A Comparative In Vitro Study on the Primary Stability of Implants in Cavities Prepared by PiezoSurgery and Conventional Methods

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Keywords:
Piezosurgery; Dental Implants; In Vitro Techniques.

Abstract

The primary stability of dental implants is dependent on mechanical characteristics including bone quality or quantity, type of implant, and insertion technique. The objective of this study was to evaluate drilling times, temperatures during drilling, and implant stability in cavities created using piezosurgery and rotary instruments. Polyurethane blocks were used to simulate the densities of bone types I, II, III, and IV. The surface temperature of the block was measured in the cavity during drilling, and the highest temperature variation was recorded. The stability of the implants was measured by insertion torque, removal torque, and resonance frequency. The cylindrical implant TitaOss (3.75 mm × 11 mm) was used in all cavities. The results showed higher drilling times and temperatures in the group where piezosurgery was used. Primary stability showed no significant difference between the groups. It is concluded that implant primary stability was not influenced by the method used, but cavity preparation using piezosurgery required more time and generated more heat than the conventional method using rotatory instruments.

Introduction

Primary dental implant stability is understood as the absence of implant mobility immediately after insertion1, and is dependent on mechanical characteristics including bone quality or quantity, type of implant and milling, and insertion technique2,3. It is achieved by macro-retention or friction of the implant in the receptor bed4 and is one of the most important factors in determining the success of the dental implant5. Movement above the acceptable threshold may prevent osseointegration6.

With regard to implant installation, bone quality falls into one of four categories: types I, II, III, and IV, where type I represents the most compact bone. The degree of bone porosity is increased progressively in types II, III, and IV. The higher the degree of porosity, the poorer is the primary stability expected7.

The process of bone healing around implants is a complex phenomenon that requires an intact cascade of proliferation and differentiation of pre-osteoblasts into osteoblasts, together with the activation of periosteal and endosteal cells in addition to the production and mineralization of the bone matrix8. In 1984, Eriksson and Albrektsson9 demonstrated that heating of bone at 47°C for 1 min reduced the amount of bone in the pores of implants inserted in rabbit tibiae9. This demonstrated that the temperature applied during cavity preparation plays an important role in the success of dental implantation.

Piezosurgery is characterized by ultrasound microvibrations promoted by a piezoelectric motor at a frequency of 29 kHz and a range of 60–200 Hz10. These microvibrations facilitate selective cutting of mineralized structures without damaging soft tissues, even in case of accidental contact10. Baker et al.11 reported in an ex vivo study that there was no difference in primary stability between the piezoelectric technique and the conventional technique, but the study evaluated only type I and type II bones11. There are several methods available for assessing the primary stability of the implant, including reverse torque testing and resonance frequency analysis11.

Currently, the literature includes a small number of studies evaluating the primary stability of implants inserted in surgically prepared cavities compared to those created by conventional rotary instruments. In addition, there is a need for standardization of studies regarding the method of evaluation and the type of bone in which the implants are inserted. Thus, further studies are needed to better understand the role of piezosurgery in the preparation of implant insertion cavities.
The objective of this study was to evaluate, in vitro, the primary stability of implants inserted in cavities prepared with the aid of surgical ultrasound and conventional rotary instruments. An additional aim was to evaluate the working temperature, milling time, and quality of the cavities thus created.

Materials and methods

The study was conducted at the Faculty of Dentistry of Araçatuba-FOA-UNESP, Department of Surgery and Integrated Clinic, in an air-conditioned environment at a constant temperature of 23°C. The work consisted of two groups, Rotatory and Piezo. The Rotatory group comprised cavities made using conventional rotary instruments; the Piezo group comprised cavities prepared using surgical ultrasound.
The following variables were evaluated: temperature immediately before and during preparation of the cavities, the time required to prepare them, and the primary stability of the inserted implants.
A total of 64 cavities were made in four polyurethane blocks (Nacional Ossos, Jaú, São Paulo, Brazil). Type I bone was represented by one block of dimensions 9.7 cm × 10 cm × 5 cm with no cortical layer, while types II–IV were each represented by one block measuring 4.5 cm × 9.5 cm × 3.2 cm, with a cortex measuring 2 mm (Fig. 1A). Each block received 16 cavities, 8 corresponding to the Rotatory group and 8 to the Piezo group. All cavities were made by the same operator.
The milling cutters used in the Rotatory group were made of thermally hardened stainless steel with a carbon-based coating. The sequence used followed the guidelines of the manufacturer: 1 – initial drill Ø 2.0 mm; 2 – helical drill Ø 2.0 mm; 3 – pilot drill Ø 2/3; and 4 – helical drill Ø 3.0 mm (Intraoss, São Paulo, São Paulo, Brazil). An electric motor (BLM 600; Driller®, Carapicuíba, São Paulo, Brazil) was used with a contra-angle (KaVo do Brasil Ind. Com. Ltda, Joinville, Santa Catarina, Brazil) at 20:1 reduction. The motor was calibrated at a speed of 1200 rpm, irrigation 50%, 12 rpm, and torque of 20 Newton centimeters (N·cm) for insertion of the implants.
The sequence of tips used in the Piezo group, according to the manufacturer's guidelines, was: 1 – IPL 30D, 2 – IPR 20D, and 3 – IPR 30D (Piezosonic Driller®, Carapicuíba, São Paulo, Brazil) (Fig. 1B). The surgical ultrasound (Piezosonic Driller®, Carapicuíba, São Paulo, Brazil) was configured as follows: modulation 100, power 50 W, and irrigation of the ultrasound system at 50%. All cavities were prepared to a length of 11 mm and received TitaOss cylindrical implants (Intraoss) of size 3.75 mm x 11 mm and a platform of 4.1 mm.
Analysis of variables

Time

The time required for preparation of the cavities was measured using a digital timer. The total time of each milling was obtained by adding the contact times of each milling cutter with the block.
Temperature

The temperature in the cavity preparation region was measured immediately before and during milling using a digital thermometer (Kiray 50, Emerainville, France), with the highest temperature value being recorded in degrees Celsius.

