Original Article

Effect of Piezoincision on the Rate of Mandibular Molar Mesialization: A Randomised Clinical Trial

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Abstract

Background and Aim: The aim of this clinic study was to investigate the effect of piezoincision on the rate of mandibular molar mesialization using clinical, radiological, and biochemical methods. **Materials and Methods:** Twenty-one patients requiring mandibular first molar extraction and second molar mesialization were included in the study which was designed as split-mouth study. Piezoincision was performed on the buccal surface of alveolar bone following regional alignment to the randomly selected side. 150 g of force was applied to the second molar teeth using mini-screw-supported anchorage after the piezoincision. Cone beam computed tomography (CBCT), gingival crevicular fluid (GCF) and digital model records of the patients were obtained. Two- and three-dimensional measurements were performed and compared on the CBCT images in a study which lasted 24 weeks. **Results:** According to the model analysis, the canine-second molar distance was consistently reduced and a greater decrease was measured on the experimental group ($p < 0.05$). Second molar mesial rotations increased in both groups ($p < 0.001$). Two-dimensional measurements on CBCT images showed increased mesial and buccal tipping of second molars in experimental group ($p < 0.001$). There was a significant increase in mesialization measurements of experimental group ($p < 0.001$). Three-dimensional measurements on the CBCT images showed a decrease of root length in both groups ($p < 0.001$), and a greater decrease was found in the experimental group ($p < 0.001$). When intra-group changes in GCF results were examined, it was observed that there was no significant change in osteoprotegerin (OPG) values over time in experimental group ($p = 0.148$). **Conclusion:** The piezoincision technique provided acceleration of mandibular molar mesialization and did not cause further damage to the buccal alveolar bone. Piezoincision can be used as a safe method in the mandibular molar region.

Keywords: *Accelerated tooth movement, mandibular molar mesialization, Piezoincision*

Introduction

Orthodontic tooth movement is the result of applying a mechanical force to a tooth. It is characterized by remodeling changes in the dental and paradental tissues, including the dental pulp, periodontal ligament (PDL), alveolar bone, and gingiva. Orthodontic tooth movement can occur rapidly or slowly, depending on the physical characteristics of the applied force and biological response of the PDL.[1]

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One of the major concerns of the patients in terms of orthodontic treatment is the duration of the treatment. Prolonged treatment negatively affects patient co-operation and may cause undesirable outcomes such as an increased risk of caries, the occurrence of

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periodontal disease and root resorption.[1-4] Therefore, several studies have been conducted to accelerate orthodontic tooth movement and reduce the duration of orthodontic treatment.[5-11]

Previous investigations have tried to accelerate orthodontic tooth movement by assessing biochemical agents such as prostaglandin E2,[12] corticosteroid,[13] parathyroid hormone,[10] and 1,25-dihydroxycholecalciferol.[9] When used to accelerate orthodontic tooth movement, biochemical agents have been reported[7] to produce local pain, root resorption, and undesirable systemic effects. The role of mechanical vibrational stimulation, gene transfer stimulation, laser biostimulation, and electromagnetic stimulation have additionally been studied to determine their effects on accelerating orthodontic tooth movement.[7,8,14,15]

Surgical techniques have a long history of describing the acceleration of tooth movement. Acceleration is generally achieved by reducing bone resistance by raising a full thickness flap and subjecting the exposed bone surface to a corticotomy. A regional acceleration phenomenon (RAP) begins due to the reduction of bone resistance and the increase in osteoclastic activity after the surgical procedure. A noxious stimuli initiates a local inflammatory response to produce accelerated physiologic healing which begins in few days, peaks for initial few months and may last 6 months to more than a year.[5] Following the corticotomy technique defined by Kole, it was planned to cut the buccal and lingual cortical bone surfaces completely and move the teeth together within the bone blocks.[6]

The major disadvantage of surgical techniques is their low patient acceptance due to the invasive procedures. In addition, a disruption of the regeneration mechanism and bone osteonecrosis zones can be created due to the heat released by the surgical diamond and carbide burs.[16] Research for a more minimally invasive method has resulted in "piezoelectric bone surgery" which provides the possibility of working more safely and precisely in areas close to soft tissues.[17]

Piezoelectric surgery, introduced by Vercellotti in 1988, has allowed for incisions in the bone by ultrasonic vibrations.[18] In 2007, Vercellotti and Podesta[19] published the "Monocortical tooth dislocation and ligament distraction" (MTDLD) technique in which adult patients were included. In 2009, Dibart *et al*.[5] introduced the "piezocision" technique defined by piezoelectric microincision which made it possible to accelerate orthodontic tooth movement and shorten the duration of treatment using a technique that followed a minimally invasive surgical approach.

