Original Article

Analysis of canine retraction and anchorage loss in different facial types with and without piezocision: a split-mouth–design, randomized clinical trial

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ABSTRACT

Objectives: To investigate canine retraction (CR) and anchorage loss (AL) among average facial height (AFH) and high facial height subjects (HFH) with or without piezocision surgery (PS).

Materials and Methods: This was a split-mouth, randomized clinical trial. Twenty-three females (aged 19.05 ± 2.95 years) who presented with Class II division I malocclusion requiring bilateral maxillary extraction and who fulfilled eligibility criteria were included and categorized into two groups: AFH (12 participants) and HFH (11 participants). Atraumatic extractions were performed 10 weeks following bonding. Before space closure, impressions were taken to fabricate models, which were scanned to generate digital models. Each participant had PS on the randomly assigned side. Space closure was undertaken using 100-g nickel-titanium coil closing springs on 0.019 × 0.025-inch stainless steel archwire. Digital models were collected 6 and 12 weeks post-PS. They were superimposed using reliable reference points and a region of interest on the palate, and crown movements were analyzed in three dimensions.

Results: Three months post-PS, intergroup comparisons showed that rates of CR for control sides (mean = 1.88 ± 0.83 mm for AFH, mean = 1.76 ± 0.62 mm for HFH) and intervention sides (mean = 1.48 ± 0.74 mm for AFH, mean = 1.40 ± 0.85 mm for HFH) were not significantly different. AL was not significantly different ($P > .05$) between groups.

Conclusion: Regardless of whether the patient underwent PS, CR and AL rates for AFH and HFH patients were not significantly different. (*Angle Orthod.* 2022;92:746–754.)

KEY WORDS: Facial divergence; Canine retraction; Anchorage loss; Piezocision

INTRODUCTION

The rate of orthodontic tooth movement (ROTM) and, consequently, the duration of orthodontic treatment are affected by age, gender, arch, and bone quality.[1–4] Less attention has been focused on the inherent density of the bone. Nonetheless, it is of interest to clarify some of the clinical practice variations observed for implant success rates, physiologic and therapeutic tooth movement, etc.[4] It has been concluded that different cortical bone thickness,[5] masticatory force, and occlusal interferences[6] in different facial types might be predictive of a possible difference in the rate of tooth movement—either canine retraction (CR) or anchorage loss (AL)—in subjects with different facial divergence patterns.[5]

There are several inherent adverse effects of orthodontic treatment, such as periodontal disease, pulpal changes, pain, and orthodontically induced iatrogenic root resorption (OIIRR).[7] It has been speculated[8] that shortening orthodontic treatment duration by accelerating the ROTM might minimize those inherent risks. There are numerous surgical[9] and nonsurgical[8] techniques one can use to accelerate ROTM, each of which has its advantages and limitations.[10] When the bone is traumatized, tissue

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Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Females with an age range between 15 and 29 y	Systematic diseases
Middle Eastern Caucasian ethnicity	Participants with low facial height
Class II division I of moderate space requirement requiring bilateral maxillary first premolar extractions	Old extraction sites
Average or high facial type assessed using five defining cephalometric yardsticks after meeting at least three of them to reduce possible error; three of them were angles, while two were ratios. Angular measurements were (a) maxillary mandibular plane angle (MMPA) ($\geq$27° $\pm$ 4°)[18,19] and (b) Frankfort mandibular plane angle (FMPA) ($\geq$27° $\pm$ 5°)[6] and (c) Steiner mandibular plan; sella-nasion-gonion-gnathion angle (SN.GoGn) ($\geq$32° $\pm$ 4°)[20], and the ratios were (a) lower anterior facial height/total anterior facial height (LAFH/TAFH) ratio ($\geq$55% $\pm$ 2%)[19,21] and (b) Jarabak ratio ($\leq$62%–65%)[22]	Active periodontal diseases
Good oral hygiene	Evidence of bone loss Smoking

remodeling takes place, increasing the healing process, which results in functional recovery. This is called the Regional Acceleratory Phenomenon (RAP).[11] One of the surgical approaches is piezocision, which involves creating microincisions using a piezotome.[12]

AL can be measured by the distance that the anchorage unit has moved in an unwanted direction.[13] Unlike subjects with average facial height (AFH), subjects with high facial height (HFH) have the most distally tipped maxillary first molars.[14,15] This is highly correlated with AL, as the first molar tends to tip mesially during orthodontic treatment.[16] Additionally, AL was claimed to be greater in HFH subjects because of the lighter occlusion forces and the lack of occlusal interferences.[6]

The purpose of this trial was to investigate CR and AL among AFH and HFH subjects with or without piezocision surgery (PS).