Cavity quality

Qualitative analysis of the cavities was carried out with the aid of a digital camera (Digital Microscope, Shenzhen, Guangdong, China), with a 1000× facility for the evaluation of circumference, design, and texture. A cut was made in each block by means of a carborundum disc (Dentorium, Farmingdale, NY), dividing them into equal-sized cavities for evaluation of the design and texture. The circumference, texture, and design were evaluated in both cavities of the blocks, these being chosen at random. At the end of instrumentation, top-view images of the holes were obtained to evaluate the regularity of the circumference.

Primary stability

Primary stability was evaluated by means of insertion torque, resonance frequency, and removal torque. The insertion torque was evaluated (in N·cm) using a ratchet (Intraoss, São Paulo, São Paulo, Brazil) shortly after insertion of the implant. The resonance frequency was evaluated using an Osstell (Integration Diagnostics AB, Gothenburg, Sweden). Measurements were performed according to the manufacturer's instructions, four measurements were performed for each implant using the transducer in a standardized way, and the mean values obtained were obtained. The results were measured as implant stability ratio (ISQ), with values ranging from 1 to 100. The higher the ISQ value, the greater is the stability of the implant.

Removal torque was measured using an insertion key (Intraoss, São Paulo, São Paulo, Brazil) adapted to the implant hexagon and an analog torque wrench (15-BTG, Tohnichi, Tokyo, Japan). Anticlockwise movement was applied by increasing the reverse torque during rotation of the implant inside the block, at which point the torquemeter recorded the maximum torque peak in N·cm.

Statistical analysis

Data were tabulated and compared statistically in the statistical program SigmaPlotTM 12.3 (SigmaPlot Exakt Graphs and Data Analysis, San Jose, CA). Initially, the data were compared by the Shapiro–Wilk homoscedasticity test, which shows homogeneity. Analysis of variance (two-way ANOVA) and Tukey post-test were then applied when the ANOVA test showed statistical significance. For all tests, the level of 5% was considered significant.

Results

Sixty-four cavity preparations were made in 4 blocks of polyurethane, with 16 preparations per block. Four implants were installed in the cavities (one implant per block type) and were evaluated for primary stability (Fig. 2). The mean values of the results obtained are shown in Table 1.

Time and temperature

In relation to time, the Piezo group presented a mean value superior to that of the Rotatory group in all blocks, this difference being statistically significant ($p < 0.001$) (Table 2). In the type I block, the Piezo and Rotatory groups presented a mean of 89.81 ± 13.42 and 21.95 ± 3.05 s, respectively; in the type II block, 46.37 ± 4.46 and 16.68 ± 0.67 s, respectively; in the type III block, 36.74 ± 5.08 and 17.36 ± 1.15 s, respectively; and in the type IV block, 32.65 ± 7.60 and 12.48 ± 1.68 s, respectively. The time required for preparation of the wells increased according to the type of block, with the highest values being for types I and II and the lowest for types type III and IV (Fig. 3). Table 3 shows the total milling time required, according to group and bone type. Regarding the temperature in the region being milled, wider variation was observed for the Piezo group in all blocks ($p < 0.001$) (Fig. 4). In the type I block, the Piezo and Rotatory groups showed a mean temperature variation of 0.77 ± 0.52 and 0.12 ± 0.26°C, respectively; in the type II block, 0.99 ± 0.98 and 0.21 ± 0.18°C, respectively; in the type III block, 1.08 ± 1.01 and 0.11 ± 0.18°C, respectively; and in the type IV block, 1.06 ± 0.57 and 0.06 ± 0.14°C, respectively.

Cavity quality

The texture of the cavities in all blocks in the Piezo group was more irregular than in the Rotatory group. With respect to design, the Piezo group presented less well-defined cavities, these tending toward conicity (Fig. 5). Regarding cavity circumference, those of the Piezo group were more oval than those of the Rotational group (Fig. 6).

Primary stability

A decrease in insertion torque due to reduction in block density was observed for both groups (Fig. 7). In type I blocks, a trend of higher mean insertion torque was observed for the Piezo than the Rotatory group (73.13 ± 8.84 versus 68.125 ± 6.51 N·cm, respectively), while results were similar between groups for the other three types ($p > 0.05$) (Table 2).

Regarding resonance frequency, the Piezo group presented higher results for type I (Piezo 64.81 ± 4.38 ISQ; Rotatory 60.5 ± 1.87 ISQ, $P = 0.043$; Piezo 63.53 ± 3.72 ISQ, Rotatory 67.5 ± 1.16 ISQ), but this was not statistically significant ($P = 0.061$) (Table 2). The results for types III and IV were very similar ($p > 0.05$). These results are shown in Fig. 6 and Table 4.

The evaluation of removal torque showed higher values for the Piezo group regardless of the type of bone (Fig. 8); however, there was no statistically significant difference between groups ($p > 0.05$) (Table 2).

Discussion

The primary stability of an implant is a prerequisite for adequate peri-implant bone healing, and can be evaluated by several methods including insertion torque, resonance frequency, Periotest, and removal torque12,13. However, obtaining standardized samples of bone density and similar trabecular structures in clinical studies and laboratory experiments is very difficult14. Thus, aiming at standardization of results, we chose to use polyurethane blocks to perform this study as described in previous studies12–15.

