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Randomized Controlled Trial

Efficiency of piezosurgery technique in miniscrew supported en-masse retraction: a single-centre, randomized controlled trial

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Summary

Background: Piezoelectric surgery is a newly introduced technique for rapid tooth movement. However, the efficiency of this technique has not been investigated on en-masse retraction cases yet.
Objective: To investigate the efficiency of piezosurgery technique in accelerating miniscrew supported en-masse retraction and study the biological tissue response. In addition, to show if this technique induces a difference in dental, skeletal and soft tissue changes on lateral cephalograms, and in canine and molar rotations, besides intercanine and intermolar widths on dental casts.
Design, setting, participants: We conducted a randomized, single-centred, parallel-group, controlled trial, requiring upper right and left first premolar extractions on 30 patients above the minimum age of 14 years at the beginning of retraction.
Interventions: Piezosurgery-assisted versus conventional en-masse retraction anchored from miniscrews placed between second premolars and first molars, bilaterally.
Outcomes: The main outcome was the en-masse retraction rate. Secondary outcomes were gingival crevicular fluid (GCF) volume and GCF content of receptor activator of nuclear factor κβ ligand (RANKL), changes regarding cephalometric and dental cast variables, and miniscrew success rates.
Randomization: Accomplished with opaque, sealed envelopes.
Blinding: Applicable for data assessment only.
Recruitment: Commenced in February 2013 and ended in October 2014.
Results: Thirty-one patients were included in the study and divided into 2 groups of piezosurgery ($n = 16$) and control ($n = 15$). After 9.3 months of follow-up, no statistically significant difference was observed between groups for neither retraction rates ($P = 0.958$) nor GCF parameters ($P > 0.05$). Changes in lateral cephalometric and dental cast variables, and miniscrew success rates did not show significant differences either.
Conclusion: Based on the results of this study, piezosurgery technique was found to be ineffective in accelerating en-masse retraction, and promoting a difference in the studied GCF parameters, skeletal and dental variables.
Registration: The trial was not registered.
Protocol: The full protocol of this PhD thesis study can be accessed from tez.yok.gov.tr.
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Introduction

Adult patients who want to improve their dental aesthetics usually tend to prefer prosthodontic or restorative treatments, which give faster results. Yet, the final look may sometimes be far from being satisfying. Orthodontic treatment, on the other hand, gives superior results but is associated with increased risk of caries, periodontal problems and root resorption, besides negative effect on psychosocial well-being because of the prolonged treatment times (1,2). These shortcomings of orthodontic treatment, encouraged the researchers to conduct studies in order to answer the question if it is possible to reduce treatment time and cause less periodontal problems, at the same time.

The first techniques used in the clinical practice were mostly surgery-assisted (3–5). However, these techniques were shown responsible from marginal osteonecrosis and impaired alveolar regeneration because of the extensive cuts and the heat generated by diamond and carbide burs (6). In quest of finding a safer surgical approach, Vercellotti (7) introduced piezoelectric surgery in 1988 through modifying and improving conventional ultrasound technology. Following that in 2007, Vercellotti and Podesta (8) published their study of 'monocortical tooth dislocation and ligament distraction' (MTDLD) technique in which they used piezoelectric surgery to improve and simplify orthodontic therapy in adult patients. Then in 2009, Dibart *et al.* (9) introduced 'piezocision' technique as a minimally invasive surgical approach to accelerate orthodontic tooth movement and shorten treatment time. In a recent systematic review on interventions for accelerating orthodontic tooth movement, Long *et al.* (10) concluded that corticotomy was safe and able to accelerate orthodontic tooth movement.

En-masse retraction, on the other hand, is another way to decrease treatment time in extraction cases (11,12). However, rapid tooth movement studies are seldom conducted on en-masse retraction cases, such that none of these studies involves piezosurgery (13,14). Therefore, controlled studies are needed to compare en-masse retraction rates and type of retraction, i.e. parallel, tipping or a combination of both, during piezosurgery-assisted en-masse retraction. So that the orthodontist can decide whether this technique is worth employing in an en-masse retraction case demanding shorter treatment time.

Recently rapid tooth movement studies are corroborated with gingival crevicular fluid (GCF) analyses to offer an insight into the molecular mechanisms of what is happening in the alveolar bone. GCF is a valuable tool for assessing the tissue-related changes and responses to orthodontic tooth movement as it is composed of cellular exudates from neighbouring periodontal tissues, immune cells, and microbial plaque (15–17).

Objectives

Our purpose in this study was to investigate the effects of piezosurgery on retraction rates and biological response, by means of receptor activator of nuclear factor κβ ligand (RANKL) amount and concentration, which provide information about the osteclastogenesis activity, and GCF volume in miniscrew supported en-masse retraction cases. In addition to investigate the effects of piezosurgery on dental, skeletal and soft tissue changes on lateral cephalograms, on canine and molar rotations, and intermolar and intercanine widths on dental casts, besides the miniscrew success rates.

Subjects and methods

Trial design and any changes after trial commencement

This was a single-centred, parallel-group, randomized trial on 30 patients. There were no changes after trial commencement.

Participants, eligibility criteria and study settings

Recruitment process began after obtaining formal approval from the ethical committee of Başkent University (Ankara, Turkey) and patients were expected to meet the following criteria: (1) Class I malocclusion requiring four first premolar extractions or Class II malocclusion requiring upper right and left first premolar extractions, (2) no systemic disease or drug use which would affect tooth movement rate, (3) minimum age at the beginning of retraction of 14 years and above, also skeletal maturity stage of MP_{3U} or R_U according to the hand and wrist radiographs (18), (4) full permanent dentition, (5) no congenitally missing or impacted teeth except third molars, (6) no previous orthodontic treatment history, and (7) adequate oral hygiene.

Patients who consulted Orthodontics Department of our university were assessed for eligibility on the session they came for an orthodontic examination. The eligible patients were informed thoroughly about the procedures of the study and were asked whether they want to participate in the study.

Informed consent was obtained before recruitment, from patients and both from patients and parents if the patients were adolescents. No changes in the methods were made after trial commencement occurred.

Interventions

All patients were treated with 0.018 × 0.025-inch incisor and canine brackets, and 0.022 × 0.028-inch premolar brackets and molar tubes (Victory™ Series MBT prescription, 3M Unitek, California, USA). Second molars were not bonded until the end of retraction in order not to increase friction. Premolar extractions were performed at least 4 months prior to the beginning of retraction.

