Insertion torque of hybrid tapered implants with different types of instrumentation: an in vitro analysis and report of two cases

G. THOMÉ, S. PIRES, R. C. SALLATI[1], C. A. CARTELLI, M. B. MOURA[2], L. C. TROJAN

Department of Implantology, Latin American Institute for Research and Dental Education (ILAPEO), Curitiba, Brazil
[1] Positivo University, Curitiba, Brazil
[2] Department of Occlusion, Fixed Prosthodontics and Dental Materials, School of Dentistry, Federal University of Uberlandia, Uberlandia, Brazil

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ABSTRACT

Aim The aim of this study was to observe the behavior of the hybrid implants, evaluating the insertion test with different drilling protocols and present two case reports of hybrid implant placed in the upper arch.
Materials and methods For the *in vitro* study 50 implants were placed in 2 different types of synthetic bone blocks composed of rigid solid polyurethane (high density, type I, and low density, type IV). The implants were divided into five groups (n=10): Group 1 (Test) hybrid/conical implants of 3.75 mm x 13 mm placed in a high density bone block with oversized instrumentation; Group 2 (Control) cutting/cylindrical of 3.75 mm x 13 mm, placed in a high density bone block with regular instrumentation; Group 3 (Test) hybrid/conical implants of 4.3 mm x 13 mm placed in a low density bone block with undersized instrumentation; Group 4 (Test) hybrid/conical implants of 4.3 mm x 13 mm placed in a low density bone block with regular instrumentation; Group 5 (Control) compact/conical implants of 4.3 mm x 13 mm placed in a low density bone block with regular instrumentation. Two cases are reported of hybrid implants placed in the maxilla with 12-month follow up.
Results No significant difference was observed between hybrid/conical implants and the control group, according to final placement torque in high and low density bone. However, undersized instrumentation showed a significantly increased final torque placement for hybrid/conical implant.
Conclusions Implant macrostructure, bone instrumentation technique influence the insertion torque for hybrid/conical implants. At the 12-month follow-up the implants were stable.

KEY WORDS: Bone quality, Dental implants, Primary stability, Secondary stability.

INTRODUCTION

The success of treatment with dental implants is strongly related to osseointegration, defined as an intimate apposition of newly formed bone and reformed without interposition of connective or fibrous tissue. It is a direct structural and functional structure between the organized bone and an implant surface under load (1).
The deposition of bone tissue on the surface of the implants is strongly dependent on the interactions between cells and the titanium surface of the implants and is related to the phenomena of primary or mechanical stability and secondary or biological stability (1,2).
The primary stability is a mechanical factor established by the contact that occurs between the threads of the implant with the bone tissue immediately after placement (3). It is an important prognostic parameter for the success of osseointegration (3). It is dependent on several factors, such as bone quality and quantity, implant macrogeometry, surface milling and the surgical technique used (4). Secondary stability concerns the ability of an implant to remain stable after deposition and regeneration of peri-implant living tissue (5). The establishment of this depends on factors such as primary stability, local physiology and surface type (6).
Another important factor that can affect primary stability is the macrogeometry of the implant (7). Implants with expanded coronal thirds, reduced thread pitch design and slightly tapered core provide greater primary stability than conventional implant designs, thanks to their ability to compress the bone during implantation (8). The implant surface plays a posterior role as osseointegration occurs, modulating the tissue-implant interaction at the bone-implant interface (9).
In order to increase the success rate of the treatments, several researches have been conducted in measuring the primary stability with biomechanical tests. Based on this fact, studies have been outstanding in evaluating the macrogeometry of the implants and their capacity to interfere in the cicatricial process (10,11). In this sense, the objective of this study is to observe the behavior of the hybrid implant, evaluating the insertion behavior with

FIG. 1 Illustrative image of the implants (Neodent, Curitiba, Brazil) used, from left to right: group 1, 3.75 mm x 13 mm (Helix GM); group 3 and 4, 4.3 mm x 13 mm (Helix GM); group 5, 4.3 mm x 13 mm (Drive GM); group 2, 3.75 mm x 13 mm (Titamax GM).
FIG. 2 Drills sequence for conical implants.

different drill protocol in different bone densities, and the influence of the drill protocol for hybrid implants, in relation to two variables: implant exposure with 32 Ncm of placement torque and final placement torque. Two case reports of the placement of immediate implants after extraction of upper lateral incisors are described. Clinically placed implants have the same manufacturing characteristics as the implants used *in vitro*.