The choice of implant type may also influence its primary stability16. Divac et al.17 considered it a clinical challenge to achieve good primary stability with cylindrical implants in regions of low bone quality17. In order to perform this work, we opted for the use of identically sized cylindrical implants in bones of varying density in order to obtain reliable results regarding primary stability.

Regarding temperature variation during milling, the relevant factors are usually associated with the following factors: operator (pressure, speed and duration of milling), manufacturer (milling cutter, irrigation system), location (cortical thickness, site condition, and depth of milling), and patient (age and bone density)18. In order to enhance the reliability of the results, a single operator performed all cavity preparations and the blocks were used to simulate different bone densities. However, the pressure values applied to the blocks at the time of preparation were not measured.

Rashad et al.8 performed an in vitro study comparing heat production in beds prepared with ultrasonic and rotary instruments and concluded that ultrasonic milling required longer times and generated more heat. Using a different methodology, Sagheb et al.19 did not observe any statistical difference regarding the generation of heat in cavities prepared with ultrasound and rotary instruments; they found that the time required was higher in the preparations using ultrasound. The findings of the present study are in agreement with those of Rashad et al.8, but despite the greater production of heat by ultrasound, patient safety was found not to be compromised providing adequate irrigation is provided. The temperature values these workers found for ultrasound instrumentation remained below the limits capable of generating tissue damage.

The most widespread method of measuring the primary stability of implants utilizes insertion torque16. Low insertion torque values are associated with implant loss, whereas excessive implant insertion forces may lead to the collapse of the surrounding bone tissue leading to implant failure16. In a systematic review performed by Li et al.20, it was observed that there was no statistical difference regarding marginal bone loss and cumulative success rate between implants installed with high-insertion torque (>50 N·cm) and those using conventional torque (35–45 N·cm). However, these authors believed that more studies were needed to obtain stronger evidence for these findings. In the present study, high insertion torque was observed in types I and II for both groups and conventional torque in types III and IV. It was observed that the Piezo group showed superior torque for the type I blocks (Piezo and Rotatory groups, 73.13 ± 8.84 and 68.125 ± 6.51 N·cm, respectively); for the other three types, results were similar between the two groups.

Although the results of this study showed no evidence of overheating, regardless of the situation analyzed, for type I blocks – especially for the Piezo group – the mean values of insertion torque were certainly incompatible with the biological behavior expected during the initial phase of peri-implant bone repair. This is because the excessive increase in torque during implant insertion (values >70 N·cm) may lead to decreased blood supply, delayed bone repair, and the interposition of fibrous tissue.

Regarding the resonance frequency, Canullo et al.21 performed a clinical study in human subjects using implants installed in beds prepared with ultrasound and rotating instruments, and adopted ISQ values ≥60 as being suitable for primary stability. Baker et al.11 and Sagheb et al.19 observed no significant difference in the values found for the preparation of the cavities with ultrasound and rotary instruments. In the work of Gandhi et al.22, implants installed in cavities prepared in wells with ultrasound showed higher ISQ values than those installed prepared using rotating instruments, suggesting the superior primary stability of the former method. In the present study, a statistical difference was observed only for the type I block, values being higher in the Piezo group. Regarding the type of block, higher ISQ values were found for types I and II (both >60) than for types III and IV (both <60).

In the study by Sagheb et al.19, statistically higher values for implant removal torque were observed in wells prepared with ultrasound. However, Baker et al.11 found no statistical difference in implant removal torque between the use of ultrasound and rotary instruments. In the present study, the Piezo group presented higher values of removal torque; in addition, it was observed for both groups that removal torque was reduced according to decrease in block density.

In general, although no statistically significant difference was found, there was a tendency toward better primary stability of the implants installed in cavities made using surgical ultrasound. This can be explained by the design and irregularity of the cavities made using ultrasound, these being more conical and with oval holes, in contrast to those made using conventional rotary instrumentation.

Conclusion

Although some previous studies comparing the two techniques (ultrasound and rotational) used animal-derived bone blocks11,19,22, the findings of this study using polyurethane blocks are in accordance with similar studies in the literature. It can thus be concluded that the primary stability of the implants was not influenced by the milling methods used. Milling performed with surgical ultrasound showed higher values regarding time and temperature, but these do not imply deleterious effects on bone tissue, as confirmed in the literature.

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Figures:

