Comparison of Orthopanand Computerized Tomographic Examination of Root and Alveolar Bone Resorption in Orthodontic Patients

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Abstract

Purpose: The aim of the study was to determine whether fixed orthodontic appliances cause root and alveolar bone resorption and to compare the precision of orthopantomography and computerized tomography in detection of resorption process.

Methods: Eighty-five patients scheduled for orthodontic therapy with fixed appliances were included in prospective self-controlled study. Before and after orthodontic treatment orthopantomography was done for all patients and thirty-five patients were sent to CT scan of upper or lower incisors and canines in order to compare the precision of two radiographic procedures. The root lenght was measured as the distance from cementoenamel junction to the root apex and the alveolar bone height from root apex to the most coronar point of alveolar bone.

Results: During orthodontic therapy root length of anterior teeth changed. The decrease of root length was detected on OPT for upper incisors (central right 0.3033 mm, central left 0.6711 mm) and lower left central incisors (0.3176 mm). Saggital CT scan of central incisors showed root resorption of 0.7750 oraly and 0.555 mm buccaly. Orthodontic appliances induced also alveolar bone resorption around anterior teeth. The highest values for alveolar bone resorption on OPT were detected around maxillary right (1.2169 mm) and left lateral incisors (1.2284 mm) and lower central incisors (1.0873 mm). The alveolar bone resorption detected on CT scan of central incisors was less than on OPT (0.11 mm bucally, 0.1550 oraly).

Conclusion: Fixed orthodontic appliances cause root and alveolar bone resorption which is more accurately determined by using computerized tomography than orthopantomography.

Key Words: Root resorption, Fixed appliances, Computed tomography, Alveolar bone, Anterior teeth

Introduction

Fixed orthodontic appliances transmit orthodontic forces to teeth and adjacent alveolar bone which results in tooth movement. Many epidemiologic studies tried to discover weather fixed orthodontic appliances also induce root resorption [1,2]. The results of these investigations showed that orthodontic forces may produce apical root resorption and that incisors are often affected. There are contradictory results regarding the correlation between the amount of tooth movement and apical root resorption. Hemley [3] and Mc Nab et al. [4] found positive correlation between the amount of tooth movement and apical resorption, while Phillips [5] reported opposite findings. Investigating the risk factors for root resorption in orthodontic patients Mirabella [6] found that there is no correlation between the type of malocclusion and the incidence of root resorption. It seems that shortening of dental roots happens among the majority of orthodontic patients [7].

The question of radiographic method used in diagnosis of resorptive process has always been very interesting among investigators. The first study dedicated to root resorption in orthodontic patients was based on retroalveolar radiographs. Since the method for alveolar bone height and root lenght measuring was described [8] many studies have been published in order to determine resorptive processes using retroalveolar radiographs [9,10]. Meanwhile, several studies tried to diagnose root resorption using lateral teleradiographs [11,12] and occlusal radiographs[13]. Finally, Hendrix [14] suggested the use of Orthopantomography (OPT) in detecting root and alveolar bone resorption in orthodontic patients. During the last decade investigators have been rising the question of OPT and retroalveolar radiography precision in resorption diagnostics [15]. With introduction of Computed Tomography (CT) in dentistry started the new era in the field of dentomaxillofacial radiology [16]. There are several indications for CT in orthodontics [17,18]. Just recently two studies dedicated to the incidence of the root and alveolar bone resorption during orthodontic treatment have been published [19,20]. Both studies compared the diagnostic precission of OPT and retroalveolar radiographs with CT but only after the removal of fixed appliances. The most accentuated difference in level of root resorption on OPT and CT was shown among maxillary incisors.

Based on all these facts the aim of our study was to compare the precision of orthopantomography and computerized tomography in diagnostics of apical root and alveolar bone resorption in patients treated with fixed orthodontics appliances.

Materials and Methods

Our study included 85 patients (27 male, 58 female) aged between 10 and 22 years who were scheaduled for orthodontic therapy with upper and/or lower fixed appliance. Metal brackets with slot size 0.022 inches were directly bonded on the vestibular surfaces of incisors, canines and premolars using No-mix (Dentaurum, Germany) orthodontic adhesive

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while first molars were banded. The NiTi archwires for nivelation phase and later stainless steel archwires for teeth movement were ligated with elastic ligature in brackets slots. The average lenght of treatment was 1.9 year. In 43 patients (50.6%) there was no need for extraction in upper or lower jaw. In the most patients who needed extraction two teeth were extracted (34.1% patients in the upper and 17.6% in the lower jaw).

