ALVEOLAR BONE DIMENSIONAL CHANGES AND BUCCOLINGUAL INCLINATION OF LOWER INCISORS AFTER SURGICALLY ACCELERATED ORTHODONTICS

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ABSTRACT

Objective: To evaluate the dimensional changes in height and thickness at the alveolar bone and delimitating the buccolingual inclination of the lower incisors, before and after the accelerated orthodontics with a modified piezocision protocol.

Materials and Methods: In this retrospective study, 37 subjects with Angle malocclusion class I, II or III, mild crowding and a thin periodontium at level of lower incisors were divided randomly into 4 treatment groups: group 1 control; group 2 lower piezocision; group 3 lower piezocision and soft tissue graft; group 4 lower soft tissue graft. In Cone beam computed tomography (CBCT) T0 before and T1 after treatment, 148 lower incisors were assessed in buccolingual inclination, alveolar bone height and thickness.

Results: There was proclination of lower incisors after treatment except in group 3 (−4.7º ± 13.6º). Buccal and lingual alveolar ridge decreased vertically in all the groups, but group 3 showed less lingual decrease (0.9 mm ±1.9). All the groups showed a decrease in buccal and lingual alveolar thickness but group 3 showed less change thickness (−0.2 mm ± 0.7).

Conclusion: In cases of mild to moderate crowding with decreased periodontal biotype a negative torque in lower incisors with orthodontic light forces, wide arch wires, and low friction that allow to solve crowding through transversal development, reasonable IPR, minimal proclination of incisors, and periodontal phenotypic protection are recommended.

Key words: Alveolar bone thickness and height; Orthodontics; Surgical acceleration; Lower incisor inclination.

INTRODUCTION

Lower incisors are often considered more vulnerable to undesirable changes during orthodontic treatment in the context of a thin biotype. They could be more susceptible to mucogingival defects and periodontal attachment loss if proclination or retroclination movements exceed the alveolar cortical limits, compromising the thickness and height of the alveolar bone. [1] In general terms, for every millimeter of crowding resolution there are four degrees of lower incisors inclination.[2] This proclination could be further magnified in orthodontic accelerated treatment protocols in patients with a periodontal thin biotype. Therefore, the relationship between roots within the alveolar bone is a critical issue in periodontal tissue behavior that requires clinical awareness for optimal long-term stability and treatment success. [3] Hence, adequate diagnosis, treatment planning, and optimal mechanics in orthodontics are imperative.

In today's practice, surgical accelerated treatment protocols are becoming more popular among practitioners. Corticotomy or piezosurgery have been implemented by generating transient osteopenia, facilitating dental movement and the resolution of crowding [4,5.] Within this context, soft tissue grafts have been suggested for periodontal regenerative purposes to compensate for patients with a more vulnerable periodontal biotype. The use of a bilayer porcine-derived collagen matrix is a known soft tissue graft alternative shown to reduce surgical morbidity and represents an optimal alternative to autogenous sources. Despite the popularity of this clinical alternative, our understanding about its effect in the periodontal anatomy is limited. Furthermore, acceleration techniques combined with soft tissue graft have not been reported quantitatively and it is important to evaluate the alveolar bone dimensional changes after these procedures. This includes the evaluation of crowding severity and the resulting changes in root inclination of the incisors within the alveolar bone [6–8.]

While it is clinically desirable to find a treatment protocol to protect the periodontium and make it more time-efficient for patients, the safety and efficacy remains partially unanswered. Therefore, the aim of this study was to evaluate the dimensional changes in height and thickness at the alveolar bone and the buccolingual inclination of the lower incisors after accelerated orthodontics with piezocision and/or a soft tissue graft.

MATERIALS AND METHODS

This study was nested in a randomized, controlled clinical trial (NCT02866929:) reviewed and approved by a Research Ethics Committee. A sample of 40 subjects was reviewed (29 men, 11 women, aged between 18 and 40) who presented mild class I, II, or III malocclusion with grade II or III Little's Irregularity Index, healthy periodontium and 2 mm or less of gingiva in the anteroinferior region, and those patients with presence of gingival recessions in lower incisors. These patients had passive self-ligating Damon Q, Ormco, Monrovia, CA, low torque. Three subjects were excluded: one for presenting artifacts in the CBCT, one for absence of a lower incisor, and the third one for receiving extractions during the treatment; thus, 37 patients were determined as a unit of analysis and allocated into four groups in which 148 incisors were the unit of observation in two moments of time (T0 before treatment-T1 after treatment). Each group was characterized as follows: group 1 or control included 8 subjects with orthodontics; experimental group 2 included 9 subjects with orthodontics, upper and lower piezocision; experimental group 3 included 10 subjects with orthodontics, upper and lower piezocision with anteroinferior soft tissue graft; experimental group 4, comprised 10 subjects with orthodontics, upper piezocision with anteroinferior soft tissue graft.