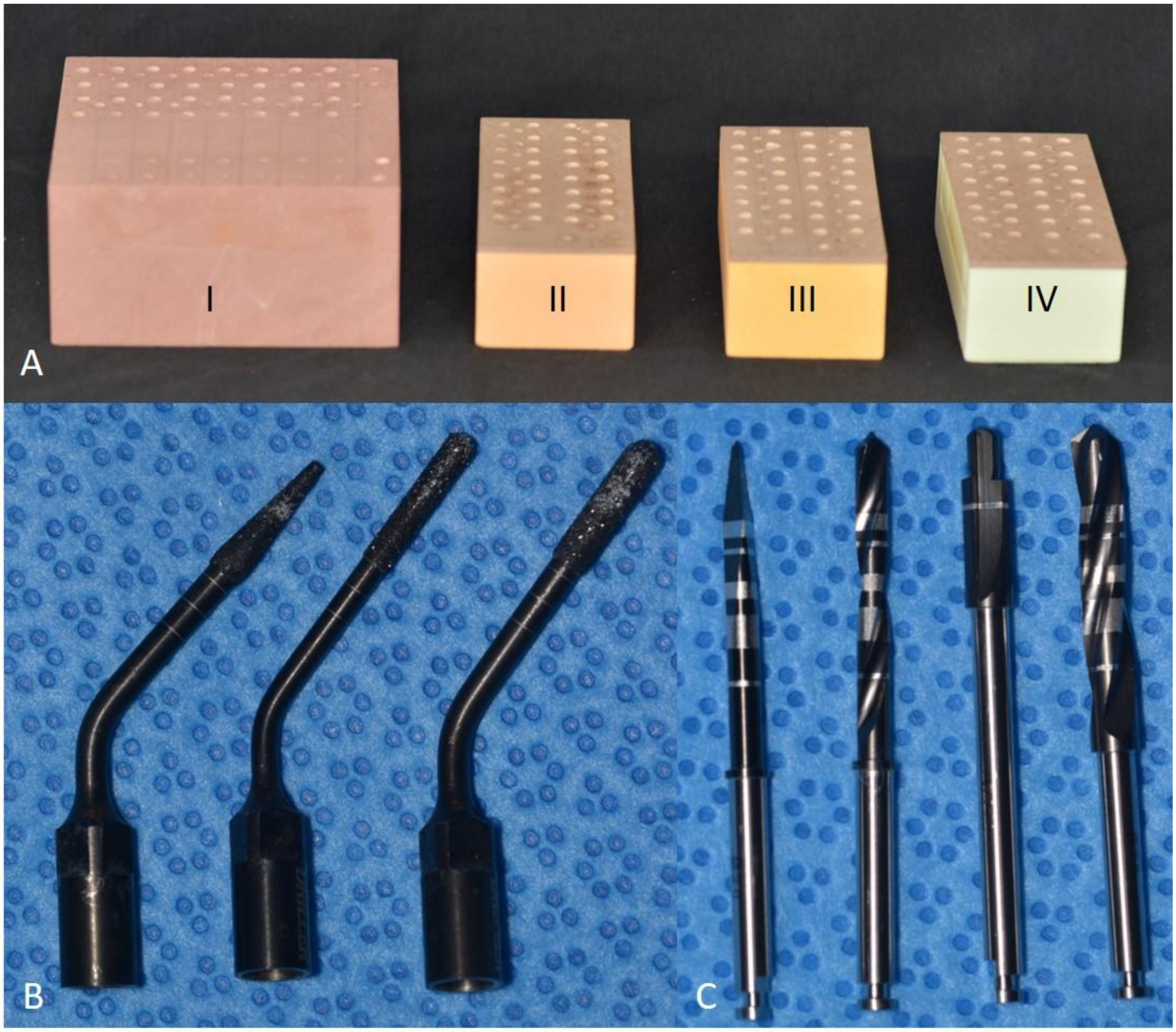

Figure 1- (A) Blocks that simulate bone densities type I, II, III and IV; (B) sequence of tips used in the Piezo group; (C) Sequence of cutters used in the Rotatory group.

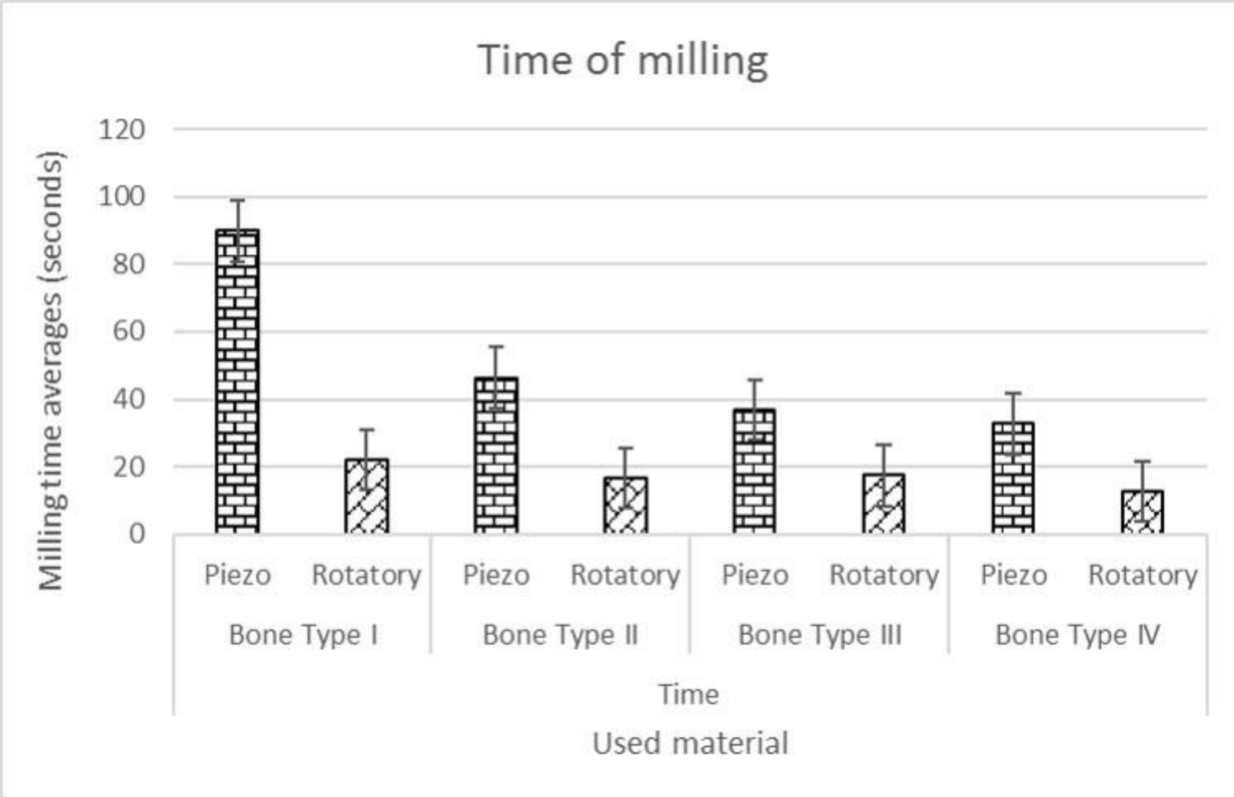

Figure 2- Milling time according to the instrument used and the type of density of the blocks.