MATERIALS AND METHODS

Trial Design

This was a split-mouth, randomized, double-blinded, parallel-group, 1:1 allocation clinical trial. This design was used as it reduced the sample size and biological variability.[17] The follow-up duration was changed from 4.5 months to 3 months because of the curfew caused by the Coronavirus-19 (COVID-19) pandemic, which made it difficult to follow up with patients at their scheduled times.

Participants and Settings

Ethical approval was obtained from the institutional review board of King Abdullah University Hospital, Jordan University of Science and Technology, Irbid, Jordan (approval No. 4-123-2019). The trial was registered at Clinicaltrials.gov with identifier number NCT04202016. Participants were consecutively recruited between November 2018 and December 2019, with the end of data collection in September 2020, at the Postgraduate Dental Clinics at the Jordan University of Science and Technology, Irbid, Jordan. Written consents were obtained from the participants before the trial, and all inclusion criteria, including five defining cephalometric yardsticks that are summarized in Table 1, as follows: (1) maxillary-mandibular plane angle (MMPA) ($\geq$27° $\pm$ 4°),[18,19] (2) Frankfort-mandibular plane angle (FMPA) ($\geq$27° $\pm$ 5°),[6] (3) sella-nasion-gonion-gnathion angle (SN.GoGn) ($\geq$32° $\pm$ 4°),[20] (4) lower anterior facial height/total anterior facial height (LAFH/TAFH) ratio ($\geq$55% $\pm$ 2%),[19,21] and (5) Jarabak ratio ($\leq$62%–65%).[22]

Sample Size Calculation

Required sample size was calculated using G*power 3.0.10 software with an alpha value of .05 and a power of 95% based on a split-mouth trial.[23] Up to the point when this study was conducted, no study comparing the ROTM in patients with different facial divergence was found, so a study assessing the effect of piezocision on CR and AL was used. It reported an overall amount of CR of 2.9 $\pm$ 0.68 mm in the piezocision group and 1.73 $\pm$ 0.72 mm in the control group.[23] Power analysis showed a minimum sample of 18 maxillary canines required in each group. However, 22 in the HFH and 24 in the AFH groups were initially recruited to account for possible dropouts. A dropout was recorded if the patient discontinued treatment, acquired brackets, involved in space closure, that got debonded and failed to be rebonded, or had a coil spring dislodged and was not replaced during the space closure phase within 24 hours.

Randomization

The piezocision side was randomly assigned using a permuted block size of 2 with a 1:1 allocation ratio to

