

ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

The effect of orthodontic extrusion on alveolar bone – a prospective clinical study

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SUMMARY

Introduction/Objective Orthodontic extrusion is the procedure for moving the teeth in a vertical, coronal direction. This movement induces changes in the periodontal ligament and the production of new alveolar bone.

The objective of the study was to determine the changes on buccal, palatal and interdental alveolar bone as a result of orthodontic extrusion.

Methods Experimental group included six patients who received orthodontic treatment with the fixed appliances; the control group included four patients without orthodontic treatment. Two cone-beam computed tomography scans (initial and final) were obtained for each patient in both groups. Length of a tooth, shortest distance from tooth's center of resistance to the referent plane, distance from buccal or palatal plate tip to the enamel-cement junction, the height of interdental septum, buccal and palatal plate vertical gain, buccal and palatal plate thicknesses were measured on initial and final scan in the experimental and control group.

Results The reduced length of the extruded tooth was observed in the experimental group. The distance from buccal and palatal plate tip to the enamel-cement junction, mesial interproximal bone septum and buccal plate gain significantly increased in the experimental group. No significant difference was found in the distal interproximal bone septum, palatal plate gain and buccal/palatal plate thickness between groups.

Conclusion Orthodontic extrusion affects alveolar bone level by gaining the hard tissue buccal and mesial of extruded teeth, while buccal and palatal plate thickness insignificantly changed.

Keywords: orthodontic extrusion; alveolar bone level; CBCT

INTRODUCTION

Orthodontic extrusion (OE) is an orthodontic procedure used for moving the teeth in vertical coronal direction [1]. OE is also known as forced extrusion or forced tooth eruption. It can be achieved with various orthodontic appliances. However, the most effective OE is provided with the use of fixed orthodontic appliance [1]. During the stage of alignment, in the straight wire technique, extrusive forces are often present, especially in the brackets of vertically displaced teeth [2]. Straight wire fixed appliance, in an early stage of treatment, produces light vertically directed forces with the use of thin Ni-Ti arches [3].

There are many evidences regarding the tooth movement and its effect on surrounding alveolar bone and periodontal soft tissue. Extrusive tooth movement induces changes in the periodontal ligament, triggers the osteoblastic activity which includes the production of new bone and soft tissue growth [4]. Treatment of missing teeth, with the alveolar ridge resorption, often requires multidisciplinary approach. Orthodontic tooth

movement affects the surrounding periodontal tissue, depending on the direction of the orthodontic force application [5].

Before insertion of a dental implant, OE (slow extraction) of the tooth with poor prognosis is indicated for producing sufficient new bone and increasing the height of the alveolar ridge [6, 7]. This procedure is named Implant Site Development (ISD). Some authors state that it is necessary to augment soft and hard periodontal tissue before dental implant planning [8, 9].

OE provides coronal movement of the tooth, thus stretching periodontal fibers and initiating osteoblastic activity. Fibroblasts differentiate into osteoblasts and the production of new bone begins [2]. This effect of OE may also be used in decreasing the depth of an isolated periodontal pocket [3]. OE indications are classified into four different categories: 1. Orthodontic indications (vertically displaced, infraocclusal teeth, impacted teeth, dentoalveolar open bite, traumatically intruded teeth) [10, 11]; 2. Restorative and prosthetic indications (subcrestal dental caries or oblique/transversal fractures) [12, 13]; 3. Periodontal indications (vertical and/or angular infrabony pockets,

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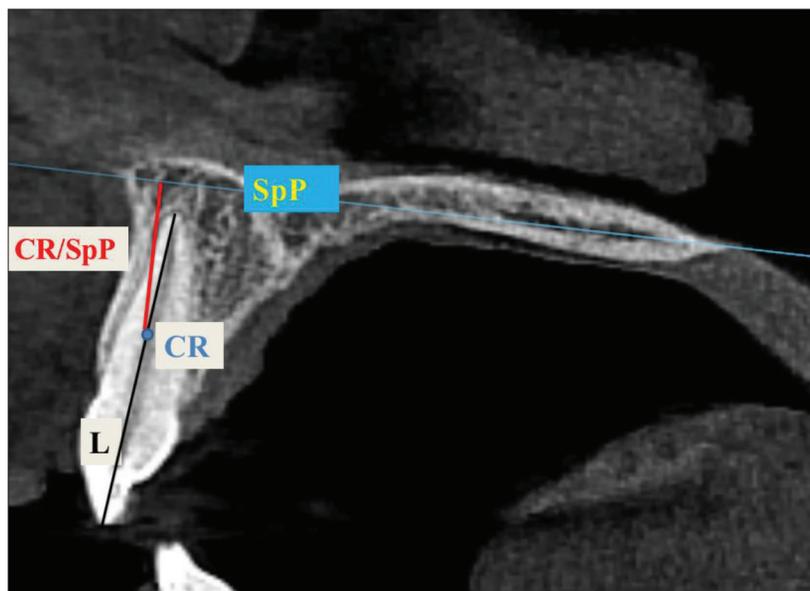