- **Periodontal accelerated orthodontics protocol**

The study used a slightly modified technique to the piezocision protocol described by Dibart [9], in addition to the use of a porcine collagen matrix (Geistlich Mucograft®).

- **Data collection**

In stereolithographic models: With the software Ortho insight 3D, the amount of crowding was calculated according to Little's Irregularity Index [10.] The quantity of interproximal enamel reduction (IPR) was calculated by measuring the mesiodistal widths of the four lower incisors and canines before and after treatment, considering the difference between both as the amount of IPR performed. Changes of the mandibular transversal width were measure between cusps of lower canines, buccal cusps of the first and second lower premolars, and finally from the buccal and medial cusps of the lower first molars before and after treatment [11.]

In cephalic X-rays, the incisors mandibular plane angle (IMPA) and the mandibular rotation pattern (gonial angle) before and after orthodontics was evaluated. The CBCT were taken with the equipment J Morita R100, Kyoto, Japan using I-Dixel software.

Every method was subjected to calibration. Two measurements of 10 subjects were made one week apart from each other by the same operator. Therefore, the reliability of every method and measurement was ensured and statistically validated (Table 1)

- **Measurement of buccolingual inclination of lower incisors with CBCT**

The segmented CBCTs were analyzed in an axial section using the Simpleware Scan IP version 6.0 (Synopsys, Mountain View, USA). The buccolingual inclination of the lower incisor was measured by calculating the angle between a stable plane called foraminal and a plane defined by the longitudinal axis of the incisors called pulpar plane. The foraminal plane was defined by three points: the first point at the right mental foramen (FR, Figure 1A), the second point at the left mental foramen (FL, Figure 1B) and the third point on symphysis (Me, Figure 1C). To define the pulpar plane, the set of CBCT images were rotated by an angle defined between the midpoint of the lingual surface of the tooth (LMP, Figure 2A) and the midpoint of the buccal surface of the tooth (BMP, Figure 2A) in a coronal view. This orientation produced a transversal view in which another rotation was performed by an angle defined between the midpoint of the apex (AMP, Figure 2B) and the midpoint of the upper most coronal surface (CMP, Figure 2B). In this way a sagittal view was obtained and the longitudinal axis of the tooth was defined by the highest point of the pulp chamber (UPP, Figure 2C) and the lowest point of the pulpar canal (LPP, Figure 2C). Finally, the pulpar plane was defined by the longitudinal axis (UPP-LPP, Figure 2C) and a second axis normal to the sagittal plane as defined by the points LPP-OLPP (Figure 2C). Normal vectors to foraminal and pulpar plane were defined and the angle between them provided the buccolingual inclination of each incisor. Additionally, a sagittal image of each incisor was obtained with the CREO 4.0 program to measure the height and thickness of the alveolar bone of each incisor on its buccal and lingual surface (Figure 3), using methods reported in other studies as a reference. [8, 12, 13]

- **Measurement of dimensional changes of alveolar bone in lower incisors with CBCT (Figure 3)**

Bone height at the buccal and lingual alveolar ridge (ACB-ACL): the image of each incisor was scaled for each patient. The pulpar axis line, (PA) and the line perpendicular to the pulpar axis passing through the cementoenamel junction (CEJ) were drawn together as parallel lines that passed through the buccal lingual alveolar ridge. Then the height of the alveolar crest was determined by measuring the distance between the CEJ and each alveolar crest of each tooth.

Bone thickness of the buccal and lingual alveolar bone: contours of cortical bone and root were plotted in a sagittal view for each tooth and then parallel lines were drawn every 0.5 mm from the highest alveolar ridge to the root apex, intersecting root and cortical contours on both buccal and lingual surface and forming two sets of lines that define the alveolar buccal and lingual thickness (BAT-LAT). The length of each line in the set was measured and averaged per tooth before and after treatment. As result, the difference between the averaged lengths (T1-T0) states the quantity of the change in thickness of the alveolar bone.

- **Statistical analysis**

A Shapiro Wilks test were carried out to establish the distribution of the data (Table 2). Most of the variables measured did not distribute normal, except IMPA and gonial angle (Table 3). Consequently, a Wilcoxon signed rank test to paired data was used for intragroup comparisons of each incisor at two moments of time (table 4). Finally, an ANOVA of Kruskall Wallis was used to find differences between the groups for each variable and incisor at two moments of time (Table 5). The estimated significance value was $p < 0.05$.

RESULTS

Of the 37 patients included in the study, 73% were men of 25.4 years old on average and had a Little's Irregularity Index grade III (6.59 mm). An IPR of 1.15 mm ± 0.87 and a significant transversal development also happened in the premolars region after treatment. The gonial angle remained the same with a counter-clockwise rotation. (Tables 2, 3, 4, 5).