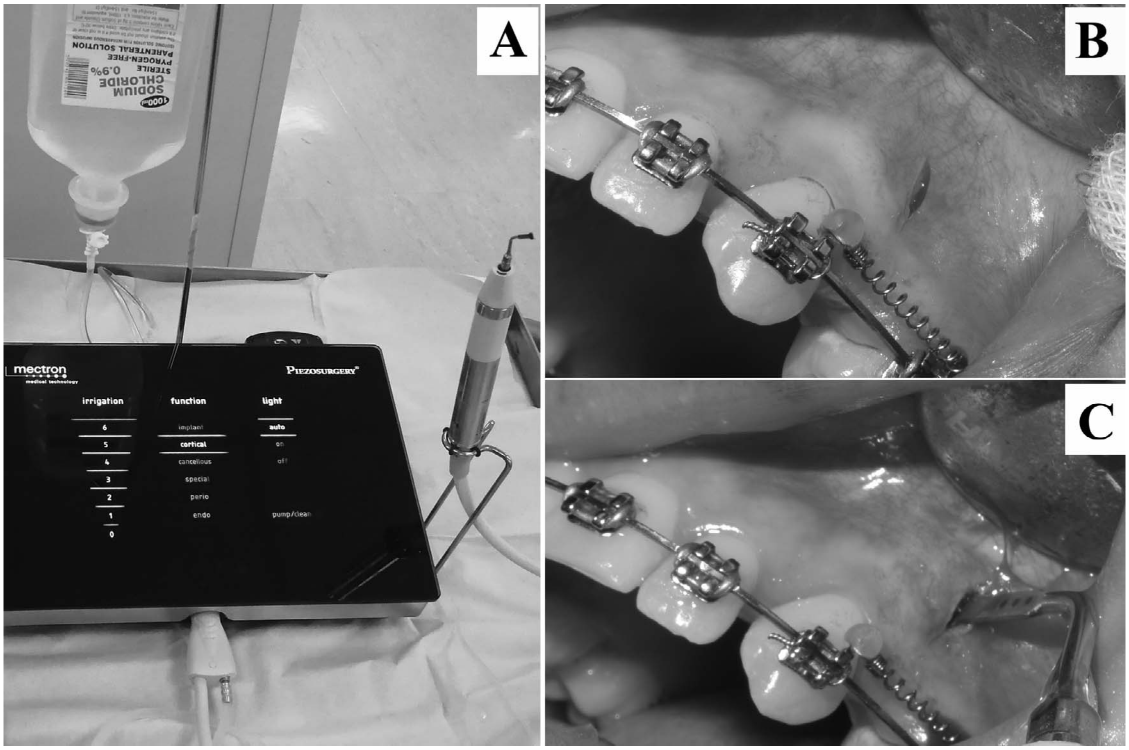

Figure 1. (A) Piezotome unit; (B) vertical incision; and (C) vertical piezocision cut.

either the right or left by preparing two randomized digital lists with "AFH" and "HFH" in the columns. For each list, an equal number of right (R) and left (L) letters were randomly generated. An independent staff member prepared opaque, sealed envelopes to allocate either R or L, accordingly, and then referred the participants to have periapical images of the assigned sites; these images were later provided to the periodontist to perform piezocision.

Blinding

Because of the study's nature, patients could not be blinded. After piezocision, the main researcher (Dr Al-a'athal) was blinded for 6 weeks and, 2 months after finishing the data collection stage, she performed the three-dimensional (3D) analysis on coded digital models. All statistical analyses were performed blindly.

Interventions

Initial orthodontic phase. All participants had upper and lower pre-adjusted fixed appliances (Roth prescription, 0.022 × 0.02 inches; GC LEGEND metal mini-twin brackets). Ten weeks after bonding, when all participants reached the point of acquiring 0.016 × 0.022-inch nickel-titanium (NiTi) archwires, atraumatic extractions were performed in the upper arch only. Following extractions, alignment and leveling of the arches continued until 0.019 × 0.025-inch stainless-steel (SS) archwires were placed.

The canines, which were in different degrees of Class II and had moderate anchorage demands, were ligated with short SS ligatures. One hundred-gram NiTi closing springs (light) were stretched between the upper canines and first molars bilaterally. Piezocision was then performed only once on the intervention side.

Piezocision procedure. Local anesthesia (2% lidocaine with 1:100,000 epinephrine; Septodont, Saint-Maur-des-Fosses, France) was given before the surgery. Only one cut was made using a No.15 surgical blade in the attached gingiva, 2 mm distal to the distal surface of the canine, around its middle third, 3 mm away from the gingival line (Figure 1B). Afterward, piezosurgery was performed through a cut 3 mm in length and 3 mm in depth using a piezosurgery unit (Mectrone; Piezosurgery®touch, Genoa, Italy) and tips (Mectrone; OT7 insert implant and EMS; SL1; Figure 1A,C).