The mandibular molar is the most resistant tooth to orthodontic tooth movement due to the thicker cortical bone in mandibular posterior region, the root shapes of the mandibular molar teeth, and their large volume compared to other teeth. Treatment process may be prolonged and difficult in cases requiring mandibular first molar tooth extraction and second molar tooth mesialization to first molar tooth region. Complications such as root resorption and overtipping in the direction of movement may occur.[20]

The aim of this prospective randomized clinical study was to investigate the effect of piezoincision on acceleration of tooth movement in patients who were planned for mandibular first molar extraction and mandibular second molar mesialization. Comparative measurements on digital models and cone beam computed tomography (CBCT) images used for the evaluation of dentoalveolar changes were conducted in areas with and without piezoincision. In addition, by evaluating the concentration of receptor activator of nuclear factor β ligand (RANKL) and osteoprotegerin (OPG) in gingival crevicular fluid (GCF) samples, it was aimed to better understand the bone tissue response after piezoincision. The null hypothesis stated that the piezoincision corticotomy procedure to be applied to the alveolar bone before the mesialization of the mandibular second molars would accelerate the bone resorption-apposition cycle and orthodontic tooth movement would accelerate.

Material and Methods

Participants, eligibility criteria and study settings

This prospective randomized study was conducted with the permission of Aydın Adnan Menderes University Faculty of Dentistry Clinical Research Ethics Committee (E.47158). G*Power version 3.0.10 (Franz Faul, Universität Kiel, Kiel, Germany) program was used to determine the number of individuals for inclusion. The power of the study was calculated as 80%, at $\alpha = 0.05$ significance level and 0.80 effect size. This analysis indicated that the sample size required was 21 participants. The CONSORT statement was used as a guide for this study.[21] Patients were selected for the study based on the following inclusion criteria:

- Mandibular first molar teeth extraction at least 4 months before the piezoincision technique,
- A present mandibular third molar teeth even if they were unerupted but in appropriate position for eruption after the second molar mesialization,
- Minimum age >14 (at the beginning of retraction)
- No systemic disease or drug use which would affect tooth movement rate,

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- Full permanent dentition,
- No previous orthodontic treatment history,
- Adequate oral hygiene.

The present study was planned as a split-mouth design as the patients acted as their own controls. All patients participated in both experimental and control groups. The right or left side of the same patient was included in the experimental group, and the contralateral side was included in the control group. The genetic, physiological, and environmental factors that may arise between the experimental and control groups were unlikely to influence the results.[22] The patients were selected to the groups randomly by using the SPSS program (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). The right side of 10 patients and the left side of 11 patients were included in the experimental group.

Patients who consulted the university Orthodontics Department were assessed for eligibility on the session of orthodontic examination. The eligible patients were thoroughly informed about the procedures of the study and were asked whether they would participate. Informed consent was obtained before recruitment from patients, and from parents if the patients were adolescents. No changes in the methods were made after trial commencement occurred.

All patients were treated with 0.022×0.028 inch brackets and molar tubes (Gemini Series, Roth prescription, 3M Unitek, Monrovia, CA, USA). All tooth extractions were performed at least 4 months prior to the piezoincision. Between the roots of the mandibular premolar teeth, which were parallelized by alignment, 8-mm-long and 1.5mm-diameter mini screws (The Aarhus System Miniscrews, American Orthodontics, Sheboygan, WI, USA) were inserted to provide anchorage. Plaster models were obtained from the lower arch before piezoincision and essix appliances that added acrylic elevation were prepared to cover premolar and anterior teeth on these plaster models. The purpose of these appliances was to ensure that the tight occlusal relationship between the maxillary and mandibular teeth in the molar region did not interfere with mandibular second molar mesialization. A mesial force of 150 gr was applied to the second molars by 9-mm nickel titanium closed coil springs (American Orthodontics, Sheboygan, WI, USA) directly anchored to mini screws immediately after the piezoincision. The force was activated and calibrated by using a strain gauge. Molar mesialization was performed by placing 0.019x0.025-inch stainless steel arch wires (American Orthodontics, Sheboygan, WI, USA).

Piezoincision technique

Piezoincisions were performed in the alveolar bone 2 mm and 5 mm mesially from the second mandibular molar by an experienced surgeon (U.D.) in the university's Oral and Maxillofacial Surgery Department. After local infiltration anesthesia, vertical soft tissue incisions were made on the buccal side by using a depth-coded piezoelectric knife (SL 1, EMS, Nyon, Switzerland). Piezosurgical cuts 3 mm in depth were made in medullary bone under saline irrigation [Figure 1]. Patients were advised to apply ice-bags for the first day and informed about diet. Chlorhexidine mouthwash and paracetamol were prescribed. The sutures were removed after the first week. All patients were strictly advised to maintain good oral hygiene.