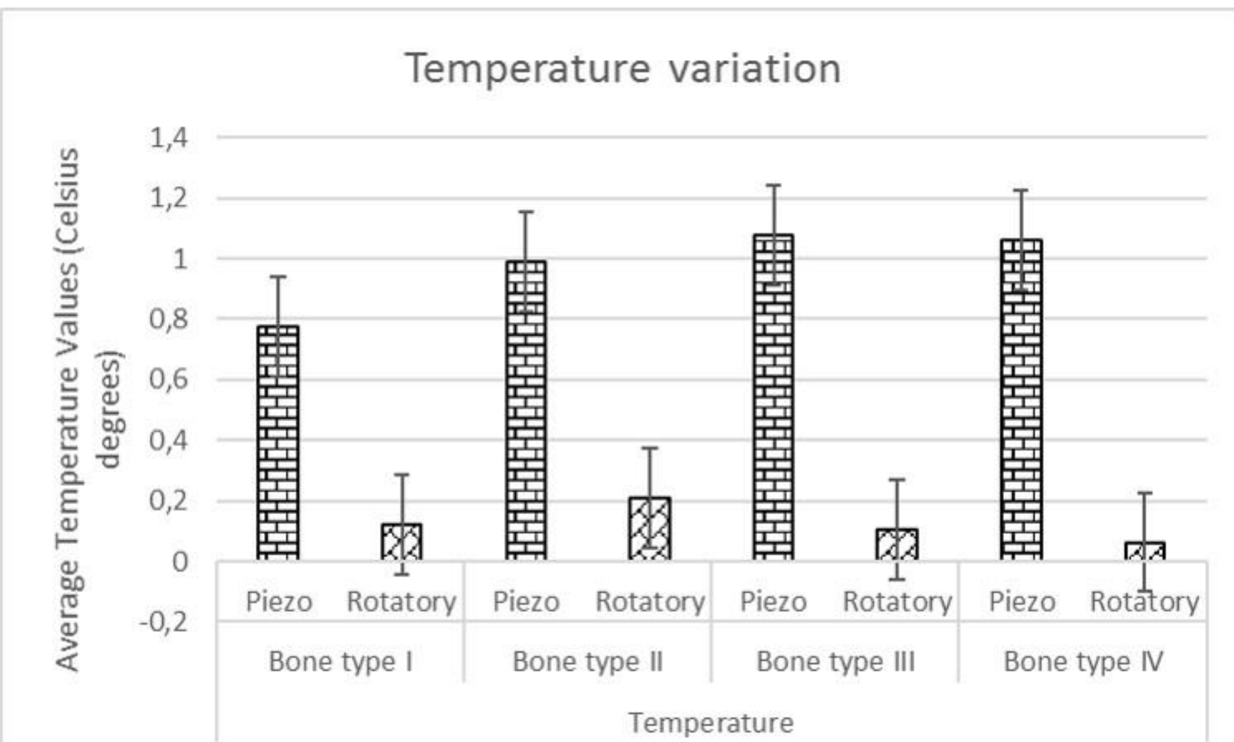

Figure 3- Temperature variation according to the studied groups and the type of density of the blocks.

