Buccal bone defects and transversal tooth movement of mandibular lateral segments in patients after orthodontic treatment with and without piezocision: a case control study

Introduction: This study aimed to compare the extent of buccal bone defects (dehiscences and fenestrations) and transversal tooth movement of mandibular lateral segments in patients after orthodontic treatment with and without Piezocision in Cone-beam computed tomography (CBCT) and digital dental models (DDM).

Materials and Methods: The study sample of this study consisted of CBCT scans and digital dental models taken before (T0) and after (T1) orthodontic treatment for 36 patients with moderate lower anterior crowding. The experimental group consisted of 17 patients that had Piezocision performed at the beginning of treatment with the goal of accelerating tooth movement, compared to 19 patients who did not receive Piezocision. The measurement of bone defects, bucco-lingual inclination and transversal distances of the tooth in the mandibular lateral segments (lower canines, premolars, and first molars) were evaluated at baseline and at the end of the orthodontic treatment.

Results: Overall, an increase in dehiscences, buccal inclination and arch width from T0 to T1 was observed in both groups, but no statistically significant difference was found between the groups. Significant increase in fenestrations from T0 to T1 was observed only for the canines in the experimental group. No statistically significant association was found between the increase of dehiscences and the amount of bucco-lingual inclination or transversal width changes. However, the changes in transversal width were statistically significant associated with the increase in buccal inclination at the canines, first and second premolars.

Conclusions: There were no significant differences in buccal dehiscences and transversal tooth movement (bucco-lingual inclination and arch width) of mandibular lateral segments between patients after orthodontic treatment with and without Piezocision.

Key words: Accelerated orthodontics, Piezocision, Dehiscences, Fenestrations, Cone-beam computed tomography, digital dental models.

Introduction

The duration of orthodontic treatment has become one of the most frequent concerns in patients, due to the aesthetic demands of society, that makes them request shorter duration of orthodontic treatment.(1) Thus, accelerating orthodontic tooth movement and reducing treatment time has become one of the main areas of research in orthodontics. Surgical interventions to accelerate the rate of tooth movement aim to accelerate bone remodeling by cutting the cortical layer of alveolar bone in order to induce the regional acceleratory phenomenon (RAP).(2) The RAP is a localized reaction of soft and hard tissues adjacent to the corticotomy, resulting in increased bone remodeling and a temporary decrease in bone density,(3) which along with conventional orthodontic forces allow an increased rate of orthodontic movement.(1)

Piezocision is a minimally invasive procedure combining gingival microincisions followed by minimal piezoelectric osseous cuts to the buccal cortex to accelerate orthodontic tooth movement, and bone or soft-tissue grafting concomitant with a tunnel approach to enhance periodontium if needed.(4) Recently, several publications have evaluated the effectiveness of Piezocision in accelerating orthodontic tooth movement with contradictory results.(5) The relationship between Piezocision and the periodontal health remains unknown. The region where the osteotomy cuts are made with the piezoelectric knife, usually without bone graft, is a susceptible area for bone defects such as dehiscences and fenestrations even prior to orthodontic treatment(6,7) as well as after conventional orthodontic treatment,(8) due to the transverse expansive tendency during the alignment of the arches. Charavet et al(9) reported that dehiscences and fenestrations were similar with or without Piezocision; however, no standardization of the methods to evaluate dehiscences and fenestrations, nor transverse dimensions or changes in bucco-lingual inclination of the mandibular lateral segments were described. Recently, Chandra Raj et al(10) employing CBCT scans in a randomized clinical trial with and without Piezocision, evaluated the marginal crestal bone when retracting canines, they demonstrated that with Piezocision there was a statistically significant gain in bone level in buccal and mesial alveolar bone level.

Little is known regarding the use of Piezocision to accelerate orthodontic tooth movement and how it influences the risk of alveolar bone defects. Furthermore, the Piezocision relationship with the type and amount of transverse tooth movement that occur during orthodontic alignment is still unknown. Specifically, this study compared the extent of buccal bone defects (dehiscences and fenestrations) and transversal tooth movements of mandibular lateral segments in patients before and after orthodontic treatment with and without Piezocision.

Materials and Methods

This study was approved by the Ethics Committee of Universidad CES (Ae-209). Based on the mean values and standard deviation of tooth inclination obtained in the study by Abbas,(11) with an alpha value of 0.05 and a potency of 0.8, a sample size of 15 subjects per group was required. The sample of the present study was secondary data analysis and no CBCT scans and DDM was prescribed for this research.