In group 1, subjects were 23.9 years of age on average with a Little's Irregularity Index of 6.62 mm and a total IPR of 0.9 mm. This group showed a transversal augmentation of 10.5 mm at the end of treatment, the IMPA measurement showed a proclination of 4.18º ± 3.95º and in CBCT of 3.1º ±10.1. Regarding the dimensional changes of alveolar bone, a statistically significant buccal thickness decrease of −0.5 mm ± 0.4 mm as well as a lingual thickness of −0.3 mm± 0.4 mm were demonstrated, while the distance between CEJ to the buccal and lingual alveolar ridge showed an increase of 4.4 mm and 2.2 mm respectively, being statistically significant at buccal level and indicating a reduction of alveolar bone height (Tables 3, 4, 5).

In group 2, subjects had an average age of 21.3 years with a Little's Irregularity Index of 6.42 mm and a total IPR of 1.1 mm. A transversal expansion of 7.7 mm and an increase of the IMPA of 6.83º

± 7.02 and in CBCT of 4.1º ± 7.8. Regarding the dimensional changes of the alveolar bone, a decrease in buccal thickness of −0.1 mm ± 0.9. Lingual thickness also showed a statistically significant decrease of −0.5 mm ± 0.8 and the distance between CEJ to the alveolar buccal and lingual ridge showed an increase of 3.5 mm and 1.2 mm respectively, being statistically significant and indicating a clear loss of alveolar buccal bone height (Tables 3, 4, 5).

In group 3, subjects had an average age of 30 years with a Little's Irregularity Index of 5.77 mm and a total IPR of 1.2 mm. Also, this group had a transversal improvement of 7 mm with a lingualization of lower incisors of −0.53º ± 5.33º by IMPA and by CBCT of −4.7º ±13.6º. Regarding the dimensional changes of the alveolar bone, a decrease in the buccal thickness of −0.3 mm ± 0.5 mm was demonstrated, taking into count that thickness of the right lateral incisor did not change and lingual thickness bone showed a reduction of −0.2 mm ± 0.7 mm. Thus, the distance of the CEJ to the buccal and lingual alveolar ridge increased 3.2 mm and 0.9 mm respectively and was statistically significant, which means that it was a loss in alveolar bone height (Tables 3,4,5).

In group 4, subjects had an average age of 25.7 years with a Little's Irregularity Index of 7.55 mm and a total IPR of 1.4 mm. Also, the results showed a transversal development of 9 mm and a proclination of lower incisors of 2.44º ±4.7 by IMPA and 0.5º ± 9.2 by CBCT. Regarding the dimensional changes of the alveolar bone, a decrease in the buccal thickness of −0.2 mm ± 0.7 and in lingual thickness of −0.6 mm ± 0.8 was seen; however, it is important to notice that buccal thickness of the left central incisor remained the same. In addition to this, the distance between the CEJ to buccal and lingual alveolar ridge showed a statistically significant increase of 2.5 mm and 2.4 mm respectively, which was interpreted as a reduction in height of the buccal and lingual alveolar bone (Tables 3,4,5).

Finally, the changes evaluated for each variable between the groups were not statistically significant.

DISCUSSION

The IMPA is influenced by functional and developmental factors. In Caucasians, the average inclination has been reported to be 93 degrees. [2] In skeletal class II malocclusion patients, a reduced bone thickness is associated with a vertical growth pattern and incisor proclination, while the effect in class III favors retroclination [14,15.]

Within the scope of our study, the hypodivergent rotation pattern and lower anterior incisors showed normal values before orthodontics treatment, except in group 4. At the end of treatment, the pattern of mandibular rotation did not change indicating that this variable did not influence the inclination. Every group showed a statistically significant transversal development and minimal IPR. In addition, the three experimental groups that included surgical intervention showed a contrasting behavior in the buccal and lingual bone thickness as the changes were lower in comparison with the control group. This draws the attention to group 3 in which only minimal loss of both the buccal and lingual bone plate was observed. In this group, the lingual and buccal alveolar ridge also showed minimal height loss with respect to the other three groups. These observations are related to the alveolar bone changes showed by Wilcko after 2 and 11 years after corticotomy interventions. They didn't find bone increase at the beginning, but it was recovered and increased after retention, showing an improvement in alveolar bone thickness.[16]

The orthodontic protocol and prescription followed in this cohort of patients provided a resolution of crowding with a transversal arch expansion and the control of inclination on lower incisors, avoiding the need for extractions and reducing the risk of periodontal defects. [17–19]

A statistically significant incisor proclination was observed in groups 1 and 2. In contrast, groups 3 and 4 showed a controlled behavior in inclination. Both groups had in common the surgical application of a soft tissue graft. This is an important aspect to be considered in cases of mild or moderate crowding with decreased periodontal biotype. While more prospective or randomized studies are needed to clarify to what extent the incisor proclination should be considered a risk factor for periodontal health, [20] considering the long-term implication of having a thicker biotype makes these aspects relevant to support a more desirable outcome to guarantee successful long-term treatment results, as described by Cook et al. in their in vivo study. [21]

These results suggest that for the group of patients treated in this study, adding a porcine collagen matrix in combination with the use of piezocision and an orthodontic prescription of low torque could potentiate not only the molecular reaction during orthodontic forces, but also reinforce periodontal tissue as has been demonstrated in the literature. [22]

CONCLUSION

In cases of mild to moderate crowding with decreased periodontal biotype, the orthodontic therapeutic protocol should consider: negative torque in lower incisors with orthodontic light forces, wide arch wires, and low friction that allow to solve crowding through transversal development, reasonable IPR, minimal proclination of incisors, and periodontal phenotypic protection with a soft tissue graft.

