 482, $p<0.01$). The associations between the shortened root length, in different time spans for different teeth, and the severity of malocclusion were inconsistent.
Conclusions. Overall, the shortened root length during combined orthodontic and surgical treatment might not be clinically significant. After surgery, the rate of root resorption (mm per month) increased, especially for canines. The teeth with initially shorter roots showed more resorption during treatment.
Key words: root resorption, Le Fort I, orthognathic surgery, orthodontics.

INTRODUCTION

Orthodontic root resorption is a sterile infection, during which ischaemic necrotic zones develop within the periodontal ligament (6). Ischaemia develops due to reduced blood flow in the periodontal ligament, resulting in the formation of necrotic tissue. This tissue is then absorbed by macrophages, odontoclasts, and osteoclasts. If the hosts response to this infection is too active, these same cells absorb not only the necrotic tissue, but also root cementum, and even dentine (7).

Mild to severe resorption is a side effect affecting between 12 % and 17 % of orthodontic patients, with 10 – 20 % of these patients developing resorption of greater than 3 mm. The teeth most commonly affected are maxillary incisors (4, 15,16).

Although severe root resorption is rare and does not progress after orthodontic treatment is completed, it is important to know the causes and possible preventive measures. One of the reasons being that shortened root lengths affect long-term tooth prognosis, and complicates prosthetic treatment, if necessary, in the future (3).

Different risk factors for root resorption have been discussed in previous studies. A study by Sameshima et al., 2001 (15,16) demonstrated classification of these risk factors into three large groups: 1) demographic factors (age, gender, race); 2) treatment factors (treatment with extractions, bracket slot size, the type of arch wire, treatment duration, orthognathic surgery); and 3) dental factors (root length and anatomy, crown lengths, overjet, overbite, endodontic treatment, trauma in patient history, resorption prior to orthodontic treatment, and habits of the patient).

Patients with severe dentofacial deformity, for whom orthodontic treatment and orthognathic surgery is done at the age of 18 and later, have long duration orthodontic treatment and orthognathic surgery, for these patients root resorption risk factors could be at greater extent.

The subject of orthognathic surgery impact on root resorption lacks research. Some root resorption studies mention orthognathic surgery as one of the patient exclusion criteria (11,1,12); however, the underlying reasons are not explained. Moreover, no studies describing the impact of Le Fort I orthognathic surgery on root resorption were found; this raises interest, because it is a potential risk factor owing to the proximity of Le Fort I osteotomy to the apices of incisor and canine roots. In a study by Vedtofte et al. (1988) (20) tooth vitality was evaluated after Le Fort I surgery, 6 % of teeth did not regain normal pulp sensibility, and according to this study, the teeth most affected were canines. Potential causes suggested by the authors include, changes in tooth innervation post-surgery, the proximity of osteotomy and osteosynthesis screws to the root apex, and changes in blood supply. These factors can also relate to root resorption. The most commonly used radiological methods in root resorption diagnostics and research, are the orthopantomogram (OPG), periapical radiograph, and cephalogram. Despite these methods being broadly used, they lack precision in diagnostics, with the reason differing for each radiological method: image magnification and distortion, superimposition of different structures, and incorrect patient positioning, respectively (12,6).

Root resorption is a three-dimensional (3D) process; it cannot be adequately evaluated by conventional 2D radiographic methods (8). With the introduction of cone beam computer tomography (CBCT) to dental practice, it has been possible to evaluate structures in 3D. Recent studies suggest that CBCT, compared with OPG, can evaluate root resorption with greater precision. Compared to 2D radiographic methods e.g. periapical radiograph, it is possible to make linear measures more precisely with CBCT, including measuring the length of the root (12,8).

The objectives of this study were to 1) evaluate root resorption before and after orthognathic Le Fort I surgery, 2) analyse the correlation of treatment duration with root resorption, 3) analyse the correlation of crown-root ratio with root resorption, and 4) analyse the correlation of the severity of dentofacial deformity (Wits appraisal, ANB angle, and overjet) with root resorption.

AIM OF THE STUDY

To identify risk factors for apical root resorption of maxillary incisors and canines as a result of orthodontic and surgical treatment of Class III dentofacial deformity involving LeFort I osteotomy.