When maxillary dental arches were fully levelled and aligned, the first GCF samples were collected from all of the patients before starting en-masse retraction. Afterwards, only patients in the study group (G1) received piezosurgery, whereas patients in the control group (G2) did not. Following this, miniscrews with 1.5–1.4 mm diameter and 7 mm length (AbsoAnchor, Dentos, Daegu, Korea) were placed between the roots of the second premolars and the first molars bilaterally, perpendicular to the alveolus. En-masse retraction was achieved on a 0.016 × 0.022-inch stainless steel archwire with 7 mm long power hooks (Ortho Organizers, California, USA) placed distal to the lateral incisors. From these power hooks, Nickel–Titanium (NiTi) closed coil springs (Ormco Corp, California, USA) were attached to the miniscrews and adjusted to exert 250g of force per side (Supplementary Figure 1). All of the clinical procedures, from GCF sampling to force application, were performed on the same session.

Piezosurgery was performed in interradicular areas of anterior six teeth (including the distal aspects of the canines) by an experienced periodontist (B.F.O.) in the Periodontology Department of the same university. After local infiltration anaesthesia, vertical soft tissue incisions were made on the buccal side and by using a depth-coded piezoelectric knife (SG1, NSK, VarioSurg, Illinois, USA), piezosurgical cuts with 3 mm depth were done in the medullary bone under sufficient coolant irrigation (Figure 1). All of the soft tissue incisions were then sutured with a 4-0 vicryl suture (Ethicon®, Johnson&Johnson, California, USA). Patients were advised to apply ice-bags for the first day, and avoid hot and sour food for the first 5–7 days. Sutures were removed on the first week. All patients were strictly advised to maintain good oral hygiene and avoid prolonged use of nonsteroidal anti-inflammatory drugs.

In order to evaluate the biological response of the alveolar bone against piezosurgery, GCF samples were collected from right and left maxillary canines and left central incisor at the beginning of retraction (before piezosurgery) (T1), on day 28 (T2) and at the end of retraction (T3). After isolating teeth with cotton-rolls and air-drying gently, sterile paper strips (Periopaper, Oraflow, New York, USA) were inserted into the distobuccal crevices to a 1–2 mm depth and waited for 30 seconds. Periotron values were obtained for each sample by using Periotron 8000 (Oraflow, New York, USA). These values were then used to calculate the GCF volume with the aid of a computer program (Periotron Professional, Version 3.0a, Oraflow, New York, USA). The strips were disposed in separate, labelled Eppendorf tubes and kept at −80°C until ELISA testing (sRANKL ELISA, BioVendor, North Carolina, USA) was performed.

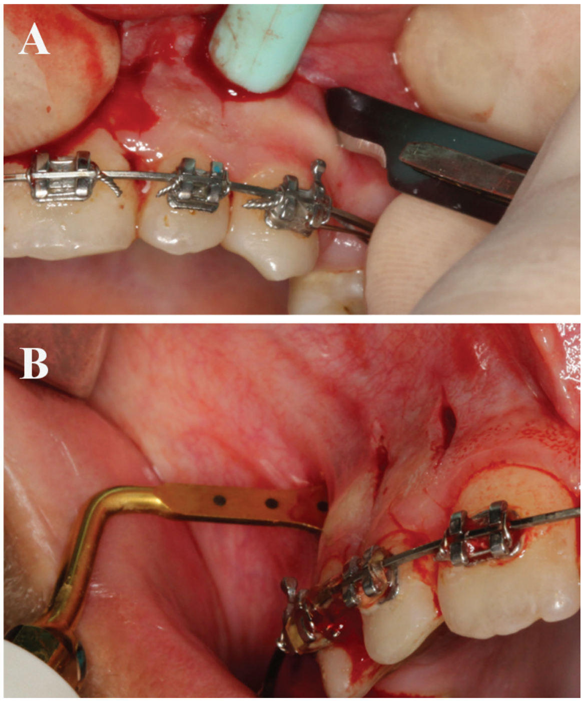

Figure 1. A, Vertical soft tissue incisions; B, depth-coded piezoelectric knife and piezosurgical cuts.

In each session, the amount of space between the contact points of canines and second premolars were measured with a digital calliper. All measurements were done in the patients' mouth and for right and left sides separately. Coil springs were reactivated if necessary.

The start point of the observation period was the beginning of retraction and the end point was the session when canines reached Class I relationship. All of the clinical procedures were performed by the same investigator (N.I.T.).

Outcomes (primary and secondary) and any changes to outcomes

Primary outcome

The primary outcome with respect to the efficiency of piezosurgery was en-masse retraction rates of maxillary anterior teeth on day 15, 30, 60, 90 and 120. For this purpose, the amount of space closure was calculated for each session and averaged for right and left sides. Then the calculated amount was divided by the number of days past between two sessions which gave the retraction rates on a daily basis.

Secondary outcomes

GCF analyses for RANKL amount and concentration, and GCF volume were the secondary outcomes. T1 and T2 samples were collected from all of the patients; however, T3 samples were only collected from 20 patients whose oral hygiene were well enough.

Lateral cephalograms, with Frankfort horizontal plane parallel to the floor and teeth in centric occlusion (Veraviewepocs 2D, Morita, California, USA), and dental casts were obtained at T1 and T3. ALARA (As Low As Reasonably Achievable) principle was implemented while taking lateral cephalograms, so that the doses and exposures were adjusted to achieve the lowest radiation exposure. A total of 20 cephalometric (Figure 2) and 5 dental cast (Figure 3) variables were measured. Lateral cephalograms were digitally traced