Among 10.6% patients' one tooth was extracted in the upper and among 11.8% patients in the lower jaw. Only in one patient three upper teeth were extracted. There was statistically significant difference between upper and lower extracted teeth (Z=-2.384; p=0.017).

The mean age of the patients at the beginning of therapy with upper fixed appliance was 14.97 years and with lower fixed appliance 14.87 years. All patients fulfilled the following criteria: the indication for fixed orthodontic therapy regardless of malocclusion type, good general and initial periodontal health and the lack of the risk factors for root resorption such as dental agenesis, taurodontism [21], dental trauma or the presence of earlier resorption. The approval of the Research Ethics Committee of the Faculty of Stomatology in Belgrade for the use of both imaging modalities, orthopantomography and computerized tomography, was obtained prior to the study (protocol number 36/7, date of issuing: 09.04.2008.). All procedures were in accordance with the ethical standards on human experimentation (institutional and national). Signed informed consent was obtained from all patients or, if minors, their parents prior to the study.

Before and after orthodontic treatment OPT was done for all patients. On the same day 35 of 85 patients included in the study were sent to CT scanning of upper or lower incisors and canines. Digital OPTs were done with Pro Max S2 (Planmeca OY, Helsinki, Finland) apparatus while CT was performed using multislice scaner Somatom Sensation 16 (Siemens, Minchen, Germany). The technical specification for panoramic protocol were anode voltage 60 kV, anode current 15 mA, with focal spot size 0.5 x 0.5 mm, image pixel size 48 microns, exposure time 14 seconds. Anterior teeth (20 central, 18 lateral incisors, 16 canines) and adjacent alveolar bone were scaned in 3 mm wide layers. The computed tomographic parameters were voltage 120 kV, effective 100 mAs, slice collimation 0.75 mm, pitch factor 0.55, kernel H31s. The threedimensional reconstruction and analysis was performed using Syngo Fastview software (Siemens, Minchen, Germany) (*Figure 1*).

The root lenght on OPT was measured as the distance from the cemento enamel junction to the root apex while the crown lenght was measured from the cementoenamel junction to the incisal edge (*Figure 2*). All measurements were obtained from the mesial and distal side of examined teeth using ruler with milimeter scale to the nearest 0.5 mm. The crown lenght was used for correction of the possible enlargement differences between initial and final OPT. This is based on the fact that the crown lenght should not be changed during orthodontic treatment. This method was described by Linge and Linge [9]. According to this method the Correction Factor (CF) is calculated by using the following formula: $CF=C_1/C_2$ where C_1 represents the crown lenght on initial and C_2 on final OPT. The root resorption in milimeters was then calculated: Apical root resorption $(ARR)=R_1 - (R_2 \times CF)$ where R_1 represents the root lenght on initial and R_2 on final OPT. Shortening of the roots in percentages using formula $ARR \times 100/R_1$ was also determined as even more precise method for measuring the root lenght changes.

The alveolar bone height was measured from the mesial and distal side of teeth on initial and final OPT [8]. The height of aproximal alveolar bone is defined as the distance between the root apex and the most coronar point of alveolar bone with normal width of periodontal space of 0.5 mm (*Figure 2*). The distance between the cementoenamel junction of the tooth and the most coronar point of alveolar bone represents the alveolar bone level. Comparing the initial and final values it was determined whether root and alveolar bone resorption occured during orthodontic treatment.

The total tooth, crown and root lenght and alveolar bone height were measured on sagittal and transversal CT plane using the same points as on OPT (*Figure 3*). The alveolar