Figure 1. Cone-beam computed tomography scan with dental and skeletal measurements; SpP – maxillary plane; CR – center of resistance of the tooth; L – tooth length; CR/SpP – vertical distance of the center of resistance of the tooth to maxillary plane

papilla height reduction, inadequate gingival margin position) [14, 15]; 4. Implant Site Development, prior to dental implant insertion [16].

OE improves the quality and structure of attached gingiva and alveolar bone, esthetics and dental implant osseointegration, both in anterior and posterior region [17].

The aim of this study was to determine the changes on buccal, palatal and interdental alveolar bone as a result of OE.

METHODS

The study initially included 22 patients who referred to University of Belgrade, School of Dental Medicine, Department of Orthodontics, for orthodontic treatment. Inclusion criteria (age above 19 years, with diagnosed vertically displaced teeth, infraocclusal frontal teeth and/or dental open bite) were met by all included participants. We excluded 12 patients from this study, based on exclusion criteria (endodontic treatment of extruded teeth during orthodontic treatment, previous orthodontic treatment, poor oral hygiene and periodontal health, smoking habit, presence of systemic diseases). Finally, this study included 10 participants (four male, six female).

Patients were divided into two groups. The first group (experimental) included six patients (three male, three female) who received orthodontic treatment with fixed orthodontic appliance (straight wire technique, Ricketts's prescription, slot 0.018"). Orthodontic treatment with the extraction of four first premolars was performed in 4 cases. Two cone-beam computed tomography (CBCT) scans were obtained for each patient in the region of the tooth with indicated OE (total of 11 teeth), initial before the treatment and final at least six months after OE. CBCT scans were obtained with Soredex 3D SCANORA system

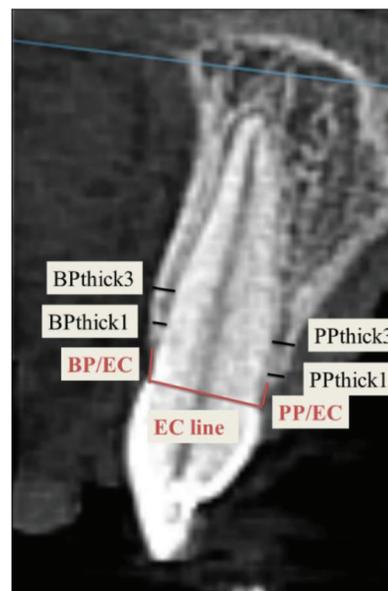


Figure 2. Cone-beam computed tomography measurements of buccal and palatal plate height and width; BP – buccal plate; PP – palatal plate; thick1/thick3 – thickness of buccal and palatal plate measured 1 mm/3 mm from the tip of the alveolar crest; BP/EC – distance from the tip of buccal plate to enamel-cement junction; PP/EC – distance from the tip of palatal plate to enamel-cement junction; EC line – enamel-cement junction line

(Soredex, Tuusula, Finland), in high-resolution (voxel size $0.1 \times 0.1 \times 0.1$ mm) in M field of view (80×100 mm), in both groups. The Ethics Committee approved this prospective study (no. 36/4), which was also performed in accordance with the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects.

The second group (control) included four patients (one male, three female). Two CBCT scans were obtained for each patient in the region of upper anterior teeth (total of 13 teeth). The final scan followed the initial after at least 14 months. These patients were not orthodontically treated between initial and final CBCT scan.

A period of time between initial and final CBCT scan for each patient is presented as ΔT value.

On CBCT's, following parameters were measured (OnDemand3D Project Viewer Limited Database, version 1.0.0.1, Cybermed, Seoul, South Korea):

L presents length of the tooth in sagittal projection.

CR/SpP and CR/MP presents shortest distance from center of resistance (CR) of the tooth to maxillary (SpP) or mandibular plane (MP). SpP (maxillary plane) was marked as a plane orthogonal to sagittal plane, connecting anterior and posterior nasal spine. MP was marked between the contact point of mandibular symphysis and corpus anteriorly and the lowest point of mandibular angle posteriorly. Vertical movement (VM) of the tooth was presented as the difference between final and initial value ($\Delta CR/SpP$ or $\Delta CR/MP$). CR was marked as a point on tooth axis in sagittal projection, between coronal and middle third of the root of the tooth, measured from alveolar crest to the apex of the root (Figure 1) [18].