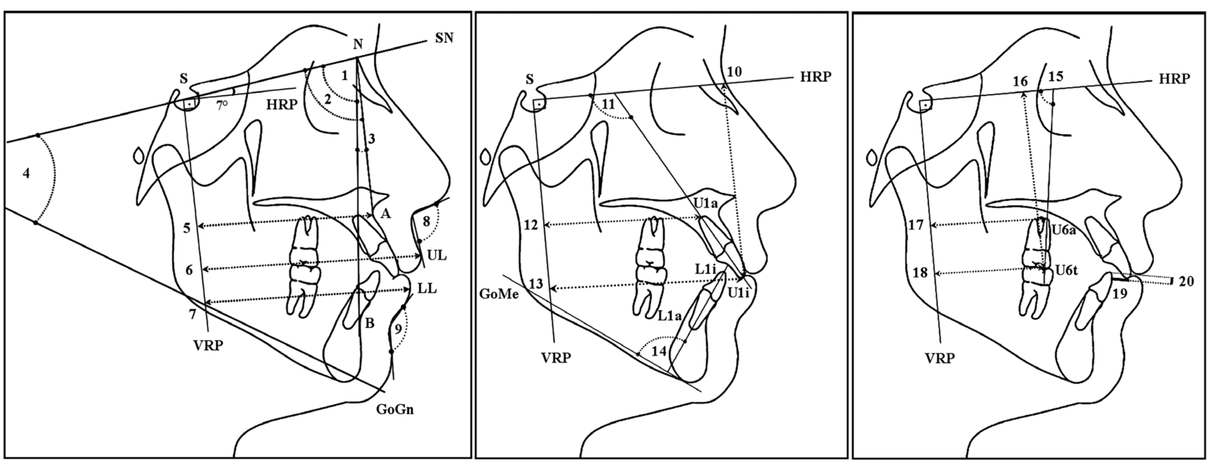

Figure 2. Reference planes and cephalometric measurements used in the study. Reference planes: Horizontal reference plane (HRP), a horizontal plane angulated 7° clockwise to the Sella–Nasion plane at Sella; Vertical reference plane (VRP), a perpendicular plane to the HRP passing through Sella; SN (Sella–Nasion) plane; GoGn (Gonion-Gnathion) plane; GoMe (Gonion-Menton) plane. Variables: 1, SNA; 2, SNB; 3, ANB; 4, GoGnSN; 5, A-VRP (perpendicular distance from A point to VRP); 6, UL-VRP (perpendicular distance from upper lip to VRP); 7, LL-VRP (perpendicular distance from lower lip to VRP); 8, Nasolabial angle; 9, Mentolabial angle; 10, U1i-HRP (perpendicular distance from upper incisor tip to HRP); 11, U1.HRP (angle formed between the upper incisor long axis and HRP); 12, U1a-VRP (perpendicular distance from upper incisor root apex to VRP); 13, U1i-VRP (perpendicular distance from upper incisor tip to VRP); 14, L1.GoMe (angle formed between the lower incisor long axis and GoMe plane); 15, U6.HRP (angle formed between the molar axis and HRP); 16, U6t-HRP (perpendicular distance from the mesiobuccal cusp tip of upper first molar to HRP); 17, U6a-VRP (perpendicular distance from the mesial root apex of upper first molar to VRP); 18, U6t-VRP (perpendicular distance from the mesiobuccal cusp tip of upper first molar to VRP); 19, Overjet; 20, Overbite.

and measured using Dolphin Imaging program (Vers 11.5 Premium, Patterson Dental, California, USA), whereas dental cast variables were directly measured on the plaster models.

Miniscrews, which did not show displacement but an acceptable clinical mobility and/or mild inflammation were accepted as successful. On the other hand, miniscrews which needed reinstallation were accepted as failure.

There were no outcome changes after trial commencement.

Sample size calculation

Calculation of the sample size was based on the average reduction in treatment time when piezoelectric surgery is used, which is 70 per cent for maxilla as stated in the article by Vercellotti and Podesta (8). Using this value as a reference and to detect at least a 50 per cent difference in the rate of tooth movement with type I error frequency of 5 per cent and the power of the statistical test set at 80 per cent (at 95 per cent Confidence Interval), it was calculated that 15 participants in each group was required to detect a significant difference.

Randomization (allocation concealment, implementation)

Randomization was accomplished using opaque, sealed envelopes (19). For this purpose, 30 envelopes (15 for each group) containing treatment allocation cards were prepared. After the deck of cards was shuffled thoroughly, patients were asked to pick an envelope. The allocation card was shown to the patient and the parent, and kept in a separate box from the sealed ones.

Blinding

Blinding of either the investigator performing the clinical procedures (N.I.T.) or patients was not possible; however, data assessment was blinded. Cephalometric analyses and dental cast measurements were performed by the principal investigator (N.I.T.) after being given research numbers by another investigator (A.A.O.). GCF samples were numbered accordingly and analysed by another blinded investigator (J.S.G.).

Statistical analysis

All statistical analyses were performed with the SPSS software package (SPSS for Windows 20, SPSS Inc, Illinois, USA). Descriptive statistics included the means and standard deviations. Gender and malocclusion distributions were given in percentages. Shapiro–Wilk test was used to test the normality of distributions. Mann–Whitney *U* test was used to compare intergroup differences of GCF volume, RANKL concentration and amount. Student's *t*-test was used to compare retraction rates, amount of space closure, cephalometric and dental cast variables within and between groups. Miniscrew success rates were compared using Fisher exact test. The level of significance was 0.05.

Error of the method

Two weeks after the initial assessment of the radiographs and dental casts, six patients from each group were chosen randomly. A total of 24 lateral cephalograms and 24 dental casts were reanalyzed for intraexaminer reliability. Intraclass correlation coefficients at 95 per cent confidence interval for lateral cephalometric and dental cast measurements ranged from 0.978 to 1 and 0.991 to 0.999, respectively. On the other hand, the differences ranged from 0.02 to 0.29 mm for linear measurements, and from 0.01 to 1.95 degrees for angular measurements (Supplementary Table 1).

Results

Participant flow

Thirty patients were included in the study and randomized into two groups. Soon after the beginning of en-masse retraction, one patient was excluded from the study because of bad oral hygiene and noncompliance to the appointments. One patient meeting the eligibility criteria was included in the same group while patient recruitment was still proceeding and the final sample size was 30 at the end of retraction. Data of the excluded patient was not included in the assessment (Figure 4). Patient recruitment commenced in February 2013 and ended in October 2014.

Baseline data

Age, gender and maxillary tooth size-arch length discrepancy were assessed at baseline and found similar between groups. The age range of the patients was 14.3 to 25.6 years, with mean ages of 17.7 ± 3.4 years for G1 and 17 ± 1.4 years for G2. Both groups had 13 girls and 2 boys (Table 1). Cephalometric and dental cast variables

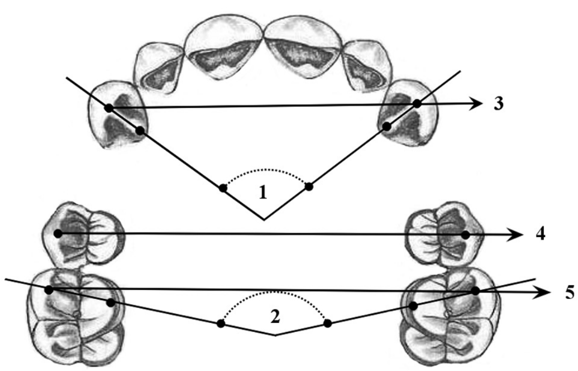

Figure 3. Schematic illustrations of landmarks and variables used in dental cast analysis: 1, UR3axis.UL3axis (angle formed between the mesiodistal axes of canines); 2, UR6axis.UL6axis (angle formed between the mesiodistal axes of molars); 3, 3t–3t (intercanine width); 4, 5bt–5bt (interpremolar width); 5, 6mbt–6mbt (intermolar width).