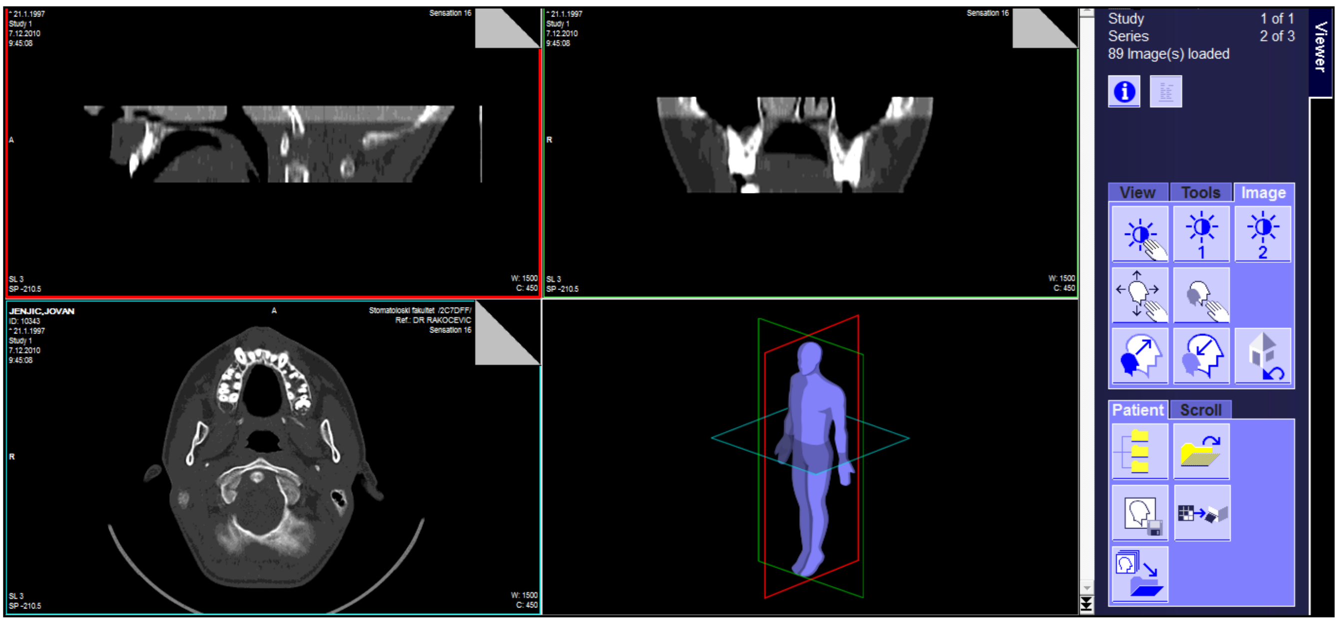

***Figure 1**. Sagittal, transversal and axial view: Syngo Fastview software.*

Figure 2. *The root, crown and total tooth length measurements on orthopantomograms.*

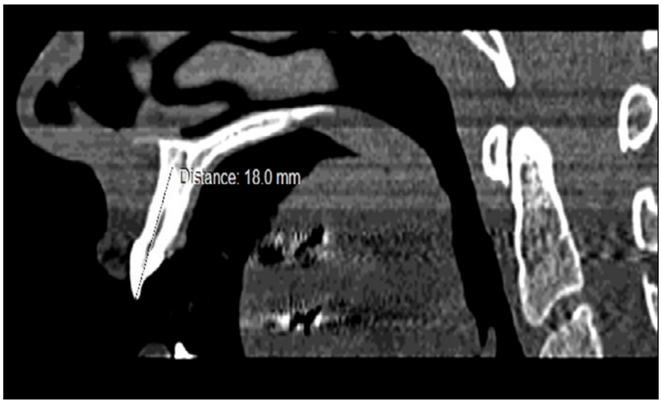

Figure 3. *The total tooth lenght: sagittal CT view.*

bone height on the buccal and oral side of incisors and canines was measured using sagittal CT plane and on mesial and distal side using transversal CT plane. Statistical analyses included descriptive statistical measurements, Student *t*-test and Chi squared test combined with McNemar test.

Results

Orthopantomography

The measurements of initial root length of anterior teeth showed that upper and lower canines have the longest roots (18.22 mm, 16.58 mm respectively). In the maxillary arch central incisors (mean value 15.88 mm) have longer roots than lateral (mean value 15.13 mm), while opposite situation is detected in the mandibular arch. Mean value for root length of mandibular central and lateral incisors was 11.96 mm and 12.87 mm respectively. During orthodontic therapy with fixed appliances the initial root length of all anterior teeth changed. Except negative values of root resorption for right and left upper canines, the decrease of root length was detected for central and lateral upper incisors (*Table 1*). The apical root resorption was slightly more evident among upper central than lateral incisors. The greatest root resorption of 4.03% was noted among left central incisors. In the mandibular arch the values for root resorption are negative for all teeth except for the left lateral incisors (*Table 2*).