MATERIAL AND METHODS

The subjects for this longitudinal study were enrolled form Riga Stradins University Institute of Stomatology orthognathic patient database (consisting of 219 patients), who received orthodontic treatment and orthognathic surgery between 2009 and 2016, One hundred and nine patients in this database had a class III dentofacial deformity, of those, 28 patients were included in this study, after evaluation of patient charts and radiographic examinations. As a criteria for root resorption was chosen the difference in root lenghts between different time point. Patients with CBCT images before orthodontic treatment, before orthognathic surgery, and after orthodontic treatment were included. Patients without all necessary CBCT images, patients with endodontically treated incisors or canines, and patients with a history of incisor or canine trauma in history were excluded.

Subjects at the beginning of orthodontic treatment were between 16 and 29 years old (average 20.45 ± 3.83 years), and included 18 females and 10 males. The average treatment duration before orthognathic surgery was 19.88 ± 8.83 months, and after orthognathic surgery was 7.08 ± 3.12 months.

CBCT imaging was performed with i-CAT (Imaging sciences International Inc., Hatfield, PA, USA), according to a standardised protocol: voltage 120 kV, 5 mA, field of view 17 cm, voxel size 0.4 mm, exposure time 4 sec.

The lengths of six teeth roots were measured - maxillary incisors and canines - on CBCT images, with root lengths being used as an indicator of apical root resorption. For each subject three CBCT images were analysed – before orthodontic treatment (before bonding of fixed appliance) – T1; before orthognathic surgery – T2; after orthodontic treatment (after de-bonding of fixed appliance) – T3.The amount of roots at each time point differed due to inability to measure all roots from cemento enamel juntion to the apex of the root, for teeth were angulated after orthodontic treatment or the anatomy of the root was not favourable for a linear measurment. The amount of central incisor rootsmeasured at T1 -55 roots; T2 - 55 roots; T3 - 56 roots. The amount of lateral incisor roots measured at T1 - 54 roots; T2 - 51 roots; T3 - 55 roots. The amount of canine roots measured were at T1 - 49 roots; T2 - 42 roots and T3 - 50 roots.

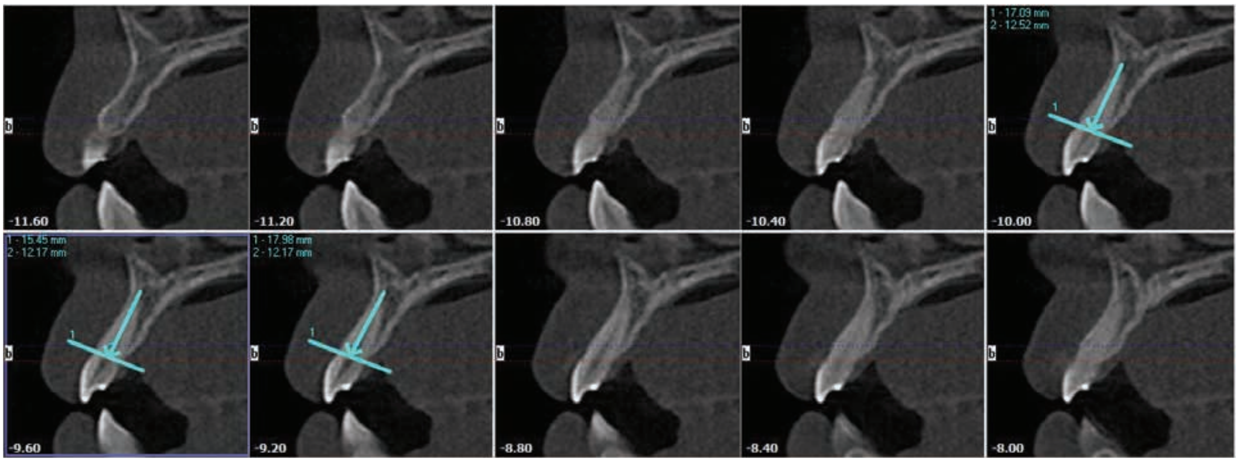

Fig. 1. Root measurements in sagittal plane in CBCT images

The lengths of the roots in the CBCT images were measured in sagittal plane. First the cementoenamel junction (CEJ) was marked from the labial CEJ point to the palatal CEJ point. Root length was measured from the apex to the previously marked CEJ. This was done to avoid a possible artefact in T2 from the metallic bracket, which can prevent accurate incisal facet location. Root lengths were measured in three further sections in which the apex of the root was best visualised through the vertical axis of the tooth, following the root canal. From these three measurements, the average was calculated. Root lengths were measured twice, with a 2-week interval.

The rate of resorption was calculated by dividing the shortening of the root (mm) by treatment duration (months).