GCF sampling

GCF samples were collected from the mesiobuccal aspects of the interproximal sites of the mandibular second molars using filter paper strips (Periopaper, Proflow, Amityville, NY, USA). The samples were obtained from one site for each group before piezoincision (T0) and on the days of 2 (T1), 7 (T2), 14 (T3), 28 (T4), and 56 (T5) after piezoincision.

Before sampling, supragingival plaque was removed by a sterile curette, and the area was gently air-dried and isolated by cotton rolls to avoid contamination. Filter strips gently placed into the gingival sulcus till mild resistance was felt and left there for 30 seconds. The GCF strips were subsequently removed, placed into sterile polypropylene tubes and frozen at -80°C until required.

Determination of RANKL and OPG Levels

250 µl phosphate-buffered saline containing 0.5% Tween (PBS-T, pH 7.4) was added to each eppendorf sampling tube. The tubes were vortexed for 1 minute, centrifuged at 10000 xg for 10 minutes and the supernatants collected.

The levels of RANKL (Human RANKL ELISA kit, Sun-Red Bio Company, Shanghai, China) and OPG (Human OPG ELISA kit, Sun-Red Bio Company, Shanghai, China) were measured by enzyme-linked immunosorbent assay (ELISA) method using commercially available kits. The instructions of the manufacturers were followed. The concentrations in the samples were determined according to the assay standard curve. The obtained results were expressed as nanograms per liters. The detection limits for RANKL and OPG were 1.0 ng/L to 300 ng/L and 2.5 ng/L to 720 ng/L, respectively.

Digital model measurements

Digital models were obtained from all participants using Trios 3D intraoral scanning device (3shape,

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Copenhagen, Denmark) before and every 14 days after the piezoincision procedure. The distance from the mandibular canine cusp tip to the mandibular second molar mesiobuccal cusp tip, the distance from the mandibular second molar mesiobuccal cusp tip to the sagittal plane, and the angle between the plane passing through the mesiobuccal and mesio-palatinal cusps and the sagittal plane were measured.

It was aimed to observe the rotations of mandibular second molars during mesialization via angular measurements and the movements of the second molars in sagittal and transversal directions by linear measurements. All model measurements were performed using Ortho Analyzer (3shape, Copenhagen, Denmark) digital model software.

CBCT measurements

CBCT images were taken from all participants with CBCT device (Planmeca ProMax 3D Max, Helsinki, Finland) in Oral and Maxillofacial Radiology Department of same university before piezoincision and 24 weeks after piezoincision. All imaging procedures were performed using the ultra-low dose capability of the device.[23] For imaging, patients' heads were positioned in an upright position with the interpupillary plane parallel to the floor.

All measurements on the CBCT images were performed using Dolphin Imaging (Dolphin Imaging 11.95 Ver, Patterson Dental, CA, USA) software. All measurements were performed by the one investigator (M.Ö.). Lateral cephalometric and antero-posterior radiographs were obtained from CBCT images. To reduce the level of error, it was preferred to make measurements on two-dimensional images in some measurements. Unlike conventional radiographs, the obtained cephalometric radiographs contained only the right or left side of the head. With the two different cephalometric images obtained from same CBCT images, the superimposition of images was removed. This allowed the anatomical marker points to remain in the same position in both images providing a clear visualization. Mandibular second molar mesialization, angulation, and inclination measurements were conducted on the 2D images. The distance from the mandibular second molar mesial margin to the mandibular ramus posterior border point, the angle between the mandibular second molar vertical plane, and the mandibular plane were measured on the 2D cephalometric images. The angle between the mandibular second molar vertical plane and the mandibular plane passing through the right and left gonion points was measured on the 2D antero-posterior images. Mesial and distal root lengths, buccal alveolar bone area, and buccal and lingual alveolar bone thickness measurements were performed on the 3D images.

Statistical analysis

The distribution of the repeated measured variables was investigated by Royston multivariate normality test. The normally distributed variables were reported as mean ± standard deviation (mean ± sd), while other variables were expressed as median (min-max).

The group, time, and group*time effects in CBCT and digital model measurements were analyzed by two-way repeated measures ANOVA. Mauchly's sphericity test was used to examine the sphericity assumption. Greenhouse–Geisser correction was applied for digital model measurements. Bonferroni adjustment was performed for multiple comparisons within group and time factors. LD-F2 design was used to examine the group, time, and group*time effects in GCF measurements. Friedman test and Wilcoxon test were performed for time and group comparisons, respectively. Dunn–Bonferroni adjustment was used after the Friedman test, if necessary.