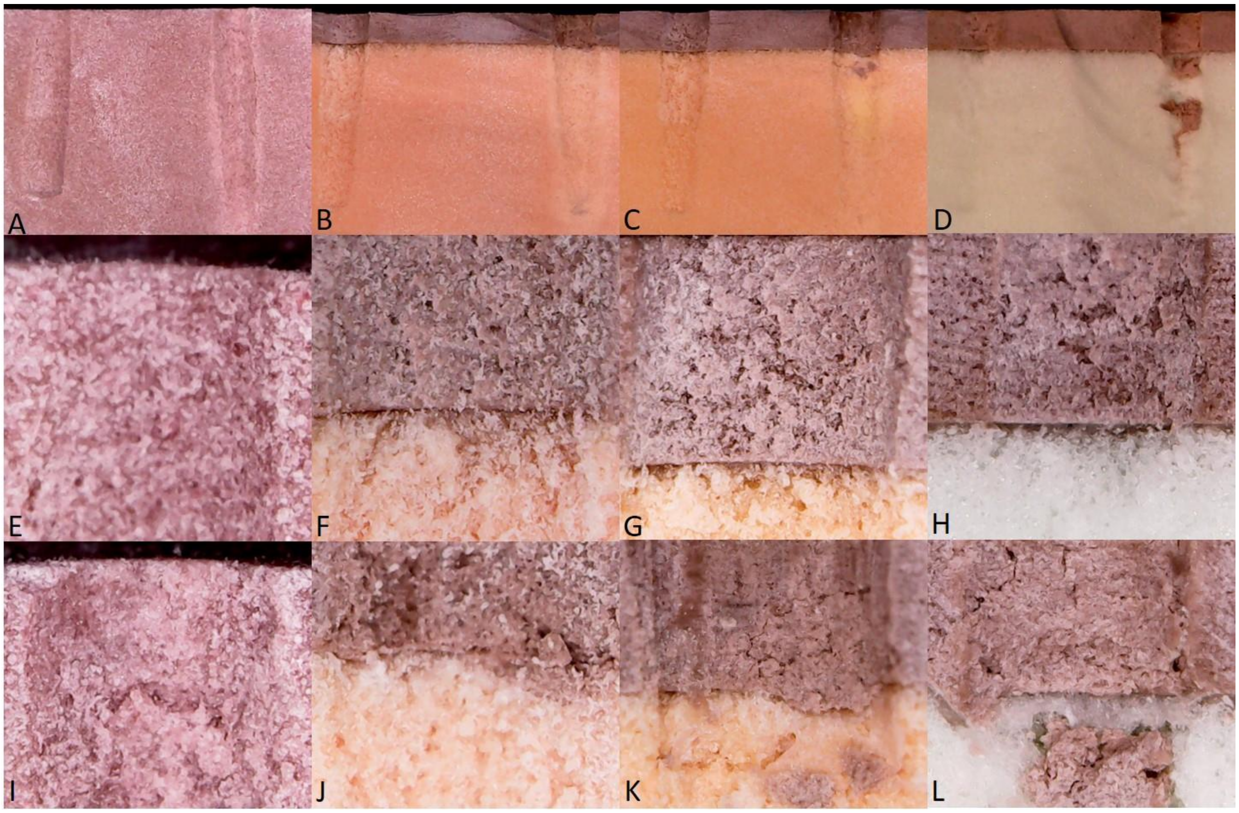

Figure 4- Quality of the cavities. A (block type I) on the right side Rotatory group and on the left side group Piezo; B (block type II), C (block type III) and D (block type IV); Approximate cavities of the Rotatory group in blocks I, II, III and IV in E, F, G and H respectively; Approximate cavities of the Piezo group in blocks I, II, III and IV in I, J, K and L, respectively.

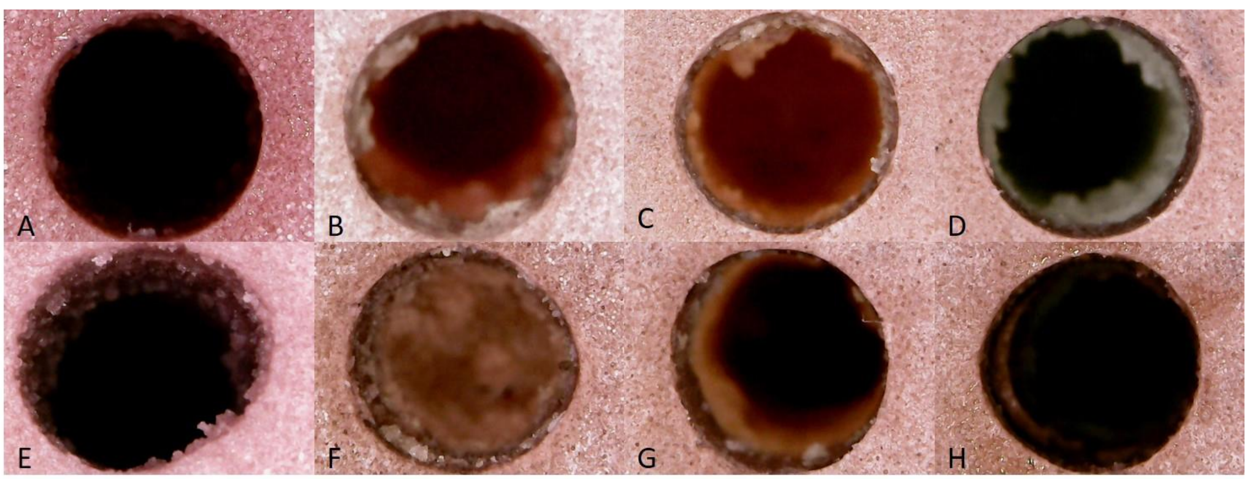

Figure 5- Cervical third of the cavities made, group Rotatory blocks types I, II, III and IV in A, B, C and D respectively; Surface portion of the prepared cavity, group Piezo blocks types I, II, III and IV in E, F, G and H respectively.