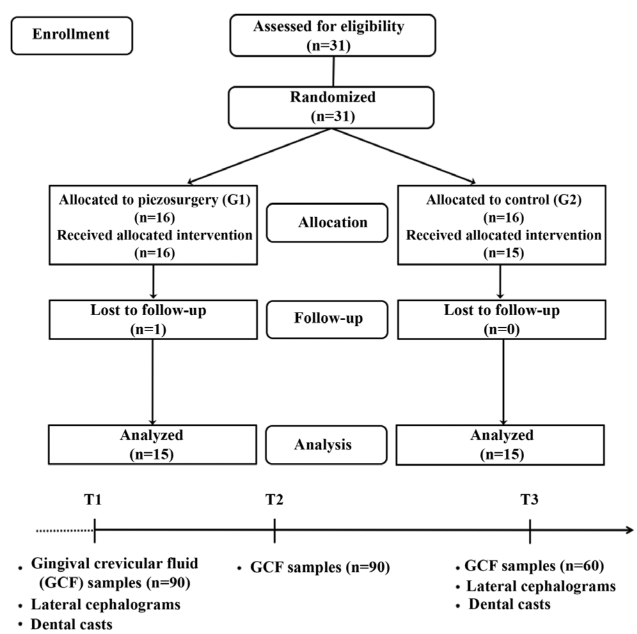

Figure 4. CONSORT flow chart and timeline of the study.

Table 1. Baseline characteristics of patients in treatment groups.

	Piezosurgery + En-masse retraction (G1) (n = 15)		En-masse retraction only (G2) (n = 15)		
Demographic characteristics	Mean or per cent	SD	Mean or per cent	SD	P
Age (years)	17.7	3.4	17.0	1.4	0.469
Sex					
Female	86.7%		86.7%		1
Male	13.3%		13.3%		1
Maxillary arch discrepancy (mm)	−3.6	3.1	−4.5	2.6	0.419
Angle Class					
I	40%		26.7%		
II	60%		73.3%		

were also similar between groups, except for nasolabial angle and the angle formed between the upper right and left first molars (Table 2).

Numbers analysed for each outcome, estimation and precision, subgroup analyses

The average retraction time was 9.33 ± 4.10 months for G1 and 9.27 ± 2.55 months for G2. No significant differences were found between the groups (effect size [ES], 0.07 [95 per cent CI, −2.38 to 2.51; P = 0.958]).

Retraction rates were expressed as the distance anterior teeth covered per day. G1 showed higher rates in all time points except for day 90, when the rates evened (P > 0.05). No statistically significant difference was present between groups (Figure 5). In accordance with this finding, the average amount of space closure on days 15, 30, 60, 90 and 120 was higher for G1, but again the difference was not significant (P > 0.05) (Supplementary Figure 2).

Line graph showing the changes in RANKL concentrations revealed that an unlike pattern was evident between groups but difference was not significant again. G1 showed a decrease followed by an increase at T2-T1 and T3-T2, respectively. G2, on the other hand, showed a steady increase at both time intervals. Line graphs for RANKL amounts and GCF volumes were similar (P > 0.05). According to these graphs, G1 showed a steady increase where G2 showed a tendency toward decrease for both variables (Figure 6).

Table 2 demonstrates the means and standard deviations of the descriptive values before and after treatment, means and standard deviations of the changes occurred with the treatment, and the comparisons of the pretreatment values and changes between the two groups in lateral cephalograms and dental casts. None of the cephalometric or dental cast changes showed significant differences between groups (P > 0.05).

Success rates for 1.5–1.4 mm diameter and 7 mm long 60 miniscrews, loaded with 250g of force, were found to be 88.3 per cent on average. Success rates for groups were 86.7 per cent for G1 and 90 per cent for G2. No significant difference was observed for miniscrew success rates between groups (Fisher exact test, P = 1).

Harms

No serious harms were observed during the research and treatment. Although 7 out of 15 patients in G1 (piezosurgery group) manifested ectopic bony growths (Supplementary Figure 3).

Discussion

Main findings in the context of the existing evidence, interpretation

This was a prospective, randomized controlled trial aiming to determine the efficiency of piezosurgery technique. Efficiency was evaluated using retraction rate and biological response by means of RANKL amount and concentration, and GCF volume.

Our results showed that the difference between retraction rates was not significant, although piezosurgery group (G1) showed slightly higher rates. As this was the first study to examine the effects of piezosurgery on en-masse retraction with a controlled, randomized study design, retraction rates from this study will be compared with two other studies (13,14) conducted on en-masse retraction cases but with using 'accelerated osteogenic orthodontics' (AAO) technique (20). The claim of these studies is that en-masse retraction can be accelerated significantly with AAO technique. However, there are some substantial differences between the study designs. The first and probably the most important difference is the nature of decortications. Contrary to the 3 mm-long vertical buccal piezosurgical incisions, AAO technique has decortications both on the buccal and palatal sides extending vertically to and horizontally at the subapical level. These extensive decortications not only lead to regional acceleration but also a slight mobility at the corticotomized sections. Piezosurgery, on the other hand, is only capable of starting regional acceleration. In addition, the risk of premature fusion of piezosurgical cuts is higher than decortications as the knives used for piezosurgery technique are considerably thinner than the round and fissure burs. Therefore, not only intensity but also duration of regional acceleration seems to be limited in piezosurgery technique. Another important difference between AAO and piezosurgery is the absence of flap reflection in piezosurgery. During flap reflection, the integrity of periosteum is lost and blood supply of the bone is disrupted which leads to an intensified inflammatory response (21,22). This procedure is also known to be capable of producing a major signal for bone resorption even if decortications are not performed (23,24). The last important difference is the timing of extractions. In the studies mentioned above, teeth are extracted at the same session or a little time before the beginning of en-masse retraction. Extraction by itself is a major reason for accelerated tooth movement (20). Because the inflammation which starts after extraction advances the effect of decortications, plus the granulation tissue is easier to resorb. To sum up all, invasive corticotomies, flap reflection and extractions seem to be possible factors contributing to the higher en-masse retraction rates in these studies. Here raises an important question; do less invasive interventions lead to vague stimuli which are inefficient in accelerating tooth movement?