Outcomes

Study models. Starting at the commencement of the space closure phase (Figure 2), each participant had alginate impressions taken at 6-week intervals

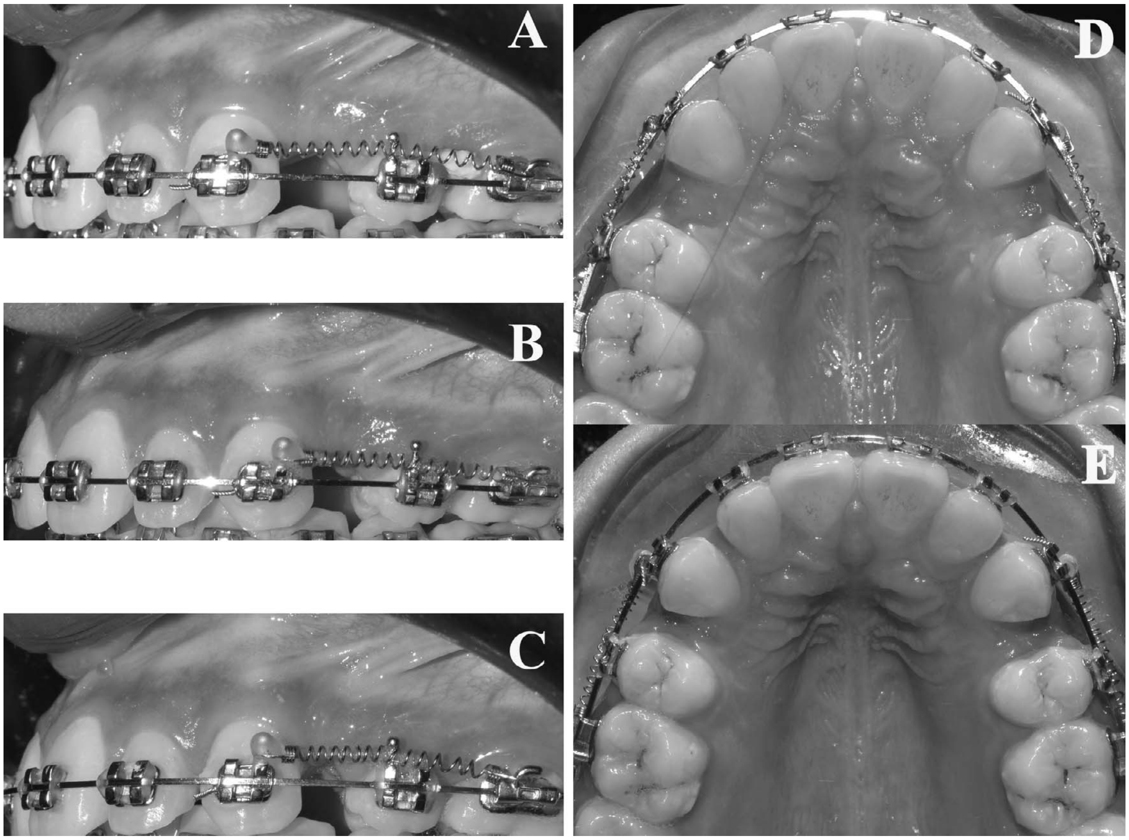

Figure 2. (A) Piezocision side at T0; (B) piezocision side at T1; (C) piezocision side at T2; (D) upper arch at T0; and (E) upper arch at T2.

to fabricate models at the baseline (immediately before space closure commencement; T0), 6 weeks (T1) and 12 weeks (T2) after piezocision. Plaster models were scanned using Ceramill Map 400+ (Amann Girrbach, Kolbach, Austria) to generate digital models.

For CR and AL assessment, 3Shape Ortho analyzer (3Shape Ortho System, 3Shape A/S, Copenhagen, Denmark) software was used to superimpose and analyze the digital models in 3D. This was done using three reliable reference points:[24] two at the medial parts of the third rugae and one at the posterior boundary of the incisive papilla (Figure 3A), and a region of interest (ROI) to maximize the superimposition's accuracy (Figure 3B). Two methods were used to confirm the superimposition quality: color mapping (Figure 3E), with the color white representing a perfect match, and coronal and sagittal cross sections (Figure 3F,G,H). Afterward, 3D analysis (Figure 3I,J) was carried out at the follow-up time points (T0, T1, and T2). The software's digital caliper was used to measure the CR, for which two points were defined at the most prominent parts of the distal surfaces of the canine crowns to establish a line parallel to the archwire in the occlusal and lateral views (Figure 3I,J). AL was assessed using two points at the most prominent parts of the mesial surfaces of the second premolar crowns in the same way described for the CR analysis.