The repeatability of CBCT and digital model measurements was assessed by the interclass correlation coefficient (ICC) obtained from the three-level linear mixed model, and the 95% confidence interval (CI) was reported. A P value <0.05 was considered as statistically significant.

The multivariate normality test and LD-F2 design were performed by using MVN and nparLD packages via R (ver. 3.5.1) and RStudio software (ver. 1.2.1335). IBM SPSS Statistics 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) was used for other statistical analyses.

Results

Illustration of the CONSORT flow diagram of patients was shown in Figure 2. Twenty-one patients were enrolled in this study. No dropouts occurred. Complete follow-up was done for all patients, and appropriate analysis was achieved.

Figure 1: Piezoincision done over buccal cortex

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Six patients chosen randomly and reanalyzed for intraexaminer reliability after two weeks following the initial assessment of the radiological images and digital models. ICC value showed significant excellent agreement (from 0.970 to 1.000, respectively) for intraexaminer reliability.

Findings of 2 dimensional radiological measurements

The mean L7 angulation angle was 89.667º ± 4.600º in the control group and 88.543º ± 3.462º in the experimental group before the piezoincision. At the end of the experiment, the mean values were 97.133º ± 4.477º in the control group and 97.990º ± 3.934º in the experimental group. The mean L7 inclination angle was 105.890º ± 6.703º before piezoincision and 101.552º ± 6.569º at the end of the experiment in the control group. In the experimental group, it was measured as 104.148º ± 7.694º before piezoincision and 99.062º ± 5.779º at the end of the experiment [Table 1]. Although there were additional angulation and inclination measurement changes in the experimental group, the change over time for both measurements was similar between

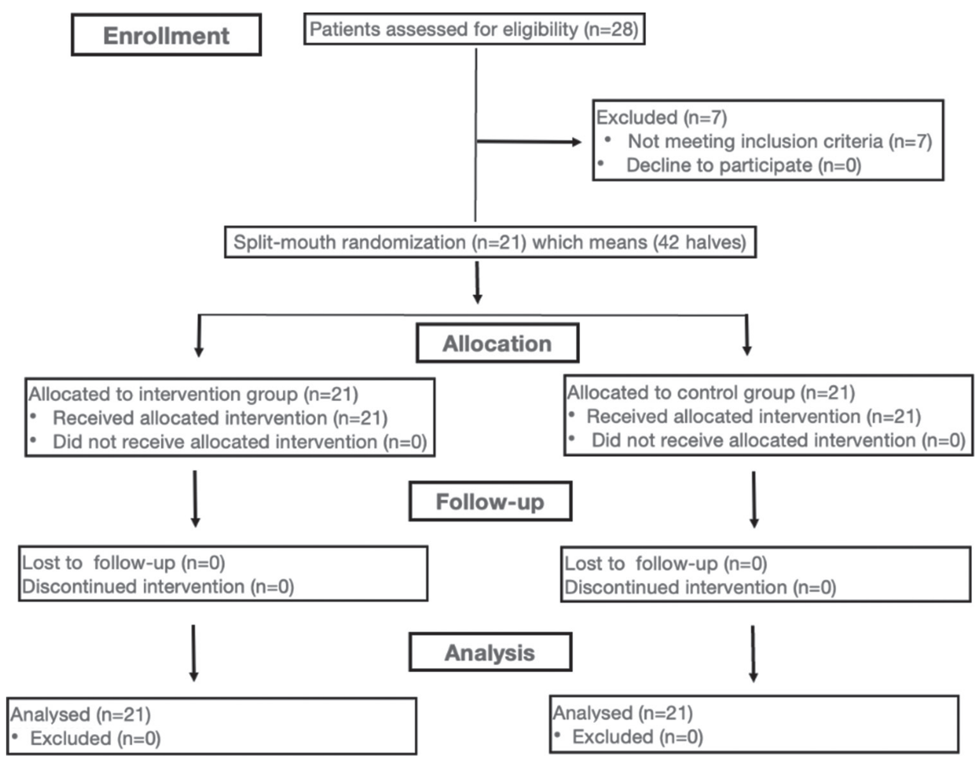

Figure 2: CONSORT flow diagram

Table 1: Measurements of two dimensional radiography obtained from CBCT images

	Control Group Mean±SD	Experimental Group Mean±SD	*P**
L7 Angulation (º)			
Pre	89.667±4.600	88.543±3.462	–
Post	97.133±4.477	97.990±3.934	–
*P***	<0.001	<0.001	
L7 Mesialization (mm)			
Pre	49.410±3.133	48.610±2.462	0.207
Post	52.967±3.015	53.205±2.520	0.670
*P***	<0.001	<0.001	
L7 Inclination (º)			
Pre	105.890±6.703	104.148±7.694	–
Post	101.552±6.569	99.062±5.779	–
*P***	<0.001	<0.001	