Before orthodontic therapy the values of alveolar bone height in the maxillary anterior region were the highest around canines. The height of marginal alveolar bone was higher around central than lateral incisors (*Table 3*). In the lower dental arch the highest values for alveolar bone height were also measured in the canine region, but the difference in

Table 1. *Root resorption of upper anterior teeth (mm) measured on OPTs.*

	N	Mean	Median	Minimum	Maximum	Range	Std. Deviation
upper right central incisor M	82	0.3033	0.0000	-4.00	8.78	12.78	1.89866
upper right central incisor D	82	0.2150	0.0000	-6.37	8.78	15.15	1.95581
upper right lateral incisor M	80	0.3452	0.1340	-6.43	6.63	13.05	2.24871
upper right lateral incisor D	80	0.1753	0.1340	-6.43	6.63	13.05	2.31891
upper right canine M	72	-0.0904	0.0000	-6.56	5.78	12.34	2.42091
upper right canine D	72	-0.0892	0.0000	-5.44	5.78	11.22	2.31820
upper left central incisor M	81	0.6652	0.3890	-4.00	8.78	12.78	2.00831
upper left central incisor D	81	0.6711	0.0000	-4.00	8.78	12.78	1.96842
upper left lateral incisor M	81	0.1423	0.0000	-4.42	5.40	9.82	1.63766
upper left lateral incisor D	81	0.1595	0.0000	-4.42	5.40	9.82	1.71471
upper left canine M	73	-0.4267	0.0000	-8.11	4.00	12.11	2.28761
upper left canine D	73	-0.4838	0.0000	-8.28	4.30	12.58	2.43874

M-mesial, D-distal

Table 2. *Root resorption of the lower anterior teeth (mm) measured on OPTs.*

	N	Mean	Median	Minimum	Maximum	Range	Std. Deviation
lower left central incisor M	63	-0.2173	0.0000	-6.60	4.67	11.27	2.03213
lower left central incisor D	63	-0.2798	0.0000	-8.40	4.67	13.07	2.15589
lower left lateral incisor M	62	0.2783	0.0000	-4.00	6.50	10.50	2.07739
lower left lateral incisor D	62	0.3176	0.0000	-5.99	6.50	12.49	2.21006
lower left canine M	55	-0.7802	0.0000	-7.29	4.00	11.29	2.79667
lower left canine D	55	-0.9101	0.0000	-7.29	4.00	11.29	2.70704
lower right central incisor M	62	-0.0071	0.0000	-6.17	4.67	10.83	2.06708
lower right central incisor D	62	-0.0402	0.0000	-6.17	4.00	10.17	2.00552
lower right lateral incisor M	62	-0.8319	-0.5000	-8.85	4.09	12.94	2.17475
lower right lateral incisor D	62	-0.8207	-0.5000	-8.85	4.09	12.94	2.17166
lower right canine M	60	-0.9262	-0.9000	-6.75	6.00	12.75	2.34879
lower right canine D	60	-1.2037	-0.9285	-11.56	3.46	15.02	2.69287

M-mesial, D-distal

alveolar bone height values in incisor region between maxilla and mandible was noted. Opposite to maxillary arch, alveolar bone in the mandible was higher around lateral than central incisors (*Table 4*). Orthodontic forces induced alveolar bone resorption around upper and lower incisors and canines. In the maxillary dental arch the highest mean value for alveolar bone resorption of 1.25 mm were detected around lateral incisors (*Figure 4*). On the both sides of the lower jaw orthodontic forces affected the most alveolar bone height around central incisors and the mean resorption values were 0.93 mm on mesial and 0.86 mm on distal side. It seems that maxillary and mandibular alveolar bone in the canine region is the most resistant to resorption process.

Computerized tomography

The vertical measurements of the teeth and alveolar bone were done by analyzing the reconstructed sagittal and transversal CT plane. The CT analysis of central incisors showed that orthodontic appliances cause resorption of adjacent alveolar bone (*Figure 6*). Even in cases where OPT fails in root resorption detection, CT scan of the same teeth showed that apical root resorption occurred during orthodontic treatment (*Figure 5*). The higher resorption values for central incisors were noted on sagittal CT plane (*Table 5*). The alveolar bone level around lateral incisors increased during orthodontic treatment as the consequence of alveolar bone resorption (*Figure 7*). The root resorption of lateral incisors was also found on mesial and distal side of these teeth on transversal and oral and buccal side on sagittal CT plane (*Table 6*). The alveolar bone height around canines decreased during orthodontic treatment (*Figure 8*). The canine root resorption was found only on the oral side of the root by analyzing the sagittal CT plane (*Table 7*).

Discussion

In the last twenty years investigators have been paying more attention to the phenomenon of external root resorption in orthodontic patients [15,22]. Many studies revealed wide range of orthodontically induced apical root resorption between 1% and 100% [23,24]. These variations in results depended on many factors such as type of orthodontic appliance and method used for investigation. It is evident that radiograms are the most frequently used diagnostic method in investigation of root and alveolar bone resorption. With the development of digital radiograms and computerized tomography the great improvement in understanding the root and bone resorption process in orthodontic patients has been achieved.