The efficiency of piezosurgery technique in en-masse retraction cases can be further investigated with a palatal surgical approach. Although the original surgical technique was employed in this study, the general idea of tooth movement accelerating techniques is to decrease the resistance of the bone on the direction towards teeth will move (3,8,20,25). Therefore, as teeth are intended to move palatally during en-masse retraction, piezosurgical cuts can be performed

Table 2. Comparison of cephalometric and dental cast measurements at the beginning of retraction (T1), changes with en-masse retraction (T3–T1) and at the end of retraction (T3).

	Piezosurgery + En-masse retraction (G1)				En-masse retraction only (G2)				Between the groups		
	T1	T3	Changes		T1	T3	Changes				
Measurements	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	Mean ± SD	*P*	Comparison at T1 P	Mean difference of the changes (%95 CI)	*P*
Cephalometric Variables											
Skeletal											
SNA (°)	81.71 ± 4.00	80.83 ± 4.07	−0.88 ± 1.71	0.067	81.49 ± 3.30	80.60 ± 4.15	−0.89 ± 1.41	0.028*	0.871	0.01 (−1.11, 1.14)	0.982
SNB (°)	77.88 ± 3.54	77.03 ± 3.61	−0.85 ± 1.06	0.008*	76.45 ± 3.29	75.43 ± 3.78	−1.02 ± 1.00	0.001*	0.261	0.17 (−0.56, 0.91)	0.648
ANB (°)	3.84 ± 2.48	3.79 ± 2.45	−0.05 ± 0.91	0.846	5.05 ± 1.86	5.15 ± 1.74	0.10 ± 0.97	0.695	0.142	−0.15 (−0.82, 0.53)	0.673
VRP-A (mm)	63.65 ± 4.11	62.79 ± 3.94	−0.87 ± 1.78	0.080	64.66 ± 4.42	63.79 ± 4.91	−0.87 ± 1.41	0.032*	0.523	0.00 (−1.15, 1.15)	1.000
GoGn.SN (°)	31.73 ± 4.52	32.33 ± 4.75	0.61 ± 1.70	0.189	32.13 ± 7.62	33.50 ± 7.68	1.37 ± 1.19	0.001*	0.861	−0.76 (−1.81, 0.29)	0.167
Dental											
U1.HRP (°)	114.27 ± 6.35	105.40 ± 8.36	−8.87 ± 5.38	0.000*	111.07 ± 8.75	101.09 ± 9.77	−9.98 ± 8.08	0.000*	0.261	1.11 (−3.81, 6.02)	0.662
U1i-VRP (mm)	68.89 ± 5.48	63.68 ± 5.34	−5.21 ± 2.44	0.000*	67.97 ± 6.65	62.34 ± 5.98	−5.63 ± 2.72	0.000*	0.683	0.42 (−1.43, 2.27)	0.661
U1a-VRP (mm)	58.68 ± 3.39	57.61 ± 4.15	−1.07 ± 2.57	0.130	59.52 ± 4.24	57.93 ± 4.70	−1.59 ± 2.26	0.016*	0.554	0.52 (−1.21, 2.25)	0.561
U1i-HRP (mm)	70.69 ± 4.41	69.75 ± 4.25	−0.95 ± 1.77	0.057	71.73 ± 4.96	70.91 ± 4.73	−0.82 ± 1.71	0.085	0.551	−0.13 (−1.37, 1.12)	0.843
U6.HRP (°)	87.29 ± 6.23	83.80 ± 7.29	−3.49 ± 3.31	0.001*	84.97 ± 4.48	82.41 ± 6.41	−2.55 ± 4.59	0.049*	0.251	−0.94 (−3.80, 1.92)	0.525
U6t-HRP (mm)	64.95 ± 3.30	65.09 ± 3.48	0.14 ± 1.28	0.679	65.14 ± 4.48	64.72 ± 4.44	−0.42 ± 1.24	0.211	0.898	0.56 (−0.34, 1.46)	0.235
U6t-VRP (mm)	40.35 ± 7.42	39.17 ± 4.85	−1.17 ± 4.15	0.292	39.39 ± 4.20	38.15 ± 4.63	−1.24 ± 1.59	0.009*	0.666	0.07 (−2.18, 2.32)	0.954
U6a-VRP (mm)	41.15 ± 5.55	40.69 ± 3.76	−0.45 ± 3.09	0.579	41.03 ± 3.28	40.64 ± 3.77	−0.39 ± 1.40	0.294	0.946	−0.06 (−1.78, 1.66)	0.946
L1.GoMe (°)	96.26 ± 9.99	89.11 ± 11.54	−7.15 ± 10.28	0.018*	99.08 ± 5.76	94.09 ± 8.32	−4.99 ± 6.48	0.001*	0.352	−2.15 (−8.31, 4.00)	0.498
Overjet (mm)	5.07 ± 2.24	3.07 ± 1.64	−2.00 ± 2.56	0.009*	4.49 ± 2.94	1.84 ± 1.47	−2.65 ± 2.70	0.002*	0.548	0.65 (−1.24, 2.53)	0.506
Overbite (mm)	3.39 ± 1.95	2.39 ± 1.80	−1.01 ± 2.11	0.086	3.37 ± 2.17	1.68 ± 1.31	−1.69 ± 1.50	0.001*	0.979	0.69 (−0.62, 2.00)	0.313
Soft tissue											
UL-VRP (mm)	81.03 ± 4.20	78.04 ± 5.33	−2.99 ± 2.92	0.001*	80.89 ± 6.69	77.95 ± 6.23	−2.94 ± 1.83	0.000*	0.943	−0.05 (−1.80, 1.69)	0.953
LL-VRP (mm)	76.77 ± 5.90	73.70 ± 6.53	−3.07 ± 3.55	0.005*	76.35 ± 6.51	73.30 ± 6.71	−3.05 ± 2.19	0.000*	0.854	−0.02 (−2.13, 2.09)	0.985
Nasolabial angle (°)	104.54 ± 10.39	113.57 ± 8.95	9.03 ± 8.57	0.001*	111.50 ± 5.08	120.72 ± 5.92	9.22 ± 5.61	0.000*	0.027*	−0.19 (−5.38, 4.99)	0.942
Mentolabial angle (°)	116.66 ± 16.74	125.47 ± 12.98	8.81 ± 15.24	0.042*	121.54 ± 20.11	131.82 ± 10.28	10.28 ± 13.12	0.009*	0.476	−1.47 (−11.65, 8.70)	0.779
Dental Cast Variables											
UR3axis.UL3axis (°)	85.13 ± 11.66	85.77 ± 16.60	0.63 ± 8.43	0.775	82.80 ± 12.16	86.83 ± 14.13	4.03 ± 6.87	0.039*	0.596	−3.40 (−8.90, 2.10)	0.236
UR6axis.UL6axis (°)	124.60 ± 8.06	126.27 ± 14.05	1.67 ± 10.87	0.562	117.13 ± 10.47	120.07 ± 10.31	2.93 ± 7.16	0.135	0.037*	−1.27 (−7.85, 5.32)	0.709
3t–3t (mm)	34.99 ± 1.66	34.41 ± 3.04	−0.59 ± 2.90	0.447	34.63 ± 2.73	33.69 ± 2.90	−0.94 ± 0.96	0.002*	0.661	0.35 (−1.19, 1.90)	0.658
5bt–5bt (mm)	46.41 ± 2.38	44.31 ± 1.93	−2.11 ± 2.58	0.007*	46.18 ± 2.29	44.13 ± 2.13	−2.05 ± 2.07	0.002*	0.786	−0.06 (−1.73, 1.61)	0.944
6mbt–6mbt (mm)	50.33 ± 2.36	50.11 ± 2.14	−0.22 ± 2.54	0.742	50.17 ± 2.78	49.64 ± 2.58	−0.53 ± 1.73	0.251	0.866	0.31 (−1.24, 1.87)	0.695