MATERIALS AND METHODS

The sample used has the same prosthetic interface and manufacturer (Grand Morse GM; Neodent, Curitiba, Brazil), but with 3 different types of external threads geometry (hybrid, cutting and compacting). The insertion tests were performed in laboratory using different densities of synthetic bone blocks (90 mm x 20 mm x 40 mm) composed of rigid solid polyurethane (ASTM F-1839-08) (Sawbones, Vashon Island, USA). The sample of the present study consisted of 50 implants (Neodent), equally divided into five experimental groups (Test and Control Groups) (Fig. 1).

- Group 1 (Test Group): hybrid/conical implants (Helix GM, Neodent, Curitiba, Brazil) of 3.75 mm x 13 mm, placed in a high density bone block with oversized instrumentation (n=10).
- Group 2 (Control Group): cutting/cylindrical implants (Titamax GM, Neodent, Curitiba, Brazil) 3.75 mm x 13 mm, placed in a high density bone block with regular instrumentation (n=10).
- Group 3 (Test Group): hybrid/conical implants (Helix GM, Neodent) 4.3 mm x 13 mm, placed in a low density bone block with undersized instrumentation (n=10).
- Group 4 (Test Group): hybrid/conical implants (Helix GM, Neodent) 4.3 mm x 13 mm, placed in a low density bone block with regular instrumentation (n=10).
- Group 5 (Control Group): compact/conical implants (Drive GM, Neodent, Curitiba, Brazil) 4.3 mm x 13 mm, placed in a low density bone block with regular instrumentation (n=10).

All implants used were 3.75 mm or 4.3 mm in diameter and 13 mm in length. Two different implant diameters were used, due to the absence of cutting/cylindrical implants (Titamax GM) with a diameter of 4.3 mm. The density of the polyurethane block used followed the recommendations of the implant manufacturer (Neodent, Curitiba, Brazil), foam of 40 pound per cubic foot (pcf) to represent a bone block of high density, and for low density, a foam of 10

Values of density, compression and tension of artificial bone							
Density		Compression Load		Traction Load		Shear load	
		Resistance	Modulus of elasticity	Resistance	Modulus of elasticity	Resistance	Modulus of elasticity
Pcf	g/cc	MPa	MPa	MPa	MPa	MPa	MPa
10	0.16	2.2	58	2.1	86	1.6	19
40	0.64	31	759	19	1000	11	130

TABLE 1: Values of density, compression and tension of artificial bone (Sawbones, Vashon Island, USA)*g/cc - gram/cubic centimetre (Unit of measurement); **MPa - Mega Pascal (Unit of measurement)

Sequence of drills used for the placement of compacting/tapered implants								
Ø Implant	Bone Type	Lance	2.0	Conical 3.5	Conical 3.75	Pilot 3.75	Conical Contour 3.75	Conical 4.3
Helix 3.75	High density	*	*	*		*	*	
Helix 4.3	Low density	*	*	*	**			***
Drive 4.3	Low density	*	*	*				*

TABLE 2 Sequence of drills used for the placement of compacting/tapered implants (Helix GM and Drive GM, Neodent®; Curitiba/ Brazil). * Drills used in all groups; ** Drill used in the group of the Helix GM 4.3 implant in a group with sub instrumentation; *** Drill used in the group of the Helix GM 4.3 implant in a group with regular instrumentation.

Sequence of drills used to placed cutting/cylindrical implants						
Ø Implant	Bone type	Lance	Helical 2.0	Pilot 2/3	Helical 3.0	Pilot 3/3.75
TITAMAX 3.75	High density	*	*	*	*	*

TABLE 3 Sequence of drills used to place cutting/cylindrical implants (Titamax GM, Neodent; Curitiba, Brazil).

pcf. The foam mechanical properties are summarized in Table 1. The drill sequences used for implant placement are summarized in Figure 2 and Table 2, 3, and followed the manufacturer's recommendations.

The perforations of the specimens were performed at a speed of 800 rotations per minute (RPM). The implants were placed at a speed of 30 RPM by the Multi-Functional Twisting Machine (Neodent, Curitiba, Brazil) (Fig. 3), which was developed to standardize the drilling orientation of all drills following the same centering, as well as the implant insertion.