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REFERENCES

1. Hernández-Sayago E, Espinar-Escalona E, Barrera-Mora JM, Ruiz-Navarro MB, Llamas-Carreras JM, Solano-Reina E. Lower incisor position in different malocclusions and facial patterns. Med Oral Patol Oral Cir Bucal. 2013;18(2):e 343-350.
2. Miethke RR, Behm-Menthel A. Correlations between lower incisor crowding and lower incisor position and lateral craniofacial morphology. Am J Orthod Dentofacial Orthop 1988;94(3): 231–9.
3. Evangelista K, Vasconcelos K de F, Bumann A, Hirsch E, Nitka M, Silva MAG. Dehiscence and fenestration in patients with Class I and Class II Division 1 malocclusion assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2010;138(2):133-7
4. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. Angle Orthod. 1996;66(2):95-109-110.
5. Qu X, Liu Z, Wang Y, Fang Y, Du M, He H. Dentofacial traits in association with lower incisor alveolar cancellous bone thickness: A multiple regression analysis. Angle Orthod. 2017; 87(3):409-415.
6. Ahn HW, Seo DH, Kim SH, Park YG, Chung KR, Nelson G. Morphologic evaluation of dentoalveolar structures of mandibular anterior teeth during augmented corticotomy-assisted decompensation. Am J Orthod Dentofacial Orthop 2016;150(4):659–69.
7. Coscia G, Coscia V, Peluso V, Addabbo F. Augmented corticotomy combined with accelerated orthodontic forces in class III orthognathic patients: morphologic aspects of the mandibular anterior ridge with cone-beam computed tomography. J Oral Maxillofac Surg 2013;71(10): 1760.e1-9.
8. Wang B, Shen G, Fang B, Yu H, Wu Y. Augmented corticotomy-assisted presurgical orthodontics of class III malocclusions: a cephalometric and cone-beam computed tomography study. J Craniofac Surg. 2013;24(6):1886–90.

9. Dibart S, Sebaoun JD, Surmenian J. Piezocision: a minimally invasive, periodontally accelerated orthodontic tooth movement procedure. Compend Contin Educ Dent 2009;30(6):342–4, 346, 348–50.

10. Little RM. The Irregularity Index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975; 68:554-63

11. Oz AA, Oz AZ, Yazicioоğlu S, Arici N, Ozer M, Arici S. Comparison of arch width changes following orthodontic treatment with and without extraction using three-dimensional models. Niger J Clin Pract. 2017;20(5):581–6.

12. Lee KM, Kim YI, Park SB, Son WS. Alveolar bone loss around lower incisors during surgical orthodontic treatment in mandibular prognathism. Angle Orthod. 2012;82(4): 637–44.

13. Tong H, Enciso R, Van Elslande D, Major PW, Sameshima GT. Techno bytes: A new method to measure mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric cone-beam computed tomography images. Am J Orthod Dentofacial Orthop. 2012;142(1):133–43.

14. Yamada C, Kitai N, Kakimoto N, Murakami S, Furukawa S, Takada K. Spatial relationships between the mandibular central incisor and associated alveolar bone in adults with mandibular prognathism. Angle Orthod. 2007;77(5):766–72.

15. Baysal A, Ucar FI, Buyuk SK, Ozer T, Uysal T. Alveolar bone thickness and lower incisor position in skeletal Class I and Class II malocclusions assessed with cone-beam computed tomography. Korean J Orthod. 2013;43(3):134–40.

16. Wilcko MT, Wilcko WM, Bissada NF. An Evidence-Based Analysis of Periodontally Accelerated Orthodontic and Osteogenic Techniques: A Synthesis of Scientific Perspectives. Semin Orthod. 2008;14(4): 305–16.

17. Al-Thomali Y, Mohamed RN, Basha S. Torque expression in self-ligating orthodontic brackets and conventionally ligated brackets: A systematic review. J Clin Exp Dent. 2017;9(1): e123–8.

18. Vajaria R, BeGole E, Kusnoto B, Galang MT, Obrez A. Evaluation of incisor position and dental transverse dimensional changes using the Damon system. Angle Orthod. 2011;81(4):647–52.

19. Badawi HM, Toogood RW, Carey JPR, Heo G, Major PW. Torque expression of self-ligating brackets. Am J Orthod Dentofacial Orthop 2008;133(5):721–8.