Statistical Methods

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software (version 27.0; IBM, Armonk, NY) and was considered significant when $P \leq .05$. The data were not normally distributed. Therefore, the Mann-Whitney *U*-test for different group outcomes comparison was used. The reliability coefficient (Cronbach alpha) test was used to investigate the reliability of 22 randomly selected superimpositions and reflected excellent repeatability (0.95–0.99).

RESULTS

Participants

Twenty-three females, 12 in the AFH group and 11 in the HFH group, were recruited (flow chart, Figure 4).

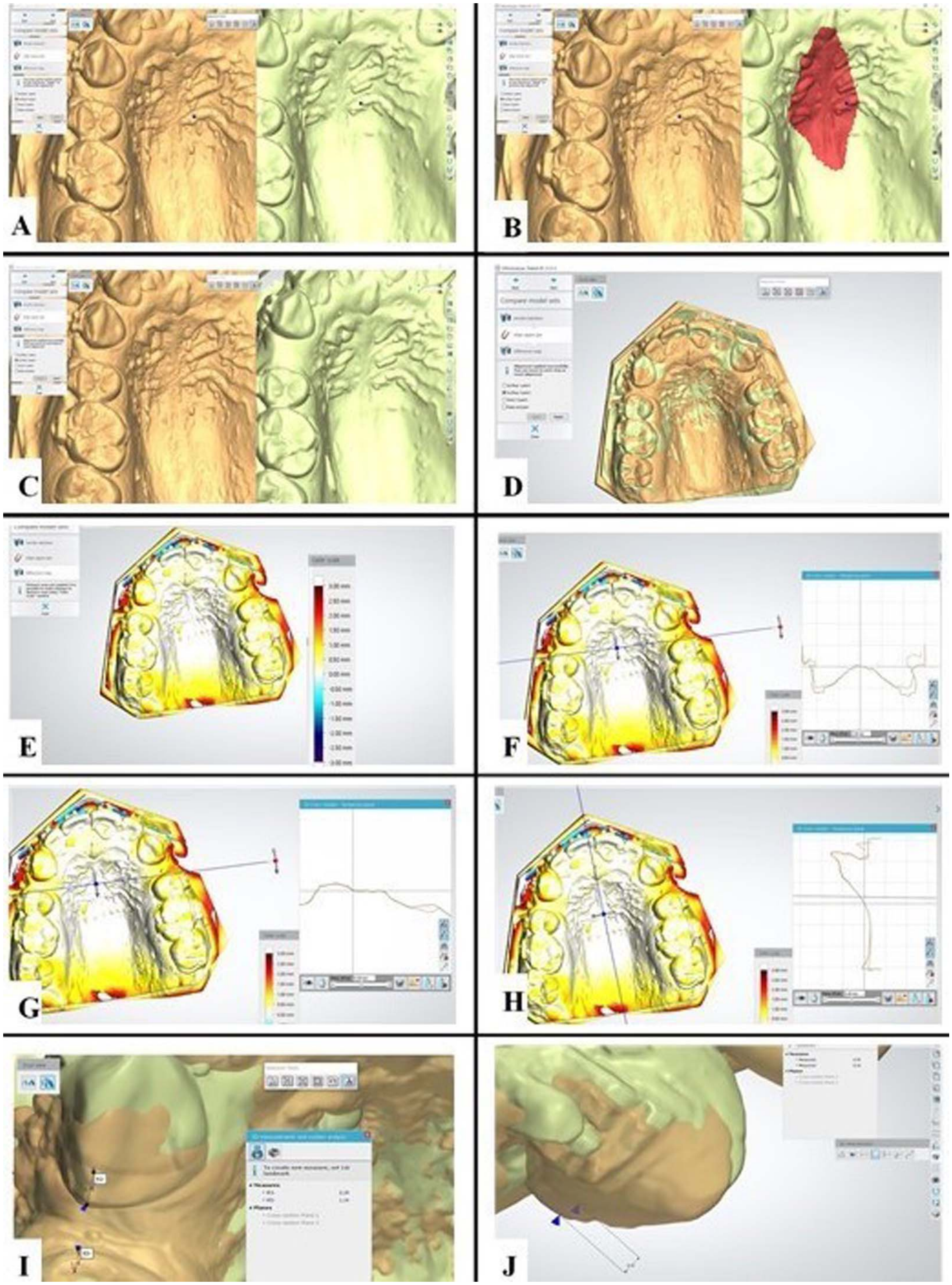

Figure 3. (A) Three reference points at the third rugae area and incisive papilla; (B) region of interest; (C) digital model alignment; (D) digital model superimposition; (E) color map; (F) coronal cross