BP/EC and PP/EC presents distance from buccal (BP) or palatal plate (PP) tip to enamel cement junction (EC). Changes in BP and PP height were presented as the difference of measured final and initial values, correlated with the vertical movement of the tooth (Figure 2).

BP vertical gain (BPgain) and PP vertical gain (PPgain), were calculated using the following formula: BPgain = VM – ΔBP/EC and PPgain = VM – ΔPP/EC.

The difference between final and initial measurement value is presented as Δ.

As shown in Figure 2, BP and PP thicknesses were measured on two levels, 1 mm (BPthick1 and PPthick1) and 3 mm (BPthick3 and PPthick3) from the tip of BP or PP.

The height of interdental septum (IS) was measured from its tip to maxillary or MP, both mesial and distal of the tooth (ISmesial and ISdistal).

All statistical analyses were done using Statistical Package for Social Science (SPSS software package, version 26.0; IBM Corp., Armonk, NY, USA). Mean and standard deviation (SD) were used description of numeric data. Numeric data were analyzed using Independent T – Test and Mann–Whitney U test according to *p* values obtained by One-Sample Kolmogorov–Smirnov test for normal distribution. Univariate and multivariate linear regression models were used to assess the relationship between parameters. Dependent variable was vertical tooth movement while other relevant observed parameters were used as explanatory variables. Differences were considered significant when the *p* value was ≤ 0.05.

The reliability of the measurements was assessed by means of Intraclass Correlation Coefficient (ICC). Calculations of the ICC were done using a single measurement, absolute agreement, two-way mixed model according to guidelines for the ICC model selection proposed by Koo and Li [19]. ICC calculations were done using IBM SPSS Software package for every variable measured at two points in time. After getting the values for the ICC, standard error of measurement (SE m was calculated using following formula: SE m = SD*√(1 – ICC)).

RESULTS

The mean ages of participants in experimental and control group were 23.91 ± 4.67 years and 22.23 ± 1.69 years, respectively. The difference between the mean ages of both group participants was not considered to be statistically significant, according to the Mann-Whitney U test (*p* = 0.791).

Mean time interval between initial and final CBCT scan in experimental (4.09 ± 2.63 years), and control group (3.04 ± 2.12 years) did not differ significantly.

A total of 24 teeth from 10 patients was investigated. The differences between final and initial measurements in both groups are presented in Table 1.

Table 1. Cone-beam computed tomography measurements of dental and skeletal parameters: difference of final and initial parameter values in both groups

Parameter	Experimental group X ± SD	Control group X ± SD	Significance
ΔL (mm)	-1.30 ± 0.84	0.04 ± 0.06	² 0.000*
VM (mm)	1.52 ± 1.32	0.11 ± 0.09	² 0.000*
ΔBP/EC (mm)	-0.66 ± 0.48	-0.07 ± 0.41	¹ 0.004*
ΔPP/EC (mm)	-1.11 ± 1.13	-0.15 ± 0.27	² 0.004*
ΔBPthick1 (mm)	-0.02 ± 0.37	0.03 ± 0.09	² 0.706
ΔBPthick3 (mm)	0.16 ± 0.37	0.07 ± 0.20	² 0.908
ΔPPthick1 (mm)	0.06 ± 0.44	-0.05 ± 0.15	¹ 0.397
ΔPPthick3 (mm)	0.22 ± 0.82	-0.13 ± 0.38	² 0.622
ΔISmesial (mm)	1.35 ± 1.59	-0.03 ± 0.60	¹ 0.008*
ΔISdistal (mm)	0.27 ± 1.57	0.00 ± 0.55	¹ 0.573
BPgain (mm)	0.85 ± 1.14	0.03 ± 0.43	² 0.002*
PPgain (mm)	0.40 ± 1.79	-0.05 ± 0.27	² 0.077

Δ – difference between two measurements; L – length of the tooth in sagittal projection; VM – vertical movement; BP/EC – buccal plate tip to enamel cement junction; PP/EC – palatal plate tip to enamel cement junction; BPthick1 – buccal plate thickness on 1 mm level; BPthick3 – buccal plate thickness on 3 mm level; PPthick1 – palatal plate thickness on 1 mm level; PPthick3 – plate thickness on 3 mm level; ISmesial – height of interdental septum measured from its tip to maxillary or mandibular plane, mesial of the tooth; ISdistal – height of interdental septum measured from its tip to maxillary or mandibular plane, distal of the tooth; BPgain – buccal plate vertical gain; PPgain – palatal plate vertical gain
¹T – test;
²Mann–Whitney test, *statistically significant

The mean vertical movement of orthodontically extruded teeth was 1.52 mm, demonstrating a significant increase compared to control group (0.11 mm).