20. Tepedino M, Franchi L, Fabbro O, Chimenti C. Post-orthodontic lower incisor inclination and gingival recession a systematic review. Prog Orthod 2018;19(1). doi: 10.1186/s40510-018-0212-6

21. Cook DR, Mealey BL, Verrett RG, Mills MP, Noujeim ME, Lasho DJ, et al. Relationship between clinical periodontal biotype and labial plate thickness: an in vivo study. Int J Periodontics Restorative Dent. 2011;31(4):345–54.

22. Wang N, Tytell JD, Ingber DE. Mechanotransduction at a distance: mechanically coupling the extracellular matrix with the nucleus. Nat Rev Mol Cell Biol. 2009;10(1):75–82.

FIGURES AND TABLES

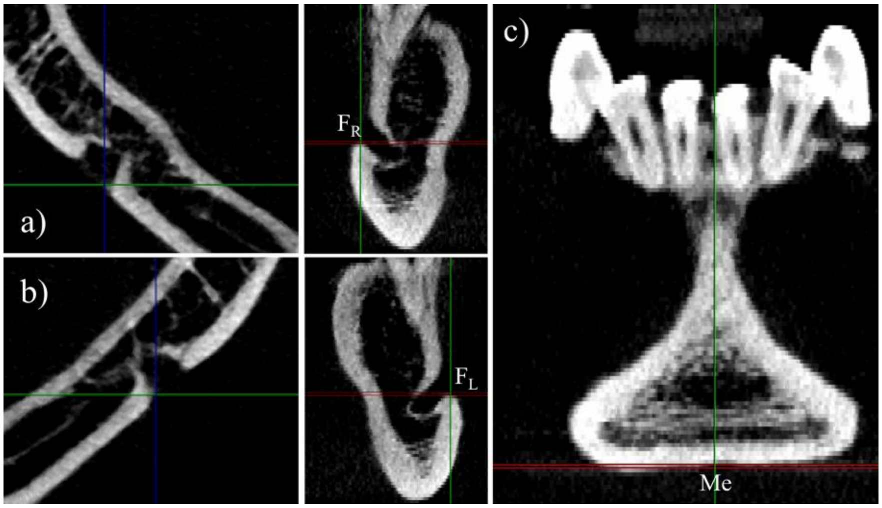

Figure 1. Foraminal plane A) Right mental foramen (FR) B) Left mental foramen (FL) C) Menton (Me).

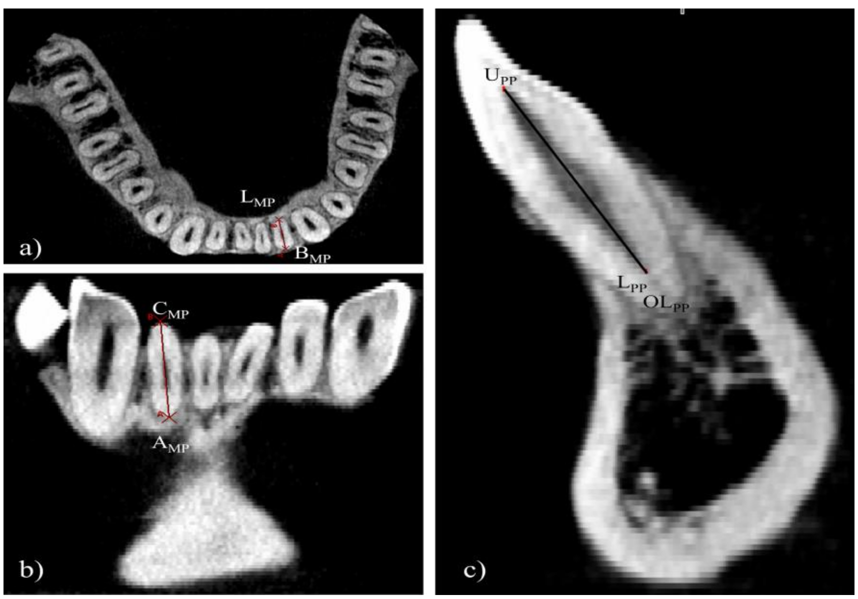

Figure 2. Pulpar plane A) Lingual (LMP) and buccal (BMP) surface of the tooth B) Apex (AMP) and upper coronal surface (CMP) C) Pulp chamber (UPP), pulpar canal (LPP) and a second axis LPP-OLPP.

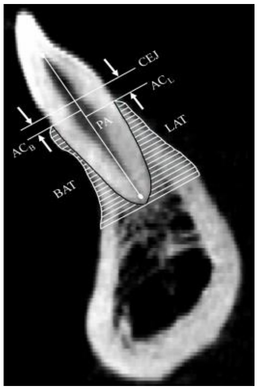

Figure 3. Dimensional changes of alveolar bone. Cementoenamel junction (CEJ), buccal alveolar ridge (ACB), lingual alveolar ridge (ACL). Buccal and lingual cortical bone contour (white color) and root contour (black color).