The study sample consisted of before (T0) and after treatment (T1) CBCT scans and DDM of 36 consecutive patients that were prospectively collected in a previous study. The patient allocation to the groups was done by a randomized draw. The patients were between 18 and 40 years old, with Angle's class I and mild class II or III malocclusion, with moderate lower anterior crowding and healthy periodontium, who underwent orthodontic treatment with passive self-ligating bracket system (Damon SL) for 13.86±5.46 months (control group 14.95±6.023 and experimental group 12.65±4.649). The experimental group consisted of 17 patients who received mandibular Piezocision at the beginning of treatment with the goal of accelerating tooth movement. The surgical procedure was carried out under local anesthesia. Vertical and inter-radicular gingival incisions were performed on the buccal surface of the mandibular arch from the right to the left first molar. The incisions were started 2-3 mm below the interdental papilla and with sufficient depth to the periosteum to allow the scalpel to reach the alveolar bone. Then, through the incision, using a piezoelectric scalpel (piezotome), several bone cuts were performed. One corticotomy per incision was performed for a total of eleven corticotomies per patient. The piezo surgical tip only penetrated the buccal cortex thickness (1-2mm). The Control group consisted of 19 patients who did not receive mandibular Piezocision. The Piezocision group was followed every 2 weeks, and the control group was followed every 4 weeks. Mandibular archwire sequence for both groups were CuNiTi 0.014, CuNiTi 0.018, CuNiTi 0.014x0.025, CuNiTi 0.018x0.025, TMA 0.17x0.25 and stainless steel 0.017x0.025 and were changed only when they were no longer active.

The mandibular CBCT scans were acquired, using the Veraviewepocs 3D R100 (J Morita Corp., Tokyo, Japan) with following the acquisition protocol: FOV 100x80mm; 0.16mm^3 voxel size; 90kVp; 3 to 5 mA and 9.3 seconds. The DDM were acquired with the TRIOS 3D intraoral scanner (3shape, Copenhagen, Denmark; software version: TRIOS 1.3.4.5.) with accuracy of 6.9µm ± 0.9.

Assessment of buccal bone defects

Dehiscences and fenestrations were quantified in T0 and T1 for each tooth in the mandibular lateral segments (lower canines, first and second premolars, and first molars), using 3D Slicer, version 4.10.1 (open source software, https://www.slicer.org), following the method validated by Sun et al:(12)

1. The DICOM files of the CBCT scans were imported into the 3D Slicer software.

2. All measurements were performed in the largest labiolingual section of each tooth (measurement plane), displayed in the sagittal view. The measurement plane of each tooth was located using 3 red, yellow and green guidelines that respectively representing the axial, sagittal, and coronal planes. The axial plane was adjusted by passing the red guideline through the cement enamel junction (CEJ) of each tooth in the coronal and sagittal views. Then, the yellow guideline was rotated until it passed through the widest part of the root canal in the axial view, and the yellow and green guidelines were rotated until they passed through the midpoint of the cusp and the root apex in the coronal and sagittal views respectively.
3. The buccal bone defects were measured using the ruler tool in the 3D Slicer. The mesial and distal roots of the first lower molars were evaluated individually.

   The variables and landmarks were described according to Sun et al:(13)

   a) Dehiscence: alveolar bone defect involving an alveolar margin 2mm or greater and concurrent with a v-shaped bone margin of the alveolar crest.

   b) Fenestration: a circumscribed defect on the alveolar bone exposing the root, not involving the alveolar crest.

   c) Dh: distance between A (CEJ at the buccal side) and B (Alveolar crest at the buccal side).

   d) Fn: distance between C (Coronal border of a fenestration and D (Apical border of a fenestration).

   We also set the critical point for dehiscence and fenestration according to Sun et al:(13) The critical point for dehiscence on the CBCT was set at 2mm and for fenestrations at 2.2mm, meaning that when Dh was greater than 2mm it was classified as dehiscence, and when Fn was greater than 2.2mm it was classified as fenestration. The flow chart of this image analysis procedures is shown in Figure 1.

Assessment of bucco-lingual inclination

Two open-source software, ITK – snap, version 2.4.0 (http://www.itksnap.org), and 3D Slicer, version 4.10.1 (https://www.slicer.org) were used to measure the changes in bucco-lingual inclination of each tooth in the mandibular lateral segments, based on the following procedures:

1. Construction of 3D volumetric label maps (segmentation) of the T0 mandibles from de-identified "gipl.gz" files.
2. From the T0 3D volumetric label maps, T0 3D surface models (CBCT models) were generated for a standardized common orientation, using the transforms tool in slicer software (mandible orientation). Model orientation was achieved by: 2.1 Aligning the lower border of the mandible with the horizontal plane in the sagittal view; 2.2 Aligning the mesial surface of mandibular first molars with the coronal axis; 2.3 Aligning the midline with the sagittal axis. Steps 2.2 and 2.3 were done in the axial view having as reference a standardized fixed coordinate system. The matrix generated from the orientation was applied to the T0 scan and segmentation.