Since investigators suggested that the most frequently resorbed teeth in patients treated with fixed appliances are incisors [12,25]we decided to further investigate this phenomenon. According to the results of this study tooth length values changed during orthodontic treatment. In the upper jaw the incisors root length decreased under the influence of orthodontic appliance. On the other hand, negative values for apical root resorption were detected among canines. In the lower jaw OPT revealed negative values for root resorption for all anterior teeth except for left lateral incisors. This phenomenon of increased root length during orthodontic treatment in correlation with the stadium of root formation was the object of investigation in several studies [26]. The results revealed that orthodontics forces cannot negatively influence the root formation process in young patients with immature roots. In these patients the final root length was the same or even bigger than of control teeth with initially immature roots which were not treated orthodontically. It seems that there

Table 3. *The alveolar bone height (mm) in the maxillary anterior region measured on OPTs.*

	N	Mean	Median	Minimum	Maximum	Range	Std. Deviation
upper right central incisor M	82	14.9116	14.3750	8.00	20.50	12.50	2.58479
upper right central incisor D	82	14.6189	14.5000	1.25	20.50	19.25	2.90094
upper right lateral incisor M	80	14.0681	14.0000	8.75	18.75	10.00	2.02416
upper right lateral incisor D	80	13.8594	13.6250	8.50	18.25	9.75	2.00231
upper right canine M	73	17.5548	17.5000	11.50	23.25	11.75	2.67422
upper right canine D	73	17.2842	17.2500	10.50	23.50	13.00	2.78803
upper left central incisor M	81	14.8241	14.7500	8.25	20.25	12.00	2.58162
upper left central incisor D	81	14.6265	14.5000	2.25	20.50	18.25	2.90880
upper left lateral incisor M	80	13.9125	13.8750	8.50	20.00	11.50	2.25372
upper left lateral incisor D	80	13.7875	13.5000	8.50	20.00	11.50	2.21370
upper left canine M	73	17.5993	17.5000	11.50	23.50	12.00	2.63877
upper left canine D	73	17.6781	18.0000	11.25	23.50	12.25	2.71297

M-mesial, D-distal

Table 4. *The alveolar bone height (mm) in the mandibular anterior region measured on OPTs.*

	N	Mean	Median	Minimum	Maximum	Range	Std. Deviation
lower left central incisor M	63	11.0873	11.0000	7.00	15.00	8.00	1.81679
lower left central incisor D	63	11.0119	10.7500	1.00	15.00	14.00	2.19623
lower left lateral incisor M	63	12.1389	12.0000	8.50	16.00	7.50	1.93429
lower left lateral incisor D	63	11.9405	12.0000	8.00	16.00	8.00	1.87874
lower left canine M	55	16.0136	16.5000	11.50	21.00	9.50	2.47927
lower left canine D	55	15.6864	15.7500	11.25	20.00	8.75	2.32848
lower right central incisor M	63	10.9563	11.0000	7.00	15.00	8.00	1.83247
lower right central incisor D	63	11.1587	11.0000	6.50	15.75	9.25	1.93091
lower right lateral incisor M	63	12.3492	12.5000	8.50	16.25	7.75	1.94508
lower right lateral incisor D	63	12.2421	12.5000	8.00	16.00	8.00	1.94945
lower right canine M	60	15.8792	16.3750	10.25	19.75	9.50	2.41091
lower right canine D	60	15.8208	16.1250	10.25	20.00	9.75	2.39972