*$P < 0.05$; SD, standard deviation.

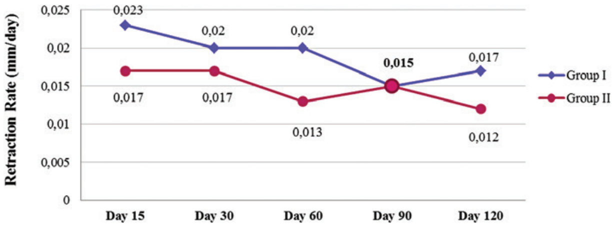

Figure 5. Retraction rates on days 15, 30, 60, 90 and 120.

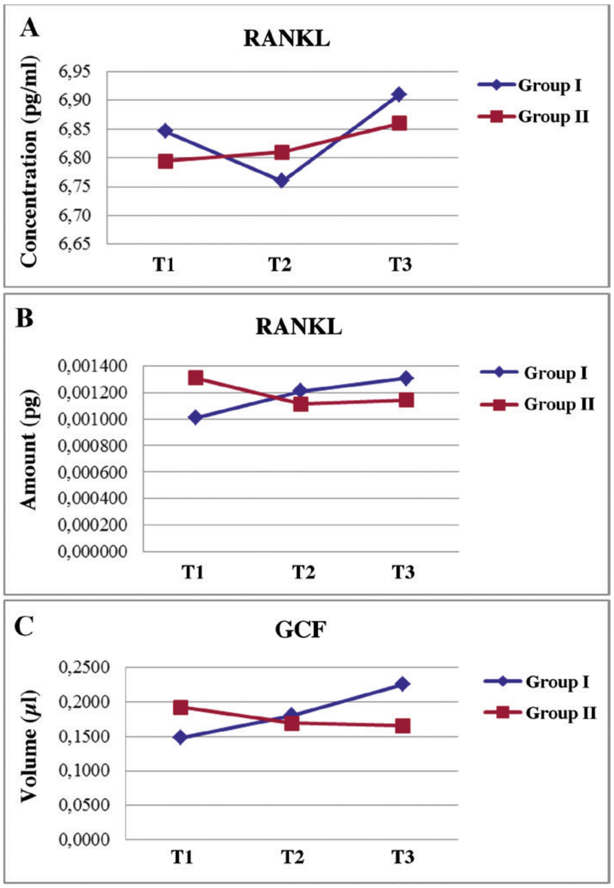

Figure 6. A, Concentration and, B, amount of receptor activator of nuclear factor κβ ligand (RANKL), C, gingival crevicular fluid (GCF) volume.

on the palatal side of the alveolar bone. In addition, repeated piezosurgeries can be suggested.

Histological studies investigating the effects of interventions to accelerate tooth movement revealed that molecules responsible for bone resorption increase in the environment (16,17). Therefore, theoretically RANKL concentration and amount are supposed to increase after piezosurgery. On the contrary, our findings showed that at T2-T1, RANKL concentration decreased in G1 and increased in G2 but the difference was significant neither between nor within the groups. While the steady increase of G2 is compatible with the biology of tooth movement, the decrease in G1 is most likely because the sampling times did not coincide with the intervals of RANKL increases. In other words, RANKL activity may have risen at an earlier time point than day 28 and this increase may have been followed by a decrease, as stated by Dibart *et al.* (15). As a conclusion final slope of the line at T2-T1 may have manifested as declining. To capture an interval of increased RANKL activity, an earlier time point can be determined for GCF sampling. Therefore, this study will also guide the researcher to decide which time points are more appropriate for GCF sampling in the future studies.

RANKL amounts and GCF volumes also didn't differ among groups. Findings, on the other hand, indicate a steady increase in G1 and a decrease followed by almost a plateau in G2 for both measurements. These differences in RANKL amounts and GCF volumes make us think that piezosurgery can induce a different tissue response than tooth movement alone.

Another aim of this study was to show if piezosurgery induces a difference in the type of tooth movement. Our results concerning cephalometric and dental cast variables showed that no significant difference was noted between groups regarding changes in the axial inclination, the amount of displacement of the incisal edge, mesiobuccal cusp tip and root apex, rotations, and intercuspal widths. This finding proves that piezosurgery do not change the type of tooth movement from parallel to tipping or vice versa. The type of tooth movement in both groups was controlled tipping and a slight bodily retraction, which can also be considered as an advantage of en-masse retraction over sequential retraction protocols.

In numerous studies, miniscrews are proven to offer reliable anchorage preservation during space closure (11,26–30). These devices not only help keeping the molars in place but also can be used to distalize them. In a miniscrew supported en-masse retraction study by Upadhyay *et al.* (31), molar distalization was shown due to the transmission of retraction forces to the posterior segment through interdental contacts as the coil springs were left in place for at least several months after space closure. However, in our study, retraction forces were discontinued when canines reached Class I relationship or extraction spaces were closed, yet molar distalization of 1.17 mm in G1 and 1.24 mm in G2 were still statistically significant for both groups. This is probably the result of friction occurred in the slots of premolar brackets and molar tubes while the archwire was sliding through them. This finding also shows that space closure was accomplished with purely en-masse retraction but not a combination of retraction and anchorage loss. Not in the sagittal dimension but also in the vertical dimension were the molars kept in place, preventing the worsening of the profile with posterior rotation of the mandible. This technique also aids in intruding incisors during retraction and makes it superior to the conventional approaches by correcting the deep-bite and/or increased gingival exposure. In our study the amount of incisor intrusion was 0.95 mm for G1 and 0.82 mm for G2.