The observed data were the exposed implant length after reaching the torque of 32 Ncm (Variable 1) and final implant placement torque for each group (Variable 2) (Fig. 4).

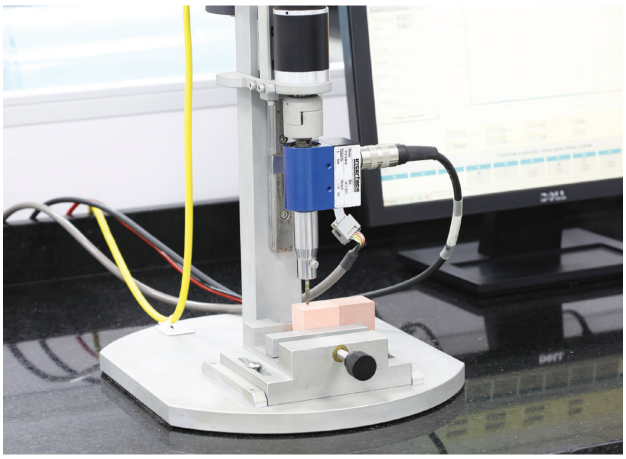

FIG. 3 Implants placed by the Multi-Functional Twisting Machine.

Statistical analysis

The results of the analyzes in both variables were described by means, medians, minimum values, maximum values and standard deviations. For the comparison of two groups in relation to the two variables, the non-parametric Mann-Whitney test was considered. Considering that 4 comparisons of groups 2 to 2 were performed, the significance level of 0.05 was corrected by Bonferroni. Therefore, values of p <0.007 indicated statistical significance. The data were analyzed with the IBM SPSS Statistics v.20 program.

CASE REPORTS

Case 1

A 28-year-old female patient attended the implant dentistry service to evaluate tooth #12 (right upper incisor), that had previously been submitted to root canal endodontic treatment, with a metallic core and clinical crown. Clinically, the dental crown presented a buccal position (Fig. 5a). The patient did not report pain on percussion or palpation. The radiographic examination revealed the presence of an extensive periapical lesion and apical root resorption (Fig. 5b). We recommended the patient to undergo CBCT in order to assess the extent of the lesion and chose the most adequate implant length and diameter (Fig. 5c). Given these clinical observations, tooth #12 extraction and immediate placement of an implant were indicated. Subsequently the patient underwent anesthetic procedures, and minimally traumatic extraction of the tooth was performed using a dental extractor (Neodent, Curitiba, Brazil). The surgical