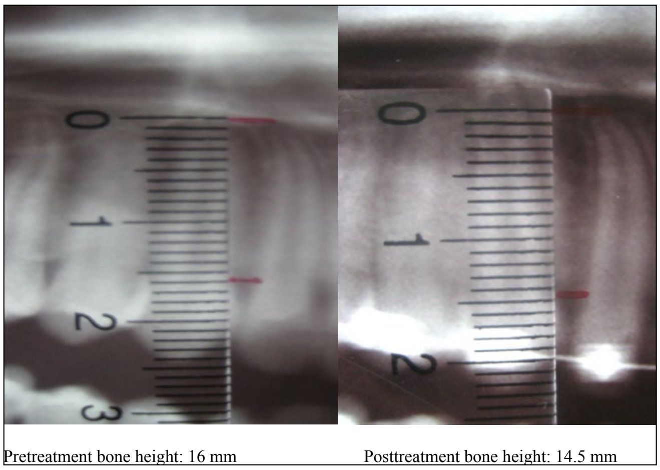

Figure 4*. The alveolar bone resorption around upper lateral incisors.*

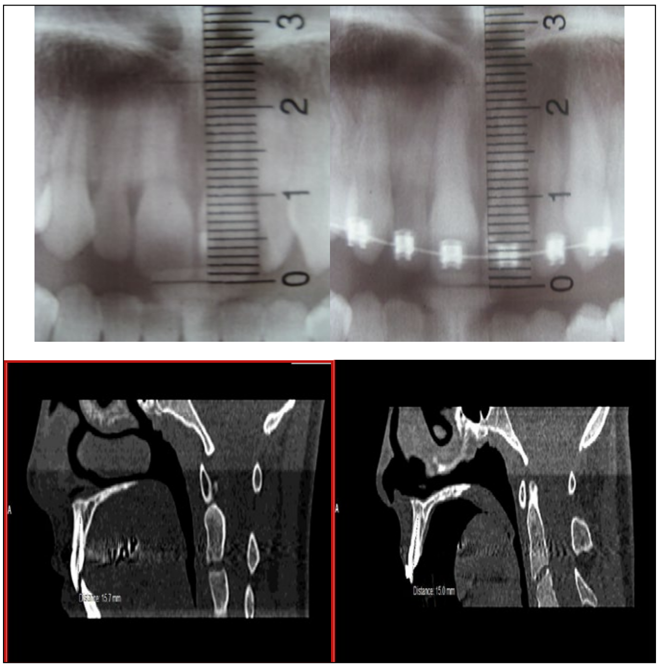

Figure 5. *OPT: No signs of apical resorption. CT: Evident apical resorption.*

Table 5. *Root resorption values for central incisors (CT).*

	N	Mean	Median	Minimum	Maximum	Range	Std. Deviation
RRM T	19	0.1737	0.2000	-4.50	5.20	9.70	2.24693
RRD T	19	0.1684	0.2000	-4.70	5.20	9.90	2.19875
RRB S	20	0.5550	0.2000	-2.70	5.80	8.50	2.10775
RRO S	20	0.7750	0.2000	-2.40	5.30	7.70	1.89289

RR-root resorption, M-mesial, D-distal, B-bucal, O-oral, T-transversal, S-sagital

exists some protection mechanism against resorption among immature teeth. But there still remains the question of root elongation in patients with completed root formation. There is evidence that elongation of the teeth with completed root formation really exists [27]. It is hard to expect additional root growth in adults, but the presence of continuous cement deposition on the root surface during lifetime was noted [28]. Ash and Ramfjord [29] found that cement formation process exists during orthodontic teeth movement. Their results correlate with the results of our study. The negative resorption values are noted for upper canines and the majority of the lower anterior teeth. Completed root formation was one of the criteria for including teeth in our investigation. Therefore, the elongation of the roots during orthodontic treatment cannot be explained by additional root growth. Possible explanation could be given by using the theory of apical cement deposition.

The investigation of the root and alveolar bone resorption is nowadays possible because of the development of radiographic methods. The initial OPT taken before the beginning of orthodontic therapy is necessary in order to collect important information about dental status, root morphology, position and development stage. On the other hand, panoramic tomogram is two-dimensional radiographic method which clearly shows only the structures in one layer. Nevertheless, there are different opinions concerning the precision of OPT in the diagnostic of root resorption. Investigation of the values of root resorption measured on periapical and panoramic radiographs showed that the values of root resorption can be