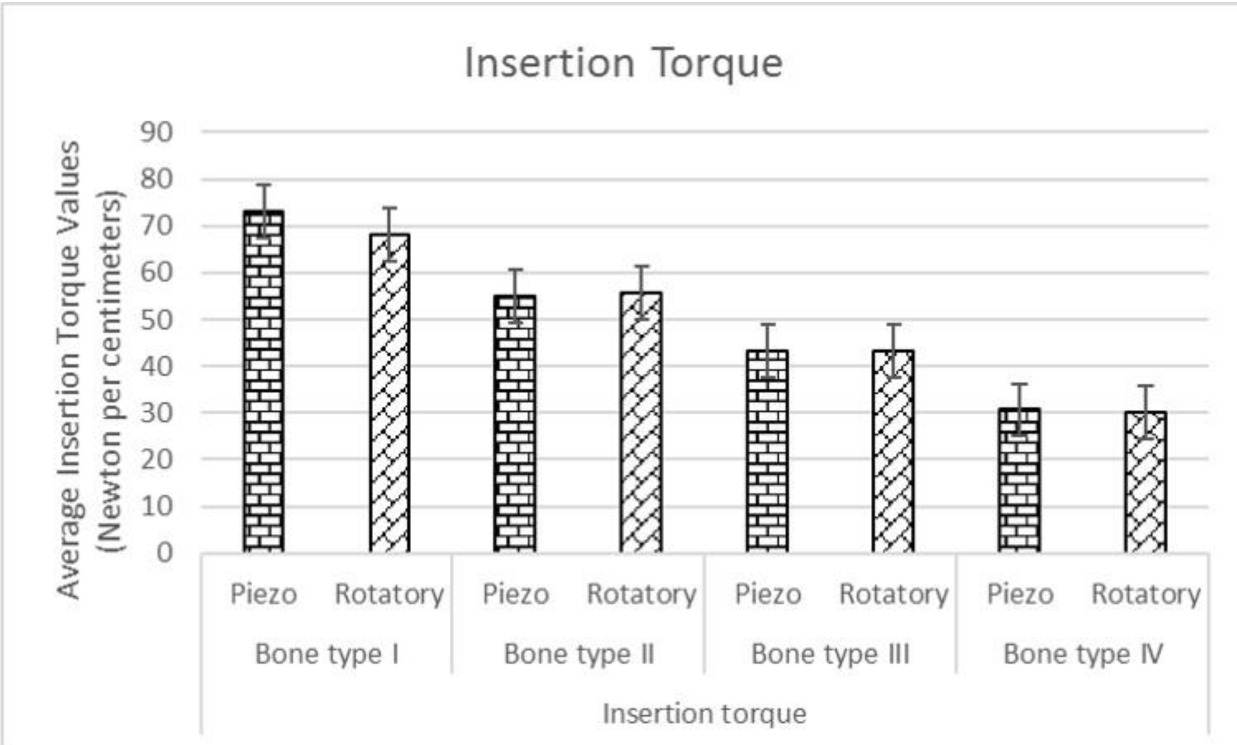

Figure 6- Insert torque according to the group studied and the density of the block.

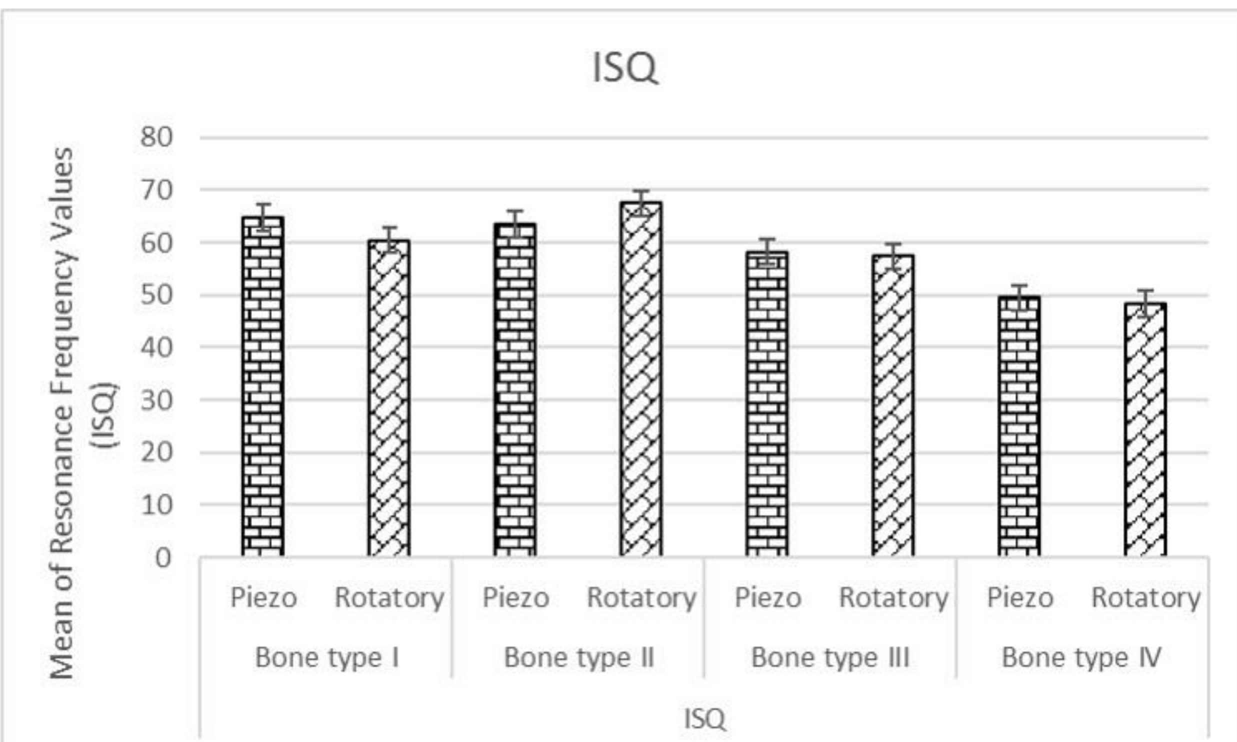

Figure 7- Mean values of the resonance frequency according to the group studied and the density of the block.