Table 1. Method reliability analysis: Intraclass correlation coefficient		
Method	**ICC Intra Observador**	**The ICC Interobservador**
Little's Irregularity Index and mesiodistal width	1,00	0,99
Vestibular alveolar thickness	0,95	0,94
Lingual alveolar thickness	0,93	0,92
Vestibular alveolar ridge height	1,00	0,87
Lingual alveolar crest height	0,99	0,97
Buccolingual inclination	1,00	1,00
Transverse lower intercanine	1,00	0,99
Transversal interpremolar (4)	0,99	0,99
Transversal interpremolar (5)	0,99	0,99
Transversal intermolar (6)	1,00	1,00

Table 2. Descriptive variables of the sample per group

Group	Unity of Analysis (Subjects)	Unity of observation (Incisors)	Gender		Age in years T0				Little's Irregularity Index T0 (mm)			
			M	**F**	$\overline{X}$	**SD +/-**	**Median**	**IQR**	$\overline{X}$	**SD +/-**	**Median**	**IQR**
1	8	32	6	2	23,9	6,1	22	6	6,62	2,30	6,91	3,43
2	9	36	6	3	21,3	3,9	19	3	6,42	1,24	6,42	1,17
3	10	40	8	2	30,0	6,8	33	10	5,77	1,13	5,47	1,71
4	10	40	7	3	25,7	4,4	27	8	7,55	4,04	6,37	3,8
Total	37	148	27	10	25,4	6,1	25	9	6,59	2,49	5,94	2,36

Table 3. Cephalometric changes of IMPA and Gonial Angle per groupIMPA									Mandible angle							
Group	$\overline{X}$ **T0**	**SD T0 +/-**	$\overline{X}$ **T1**	**SD T1 +/-**	**T1-T0**	**SD T1-T0 +/-**	**P < 0,05**		$\overline{X}$ **T0**	**SD T0 +/-**	$\overline{X}$ **T1**	**SD T1 +/-**	**T1-T0**	**SD T1-T0 +/-**	**P < 0,05**	
1	99,23º	+/- 5,09	103,4º	+/- 4,94	4,18º	+/- 3,95	0,02	*	118,23º	+/- 2,47	118º	+/- 3,9	-0,33º	+/- 2,61	0,44	
2	96,07º	+/- 6,52	103,3º	+/- 7,25	6,83º	+/- 7,02	0,03	*	115,25º	+/- 6,15	113,7º	+/- 7,9	-1,49º	+/- 4,6	0,51	
3	99,5º	+/- 7,49	98,8º	+/- 5,38	-0,53º	+/- 5,33	0,64		118,2º	+/- 6,12	118º	+/- 4,4	-0,1º	+/- 2,82	0,65	
4	103,41º	+/- 5,76	107,13º	+/- 6,43	2,44º	+/- 4,7	0,14		114,2º	+/- 7,57	103,7º	+/- 33,1	-10,45º	+/- 32,7	0,52	
Total	99,55º	+/- 6,21	103,15º	+/- 6	6,59º	+/- 5,25			116,47º	+/- 5,57	113,3º	+/- 12,3	-2,92º	+/- 10,68		

Table 4. Changes of the variables in groups 1 and 2 per tooth. Test of Wilcoxon Signed Range