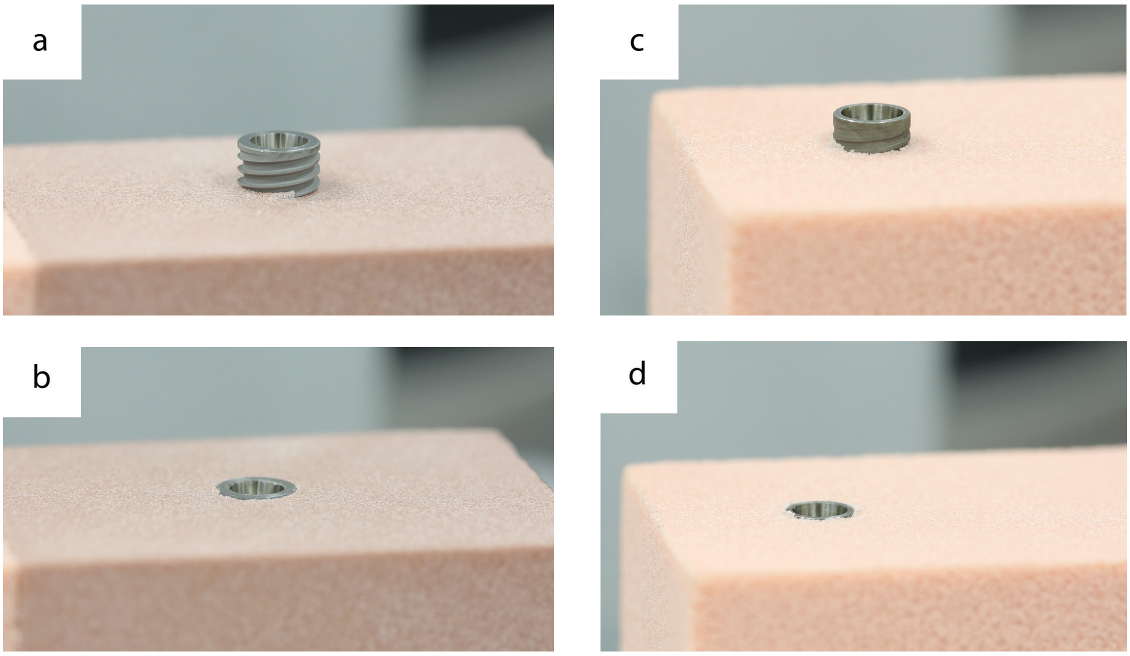

FIG. 4 Implant placed with 32 Ncm in bone type I (a). With final torque (b). Implant placed with 32 Ncm in bone type IV(c). With final torque (d).

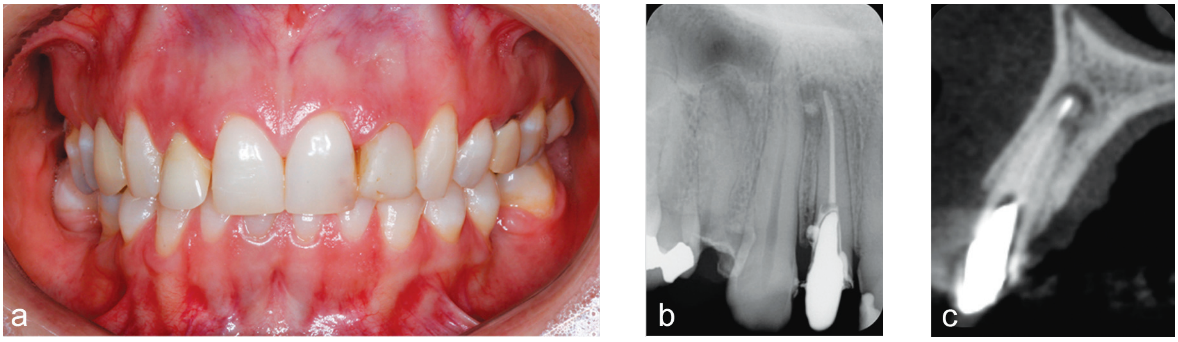

FIG. 5 Case 1 in the preoperative phase: initial clinical aspect (a); preoperative periapical radiograph (b); CBCT (c).

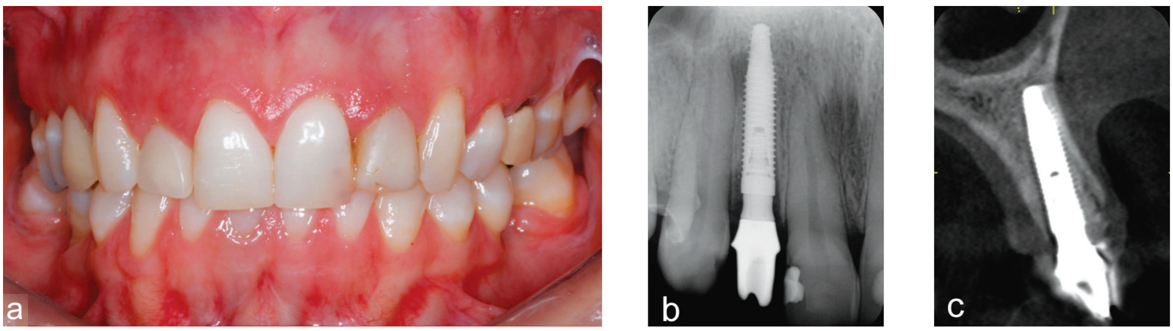

FIG. 6 Immediate postoperative phase: temporary crown installed immediately upon implant placement (a); immediate periapical radiograph (b); immediate CBCT (c).

alveolus was curetted and a 3.5 x 16 mm implant (Gran Morse Helix acqua, Neodent) was placed 2 mm infra-bony with a torque of 45 Ncm. Natural bovine bone grafting material (Cerabone®, Botiss, Zossen, Germany) was used to fill the gap around the implant after placement. A 3.5 x 4 x 2.5 mm prosthetic component (Tibase Neodent, Curitiba, Brazil) was installed on the implant, where a zirconia copping and a provisional crown were cemented. The excursion and centric occlusal contacts were adjusted (Fig. 6). After 4 months the patient returned for the definitive