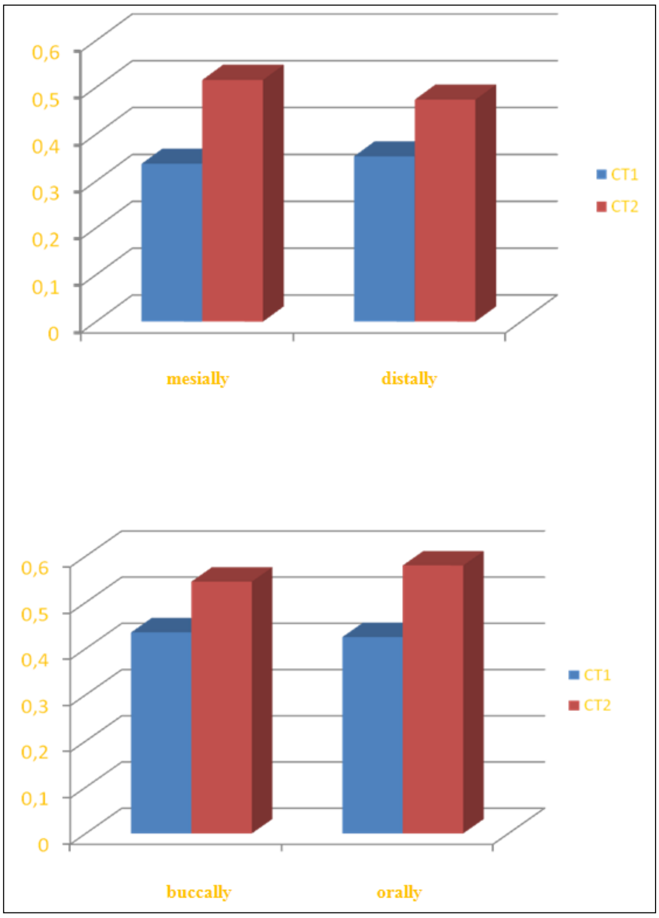

Figure 6. *Alveolar bone resorption around central incisors: transversal and sagittal CT plane.*

Table 6. *Root resorption values for lateral incisors (CT).*

	N	Mean	Median	Minimum	Maximum	Range	Std. Deviation
RRM T	18	0.0722	0.0500	-5.00	5.00	10.00	2.08462
RRD T	18	0.1778	0.0500	-4.20	5.00	9.20	2.02065
RRB S	18	0.1167	0.1500	-3.30	4.40	7.70	1.60706
RRO S	18	0.1500	0.2000	-3.80	4.00	7.80	1.43987

RR-root resorption, M-mesial, D-distal, B-bucal, O-oral, T-transversal, S-sagital

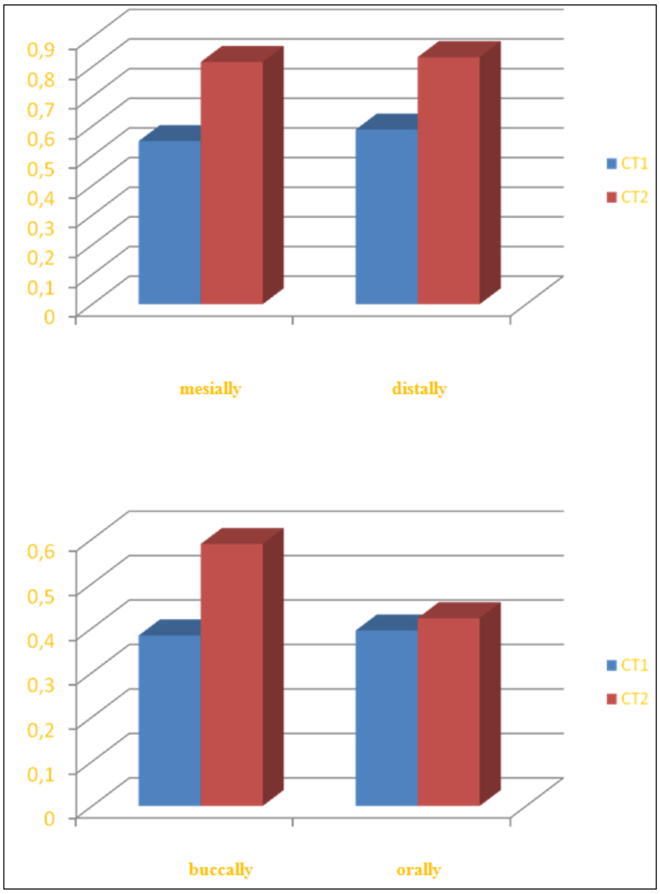

Figure 7. *Alveolar bone resorption around lateral incisors: transversal and sagittal CT plane.*