		Group 1 Control							Group 2 Piezocision						
VARIABLE	**Tooth**	$\bar{X}$ **T0**	**SD T0 +/-**	$\bar{X}$ **T1**	**SD T1 +/-**	$\bar{X}$ **T1-T0**	**SD T1-T0 +/-**	**P < 0,05**	$\bar{X}$ **T0**	**SD T0 +/-**	$\bar{X}$ **T1**	**SD T1 +/-**	$\bar{X}$ **T1-T0**	**SD T1-T0 +/-**	**P < 0,05**
Buccolingual inclination of lower incisors	**42**	14,2	8,6	17,5	3,9	3,3	7,5	0,16	18,3	8,1	20,7	8,8	2,4	8,0	0,31
	41	15,8	8,4	17,4	6,2	1,6	6,6	0,26	17,8	9,7	21,0	9,9	3,2	7,6	0,07
	31	18,0	12,0	21,4	9,4	3,4	16,2	0,12	17,8	10,7	22,3	9,8	4,5	8,2	0,11
	32	14,6	9,6	18,9	5,1	4,3	10,1	0,16	15,6	7,4	21,8	9,2	6,2	7,2	0,04 *
Total average		15,7	9,7	18,8	6,2	3,1	10,1		17,4	9,0	21,4	9,4	4,1	7,8	
Buccal height of alveolar ridge in mm	**42**	2,1	2,3	6,7	3,6	4,7	3,7	0,01 *	1,0	1,0	6,1	3,5	5,1	3,4	0,01 *
	41	3,3	2,5	7,3	2,6	4,0	3,6	0,04 *	3,1	2,8	5,3	3,5	2,3	2,1	0,02 *
	31	2,7	2,0	7,1	2,2	4,5	3,1	0,02 *	2,4	3,4	4,8	3,6	2,4	1,8	0,01 *
	32	2,6	3,5	6,8	2,7	4,2	3,8	0,05	1,6	3,0	5,8	4,0	4,1	3,4	0,01 *
Total average		2,6	2,6	7,0	2,8	4,4	3,6		2,0	2,5	5,5	3,6	3,5	2,7	
Lingual height of alveolar ridge in mm	**42**	2,3	3,2	4,8	3,7	2,5	1,7	0,01 *	4,2	4,5	2,3	0,8	-1,9	4,4	0,86
	41	1,9	0,9	4,5	2,1	2,6	2,7	0,01 *	1,9	1,3	4,2	2,8	2,2	2,6	0,05
	31	3,8	3,2	4,3	2,5	0,5	3,3	0,40	1,2	1,0	3,9	2,2	2,7	2,0	0,01 *
	32	1,9	0,6	5,1	4,7	3,2	4,3	0,09	1,3	0,6	3,2	2,9	1,9	3,0	0,05
Total average		2,5	2,0	4,7	3,2	2,2	3,0		2,2	1,9	3,4	2,2	1,2	3,0	
Alveolar Buccal thickness in mm	**42**	1,1	0,4	0,7	0,7	-0,4	0,6	0,09	1,3	0,8	1,0	0,8	-0,3	1,2	0,37
	41	1,1	0,4	0,5	0,4	-0,6	0,2	0,01 *	1,1	0,5	0,8	0,6	-0,3	0,6	0,17
	31	1,4	0,7	0,9	0,9	-0,6	0,5	0,02 *	1,3	0,7	1,1	0,9	-0,2	1,0	0,26
	32	1,3	0,7	1,0	0,9	-0,3	0,3	0,04 *	1,1	0,7	1,4	1,0	0,3	0,9	0,41

Total average		1,3	0,6	0,8	0,7	-0,5	0,4			1,2	0,7	1,1	0,8	-0,1	0,9		
Alveolar lingual thickness in mm	**42**	1,4	0,7	1,2	0,9	-0,2	0,6	0,40		1,4	0,7	1,5	0,5	0,1	0,5	0,44	
	41	1,4	0,7	1,0	0,5	-0,4	0,5	0,12		1,8	0,7	1,2	0,6	-0,6	1,3	0,31	
	31	1,1	0,5	0,8	0,4	-0,3	0,4	0,06		1,5	0,6	0,9	0,4	-0,7	0,7	0,01	*
	32	1,3	0,5	0,8	0,5	-0,5	0,2	0,01	*	1,8	0,7	1,2	0,8	-0,6	0,7	0,04	*
Total average		1,3	0,6	0,9	0,6	-0,3	0,4			1,6	0,7	1,2	0,6	-0,5	0,8		
Lower Transversal width in mm	**3 a 3**	25,5	2,3	27,9	1,1	2,4	2,1	0,03	*	27,2	2,8	27,9	0,9	0,7	2,4	0,37	
	4 a 4	28,3	11,5	31,0	12,6	2,7	1,9	0,01	*	30,0	11,5	32,1	12,1	2,1	1,6	0,01	*
	5 a 5	36,7	2,7	40,8	2,2	4,1	1,3	0,01	*	37,9	4,3	41,3	2,5	3,4	2,6	0,02	*
	6 a 6	43,8	1,7	45,2	1,7	1,4	1,2	0,03	*	39,0	15,0	40,5	15,3	1,5	1,8	0,05	
Total average		33,6	4,55	36,2	4,4	10,6	6,5			33,5	8,3	35,4	7,7	7,7	2,1		
Mesio-distal widths and IPR in mm	**3 a 3**	37,4	2,4	36,5	2,4	0,9	0,5			37,5	1,9	36,4	1,5	1,1	1,0		

Table 5. Changes of the variables in groups 3 and 4 per tooth. Test of Wilcoxon Signed Range