3. Approximation of T0 and T1 CBCT scans was achieved having as a reference the mesial-buccal cusp of the second molars, buccal cusp of the second premolars and the cusp of the canines using the surface registration tool.
4. Voxel-based CBCT registration of T1 CBCT scans in relation to oriented T0 CBCT file was achieved using a nongrowing registration module.(14)
5. Prelabeling: sixteen 3D dots were placed on the oriented (T0) and registered (T1) segmentations. The dots were positioned at the lower canines (midpoint of the cusp and the root apex), first and second premolars (midpoint of the buccal cusp and the root apex), and first molars (a midpoint of the mesio-buccal cusp and central point at the apex of mesial root). After prelabeling, the T0 and T1 mandibular 3D surface models were generated (vtk files).
6. Measurements of the bucco-lingual inclination were made using the "Quantification of 3D Components (Q3DC) tool" in 3D Slicer software. Landmarks were placed following the prelabeled 3D dots made to determine the long axis of each tooth. The flow chart of this image analysis procedures is shown in Figure 2.

Assessment of arch width and Little's Irregularity Index (LII)

The arch width and LII were measured on the DDM using Ortho Insight, version 7.0.7096. The arch width was measured between the occlusal cusp of left and right canines, buccal cusps of first and second premolars, and mesio-buccal cusps of first molars. The LII was calculated by measuring the linear displacement of the anatomic contact points of each mandibular incisor from the adjacent tooth anatomic point. The flow chart of this image analysis procedures is shown in Figure 3.

Statistical Analysis

Prior to performing the measurements of bone defects, two observers were calibrated by a radiologist, who repeated measurements for ten randomly selected CBCT Scans three times with a week interval in between. To assess intra-observer repeatability for inclination and transversal width, repeated measurements for ten CBCT scans and eight DDM were made with an interval of one week. To assess intra-observer repeatability and inter-observer reproducibility, intraclass correlation coefficient (ICC) was used.

Kolmogorov-Smirnov and Shapiro-Wilk tests revealed that the variables of the study did not have normal distribution. For this reason, non-parametric tests were used. Wilcoxon test was used to compare the right and left teeth measurements and the intragroup changes from T0 to T1 (T1-T0). Mann-Whitney test was used to compare the differences at baseline (T0) between the two groups, and the T0 to T1 changes between the two groups. Pearson correlation coefficient was used to assess the association between bucco-lingual inclination with dehiscences; transversal width with dehiscences; and bucco-lingual inclination with transversal width. All statistical analyses were conducted using SPSS Statistics for Mac, version 25.0 (SPSS Inc., Chicago, IL).

Results

All variables had excellent intra-observer repeatability and inter-observer reproducibility. The intra-observer and inter-observer ICCs for bone defects were respectively 0.98 and 0.97. The intra-observer ICCs for inclination and transversal width measurements were 0.96 and 0.99 respectively. The Wilcoxon test showed no statistically significant difference when comparing left and right sides in the mandibular lateral segments, so right and left data were pooled together for subsequent analyses.

At baseline (T0), no statistically significant differences in age, treatment time, LII, cephalometric variables, bone defects, inclination and arch width were found between the two groups; the study variables at T0 are summarized in Table 1. Means and standard deviation values for Dh, Fn, and Arch width at baseline (T0), after treatment (T1) and the changes observed (T1-T0) are summarized in Tables 2 and 3. Means and standard deviations values for Bucco-lingual inclination are summarized in Table 4.

Buccal bone defects

Mandibular buccal Dh increased from T0 to T1 for both groups. In the control group, Dh significantly increased for the canines (mean 1.8±2mm; p= 0.001), first premolars (1.4±1.7mm; p 0.004), and first molars mesial root (0.79±1.08mm; p= 0.001). In the Piezocision group Dh significantly increased for canine (1.84±2.39mm; p 0.002), first premolars (1.14±1.93mm; p 0.039), first molars distal root (0.96±2.52mm; p 0.006), second premolars (0.88±1.1mm; p 0.002), and first molar mesial root (0.53±0.73mm; p 0.003). When comparing the changes T1-T0 for Dh between both groups, no statistically significant difference was found.

In the control group, mandibular Fn were not significantly increased from T0 to T1 for all teeth. In the Piezocision group, mandibular Fn had a statistically significant increase from T0 to T1 in the buccal surface of the canines (p=0.012). When comparing the changes T1-T0 for Fn between both groups, no statistically significant difference was found, except for the canines (p=0.006, Table 2).

Table 3 shows the absolute frequency and percentage of root surfaces with Dehiscences and Fenestrations before and after treatment for both groups. In the control group, the dehiscences increased from 13.16% at T0 to 28.42% at T1. The highest increase was found in the buccal surfaces of the mesial root of the first molars (28.95%), canines (15.79%), and first premolars (15.79%). In the Piezocision group, the dehiscences increased from 8.82% at T0 to 25.88% at T1. The highest percentage of increase in dehiscences was found in the buccal surfaces of canines (23.53%), second premolars (17.65%), and mesial root of first molars (17.65%). In the control group, the fenestrations at baseline were present only in the buccal surface of canines with 2.63% and did not increase at T1. In the Piezocision group, the fenestrations in the buccal surface of premolars decreased from 2.94% at T0 to 0% at T1, and no fenestrations were found in buccal surface of canines and first molars before and after treatment.