The length of extruded teeth in experimental group reduced (-1.30 mm ± 0.84 mm, *p* = 0.000). The distances from BP and PP tip to enamel-cement junction significantly increased in experimental group (*p* = 0.004). The Table 1 reveals significant increase of mesial interproximal bone septum (*p* = 0.008) and BP gain (*p* = 0.002) surrounding the teeth that were orthodontically extruded, compared to the measurements on non-treated teeth. However, there was no significant difference between changes in distal interproximal bone septum, PP gain and BP/PP thickness on both levels of measurement in experimental and control group.

Table 2 presents linear regression analysis of association of vertical tooth movement (VM) and observed parameters. In the multivariate linear regression model in which vertical tooth movement was used as dependent

Table 2. Linear regression analysis of association of vertical tooth movement and observed parameters

Parameters	Univariate model		Sig.	Multivariate model	
	^a B (95% CI)			^b R ² _{adj} = 0.90	^a B (95% CI)
ΔL	-0.744 (-1.207 – (-0.280))		<i>p</i> = 0.003*	-0.205 (-0.515 – 0.105)	<i>p</i> = 0.181
ΔIS mesial	0.820 (0.481 – 0.910)		<i>p</i> = 0.000*	0.373 (0.58 – 0.574)	<i>p</i> = 0.019*
ΔIS distal	0.725 (0.426 – 1.044)		<i>p</i> = 0.000*	-0.14 (-0.329 – 0.301)	<i>p</i> = 0.927
BPgain	0.889 (0.851 – 1.354)		<i>p</i> = 0.000*	0.459 (0.202 – 0.938)	<i>p</i> = 0.004*
PPgain	0.701 (0.358 – 0.945)		<i>p</i> = 0.000*	0.177 (-0.60 – 0.390)	<i>p</i> = 0.142

Δ – difference between two measurements; L – length of the tooth in sagittal projection; ISmesial – height of interdental septum measured from its tip to maxillary or mandibular plane, mesial of the tooth; ISdistal – height of interdental septum measured from its tip to maxillary or mandibular plane, distal of the tooth; BPgain – buccal plate vertical gain; PPgain – palatal plate vertical gain
^aUnstandardized coefficient B;
^bAdjusted coefficient of determination; *Statistically significant difference

variable, the following explanatory variables were found to be independent predictor of variability among patients: Δ ISmesial, BPgain, (Table 2).

In order to analyze the agreement of paired measurements conducted by the same researcher, the ICC was calculated for each variable measured. ICC was higher than 0.70 for each variable measured (the lowest ICC value was for BP/EC, 0.74 (0.35–0.91)), which was considered as good reliability. ICC values for variables L, CO/SpP, BPthick1 and ISm were higher than 0.90, which was considered as excellent reliability.

DISCUSSION

This study is among a few other studies that used CBCT scans to evaluate alveolar bone dimensional alterations, surrounding orthodontically extruded teeth [20]. OE was performed with straight-wire fixed appliances that produced light vertical forces.

When comparing the changes in BP and PP thickness between the study and control groups we found no significant differences for values measured in both levels (level 1 and 3). This finding could imply that in the study group, the use of light and continuous forces during orthodontic treatment caused tooth extrusion along its central axis, removing the pressure against the buccal cortical bone that could, according to some authors [21], generate bone fenestration.

External apical root resorption is a typical side effect of orthodontic treatment [22]. It is a decrease in root length affecting the apices caused by multiple, internal and external factors [22, 23]. The majority of resorption is clinically insignificant [24], however severe root resorption could lead to greater tooth mobility in all direction and eventually to tooth loss [22]. The difference in root length between the final and initial measurements differed significantly between the study and control group, indicating that orthodontic treatment caused external apical root resorption. However, a detailed clinical examination and CBCT scan analysis confirmed that the resorption was clinically insignificant.

In this prospective clinical study, participants from study and control group were age-matched. Time interval between initial and final measurements differ insignificantly between groups which allows us to monitor changes in bone tissue in patients with and without ongoing orthodontic treatment in the same time frame. To the best of our knowledge, this is the first prospective clinical study that observed bone changes after OE with control group of healthy participants in Serbian population.