section; (G) closer view of the coronal cross section; (H) sagittal cross section; (I) occlusal view of the measurements; and (J) lateral view of the measurements.

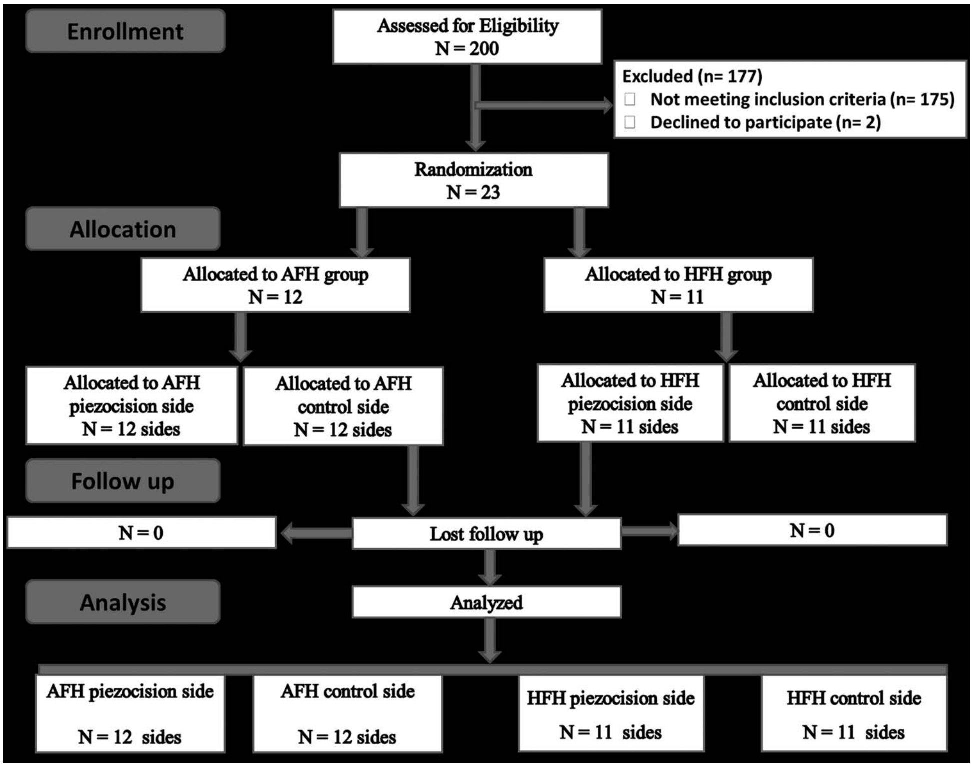

Figure 4. Consort flow diagram showing participant flow in the trial.

Baseline Data

Baseline data (Table 2) show the mean age was 19.05 ± 2.95 years, and there was no statistically significant difference ($P > .05$) between the two groups.

Primary and Secondary Outcomes

The intergroup comparison (AFH and HFH) showed no significant differences. Net movements for CR (T0–T2) in the AFH group were 1.88 ± 0.83 mm and 1.76 ± 0.62 mm while in the HFH group they were 1.48 ± 0.74 mm and 1.40 ± 0.85 mm on the control and intervention sides, respectively (Table 3). There was no significant difference in the rate of AL between groups (Table 4).