Bucco-lingual inclination

Both Control and Piezocision group showed small increases in buccal inclination for canines (2.23±2.5mm, 2.28±2.24mm), first premolars (4.9±2.6mm, 4.9±2.9mm) and second premolars (6.74±2.6mm, 6.8±4.2mm), and first molars (1.16±2.15mm, 0.66±2.19mm). The buccal inclination was greater for the first and second premolars, followed by the canines. The first molars showed less buccal inclination and more body movement. When comparing the changes for inclination between both groups, no statistically significant difference was found. (Table 4)

Arch width

Arch width increased from T0 to T1 for both groups. In the control group the transversal width significantly increased for canines (2.28±1.74mm; *p* 0.000), first premolars (2.53±2.24mm; *p* 0.002), second premolars (2.9±2.49mm; *p* 0.002), and first molars (0.95±2.25mm; *p* 0.006). In the Piezocision group the transversal width significantly increased for canines (1.36±2.13mm; *p* 0.019), first premolars (2.16±1.72mm; *p* 0.001), second premolars (3.19±2.18mm; *p* 0.000), and first molars (1.27±1.26mm; *p* 0.002). When comparing the changes T1-T0 between both groups, no statistically significant difference was found. (Table 2)

No statistically significant association was found between the amount of bucco-lingual inclination and the increase of dehiscences for the two groups (Table 5). Similarly, the changes for transversal width were also not significantly correlated with the increase in dehiscences for both groups (Table 6). However, changes in the transversal width are statistically significant associated with the increase in bucco-lingual inclination observed at the canines, first premolars and second premolars (Table 7).

Discussion

In this study, the measurements of bone defects were performed by two previously calibrated observers, and the intra and inter-observer intraclass coefficients showed respectively excellent repeatability and reproducibility. In recent years, more adult patients are seeking orthodontic treatment. Since alveolar bone defects tend to increase with age, and adult patients are more susceptible to develop dehiscences and fenestrations after orthodontic treatment,(15) this study evaluated the effect of Piezocision on the periodontium of the mandibular lateral buccal segments. Because Piezocision is a surgical procedure designed to help achieve rapid orthodontic tooth movement by a piezoelectric flapless bone injury and a transient demineralization of the alveolar bone,(4) this study investigated whether bone defects, transverse dimensions and bucco-lingual inclination of the mandibular lateral segments were different when we compared orthodontic treatment with and without Piezocision.

The present study found statistically significant increases from T0 to T1 regarding dehiscences at the canines, premolars and molars after accelerated tooth movement with and without Piezocision with the same orthodontic appliance. A very small 0.36mm in average, but statistically significant increase in fenestrations between T0 and T1 was observed for the canines in the experimental group. However, such small changes in fenestrations may not be clinically significant. These results are in conflict with the findings of Charavet et al(9) who evaluated the effect of Piezocision in the periodontium compared to a control group and found no significant increases in dehiscence or fenestration in either group, from baseline to the completion of treatment. In the present study, there were no statistically significant differences between groups when comparing the changes T1-T0 for dehiscences and fenestrations. These results do not agree with the findings of Vercellotti et al(16) who in a dog model, reported that a Piezoelectric knife provided more favorable osseous repair and also bone gain in the treated side. On the other hand, the results of the current study confirm findings in the literature showing that buccal bone thickness in the mandibular lateral segments(17) significantly decrease after orthodontic treatment with self-ligated brackets, showing that the piezocision had no significant influence on changes in the mandibular buccal bone defects.

In our study, both Control and Piezocision groups showed small increases in buccal inclination after treatment. However, no statistically significant difference was found between the groups. These results are consistent with those of Abbas et al,(11) although they evaluated the effect of Piezocision on the inclination after maxillary canine distalization. On the other hand, these findings contradict those reported by Verna et al(18) who concluded, after conducting a finite element study, that surgical interventions may influence not only the amount of tooth movement but also its type. Verna et al(18) suggested that the transitory osteopenia generated by the injury to accelerate tooth movement would allow the shift of the centre of rotation of the movement more apically, favoring larger tooth movement for the corticotomized tooth, especially for the uncontrolled tipping. In the present study, both groups showed smaller than 2.5° average changes in buccal inclination in the canines and first molars, and a larger buccal inclination in premolars, in average approximately 5° in the first premolars and 7° in the second premolars; indicating that, in both groups, the changes in transverse dimension in the canine and molar region were likely due to tooth body movement, and in the premolar region were likely due to tooth tipping movement. Although Verna's study was performed on a finite element model of a central and lateral mandibular incisor, it is the only that evaluate the effect of reduced bone density caused by surgical interventions on the magnitude and type of orthodontic tooth movement. Fu et al(19) conducted a systematic review to evaluate the effect of various types of minimally invasive surgery including piezocision on the plaque index, gingival recession, gingival index, attachment level, and probing depth. They did not find significant difference between the groups. Our study complements those results, as it provides additional clinical information about the safety of the piezocision. As the studies included in the systematic review were highly heterogenous in their approaches and radiographic assessments, the authors concluded that there is only low-quality evidence to prove that flapless corticotomy could accelerate tooth movement. Our present study complements those results, (19) as it provides additional clinical information about the safety of a carefully controlled protocol for piezocision.