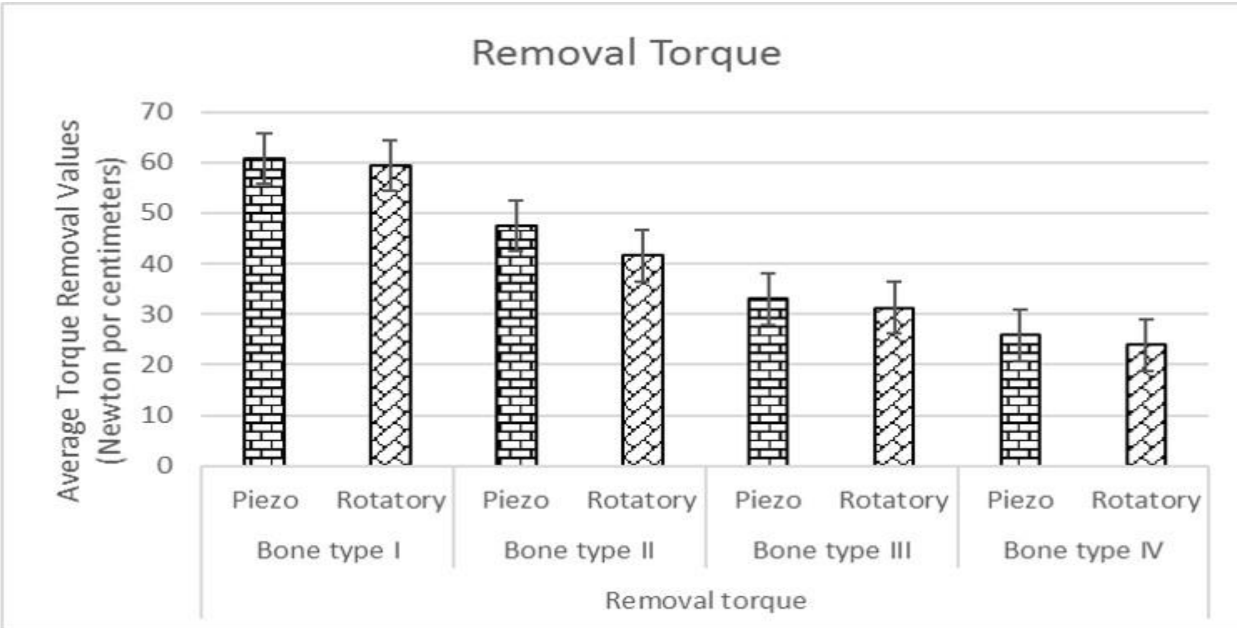

Figure 8- Mean values of implant removal torque in N.cm according to the block density type.

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Tables:

Table 1. Value of the means obtained according to the variables and the types of densities of the blocks.

Analysis of Variables								
	Bone Type I		Bone Type II		Bone Type III		Bone Type IV	
	Piezo	Rotatory	Piezo	Rotatory	Piezo	Rotatory	Piezo	Rotatory
Time (s)	89,81±13,42	21,94±3,05	46,37±4,46	16,67±0,67	36,73±5,08	17,35±1,15	32,64±7,60	12,47±1,68
Temperature (ºC)	0,77±0,52	0,12±0,26	0,99±0,98	0,20±0,18	1,07±1,01	0,10±0,18	1,05±0,57	0,06±0,14
Insertion torque (N.cm)	73,12±8,84	68,12±6,51	55,00±10,69	55,62±4,17	43,12±5,30	43,12±14,87	30,62±1,78	30,00±0,00
Resonance frequency (ISQ)	64,81±4,38	60,5±1,87	63,53±3,72	67,5±1,16	58,21±1,86	57,34±4,69	49,5±8,27	48,37±4,07
Removal torque (N.cm)	60,75±4,77	59,37±2,56	47,5±6,97	41,62±2,67	33±3,78	31,25±4,30	25,87±2,64	23,87±3,94

Table 2. The value of p in the Tukey Post-test in relation to the studied variables and the types of densities of the blocks.

Piezo Versus Rotatory				
Variable analyzed	Bone Type I	Bone Type II	Bone Type III	Bone Type IV
Time	<0,001	<0,001	<0,001	<0,001
Temperature	<0,001	<0,001	<0,001	<0,001
Insertion torque	0,443	0,522	0,466	0,567
ISQ	0,043	0,061	0,675	0,59
Removal torque	0,213	0,876	1,000	0,876

* P <0.05 was considered a statistically significant difference.

Table 3. Values in seconds of the time required to perform the cavities.

Time								
	Bone Type I		Bone Type II		Bone Type III		Bone Type IV	
	Piezo	Rotatory	Piezo	Rotatory	Piezo	Rotatory	Piezo	Rotatory
1	71,54	29,2	38,27	16,55	37,09	19,3	47,76	16,19
2	87,13	22,3	41,5	16,43	24,77	17,56	36,68	12,79
3	72,83	20,5	48,81	15,45	38,11	18,68	26,84	11,69
4	91,06	21,9	51,3	17,81	39,57	16,05	35,78	12,47
5	111,52	20,8	44,92	17,08	37,14	16,25	28,39	10,37
6	90,81	20,9	48,54	16,85	37,66	16,69	28,92	12,31
7	102,3	20,05	49,42	16,48	37,78	16,88	33,34	12,41
8	91,31	19,91	48,2	16,78	41,77	17,43	23,48	11,58
Mean	89,81	21,94	46,37	16,67	36,73	17,35	32,64	12,47
Standard-deviation	13,42	3,05	4,46	0,67	5,08	1,15	7,60	1,68

Table 4 - Resonance frequency (ISQ) values according to the groups and types of densities of the blocks.

	Resonance frequency							
	Bone type I		Bone type II		Bone type III		Bone type IV	
	Piezo	Rotatory	Piezo	Rotatory	Piezo	Rotatory	Piezo	Rotatory
1	67,25	58	63,75	66,25	57	57,75	56,75	52,5
2	68,5	62	63,5	69	58,75	58,25	54,75	47,5
3	65,5	61,75	64	69,25	57	60,25	51,75	47,75
4	66,75	58,5	63,5	66,5	57,25	63	31	54
5	62,75	58,5	55	66,5	57,75	46,75	50,5	45
6	65,5	62,5	64,75	67	58,5	58	55,5	42,5
7	63	62	67	67,5	62,5	57,5	50	45,75
8	59,25	60,75	66,75	68	57	57,25	45,75	52
Mean	64,81	60,5	63,53	67,5	58,21	57,34	49,5	48,37
Standard-deviation	0,52	0,26	0,98	0,18	1,01	0,18	0,57	0,14