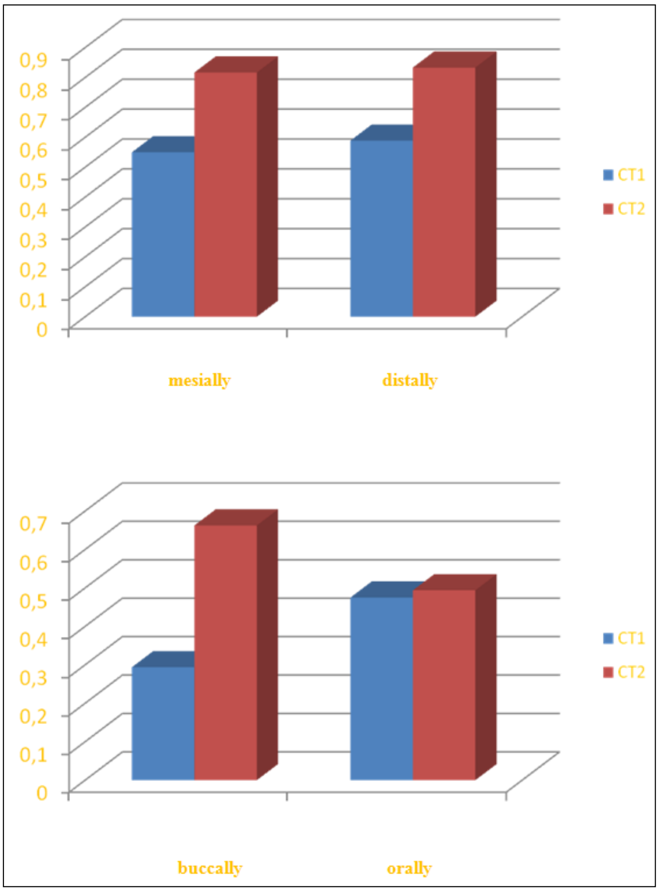

Figure 8. *Alveolar bone resorption around canines: transversal and sagittal CT plane.*

Table 7. *Root resorption values for canines (CT).*

	N	Mean	Median	Minimum	Maximum	Range	Std. Deviation
RRM T	16	-1.5813	-0.5000	-8.90	3.10	12.00	3.25929
RRD T	16	-0.9750	-0.0500	-8.20	2.50	10.70	2.88848
RRB S	16	-0.2125	0.1000	-5.70	1.50	7.20	1.71226
RRO S	16	0.1125	0.2000	-2.00	1.50	3.50	0.97014

RR-root resorption, M-mesial, D-distal, B-bucal, O-oral, T-transversal, S-sagital

overestimated for 20% when using OPT [15]. The change of incisors inclination under the influence of orthodontic forces can affect the root length values. On the other hand, it seems that the bucco lingual tooth inclination has only limited influence on root length values [30]. Therefore, the movement of the root apices for 10 mm out of the scanned layer leads to only 5% of root shortening on OPT. The introduction of CT in dentistry and orthodontics in the last few yearsgave the possibility of three-dimensional analysis of tooth length [31]. In the present orthodontic literature there has been published only one study dedicated to the comparison of OPT and CT precision in diagnosis of ortodontically induced apical root resorption [20].

Because of such controversial data regarding OPT precision our study examined 35 patients using CT. The analysis showed that orthodontic forces cause root shortening of the central and lateral incisors. These results correlate with the findings of Levander et al. [22] and Makedonas et al. [32]. CT also shows the alveolar bone resorption around incisors, especially laterals. It is important to stress that the root resorption values were higher on sagittal than transversal CT plane. It could be concluded that the analysis of sagittal CT plane provide more relevant information of incisors root resorption than transversal.

It is interesting that both, sagittal and transversal, CT planes showed the increase of the canine total and root length and, on the other hand, adjacent alveolar bone resorption. These findings correlate with the results of other authors [32] who found canine root resorption only in two patients and concluded that the canine root resorption in orthodontic patients is rare.

Conclusion

Fixed orthodontic appliances cause apical root resorption of anterior teeth and adjacent alveolar bone. Fortunately, the amount of the root resorption is less than 1 mm and, therefore, not clinically significant [33]. Although OPT still represents the primary radiographic method in orthodontics, CT is more precise for root and alveolar bone resorption diagnostics. In some patients root and alveolar bone resorption are not visible on orthopantomograms while this is easily detectable using computed tomography. In the same time, if the signs of root resorption are detected on OPT during the orthodontic treatment the additional CT scan is necessary in order to define the accurate root resorption value. In those cases combined use of OPT and CT in radiographic monitoring of orthodontically treated patients is very important in making the decision whether the orthodontic treatment should be continued or terminated earlier. According to the results of this study it can be also concluded that sagittal CT plane is the method of choice for diagnostics of apical root resorption of anterior teeth since it gives the more precise results than transversal CT plane. Saggital CT plane is also the plane of choice for buccal and oral alveolar bone resorption diagnostics in the region of frontal teeth, while transversal CT plane provides information of mesial and distal alveolar bone resorption. These data could be of clinical relevance since they can help clinicians in choosing the most adequate protocol for apical root and alveolar bone resorption detection in frontal teeth region of orthodontically treated patients.

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