This is the first study to assess changes in transverse dimensions in the mandibular lateral buccal segments of patients treated with Piezocision. This study findings revealed that arch width significantly increased for both groups after treatment. However, no statistically significant difference was found between the groups. These results are similar to those of Aksakalli et al(20) who did not find any intercanine maxillary transversal differences between the control and the Piezocision group, when retracting canines after premolar extraction.

A number of studies have indicated that buccal inclination of the posterior teeth is associated with the increase in bone defects such as dehiscences after orthodontic treatment,(21) and that the height of the alveolar ridge can decrease after the transverse expansion during the alignment of the arches, especially in adult patients.(8,15) The present study find a positively association between dehiscences with buccal inclination and transversal width, especially for the first and second premolars; however, these correlations were not statistically significant. We did find a significant correlation between transversal width and buccal inclination at the canines and a highly significant correlation at the first and second premolars, which may indicate that the majority of the arch expansion was achieved by buccal inclination in the premolar region, considering that the last archwire used in the mandible was a 0.017x0.025-in stainless steel and the 0.019x0.025-in stainless steel was not used. This study findings are in conflict with Birnie's review of the literature(22) on self-ligating brackets, who reported that transverse changes during alignment occur through body movement of the buccal lateral segments, with minimum inclination of the premolars. Our findings of a positive association between transversal changes and buccal inclination of the premolars are consistent with Cattaneo et al,(23) although they evaluated the quantity and type of tooth movement of maxillary lateral segments achieved with self-ligating bracket systems, they also showed that the transversal expansion was achieved by buccal tipping in the premolar region.

The CBCT scans in this study allowed the quantitative evaluation of dehiscences and fenestrations in patients, without the need of an invasive procedure such as a flap elevation for a direct assessment. Although the radiation exposure for conventional radiographs is lower than for the CBCT scans, its resolution does not provide the precise reproduction of the periodontium anatomical details.(24) Furthermore, CBCT have shown an acceptable diagnostic value for detecting alveolar bone dehiscences and fenestrations with also acceptable sensitivity and specificity.(12,13) However, the concerns of increased radiation dose with the use of CBCT have been discussed in different guidelines to orient clinicians how to prescribe CBCT exams.(25,26) It is important to highlight that the CBCT used for the analysis were not acquired for the purpose of the present study. The available scans had been acquired adjusting parameters to reduce ionizing radiation effects following the ALADA principles.(27)

Considering that Wilcko et al(28) showed in CBCT Scans of two patients who received surgically accelerated orthodontic treatment without bone grafting, that after two years of retention there appears to be a recovery of the alveolar bone comparable to the pretreatment, further research is needed to evaluate the long-term effect of the orthodontic treatment with piezocision on the buccal bone surface.

Conclusions

- In general, there were no significant differences in buccal dehiscences and transversal tooth movement (bucco-lingual inclination and arch width) of mandibular lateral segments between patients after orthodontic treatment with and without Piezocision.
- There were no significant correlations between the amount of bucco-lingual inclination and dehiscences. There were no significant correlations between the transversal width changes and dehiscences.
- The changes in the transversal width are statistically significantly associated with the increase in buccal inclination at the canines, first and second premolars.

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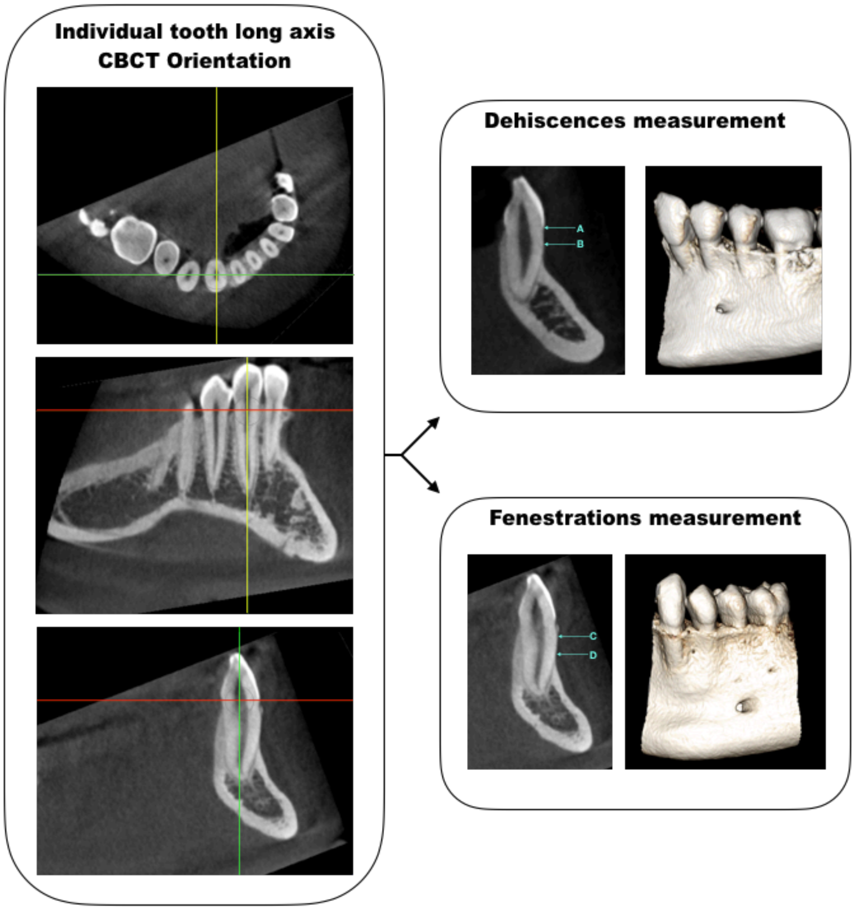