*Between-group comparison result; **Within-group comparison results. – indicates that there is no significant group effect resulted in the multivariate analysis

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Table 2: Measurements of three-dimensional CBCT images

	Control Group Mean±SD	Experimental Group Mean±SD	*P**
L7 Mesial Root Length (mm)			
Pre	17.356±0.751	17.217±0.835	0.110
Post	17.070±0.707	16.851±0.791	0.012
*P***	<0.001	<0.001	
L7 Distal Root Length (mm)			
Pre	17.061±0.774	16.917±0.804	0.061
Post	16.792±0.721	16.646±0.753	0.049
*P***	<0.001	<0.001	
Buccal Alveolar Bone Area (mm²)			
Pre	51.559±5.416	50.236±5.938	–
Post	44.843±5.038	43.115±5.603	–
*P***	<0.001	<0.001	
Buccal Alveolar BT 3 (mm)			
Pre	3.602±0.867	3.821±1.066	–
Post	2.937±0.805	3.165±0.865	–
*P***	<0.001	<0.001	
Buccal Alveolar BT 6 (mm)			
Pre	5.398±0.814	5.423±0.798	–
Post	4.708±0.556	4.709±0.691	–
*P***	<0.001	<0.001	
Buccal Alveolar BT 9 (mm)			
Pre	6.604±1.201	6.516±1.286	–
Post	5.864±0.788	5.747±0.924	–
*P***	<0.001	<0.001	
Lingual Alveolar BT 3 (mm)			
Pre	1.757±0.533	1.680±0.444	–
Post	1.635±0.411	1.486±0.344	–
*P***	0.009	0.007	
Lingual Alveolar BT 6 (mm)			
Pre	2.387±0.705	2.276±0.722	–
Post	2.243±0.638	2.195±0.687	–
*P***	–	–	
Lingual Alveolar BT 9 (mm)			
Pre	2.247±0.948	2.492±0.611	–
Post	2.292±0.754	2.380±0.633	–
*P***	–	–	

BT: Bone thickness; *Between-group comparison result; ** Within-group comparison results. – indicates that there is no significant group and time effects resulted in the multivariate analysis

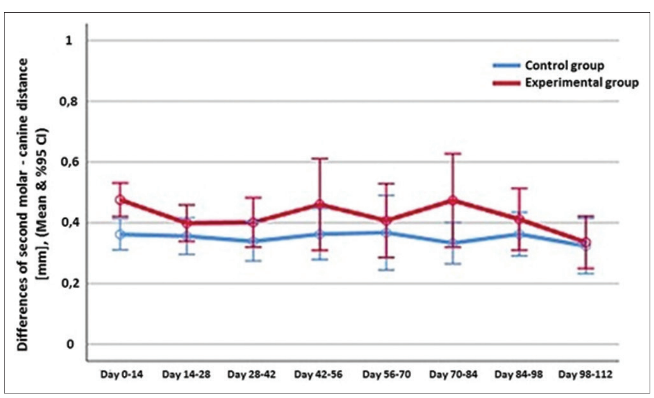

Figure 3: Differences in the mean values of mandibular second molar - canine distance measurements

the groups [Table 5]. The mean L7 mesialization increased after treatment in both groups ($p < 0.001$, Table 1); however, the increase in the experimental group was significantly higher than those in the control group (group*time effect $P < 0.001$, Table 5).

Findings of three-dimensional radiological measurements

The mean length of the L7 mesial root decreased significantly in both groups ($p < 0.001$, Table 2); however, it was determined that there was a greater decrease in the experimental group than in the control group ($p < 0.001$, Table 5). The mean length of the

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Table 3: Digital model measurements