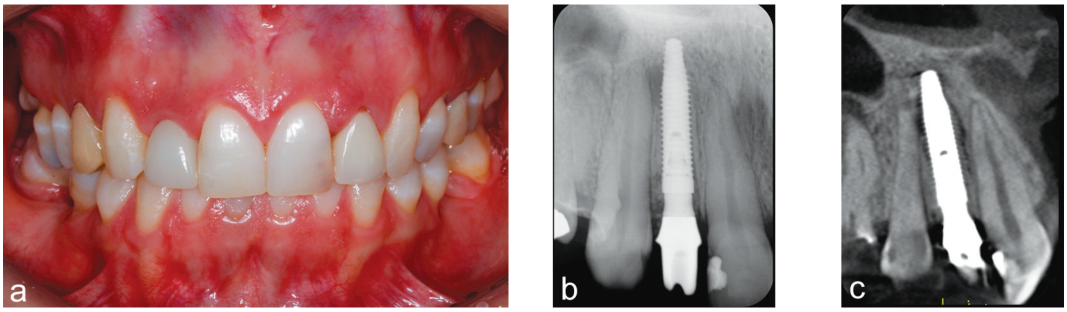

FIG 7 The 12-month follow up: intraoral clinical view (a); periapical radiograph (b); CBCT (c).

zirconia crown. After the 12-month follow-up, the clinical and radiographic examinations are good. No changes in gingival contour, prosthetic maladaptation or bone loss around the implant were observed (Fig. 7).

Case 2

A 57-year-old female patient attended the implant dentistry service to evaluate tooth #22 (left upper incisor). Clinically the dental crown presented a vestibular position, and with small mobility (Fig. 8a). The radiographic examination revealed a fracture in the middle third of the root (Fig. 8b). Given these clinical observations, tooth #22 extraction and immediate placement of an implant were indicated. The patient underwent anesthetic procedures, then minimally traumatic extraction of the tooth was performed using a dental extractor (Neodent). The surgical alveolus was curette and a 3.5 x 13 mm implant Gran Morse Helix acqua (Neodent, Curitiba, Brazil) was placed 2 mm infrabony with a torque of 60 Ncm (Fig. 8c). Natural bovine bone grafting material (Cerabone®, Botiss, Zossen, Germany) was used to fill the gaps formed around the implants after placement. A 3.5 x 4 x 2.5 mm prosthetic component (Tibase, Neodent) was installed on the implant, a zirconia copping and a provisional crown were cemented. The excursion and centric occlusal contacts were adjusted (Fig. 8d). After 4 months the patient returned for the definitive zirconia crown. The patient is in follow-up of 12 months and the clinical and radiographic aspect is good. No changes in gingival contour, prosthetic maladaptation or bone loss around the implant were observed (Fig. 9).

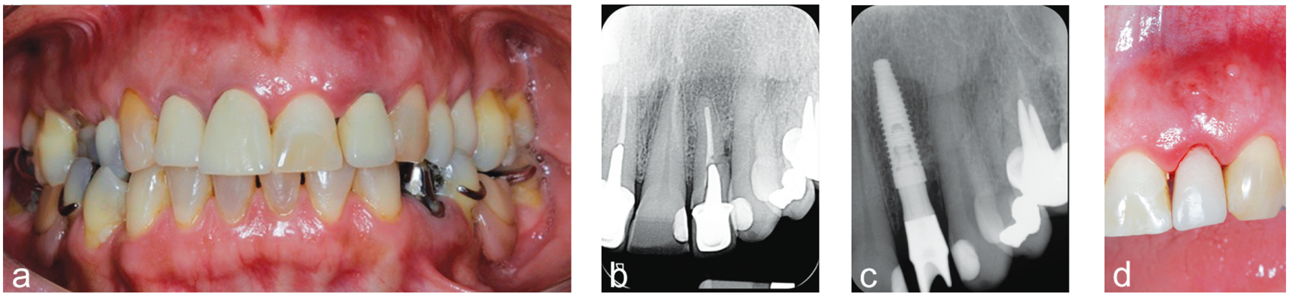

FIG. 8 Case 2 in the preoperative phase: initial clinical aspect (a); preoperative periapical radiograph (b); implant placed immediately after tooth extraction (c); immediate crown installed (d).