Figure 1. Flow chart: Assessment of buccal bone defects.

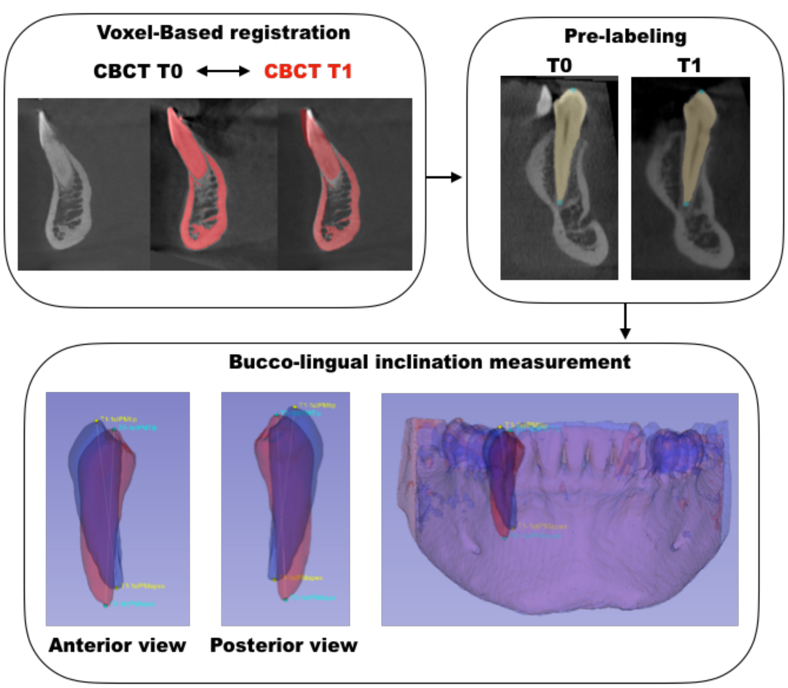

Figure 2. Flow chart: Assessment of bucco-lingual inclination.