Correlation with root resorption was analysed with the following risk factors: treatment duration (months), crown-root ratio, Wits appraisal, ANB angle, and overjet. Root resorption risk factor measurements that were related to the severity of dentofacial deformity were taken before the start of orthodontic treatment. Of those Wits appraisal before the beginning of orthodontic treatment was -10,45mm on average SD 6,43, ANB angle -3,35 SD 2,29 and overjet -0,52mm SD 2,87.

Information about treatment duration was obtained from patient charts. The crown-root ratio was calculated by measurement of the crown length and root length in CBCT images made at T1. Wits, ANB and overjet were measured in cephalometric analysis prior to orthodontic treatment.

The rate of resorption and all of the above correlations were analysed for changes in root lengths in three time spans: T1 - T2 from before orthodontic treatment until before orthognathic surgery; T2 - T3 before orthognathic surgery until after post surgical orthodontic treatment, and T1 - T3 : before orthodontic treatment until after post surgery orthodontic treatment

Statistical analysis

Statistical analysis was performed with software SPSS v.23.0 and Microsoft Office Excel v. 15.18. Descriptive statistics were conducted to analyse average, median and standard deviation, including 25th and 75th percentiles. Results were considered statistically significant when $p < 0.05$.

Student's t-test was used to analyse root lengths and any changes in root lengths: the data were normally distributed. Pearson correlation coefficient was used to analyse correlations between the treatment duration, crown/root ratio, Wits appraisal, ANB angle, and overjet. Correlation was considered significant, when $p < 0.05$. Correlation strength was classified after the coefficient as follows: 0 - 0.25 weak correlation; 0.25 - 0.75 mild correlation; 0.75 - 1 strong correlation. [19.]

RESULTS

Interobserver agreement was 0.46 with $p < 0.954$, which indicates there was no systematic bias.

During the treatment, before orthognathic surgery (T1 - T2), the roots of the lateral incisors were most affected by resorption (0.78 mm, Standard Deviation [SD] 0.83). During the treatment, after surgery (T2 - T3), the roots of the central incisors were most affected by resorption (0.49 mm, SD 0.52), but overall in the whole treatment period (T1 - T3), the roots most affected by resorption were those of the lateral incisors (1.17 mm, SD 0.89).

The speed of root resorption (mm per month) was calculated by dividing the amount of resorption by the treatment duration (months), and showed that the highest rate of root resorption was after orthognathic surgery. All results were with high statistical significance $p < 0,001$ (See Table No.1.)

More correlation to root resorption of all risk factors was met with crown-root ratio among all teeth groups, the highest being 0.482 ($p < 0.01$) for canines during the whole treatment (T1 - T3). Correlation among the dentofacial deformity related risk factors varies among tooth groups and time spans. (See Tab. No. 2.)

DISCUSSION

The results of this research correlate with the results of Sameshima et al. (2001) and Artun et al. (2005) (15, 16,2) - treatment duration affects root resorption.

Harstfield et al. (2009) (10) are also in agreement with these conclusions. A positive, although weak, correlation was found between the resorption of central incisors during the orthodontic treatment prior to orthognathic surgery, and the duration of treatment. These data can be clinically relevant for patients for whom complicated and prolonged orthodontic treatment is planned.

Positive correlation was found between root resorption and crown-root ratio - shorter roots were more resorbed. This disagrees with Sameshima et al. (2001) (16) and Artun et al. (2005) |(2). Sameshima et al. argue that a longer root is subject to a larger movement than shorter root to achieve the same amplitude of torque. But Picanco et al. (2013)(14) agree with results of this study - shorter roots show more resorption during orthodontic treatment.

All dentofacial deformity factors chosen in this study (Wits appraisal, ANB angle and overjet) were found to be related to root resorption during different time spans, but were not consistent. From the data obtained, it is possible to conclude that root resorption occurs more commonly for subjects with decreased Wits and overjet. All of the subjects in this study have class III dentofacial deformity - the lower Wits and overjet are the more severe is the dentofacial deformity. Correlation of these two factors with root resorption was found during post surgery orthodontic treatment, which may indicate that patients with a more severe dentofacial deformity have a higher risk of root resorption, after orthognathic surgery. These data do not agree with the results of a study of Picanco et al., 2013(14), but root resorption after orthognathic surgery was not measured in these studies. In this study two different results were found regarding ANB angle and root resorption. For central incisors with a larger ANB angle, root shortening was greater during treatment prior to surgery, but for canines the results were contrary - the smaller the ANB angle, the larger amount of apical root resorption was found.