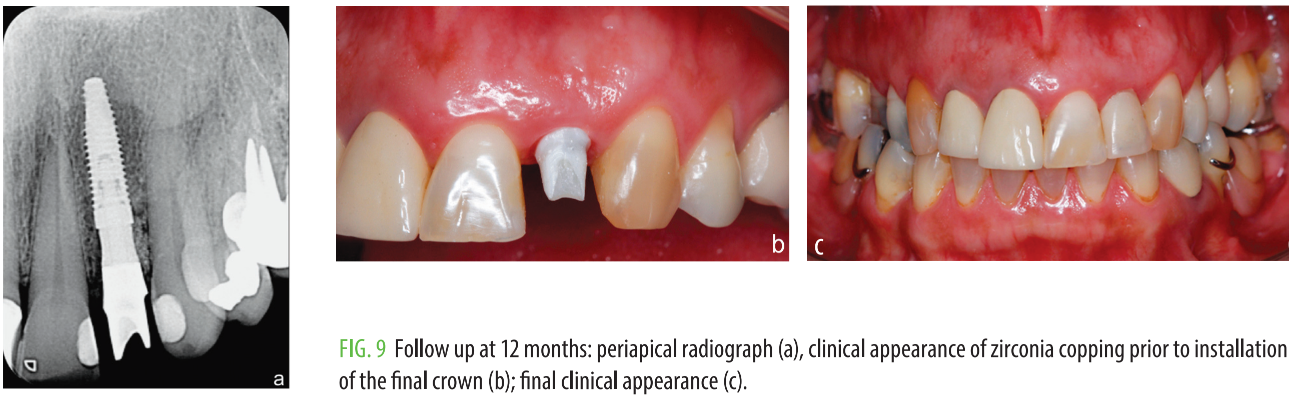

FIG. 9 Follow up at 12 months: periapical radiograph (a), clinical appearance of zirconia copping prior to installation of the final crown (b); final clinical appearance (c).

Results of the comparison of the 5 groups tested										
	GROUP 1		GROUP 2		GROUP 3		GROUP 4		GROUP 5	
	32 Ncm (mm)	FINAL TORQUE (Ncm)	32 Ncm (mm)	FINAL TORQUE (Ncm)	32 Ncm (mm)	FINAL TORQUE (Ncm)	32 Ncm (mm)	FINAL TORQUE (Ncm)	32 Ncm (mm)	FINAL TORQUE (Ncm)
Implant 1	2.00	55.52	3.56	61.33	3.16	60.34	0.00	32.00	2.35	60.10
Implant 2	2.05	57.30	3.95	62.67	2.42	59.70	0.00	32.00	2.52	58.34
Implant 3	1.88	59.44	4.01	62.40	2.37	60.14	0.05	32.00	2.74	60.38
Implant 4	1.87	58.66	3.84	60.34	2.78	61.28	0.07	32.00	2.30	60.39
Implant 5	2.08	60.74	3.80	61.54	3.07	60.51	0.00	32.00	2.60	60.56
Implant 6	2.25	61.58	3.77	60.85	2.54	60.45	0.00	32.00	2.53	60.75
Implant 7	1.91	61.87	3.46	60.19	2.72	58.38	0.00	32.00	2.48	60.10
Implant 8	2.17	58.72	3.84	59.76	3.00	59.54	0.00	32.00	2.44	60.49
Implant 9	1.50	61.15	3.57	60.03	2.83	57.12	0.06	32.00	2.63	60.06
Implant 10	1.73	61.07	3.30	59.98	2.52	59.79	0.44	32.00	2.79	60.78
Media	1.94	59.61	3.71	60.91	2.74	59.73	0.06	32.00	2.54	60.20
SD	0.22	2.07	0.23	1.04	0.28	1.19	0.14	0.00	0.16	0.70

TABLE 4 SD: standard deviation.