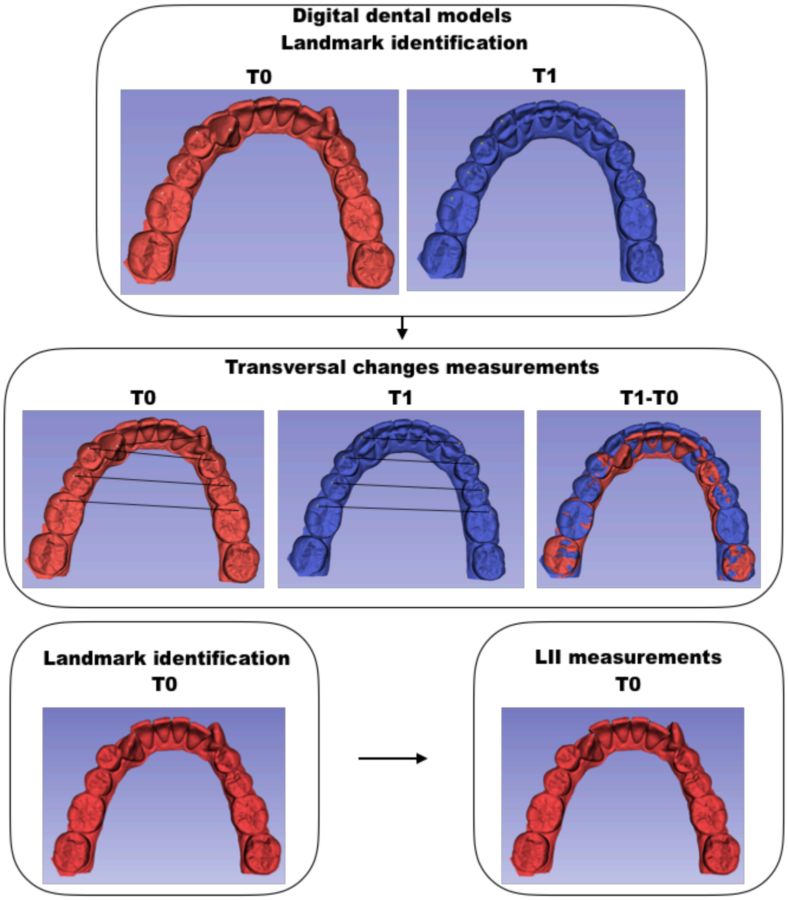

Figure 3. Assessment of arch width and Little's Irregularity Index (LII)

Table I. Statistical comparison for age, Little's Irregularity Index (LII), Treatment time and variables for Group 1 (control) and Group 2 (Piezocision) at baseline (T0). SD: standard deviation

Variables	Group 1 (n=19)		Group 2 (n=17)		Mann-Whitney test
	Mean	SD	Mean	SD	*p- value*
Age (years)	23.84	4.02	25.65	6.93	0.644
LII (mm)	10.68	3.15	9.64	1.51	0.516
Treatment time (months)	14.95	6.023	12.65	4.649	0.176
ANB (º)	4.09	2.46	3.95	2.49	0.775
Wits Appraisal (mm)	1.86	3.14	2.09	2.57	0.634
PM-FH (º)	19.29	5.27	18.71	5.03	1
Gonial angle (º)	115.88	6.45	117.38	7.33	0.274
U1-PP (º)	114.38	7.15	112.4	6.68	0.383
L1-MP (º)	101.33	5.92	99.84	8.01	0.579
Overjet (mm)	3.27	1.23	3.25	1.54	0.937
Overbite (mm)	2.44	1.25	3.11	1.99	0.318
Molar relation (mm)	-0.82	2.18	-0.55	1.55	0.210
Dh (mm) Canine	2.2	1.41	1.56	0.83	0.199
Dh (mm) First premolar	2.39	1.03	2.18	0.88	0.623
Dh (mm) Second premolar	1.73	0.702	1.43	0.525	0.358
Dh (mm) First molar mesial root	1.39	0.414	1.279	0.59	0.326
Dh (mm) First molar distal root	1.54	0.69	1.41	0.43	0.601
Fn (mm) Canine	0.128	0.558	0.219	0.432	0.147
Fn (mm) First premolar	0	0	0.28	0.714	0.06
Fn (mm) Second premolar	0	0	0.286	1.01	0.129
Fn (mm) First molar mesial root	0	0	0	0	1
Fn (mm) 1st molar distal root	0	0	0	0	1
3-3 width (mm)	25.29	2.16	25.88	2.98	0.35
4-4 width (mm)	32.8	2.08	33.4	3.1	0.35
5-5 width (mm)	38.21	2.33	38.44	4.02	0.987
6-6 width (mm)	44.48	2.26	44.93	3.18	0.476

Table II. Treatment outcome comparison of Dh, Fn, and Width in the mandibular lateral segments at baseline (T0), after treatment (T1), and the difference by time (T1-T0) for Groups 1 (control) and 2 (Piezocision). CI: confidence interval, SD: standard deviation