The results given above showed that the vertical levels of BP and mesial IS could be significantly increased by OE of infraocclusal teeth. Extrusive forces provide the correction of the defects in alveolar bone by inducing the growth of periodontal tissues [25]. Vertical movement of the tooth is followed by periodontal fibers stretching [21, 26]. In order to increase the rate of tooth movement, a suitable load need to be provided [27]. As a result, a new bone is formed in the direction of the movement. The success of OE in producing

new bone depends on an intact attachment periodontal fibers spanning at least one fourth of the apical region [28]. In this study, one of the inclusion criteria was that the tooth should have an intact periodontal ligament.

There is a great number of studies regarding forced eruption of the teeth with poor prognosis as a method for preserving alveolar ridge for dental implant insertion [16, 21, 28]. Papadopoulou et al. [20] stated that orthodontic forced eruption results in increase in the heights of palatal and proximal alveolar bone and significant reduction in the BP height. After performing forced eruption, a satisfactory amount of bone apposition may be detected [29].

In this study, OE was performed as much as the infra-occlusal position of the tooth indicated. There were no extractions of extruded teeth. Although BP height (BPgain) increased significantly as a result of OE, PP height (PPgain) did not ($p = 0.077$). Regarding the number of participants included in this study, it can be stated that, with larger number of participants, the increase in PP height might be more significant.

Results showed that the distance from BP tip to EC increased (Δ BP/EC) in experimental group, which means that the vertical tooth movement did not convert completely into new bone. However, there was a significant vertical movement of extruded teeth, followed by apposition of surrounding buccal and mesial interproximal bone. OE was performed on 11 anterior teeth. There were six canines that were extruded, and in each case orthodontic treatment followed the extraction of four first bicuspid. Bone loss can be influenced by treatment involving extractions [30]. We expected significant increase in the height of mesial and distal IS in experimental group. The results implied that the height of mesial interproximal bone did increase significantly, but distal, next to the extraction socket, did not. Initial CBCT scans were made before the extraction of first bicuspid and the extraction itself could affect the vertical level of distal interproximal bone in treated group.

It should be kept in mind that there are difficulties in controlling the directions of the tooth movement, by using fixed orthodontic appliance in straight wire technique, in leveling stage of treatment. Besides vertical movement, there are accessory teeth movements in different directions too. Therefore, different effects of alveolar bone change in buccal, palatal or interdental region can be expected.

In our linear regression model, it was found that mesial IS height change (Δ ISmesial) and BPgain could be used as independent predictors which describe 90% variabilities amongst patients regarding vertical tooth movement.

CONCLUSION

This study showed that OE affects alveolar bone levels, especially by gaining hard tissue buccal and mesial of the extruded teeth, in the same direction as the teeth moved. The thickness of PP and BP also changes, which might be a result of bone remodeling, during orthodontic treatment.

Conflict of interest: None declared.

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Ефекат ортодонтске екструзије на алвеоларну кост – проспективна клиничка студија

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САЖЕТАК

Увод/Циљ Ортодонтска екструзија је поступак померања зуба у вертикалном, коронарном правцу. Овај покрет изазива промене у пародонталном лигаменту и доводи до стварања нове алвеоларне кости.

Циљ рада је био да се утврде промене на букалној, палатиналној и интерденталној алвеоларној кости као резултат ортодонтске екструзије.

Метод Експерименталну групу чинило је шест пацијената код којих су у оквиру ортодонтског третмана примењени фиксни апарати; контролну групу чинила су четири пацијента без примењеног ортодонтског третмана. Снимак циљане регије компјутеризованом томографијом је био направљен код свих пацијената (почетни и финални). Дужина зуба, најкраћа удаљеност од центра отпора зуба до референтне равни, растојање од врха букалне или палатиналне ламеле до споја глеђно-цементне границе, висина интерденталног

септума, вертикално повећање и промена дебљине букалне и палатиналне ламеле мерени су на почетним и крајњим томографијама у обе групе.

Резултати У експерименталној групи уочена је смањена дужина екструдираних зуба. Удаљеност од врха букалне и палатиналне ламеле до глеђно-цементне границе, мезијални интерпроксимални септум кости и висина букалне ламеле значајно су повећани у експерименталној групи. Није уочена значајна разлика у дисталном интерпроксималном коштаном септуму, повећању палатиналне ламеле и дебљини букалне/палатиналне ламеле између група.

Закључак Ортодонтска екструзија утиче на ниво алвеоларне кости добијањем коштаног ткива букално и мезијално од екструдираних зуба, док се дебљина букалне и палатиналне ламеле незнатно мења.

Кључне речи: ортодонтска екструзија; ниво алвеоларне кости; компјутерска томографија с конусним снопом