Dental cast measurements showed no significant difference between groups. However, a transversal constriction was evident especially between the cusps of premolars in both groups. The significant decrease in intercanine distance and increase in the angle formed between the mesiodistal axes of canines in G2 indicate palatal tipping and distopalatal rotation. Although not significantly different between groups, this effect can be explained with the reduced resistance against tooth movement and less archwire deformation causing palatal tipping and rotation in G1.

Studies, which primarily focus on miniscrew success rates showed that miniscrews with varying diameters and lengths were successful between 83.8 per cent and 93.4 per cent (32–38). More specifically, they were successful in 87 per cent to 93 per cent of the en-masse retraction cases (26,31,39). Miniscrew success rate in our study was 88.3 per cent on average, which is compatible with the findings of the previous studies in the literature. Failures in this study were reported in the first cases and success rate gradually increased with repeated practice, which follows the clinical learning curve (40,41).

Limitations

Sampling times are a limitation for clinical interpretation in this study. Two studies in this field, one on rats and one on humans, were carried out by taking samples more frequently and at earlier dates than ours in the first month (16,17). This approach increases the possibility of capturing time points when studied chemicals are most likely to increase. On the other hand, taking too many samples does not give the guarantee of catching the interval or intervals of maximum molecular activity. Also it is tiring for the patient to visit the clinic frequently and increases the expenses of the study. For this reason, we think taking samples in appropriate numbers and at critical time points are crucial for understanding the biology of accelerated tooth movement.

Maintaining good oral hygiene is an important issue, yet a challenging factor to standardize. As plaque accumulation leads to inflammation and increases the concentrations of inflammatory markers including RANKL, we did not take T3 samples from 10 patients who were unsuccessful in maintaining good oral hygiene throughout the retraction period.

Patients in this study were not drawn from a sampling frame, instead, they were recruited one by one as were found eligible for the study. Besides, the 'opaque-sealed envelope' technique was not used step-by-step as it is described in the literature and the thirty-first patient included in G1 did not go through the randomization process. These limitations should be taken into account when interpreting the results of the study.

Although blinding of the operator and the patients was not possible, data analysis was blind; therefore, the risks of observation and detection biases can be considered as low.

Generalizability

The generalizability of these results might be representative to some extent because the patients were mostly young adults.

Conclusions

The following conclusions can be drawn from this study;

1. No evidence was found to support the claim that piezosurgery technique is an efficient way of accelerating en-masse retraction.
2. Piezosurgery can alter the tissue reaction but no significant difference was present between the groups.
3. Changes in the nature of incisor and molar movement, cephalometric and dental cast variables were similar in two groups.
4. Miniscrew supported en-masse retraction is a feasible way of controlling the overbite and preserving anchorage during retraction.
5. Molars can be distalized in case of anchorage need during miniscrew supported en-masse retraction.
6. 1.5–1.4 mm diameter and 7 mm long AbsoAnchor miniscrews can be successfully used for en-masse retraction with 250g of force per side.

Supplementary Material

Supplementary data are available at *European Journal of Orthodontics* online.

Ethical approval

This study was approved as a PhD thesis by the Institutional Review Board of Başkent University

Protocol

The full protocol of this study can be accessed from the national thesis database of Turkey tez.yok.gov.tr.

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Conflict of interest

None to declare.

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References

1. Proffit, W.R. (2007) The biologic basis of orthodontic therapy. In Dolan, J., Nebel, J. (eds.), *Contemporary Orthodontics*. Mosby Elsevier, St Louis, MO, 4th edn, pp. 331–347.
2. Huang, J.C., King, G. and Kapila, S. (2005) Biologic mechanisms in orthodontic tooth movement. In Rudolph, P., Pendill, J. (eds.), *Biomechanics and Esthetic Strategies in Clinical Orthodontics*. Elsevier Saunders, St Louis, MO, 1st edn, pp. 17–19.
3. Kole, H. (1959) Surgical operations on the alveolar ridge to correct occlusal abnormalities. *Oral Surgery, Oral Medicine, and Oral Pathology*, 12, 515–529.
4. Düker, J. (1975) Experimental animal research into segmental alveolar movement after corticotomy. *Journal of Maxillofacial Surgery*, 3, 81–84.
5. Generson, R.M., Porter, J.M., Zell, A. and Stratigos, G.T. (1978) Combined surgical and orthodontic management of anterior open bite using corticotomy. *Journal of Oral Surgery*, 36, 216–219.
6. Krishnan, V. and Davidovitch, Z. (2006) Celular, molecular and tissue-level reactions to orthodontic force. *American Journal of Orthodontics and Dentofacial Orthopedics*, 129, 469.e1–32.
7. Vercellotti, T. (2004) Technological characteristics and clinical indications of piezoelectric bone surgery. *Minerva Stomatologica*, 53, 207–214.
8. Vercellotti, T. and Podesta, A. (2007) Orthodontic microsurgery: a new surgically guided technique for dental movement. *International Journal of Periodontics & Restorative Dentistry*, 27, 325–331.
9. Dibart, S., Sebaoun, J.D. and Surmenian J. (2009) Piezocision: a minimally invasive, periodontally accelerated orthodontic tooth movement procedure. *Compendium of Continuing Education in Dentistry*, 30, 342–344, 346, 348.
10. Long, H., Pyakurel, U., Wang, Y., Liao, L., Zhou, Y. and Lai, W. (2013) Interventions for accelerating orthodontic tooth movement: a systematic review. *Angle Orthodontist*, 83, 164–171.
11. Park, H.S. and Kwon, T.G. (2004) Sliding mechanics with microscrew implant anchorage. *The Angle Orthodontist*, 74, 703–710.
12. Huang, Y., Wang, X.X., Zhang, J. and Liu, C. (2010) Root shortening in patients treated with two-step and en masse space closure procedures with sliding mechanics. *Angle Orthodontist*, 80, 492–497.
13. Sakthi, S.V., Vikraman, B., Shobana, V.R., Iyer, S.K. and Krishnaswamy, N.R. (2014) Corticotomy-assisted retraction: an outcome assessment. *Indian Journal of Dental Research*, 25, 748–754.
14. Bhattachary, P., Bhattacharya, H., Anjum, A., Bhandari, R., Agarwal, D.K., Gupta, A. and Ansar, J. (2014) Assessment of corticotomy facilitated tooth movement and changes in alveolar bone thickness - a CT scan study. *Journal of Clinical and Diagnostic Research*, 8, 26–30.
15. Dibart, S., *et al*. (2014) Tissue response during Piezocision-assisted tooth movement: a histological study in rats. *European Journal of Orthodontics*, 36, 457–464.