Variables (mm)	Group 1 (n=19)									Group 2 (n=17)									T1-T0 Group 1 vs 2
	T0		T1		T1-T0		95% CI		Wilcoxon test	T0		T1		T1-T0		95% CI		Wilcoxon test	Mann-Whitney test
	Mean	SD	Mean	SD	Mean	SD	Lower	Upper	*p- value*	Mean	SD	Mean	SD	Mean	SD	Lower	Upper	*p- value*	*p- value*
Dh Canine	2.2	1.41	4	2.13	1.8	2	0.84	2.77	0.001	1.56	0.83	3.41	2.47	1.84	2.39	0.612	3.07	0.002	0.716
Dh First premolar	2.39	1.03	3.79	1.816	1.4	1.7	0.58	2.23	0.004	2.18	0.88	3.32	1.69	1.14	1.93	0.15	2.13	0.039	0.438
Dh Second premolar	1.73	0.702	2.39	1.41	0.66	1.39	-0.01	1.33	0.053	1.43	0.525	2.32	1.15	0.88	1.1	0.32	1.46	0.002	0.274
Dh First molar mesial root	1.39	0.414	2.19	1.03	0.79	1.08	0.27	1.32	0.001	1.279	0.59	1.81	0.79	0.53	0.73	0.15	0.91	0.003	0.366
Dh First molar distal root	1.54	0.69	1.75	0.66	0.21	0.69	-0.12	0.55	0.295	1.41	0.43	2.38	2.59	0.96	2.52	-0.33	2.26	0.006	0.178
Fn Canine	0.128	0.558	0.285	1.026	0.16	1.08	-0.37	0.55	0.655	0.219	0.432	0.58	0.72	0.36	0.49	0.11	0.618	0.012	0.006
Fn First premolar	0	0	0	0	0	0	0	0	n.a	0.28	0.714	0.1	0.28	-0.18	0.76	-0.57	0.21	0.465	n.a
Fn Second premolar	0	0	0	0	0	0	0	0	n.a	0.286	1.01	0.12	0.36	-0.17	1.05	-0.71	0.37	1	n.a
Fn First molar mesial root	0	0	0	0	0	0	0	0	n.a	0	0	0.27	0.66	0.27	0.65	-0.07	0.61	0.109	n.a
Fn First molar distal root	0	0	0	0	0	0	0	0	n.a	0	0	0.99	0.28	0.09	0.28	-0.05	0.24	0.18	n.a
3-3 width	25.29	2.16	27.57	1.23	2.28	1.74	1.45	3.12	0.000	25.88	2.98	27.25	1.519	1.36	2.13	0.27	2.46	0.019	0.35
4-4 width	32.8	2.08	35.33	1.35	2.53	2.24	1.45	3.61	0.002	33.4	3.1	35.5	1.88	2.16	1.72	1.27	3.05	0.001	0.35
5-5 width	38.21	2.33	41.13	1.38	2.9	2.49	1.72	4.12	0.002	38.44	4.02	41.63	2.25	3.19	2.18	2.08	4.32	0	0.987
6-6 width	44.48	2.26	45.43	2.05	0.95	2.25	-0.14	2.03	0.006	44.93	3.18	46.2	2.5	1.27	1.26	0.62	1.92	0.002	0.476

Table III. Absolute Frequency and Percentage of Dehiscences (Dh>2mm) and Fenestrations (Fn>2.2mm) Before and After Treatment

Teeth	Group 1 (n=19)												Group 2 (n=17)											
	Total n	Dehiscences					Fenestrations						Total n	Dehiscences					Fenestrations					
		T0		T1		T1-T0	T0		T1		T1-T0			T0		T1		T1-T0	T0		T1		T1-T0
		n	%	n	%	%	n	%	n	%	%			n	%	n	%	%	n	%	n	%	%
Canine	38	7	18,42%	13	34,21%	15,79%	1	2,63%	1	2,63%	0,00%		34	3	8,82%	11	32,35%	23,53%	0	0,00%	0	0,00%	0,00%
First premolar	38	9	23,68%	15	39,47%	15,79%	0	0%	0	0%	0%		34	8	23,53%	13	38,24%	14,71%	1	2,94%	0	0,00%	-3%
Second premolar	38	5	13,16%	8	21,05%	7,89%	0	0%	0	0%	0%		34	2	5,88%	8	23,53%	17,65%	2	5,88%	0	0,00%	-6%
First molar mesial root	38	1	2,63%	12	31,58%	28,95%	0	0%	0	0%	0%		34	1	2,94%	7	20,59%	17,65%	0	0,00%	0	0,00%	0,00%
First molar distal root	38	3	7,89%	6	15,79%	7,89%	0	0%	0	0%	0%		34	1	2,94%	5	14,71%	11,76%	0	0,00%	0	0,00%	0,00%
Total	190	25	13,16%	54	28,42%	15,26%	1	0,53%	1	0,53%	0,00%		170	15	8,82%	44	25,88%	17,06%	3	1,76%	0	0,00%	-1,76%

Table IV. Treatment outcome comparison of each tooth inclination in the mandibular lateral segments between Groups 1 (control) and 2 (Piezocision). CI: confidence interval, SD: standard deviation

Inclination (°)	Group 1 (n=19)		Group 2 (n=17)		T1-T0 Group 1 vs 2
	T1-T0		T1-T0		Mann-Whitney test
	Mean	SD	Mean	SD	*p- value*
Canine	2.23	2.5	2.8	2.24	0.247
First premolar	4.9	2.6	4.9	2.9	0.862
Second premolar	6.74	2.6	6.8	4.2	0.887
First molar	1.16	2.15	0.66	2.19	0.912

Table V. Pearson correlation coefficient between Bucco-lingual inclination and Dh for the two groups.

Variables	Pearson Correlation	*p- value*
Canine	-0.139	0.429
First premolar	0.114	0.508
Second premolar	0.263	0.121
First molar	0.076	0.66

*Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level

Table VI. Pearson correlation coefficient between Transversal width and Dh for the two groups.

Variables	Pearson Correlation	*p- value*
Canine	0.086	0.616
First premolar	0.279	0.1
Second premolar	0.286	0.91
First molar	-0.136	0.429

*Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level

Table VII. Pearson correlation coefficient between Transversal width and Bucco-lingual inclination for the two groups.

Variables	Pearson Correlation	*p- value*
Canine	0.382	0.021*
First premolar	0.488	0.003**
Second premolar	0.488	0.003**
First molar	0.298	0.077

*Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level