Results about root resorption and its risk factors vary in different studies, which can be attributed to different factors. One potential explanation for such diversity in the results is genetic predisposition. Hartsfield et al. (2009)(9) and Guo et al. (2015)(8) show that patients with a specific genotype have a higher risk of root resorption during orthodontic treatment.

Differences in results can also be explained by the various methods used among research to measure root resorption, and the precision of these methods. Guo et al. (2016) (8) attribute the different radiographic diagnostic methods, used in each study, as the explanation behind the difference in root resorption measurement. The authors argue that conventional radiological methods (periapical radiographs, orthopantomogram, and cephalogram) do not show root resorption accurately, and therefor affect its precise evaluation and measurement; CBCT imaging is more suitable.

Savoldi et al. (2015) (17) study claimed that orthopantomogram can be misleading when measuring root resorption; the inclination of the tooth during orthodontic treatment changes, and therefor the tooth can appear to be shorter, and consequently be mistakenly diagnosed as having root resorption.

Despite the precision and accuracy of CBCT, it has a larger effective dose compared to conventional radiological methods. For craniofacial examinations, which require a field of view larger than 10cm, the effective dose varies from 30 to 1073 μSv. Conversely orthopanthomogram varies from 2.7 to 24.3 μSv and intraoral radiographs measures <1.5 μSv(10). Although it is proven that CBCT is more suitable for detecting and measuring root resorption, it should be noted that a higher effective dose increases the potential risks of radiological examination. The choice of radiographic examination method should be made according to the ALARA (as low as reasonably achievable) principle, (10) meaning that the patient should be examined using the method that produces the required information with the lowest radiation dose, and the value of the information attained should outweigh the associated risks of the examination.

In this study, CBCT imaging was carried out for the planning and evaluation of orthognathic surgery. As this was a retrospective study, the availability of all necessary CBCT scans narrowed the inclusion criteria, and consequently affected the sample size. Preferably a sample size calculation should be done prior to research to achieve the necessary power of study, but that was not possible for there were no previous studies that could provide the required data. Not all patients required a CBCT scan before orthodontic treatment or after de-bonding of braces; all CBCT scans were taken for an individual clinical necessity. Because patients who undergo orthodontic treatment in combination with orthognathic surgery may require more than one CBCT scan, the exposure time was 3-seconds shorter (4-seconds instead of 7-seconds).

The image quality among different CBCT scans can vary. Patel et al. (2012) (12) used two different CBCT imaging devices: NewTom 36 AFP Imaging and i-CAT - Imaging Sciences International, and the authors argue that the i-CAT CBCT is of higher quality. They also mention that metallic braces can produce an artefact, which in return affects the quality of the image. In this research, a disadvantage was the presence of metallic braces on CBCT images taken at T2 (before orthognathic surgery), which affected the precise detection of the cementoenamel junction. The artefact did not however affect the quality of the image around the apex of the root.

Other precise imaging methods are described in other studies. Sawicka et al. (2014) (18) research shows that computed micro-tomography is more precise that CBCT, but it is only applicable to extracted teeth.

Although CBCT images are 3D, only linear changes in the root were detected in this study; 3D reconstruction of the root surface was not performed. As root resorption is a three-dimensional process and can affect the whole root surface during orthodontic treatment (4), three-dimensional reconstruction would allow for changes in root volume to be measured.

An interesting finding of this study was the speed of root resorption (mm per month), which increased after orthognathic surgery. A possible explanation is the traumatic effect of surgery, which consequently increased the risk of root resorption. Orthodontic treatment was of shorter duration after orthognathic surgery, and the root resorption was therefore more notable during pre-surgery orthodontic treatment. A study by Patterson et al. 2017(13) on the effect of piezocision on root resorption associated with orthodontic force, showed that teeth that underwent piezocision had a higher amount of root resorption than the control group. During orthodontic treatment, an inflammatory process occurs; this is advantageous to the movement of teeth, but root resorption and additional inflammatory process. The authors argue that increased inflammatory marker levels that help speed up bone turnover (due to a regional acceleratory phenomenon induced by corticotomy), can cause root resorption at a higher level. Although Le Fort I osteotomy is not performed for the purpose of accelerated tooth movement, osteotomy itself can cause higher inflammatory marker levels locally, thereby affecting the root resorption process.

Because studies describing the effect of orthognathic surgery on root resorption are lacking, this phenomenon requires further, more in-depth research.

CONCLUSION

Apical root resorption during orthodontic treatment is multifactorial. During this research orthognathic surgery was found to be an additional risk factor to the developement of apical root resorption, but further, larger scale research is necessary.

Conflict of interest: None

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