Table 2. Baseline Data[a]

Measurements	AFH (Mean ± SD)	HFH (Mean ± SD)	Normal Values
Number of participants	12	11	–
Participant age	18.91 ± 03.02	19.6 ± 2.84	–
SNA, °	79.75 ± 3.22	79.85 ± 4.06	82 ± 3
SNB, °	75.15 ± 2.72	74.74 ± 3.61	79 ± 3
ANB, °	4.63 ± 2.34	5.1 ± 2.20	2–3
UI-MxP, °	118.78 ± 8.25	118.5 ± 5.97	109 ± 6
MMPA, °	23.55 ± 3.5	32.84 ± 5.48	27 ± 4
Jarabak ratio, %	64.38 ± 3.77	58.51 ± 3.21	62–65
FMPA, °	25.35 ± 2.22	32.67 ± 4.11	24 ± 5
LAFH/TAFH, %	56.13 ± 1.91	58.46 ± 1.84	55 ± 2
SN.GoGn, °	33.5 ± 5.24	40.76 ± 5.28	32 ± 4

[a] SNA indicates sella-nasion–A point angle; SNB, sella-nasion–B point angle; ANB, A point–Nasion–B point angle; Ui-MxP, upper incisors to maxillary plane; SD, standard deviation. See Table 1 for additional abbreviations.

DISCUSSION

Interpretation

Cortical bone thickness increases as the facial divergence of subjects decreases.[5] There is anecdotal evidence suggesting that the ROTM is higher in HFH subjects than in LFH subjects. However, retrospective studies[14–16] showed that AL is increased in HFH individuals, which was never investigated.

Younger (≤15-year-old) subjects and male subjects experience higher ROTM.[1,2] Therefore, they were excluded from the current study. Systemic diseases, medications, and active periodontal diseases that could affect ROTM represented exclusion criteria.[25] Because extraction is usually avoided in LFH subjects, they were excluded from the study.[26]

After extractions, a 5-month duration was considered in order to allow time for the RAP effect secondary to extractions (which may last up to 4 months) to wear-off.[27] Despite recommendations for long-term follow-up,[28] the follow-up duration was changed to 3 months

Table 3. Comparison of the Rate of Canine Retraction Between the Average Facial Height and High Facial Height Groups on the Control and Intervention Sides at Different Time Points[a]

Side	Time	Variable	Group	N	Mean, mm	SD, mm	95% CI, mm	Mann-Whitney *P*-Value
Control	T0–T1	Canine retraction	Average	12	1.03	0.41	[−0.29 to 0.49]	.65
			High	11	0.92	0.48	[−0.29 to 0.50]	
	T1–T2	Canine retraction	Average	12	0.71	0.36	[−0.51 to 0.18]	.41
			High	11	0.88	0.44	[−0.51 to 0.19]	
	T0–T2	Canine retraction	Average	12	1.88	0.83	[−0.53 to 0.75]	.93
			High	11	1.76	0.62	[−0.52 to 0.75]	
Intervention	T0–T1	Canine retraction	Average	12	1.00	0.53	[−0.14 to 0.79]	.13
			High	11	0.68	0.54	[−0.14 to 0.79]	
	T1–T2	Canine retraction	Average	12	0.56	0.32	[−0.61 to 0.004]	.07
			High	11	0.86	0.37	[−0.61 to 0.001]	
	T0–T2	Canine retraction	Average	12	1.48	0.74	[−0.61 to 0.77]	1.00
			High	11	1.40	0.85	[−0.61 to 0.77]	

[a] N indicates number of participants; SD, standard deviation; CI, confidence interval; T0, before space closure; T1, 6 wk post–piezocision surgery; T2, 12 wk post–piezocision surgery.
* $P < .05$.

because of the curfew caused by the COVID-19 pandemic. However, the space closure and the RAP effect might be at a maximum during the first 3 months.[27] A 6-week recall interval was chosen as it was found to be the most used among clinicians.[29] An inverse relationship exists between archwire dimension and the degree of tooth tipping during space closure, so all participants underwent space closure with 0.019 × 0.025-inch SS archwire.[30]

Piezocision was chosen to be the intervention as it was found to be effective and safe.[23,31–33] Since a direct relationship between OIIRR and force magnitude exists, particularly when accompanied by piezocision,[34,35] a lower force (100 g) than that commonly used for CR[36] (150 g) was adopted.