16. Alikhani, M., *et al*. (2013) Effect of micro-osteoperforations on the rate of tooth movement. *American Journal of Orthodontics and Dentofacial Orthopedics*, 144, 639–648.
17. Baloul, S.S., Gerstenfeld, L.C., Morgan, E.F., Carvalho, R.S., Van Dyke, T.E. and Kantarci, A. (2011) Mechanism of action and morphologic changes in the alveolar bone in response to selective alveolar decortication-facilitated tooth movement. *American Journal of Orthodontics and Dentofacial Orthopedics*, 139, S83–S101.
18. Helm, S., Siersbaek-Nielsen, S., Skieller, V. and Björk, A. (1971) Skeletal maturation of the hand in relation to maximum puberal growth in body height. *Tandlægebladet*, 75, 1223–1234.
19. Doig, G.S. and Simpson, F. (2005) Randomization and allocation concealment: a practical guide for researchers. *Journal of Critical Care*, 20, 187–191; discussion 191.
20. Wilcko, W.M., Wilcko, T., Bouquot, J.E. and Ferguson, D.J. (2001) Rapid orthodontics with alveolar reshaping: two case reports of decrowding. *International Journal of Periodontics & Restorative Dentistry*, 21, 9–19.
21. Oh, T.J., Shotwell, J.L., Billy, E.J. and Wang, H.L. (2006) Effect of flapless implant surgery on soft tissue profile: a randomized controlled clinical trial. *Journal of Periodontology*, 77, 874–882.
22. Fortin, T., Bosson, J.L., Isidori, M. and Blanchet, E. (2006) Effect of flapless surgery on pain experienced in implant placement using an image-guided system. *International Journal of Oral & Maxillofacial Implants*, 21, 298–304.
23. Yaffe, A., Fine, N. and Binderman, I. (1994) Regional accelerated phenomenon in the mandible following mucoperiosteal flap surgery. *Journal of Periodontology*, 65, 79–83.
24. Binderman, I., Gadban, N., Bahar, H., Herman, A. and Yaffe, A. (2010) Commentary on: periodontally accelerated osteogenic orthodontics (PAOO) - a clinical dilemma. *International Orthodontics*, 8, 268–277.
25. Liou, E.J. and Huang, C.S. (1998) Rapid canine retraction through distraction of the periodontal ligament. *American Journal of Orthodontics and Dentofacial Orthopedics*, 114: 372–382.
26. Upadhyay, M., Yadav, S. and Patil, S. (2008) Mini-implant anchorage for en-masse retraction of maxillary anterior teeth: a clinical cephalometric study. *American Journal of Orthodontics and Dentofacial Orthopedics*, 134, 803–810.
27. Rajni, N., Shetty, K.S. and Prakash, A.T. (2010) To compare treatment duration, anchor loss and quality of retraction using conventional enmasse sliding mechanics and enmasse sliding mechanics with using micro-implants. *Journal of Indian Orthodontic Society*, 44, 52–61.
28. Creekmore, T D. (1997) Where teeth should be positioned in the face and jaws and how to get them there. *Journal of Clinical Orthodontics: JCO*, 31, 586–608.
29. Williams, R. and Hosila, F J. (1976) The effect of different extraction sites upon incisor retraction. *American Journal of Orthodontics*, 69, 388–410.
30. Liou, E.J.W. and Chang, P.M.H. (2010) Apical root resorption in orthodontic patients with en-masse maxillary anterior retraction and intrusion with miniscrews. *American Journal of Orthodontics and Dentofacial Orthopedics*, 137, 207–212.
31. Upadhyay, M., Yadav, S., Nagaraj, K. and Patil, S. (2008) Treatment effects of mini-implants for en-masse retraction of anterior teeth in bialveolar dental protrusion patients: a randomized controlled trial. *American Journal of Orthodontics and Dentofacial Orthopedics*, 134, 18–29.e1.
32. Chen, Y.J., Chang, H.H., Huang, C.Y., Hung, H.C., Lai, E.H. and Yao, C.C. (2007) A retrospective analysis of the failure rate of three different orthodontic skeletal anchorage systems. *Clinical Oral Implants Research*, 18, 768–775.
33. Baek, S.H., Kim, B.M., Kyung, S.H., Lim, J.K. and Kim, Y.H. (2008) Success rate and risk factors associated with mini-implants reinstalled in the maxilla. *Angle Orthodontist*, 78, 895–901.
34. Park, H.S., Jeong, S.H. and Kwon, O.W. (2006) Factors affecting the clinical success of screw implants used as orthodontic anchorage. *American Journal of Orthodontics and Dentofacial Orthopedics*, 130, 18–25.
35. Kuroda, S., Sugawara, Y., Deguchi, T., Kyung, H.M. and Takano-Yamamoto, T. (2007) Clinical use of miniscrew implants as orthodontic anchorage: success rates and postoperative discomfort. *American Journal of Orthodontics and Dentofacial Orthopedics*, 131, 9–15.
36. Miyawaki, S., Koyama, I., Inoue, M., Mishima, K., Sugahara, T. and Takano-Yamamoto, T. (2003) Factors associated with the stability of titanium screw placed in the posterior region for orthodontic anchorage. *American Journal of Orthodontics and Dentofacial Orthopedics*, 124, 373–378.
37. Moon, C.H., Lee, D.G., Lee, H.S., Im, J.S. and Baek, S.H. (2008) Factors associated with the success rate of orthodontic miniscrews placed in the upper and lower posterior buccal region. *Angle Orthodontist*, 78, 101–106.
38. Luzi, C., Verna, C. and Melsen, B. (2007) A prospective clinical investigation of the failure rate of immediately loaded mini-implants used for orthodontic anchorage. *Progress in Orthodontics*, 8, 192–201.
39. Park, H.S., Yoon, D.Y., Park, C. and Jeoung, S.H. (2008) Treatment effects and anchorage potential of sliding mechanics with titanium screws compared with Tweed-Merrifield technique. *American Journal of Orthodontics and Dentofacial Orthopedics*, 133, 593–600.
40. Garfinkle, J.S., Cunningham, L.L., Beeman, C.S., Kluemper, T., Hicks, E.P. and Kim, M.O. (2008) Evaluation of orthodontic mini-implant anchorage in premolar extraction therapy in adolescents. *American Journal of Orthodontics and Dentofacial Orthopedics*, 133, 642–653.
41. Fritz, U., Ehmer, A. and Diedrich, P. (2004) Clinical suitability of titanium microscrews for orthodontic anchorage-preliminary experiences. *Journal of Orofacial Orthopedics*, 65, 410–418.