	Control Group Mean±SD	Experimental group Mean±SD	*P**
L7 – L3 (mm)			
Day 0	28.05±3.20	29.71±2.96	0.005
Day 14	27.68±3.22	29.24±2.95	0.009
Day 28	27.33±3.18	28.84±2.89	0.010
Day 42	26.99±3.13	28.44±2.90	0.014
Day 56	26.63±3.07	27.98±3.00	0.019
Day 70	26.26±3.02	27.57±2.99	0.023
Day 84	25.93±2.98	27.09±2.98	0.040
Day 98	25.56±2.89	26.68±2.99	0.044
Day 112	25.24±2.81	26.35±2.99	0.044
*P***	<0.001[¥]	<0.001[¥]	
L7 - Sagittal plane (mm)			
Day 0	24.10±1.41	24.45±1.64	–
Day 14	23.91±1.39	24.34±1.55	–
Day 28	23.87±1.38	24.14±1.59	–
Day 56	23.89±1.42	24.22±1.59	–
Day 84	23.94±1.55	24.21±1.79	–
Day 112	23.95±1.82	24.32±2.01	–
*P***	–	–	
L7 - Sagittal plane (°)			
Day 0	69.71±4.58	70.98±3.85	0.189
Day 14	68.23±4.56	69.93±4.03	0.100
Day 28	67.24±4.46	69.18±3.95	0.043
Day 56	65.63±4.45	67.72±4.19	0.027
Day 84	63.96±4.63	66.41±4.25	0.008
Day 112	62.10±4.99	64.88±4.44	0.004
*P***	<0.001[¥]	<0.001[¥]	

*Between-group comparison result; **Within-group comparison results; [¥]*P*<0.001 for all pairwise comparisons. – indicates that there is no significant group and time effects resulted in the multivariate analysis

Table 4: Changes of RANKL and OPG concentrations in GCF measurements

	Control Group Median (min-max)	Experimental Group Median (min-max)	*P**
RANKL (ng/μL)			
Day 0	42.17 (13.83-164.31)	70.31 (11.56-253.98)[a]	0.019
Day 2	55.26 (12.35-158.83)	25.52 (13.73-82.66)[a,b]	0.006
Day 7	26.81 (15.36-154.68)[a,b]	38.82 (11.28-315.54)	0.881
Day 14	60.10 (18.85-173.72)[a]	46.27 (6.23-119.67)	0.232
Day 28	55.65 (14.71-113.86)	43.30 (13.69-183.52)	0.391
Day 56	61.06 (19.69-510.35)[b]	75.02 (5.68-202.16) [b]	0.940
*P***	0.007	0.005	
OPG (ng/L)			
Day 0	279.72 (38.39-818.59)	403.78 (110.66-1889.61)	–
Day 2	294.79 (99.17-1551.68)	237.19 (59.50-581.72)	–
Day 7	159.21 (20.33-475.15)[a]	221.22 (62.55-672.48)	–
Day 14	348.38 (124.78-887.57)	323.61 (93.73-751.38)	–
Day 28	297.34 (39.86-1005.96)	245.98 (138.32-966.08)	–
Day 56	518.80 (117.95-2218.92)[a]	383.08 (57.90-1846.25)	–
*P***	0.001	0.148	

*Between-group comparison result; **Within-group comparison results; [a, b]Shows significantly different time points within the group (*P*<0.05). – indicates that there is no significant group effect resulted in the multivariate analysis

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Table 5: Two-way repeated measures ANOVA and LD-F2 design results

Measurements	Group Effect *F*; *P*	Time Effect *F*; *P*	Group*Time Effect *F*; *P*
L7 Angulation (º)	0.168; 0.686	264.027; <0.001	1.614; 0.219
L7 Mesialization (mm)	0.243; 0.628	280.167; <0.001	18.603; <0.001
L7 Inclination (º)	2.108; 0.162	54.393; <0.001	0.820; 0.376
L7 Mesial Root Length (mm)	4.924; 0.038	326.033; <0.001	21.000; <0.001
L7 Distal Root Length (mm)	4.229; 0.053	273.921; <0.001	0.019; 0.891
Buccal Alveolar Bone Area (mm²)	1.676; 0.210	429.772; <0.001	0.993; 0.331
Buccal Alveolar BT 3 (mm)	1.784; 0.197	98.942; <0.001	0.007; 0.933
Buccal Alveolar BT 6 (mm)	0.005; 0.943	50.847; <0.001	0.097; 0.759
Buccal Alveolar BT 9 (mm)	0.341; 0.556	22.570; <0.001	0.102; 0.752
Lingual Alveolar BT 3 (mm)	1.130; 0.300	15.698; 0.001	0.961; 0.339
Lingual Alveolar BT 6 (mm)	0.256; 0.619	1.699; 0.207	0.440; 0.515
Lingual Alveolar BT 9 (mm)	1.732±0.203	0.272; 0.608	1.555; 0.227
L7-L3* (mm)	6.749; 0.017	179.786; <0.001	5.623; 0.018
L7 - Sagittal plane* (mm)	1.272; 0.273	0.946; 0.365	0.569; 0.536
L7 - Sagittal plane* (º)	5.422; 0.030	105.916; <0.001	6.513; 0.007
RANKL** (ng/µL)	0.139; 0.710	4.618; 0.002	3.236; 0.011
OPG** (ng/L)	0.031; 0.861	6.209; <0.001	1.795; 0.133

BT: Bone thickness; *Greenhouse–Geisser correction was applied; **ANOVA-type test statistic is given

L7 mesial root was lower in the experimental group compared to the control group at the end of the study ($p = 0.012$, Table 2).