RESULTS

The results obtained for each implant are described in Table 4. The groups were compared according to the bone density where they were placed: for high bone density it was compared the placement behavior of hybrid/conical implants - Group 1/test and cylindrical implants – Group 2/control.
The hybrid/conical implant with oversized instrumentation (Group 1) showed, significantly, less implant exposure for 32 Ncm of placement torque (1.94 ± 0.22) than cylindrical implants (Group 2), 3.71 ± 0.23 mm. However, in relation to the final placement torque, no significant difference was observed between the groups (Table 5).
For low bone density it was compared the placement behavior of hybrid/conical implants with undersized instrumentation - Group 3 and conical implants – Group 5/control. The Group 3 and 5 showed similar implant exposure for 32 Ncm of placement torque (2.74 ± 0.28 and 2.54 ± 0.16, respectively). In relation to the final placement torque, no significant difference was observed between the groups (Table 6).
To evaluate the behavior of hybrid/conical implants with different drill sequence for bone instrumentation the results between groups of same outer design and undersized instrumentation (Group 3) and regular instrumentation (Group 4) were compared. Group 3 obtained a significantly higher average of implant above the bone level when reaching the torque of 32 Ncm, 2.74 mm (±0.28), than regular instrumentation (Group 4), 0.06 mm (±0.14) (Table 7). This difference was also observed for final placement torque (Table 7).

DISCUSSION

The stability of an implant plays a fundamental role in the prognosis and success of osseointegration (12). This stability, defined as primary stability, is a mechanical factor established by the contact of the implant threads with the bone tissue immediately after placement. For some authors, it is a fundamental characteristic that allows the bone formation and regeneration without disturbances, based on the proper stress distribution of the masticatory

Group	Implant exposure with 32 Ncm						P value*
	n	P value*	Median	Minimum	Maximum	Standard deviation	
1	10	P value*	1,96	1,50	2,25	0,22	<0,001
2	10	3,71	3,79	3,30	4,01	0,23	
	Final Torque						
	n	Average	Median	Minimum	Maximum	Standard deviation	
1	10	59,6	60,1	55,5	61,9	2,1	0,218
2	10	60,9	60,6	59,8	62,7	1,0	

TABLE 5 Comparison table of the implant exposed lengh (mm) with 32 Ncm of placement torque and the final placement torque of Groups 1 (Helix GM 3.75 mm x 13 mm, with oversized instrumentation) and 2 (Titamax GM 3.75 mm x 13 mm), placed in high density bone. Non-parametric Mann-Whitney test, p <0.007 (corrected by Bonferroni).

Group	Implant exposure with 32 Ncm						P value*
	n	Average	Median	Minimum	Maximum	Standard deviation	
3	10	2,74	2,75	2,37	3,16	0,28	
5	10	2,54	2,53	2,30	2,79	0,16	0,105
	Final Torque						
	n	Average	Median	Minimum	Maximum	Standard deviation	
3	10	59,7	60,0	57,1	61,3	1,2	
5	10	60,2	60,4	58,3	60,8	0,7	0,280

TABLE 6 Comparison table of the explant exposed lengh (mm) to 32 Ncm of placement torque and final placement torque of Groups 3 (Helix GM 4.3 mm x 13 mm, with undersized instrumentation) and 5 (Drive GM 4.3 mm x 13 mm), installed in low density bone. Non-parametric Mann-Whitney test, p <0.007 (corrected by Bonferroni).

Group	Implant exposure with 32 Ncm						P value*
	n	Average	Median	Minimum	Maximum	Standard deviation	
3	10	2.74	2.75	2.37	3.16	0.28	
4	10	0.06	0.00	0.00	0.44	0.14	<0,001
	Final Torque						
	n	Average	Median	Minimum	Maximum	Standard Deviation	
3	10	59.7	60.0	57.1	61.3	12	
4	10	32.0	32.0	32.0	32.0	0.0	<0,001

TABLE 7 Comparison table of the implant exposed length (mm) to 32 Ncm of placement torque and the final placement torque of Groups 3 (Helix GM 4.3 mm x 13 mm, with undersized instrumentation) and 4 (Helix GM 4.3 mm x 13 mm, with regular instrumentation), placed in low density bone. Non-parametric Mann-Whitney test, p <0.007 (corrected by Bonferroni).

loading on the bone/implant interface (13). Thus, the analysis of changes in implant stability can measure the degree of osseointegration. Factors related to the implant stability are quality and quantity of bone, surgical technique and bioengineering, which can influence the period of activation for each individual situation (14). In this perspective, the present study evaluated the insertion performance of hybrid/conical, compacting/conical and cutting/cylindrical implants, varying the density of foam blocks and drill protocol, considering two variables:

1) Implant exposure with 32 Ncm;
2) Final placement torque.