		Group 3 Piezocision and porcine collagen matrix (Geistlich Mucograft®)							Group 4 Porcine collagen matrix (Geistlich Mucograft®)						
VARIABLE	**TOOTH**	**$\overline{X}$ T0**	**SD T0 +/-**	**$\overline{X}$ T1**	**SD T1 +/-**	**$\overline{X}$ T1-T0**	**SD T1-T0 +/-**	**P < 0,05**	**$\overline{X}$ T0**	**SD T0 +/-**	**$\overline{X}$ T1**	**SD T1 +/-**	**$\overline{X}$ T1-T0**	**SD T1-T0 +/-**	**P < 0,05**
Buccolingual inclination of lower incisors in degrees	**42**	19,2	12,1	15,3	15,7	-3,9	13,9	0,39	14,8	1,7	17,3	7,8	2,5	11,3	0,24
	41	21,7	15,1	16,2	14,6	-5,6	12,8	0,11	16,1	8,7	17,5	9,5	1,4	7,7	0,68
	31	21,6	16,5	17,3	15,3	-4,3	11,9	0,28	20,0	9,1	17,9	9,6	-2,1	6,1	0,39
	32	20,5	14,1	15,4	15,6	-5,1	15,7	0,28	16,8	9,7	17,3	10,1	0,5	11,5	0,39
Total average		20,7	14,4	16,0	15,3	-4,7	13,6		16,9	7,3	17,5	9,3	0,5	9,2	
Buccal height of alveolar ridge in mm	**42**	2,3	2,3	4,6	2,7	2,3	2,5	0,02 *	2,5	3,1	4,9	3,1	2,3	2,7	0,02 *
	41	2,4	2,4	5,6	3,1	3,3	2,5	0,01 *	3,8	2,5	6,2	2,7	2,4	2,8	0,04 *
	31	2,0	1,9	5,4	2,6	3,4	2,6	0,01 *	3,2	2,8	5,3	3,3	2,2	1,9	0,01 *
	32	2,1	1,8	5,8	3,3	3,7	3,5	0,02 *	2,8	3,0	5,9	3,1	3,2	3,2	0,02 *
Total average		2,2	2,1	5,3	2,9	3,2	2,8		3,1	2,8	5,6	3,1	2,5	2,7	
Lingual height of alveolar ridge in mm	**42**	2,0	1,5	2,8	1,4	0,7	1,9	0,20	2,6	1,9	5,1	3,8	2,5	3,8	0,04 *
	41	3,5	2,9	4,6	3,2	1,1	1,7	0,07	2,3	2,2	5,0	2,7	2,7	3,5	0,04 *
	31	4,7	3,5	5,3	2,5	0,6	1,8	0,39	2,4	2,1	5,3	3,7	2,9	4,9	0,11
	32	2,5	1,6	3,5	3,1	1,0	2,0	0,09	3,2	3,8	4,8	4,3	1,6	5,0	0,05
Total average		3,2	2,4	4,0	2,5	0,9	1,9		2,7	2,5	5,1	3,6	2,4	4,3	
Alveolar Buccal	**42**	1,1	0,4	1,1	0,8	0,0	0,5	0,92	1,2	0,7	1,0	0,6	-0,3	0,9	0,24

thickness in mm	**41**	1,3	0,9	0,9	0,9	-0,4	0,7	0,09		1,3	0,6	0,7	0,7	-0,6	0,4	0,01	*
	31	1,6	1,0	1,0	1,2	-0,6	0,3	0,01	*	1,1	0,5	1,1	1,0	0,0	0,7	0,72	
	32	1,4	0,9	1,1	1,0	-0,3	0,6	0,20		1,2	0,4	1,1	0,9	-0,1	0,8	0,51	
Total average		1,3	0,8	1,0	1,0	-0,3	0,5			1,2	0,6	1,0	0,8	-0,2	0,7		
Alveolar lingual thickness in mm	**42**	1,8	0,8	1,7	0,9	-0,1	0,8	0,57		1,7	0,7	1,4	1,2	-0,3	0,9	0,28	
	41	1,2	0,7	1,1	0,7	-0,1	0,4	0,28		1,9	1,0	0,9	1,1	-0,9	1,1	0,02	*
	31	1,1	0,7	1,0	0,7	-0,1	0,6	0,80		1,5	0,8	0,8	0,7	-0,7	0,4	0,01	*
	32	2,1	1,5	1,8	1,1	-0,3	1,0	0,58		1,5	1,0	1,2	1,0	-0,3	0,7	0,09	
Total average		1,6	0,9	1,4	0,8	-0,2	0,7			1,6	0,9	1,1	1,0	-0,6	0,8		
Lower Transversal width in mm	**3 a 3**	25,2	1,3	27,0	1,1	1,8	1,4	0,01	*	25,4	2,7	27,8	1,2	2,4	1,8	0,01	*
	4 a 4	30,4	11,0	31,9	11,4	1,5	1,3	0,02	*	32,7	2,0	35,7	1,2	2,9	1,3	0,01	*
	5 a 5	38,6	3,6	41,1	2,9	2,5	1,3	0,01	*	38,3	1,9	41,3	1,3	3,0	1,3	0,01	*
	6 a 6	44,9	3,8	46,0	3,2	1,2	1,2	0,02	*	44,6	2,4	45,8	2,4	1,2	0,5	0,01	*
Total average		34,7	4,92	36,5	4,6	7	1,3			35,2	2,2	37,6	1,52	9,5	1,22		
Mesio-distal widths and IPR in mm	**3 a 3**	37,4	1,5	36,2	1,5	1,2	0,8			37,8	1,7	36,5	1,7	1,4	1,2		