L7 distal root length was similar between the groups before treatment ($p = 0.061$, Table 2), but was greater in the control group at the end of the study ($p = 0.049$). It was found that this measurement showed a statistically significant decrease in both groups ($p < 0.001$, Table 2).

Buccal alveolar bone area measurements decreased significantly in both groups compared to pre-treatment levels ($p < 0.001$, Table 2). There was no significant difference between the groups (group effect $P = 0.210$, Table 5).

Findings of Digital model measurements

It was found that the L7-L3 distance continuously decreased in both groups ($p < 0.001$) but was greater in the experimental group compared to the control group at each measurement time ($p < 0.05$, Table 3, Figure 3). The L7-sagittal plane distance did not change according to group or time (group effect, time effect, and group*time effect $P > 0.05$, Table 5).

The L7-sagittal plane angle was higher in experimental group compared to the control group at most times except the first two measurement times ($p < 0.05$); both groups were found to continuously decrease over time ($p < 0.001$) [Table 3].

Findings of gingival crevicular fluid analysis

When RANKL concentration levels were considered, the time effect and group*time interaction effect were significant ($p = 0.002$, $P = 0.011$, Table 5, respectively). A significant difference was found between the groups at day 0 and day 2 ($p < 0.05$, Table 4). In the control group, the concentration level of the day 7 was lower than the day 14 and day 56; in the experimental group, it was determined that the level of RANKL at day 2 was lower than the levels of pre-piezoincision and day 56 ($p < 0.05$, Table 4).

When the OPG concentration levels were considered, only the time effect was found to be significant ($p < 0.001$, Table 5). In the control group, the day 7 concentration level was lower than the day 56 level ($p < 0.05$, Table 4). In the experimental group, it was determined that the OPG concentration level did not show a significant change over time ($p = 0.148$, Table 4).

Discussion

The piezoincision technique has been used in studies of anterior tooth alignment and canine distalization.[24-27] The present study aimed to investigate the effect of piezoincision on mandibular molar mesialization using clinical, radiological, and biochemical methods in a prospective, randomized clinical trial.

The present findings indicated that mesial movement measurements of the mandibular second molars were found to be statistically different between the groups and at the measurement timepoints. It was noted that there was an average of 3.55 mm mesial movement in the control group and 4.59 mm in experimental group. As reported by Huang *et al*.[28] and Dibart *et al*.,[26] it was considered that osteoclastic activity in the alveolar bone

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was accelerated along with orthodontic tooth movement following piezoincision. In our study, rapid mandibular molar mesialization movement couldn't be obtained in contrast to the study of Arsenina *et al*.[29] The difference was thought to be due to piezocorticotomy is more invasive than the piezoincision. Piezocorticotomy method affects alveolar bone integrity to a greater extent than piezoincision. Abbas *et al*.[30] stated that the corticotomy method was more effective in accelerating tooth movement than piezoincision. In the present study, piezoincision was preferred because it is minimally invasive.

In the experimental group, the tipping movements of the mandibular second molars were greater albeit with small differences, compared to the control group. In the present study, no mechanical appliance changes were used to prevent mesial or buccal tipping movements of the teeth to reduce friction. Therefore, it was thought that undesirable tipping movements increased as a result of the decreasing bone resistance as a result of the piezoincision technique. Aboul Ela *et al*.[31] reported that there was no difference between the experimental group and control group 2 months after the corticotomy procedure. In the present study, force was applied to mandibular second molar teeth for 16 weeks, and piezoincision was performed only at the beginning of the experiment. It was considered that there was no statistically significant difference between the groups since the effect of the RAP created by piezoincision decreased over time and the alveolar bone resistance normalized.