Superimposition using the third rugae area's medial parts and posterior to it and the mid-palatal raphe (MPR) was used as it was found to result in the most reproducible, precise, and accurate outcomes.[24] Additionally, defining an ROI that included thousands of points was found to enhance the superimposition quality and, subsequently, the measurement reliability and consistency.[37] This is mainly true because choosing reference points on the rugae area manually[38] creates an error.[39] Color mapping was used in several studies[40,41] to evaluate the accuracy of superimpositions. The 3Shape Ortho analyzer used was found to be excellent in terms of the repeatability of the measurements it afforded.[23] Future studies are needed to evaluate the reliability and validity of color mapping and different 3D software.

This trial showed that facial divergence did not influence the rate of CR and AL.

A recent systematic review and meta-analysis[28] included four split-mouth RCTs[23,31–33] that had the aim of assessing the effect of PS on ROTM and concluded that there was a statistically significant increase in ROTM after PS. Another recent RCT[42] found no significant differences between the piezocision and control sides. The five studies were comparable but

Table 4. Comparison of the Rate of Anchorage Loss Between the Average Facial Height and High Facial Height Groups on the Control and Intervention Sides at Different Time Points[a]

Side	Time	Variable	Group	N	Mean, mm	SD, mm	95% CI, mm	Mann-Whitney *P*-Value
Control	T0–T1	Anchorage loss	Average	12	0.48	0.25	[−0.19 to 0.23]	.92
			High	11	0.45	0.23	[−0.18 to 0.23]	
	T1–T2	Anchorage loss	Average	12	0.59	0.27	[−0.02 to 0.51]	.03*
			High	11	0.32	0.29	[−0.02 to 0.51]	
	T0–T2	Anchorage loss	Average	12	0.93	0.35	[−0.18 to 0.46]	.45
			High	11	0.79	0.38	[−0.18 to 0.46]	
Intervention	T0–T1	Anchorage loss	Average	12	0.44	0.18	[−0.41 to 0.19]	1.00
			High	11	0.54	0.46	[−0.43 to 0.22]	
	T1–T2	Anchorage loss	Average	12	0.47	0.40	[−0.26 to 0.37]	.83
			High	11	0.42	0.31	[−0.25 to 0.37]	
	T0–T2	Anchorage loss	Average	12	0.82	0.34	[−0.48 to 0.26]	.65
			High	11	0.94	0.51	[−0.50 to 0.27]	

[a] N indicates number of participants; SD, standard deviation; CI, confidence interval; T0, before space closure; T1, 6 wk post–piezocision surgery; T2, 12 wk post–piezocision surgery.
* $P < .05$.

differed in certain parameters compared to the current trial.[23,31–33,42] The differences in outcomes between these RCTs and the current study might be attributable to several factors. Among the five studies, two studies did not specify the gender of subjects,[32,42] while the other three had mixed-gender samples, with one study having one growing patient,[23,31,33] which might have affected the ROTM.[1,2] The facial divergence of the samples were not clarified in four studies,[23,32,33,42] while the fifth[31] had subjects of various facial divergence.

The timing of extractions and the duration following extractions before the commencement of space closure were different among previous studies. Two studies had the extractions performed on the day of bonding[31,42] and one study had the extractions performed on the day of piezocision,[32] while two studies did not specify when the extractions were performed in relation to the day of piezocision.[23,33]

Five studies used 150-g force,[23,31–33,42] which is optimal for segmental CR. Nevertheless, 150-g force was found to aggravate OIIRR significantly, predominantly on the piezocision side.[35]

Limitations

This trial included only female patients, which limits generalization of the findings. Alginate impressions were used to fabricate the models because of the unavailability of an intraoral scanner. However, direct intraoral scanning is recommended in any future research, as it is more accurate and time/effort efficient. The follow-up duration was short; thus, studies with long-term evaluation are required.

CONCLUSION

- The rates of CR and AL were not significantly different between the AFH and HFH groups, with and without PS.

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