Kim *et al*.[32] and Winkler *et al*.[33] evaluated root resorption and alveolar bone height in mesialized mandibular molars. It was reported that there was 0.7–0.8 mm in average resorption involving the mesial root of mesialized mandibular molar teeth and that the difference between the experimental and control groups was not more than 1 mm in any case. In the current study, it was determined that resorption of the mesial roots was 0.28 mm in the control group and 0.42 mm in the experimental group; resorption of distal roots was 0.27 mm in the control group and 0.29 mm in the experimental group. Root resorption after 16 weeks of mesialization became normal according to current literature.[34]

The data obtained in the present study contradicted studies published by Dibart *et al*.[35] and Abbas *et al*.[30] in that the piezoincision technique prevents root resorption. Previous research argued that the risk of bone resistance and hyalinization will be reduced by the surgical procedure performed, while ignoring the increase in synthesis of intercellular molecules responsible for both bone and root resorption.[36] Göllner *et al*.[37] reported that mandibular molar mesialization did not reduce alveolar bone height. In the present study, it was thought that the piezoincision technique did not increase the resorption in the buccal alveolar bone region and did not cause additional damage to the alveolar bone after mandibular molar mesialization.

The results show that the amount of mesialization of mandibular second molar teeth was higher in the experimental group. The findings of the digital model analysis were similar to the radiological measurement findings. It was considered that the mandibular second molars moved more mesially following the piezoincision procedure.

It was found that the distance between the mandibular second molar teeth and the sagittal plane did not statistically change during the experiment. Kim and Gianelly[38] reported that the distance between the teeth and the sagittal plane decreased as the molars mesialized due to the nature of the arch form. However, due to the buccal tipping of the teeth in both groups, the decrease in distance between the sagittal plane and the molar teeth as a result of mesialization was overshadowed, and therefore, no significant change was detected.

The angle between the sagittal plane and the mandibular second molar decreased significantly in both groups, and it was determined that the teeth mesially rotated. Molar rotation in the control group was found to be greater than that in the experimental group at all measurement timepoints. However, it was determined that the difference between the measurements decreased after 28 days. It was considered that the teeth moved more upright in the experimental group during the first month owing to the RAP created by the piezoincision following which the difference between these effects considerably decreased.

RANKL concentration changes in the control group were mirrored the biology of orthodontic tooth movement. The receptor activator of nuclear factor kappa-B ligand molecule exerts counterbalancing regulatory effects on osteoclastogenesis, including osteoclast differentiation, activation, and survival, and are as a result critical for initiation and maintenance of orthodontic tooth movement. Osteoclast differentiation and function appear to be regulated by a counterbalancing system, which has been referred to as the RANKL/RANK/OPG regulatory axis. An increased RANKL/OPG ratio will favor osteoclast formation and activation, so bone resorption will occur.[39]

RANKL concentration measurements showed an increase at the day 2 as expected, it has risen again to

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show decline after 14 days. Subsequent measurements continued to rise and fall in the same way. Baloul *et al*.[40] found the low measurements after high measurements, and that RANKL and OPG achieved a certain balance in the range of motion examined in their study. Dibart *et al*.[35] reported that osteoclastic activity was interrupted between days 3 and 7, and osteoclastic activity was greater at the day 14 in the control group.

Wang *et al*.[41] addressed how dentaoalveolar surgery alters the biology of tooth movement. Authors showed the increase of RANKL levels at day 3 and day 15 after corticotomy; these data are consistent with other study by Ren *et al*.[42] showing that osteoclastogenesis started at day 3 after surgery, and recruitment peaked between 2 and 4 weeks after tooth movement began.

In the experimental group, there was a rapid decrease in OPG and RANKL concentration measurements at the day 2 compared to the baseline. The excessive decrease observed in construction value at the day 2 due to the increased edema and DOS volume after the piezoincision area close to the gingival groove. At the day 14 measurements, OPG concentration increased, similar to Baloul *et al*.[40]

The current study has some limitations. First, more buccal and mesial tipping was observed in the experimental group. The piezoincision technique was not successful in preventing tipping movements. It may be considered to apply a force from the lingual to prevent unwanted tipping and rotational movements. Secondly, according to GCF results, measurements taken on the second day gave results contrary to expectations. Especially in the first days after the surgical procedures, when GCF samples are taken, we think that taking the samples at points farther away from the surgical site will give more accurate results.

Conclusions

The following conclusions can be drawn from this study;

1. The piezoincision technique provided acceleration of mandibular molar mesialization.
2. More buccal and mesial tipping was observed in the experimental group.
3. Root resorption was higher in the mesial roots in experimental group. However, the difference is insignificant according to the literature. Further studies are needed to demonstrate the effect of piezoincision on root resorption.
4. There was no significant difference between the groups related to the changes in alveolar bone. The piezoincision technique did not cause further damage to the buccal alveolar bone. Piezoincision can be used as a safe method in the mandibular molar region.
5. According to GCF results, measurements taken on the second day gave results contrary to expectations.

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Conflicts of interest

There are no conflicts of interest.

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