All implants obtained final placement torque above 32 Ncm, regardless bone density and the drill sequence, these results could encourage the immediate loading practice. Group 1, which hybrid/conical implant of 3.75 mm x 13 mm was placed with oversized instrumentation, obtained an average exposure of 1.94 mm above the bone level when reaching the torque of 32 Ncm (Table 4). The cutting/cylindrical implants, 3.75 mm x 13 mm (Group 2), remained, on average, with 3.71 mm of implant above the bone level with the same torque (32 Ncm). This difference was significant. However, in relation to the final placement torque no significant difference was observed between the groups (Table 5). This greater difference in the results related to variable 1 can be explained by the implant outer design (tapered implants from group 1). However, with the adequacy of the drill sequence, the cervical third with compaction threads of the hybrid implants can not exert completely its compaction function, resulting in an adequate final torque, similar to the implant already consecrated for use in high density bone. The contour drill used for overfilling performs a wear on the walls of the middle and cervical thirds of the high density foam block, relieving around 0.35 mm and allowing the final placement torque adjustment. This fact has been presented in the literature, where it is reported that the larger the last milling cutter diameter used to prepare the implant insertion site, the smaller the insertion torque (15). Besides, the geometry of the shear helical chambers allows the necessary implant encircling in high density bone, proved by the results of the final torque average (Variable 2) very close to the one achieved with the cylindrical implants, with sharp chambers at their apexes (Group 2).

These results reaffirm the importance of the adequacy of the bone instrumentation technique according to bone density, corroborating with other findings in the literature in which the strength of association between implant design and initial stability is less relevant than other factors such as depth of insertion and density of the block (16). Bone density is considered the most important factor for fixation of an implant aiming at initial stability and absence of movement during the early stage of surgical healing (17,18).

Group 3, in which the 4.3 mm x 13 mm hybrid/conical implant was placed with undersized instrumentation, obtained an average of 2.74 mm (±0.28) of implant above the bone level when reaching the torque of 32 Ncm (Table 5). The Conical/Compacting implant 4.3 mm x 13 mm (Group 5), remained on average 2.54 mm (±0.16) of implant above the bone level at the same torque. This difference was not significant. As well as the final placement torque comparison, between the groups (Table 5). This occurred because the undersized instrumentation for low-density bone bed favored the performance of the progressive compacting threads of the mid-cervical thirds of the hybrid/conical implant, thus obtaining the same stability of a compacting implant model already enshrined in the literature (19,20) and that has this function in lower density bone sites. Regarding conicity, several studies have shown that the initial stability of the implant is increased by it and therefore tapered implants in areas of lower density are well indicated (21,22).

As previously mentioned, group 3, in which the hybrid/conical implant 4.3 mm x 13 mm was placed with undersized instrumentation, obtained an average of 2.74 mm (±0.28) of implant above the bone level on reaching the torque of 32 Ncm. When the same implant underwent regular instrumentation (Group 4) a significant difference was observed. The exposure remained with an average of 0.06 mm (±0.14) of implant above the bone level when reaching the same torque (Table 7). Regarding the placement torque, a significant difference was also observed between the groups. This is because the success in primary stability consists of preparing the bone bed slightly less than the structural dimensions of the implant to be placed and insertion torques above 40 Ncm (15). Thus, the contact of walls of a larger implant with the smaller bone bed, made in the bone tissue, favors the stability required for the osseointegration process then it is suggested that a undersized instrumentation be made in low density bones to achieve higher torques for hybrid/conical implants (23).

Studies suggest that the placement of rough tapered implants in synthetic bone models using the undersized instrumentation technique results in greater primary stability of the implant. In addition, they also found a correlation between primary stability and bone density of the synthetic model, implying that, in the case of a site with low bone density, an implant with an optimal surface roughness can significantly increase primary stability (24).

The understanding of the biology of osseointegration combined with the skill in the surgical technique and a reliable implant system that favors the achievement of primary stability in different bone densities plays an important role in the predictability of the treatment, facilitating clinical success. So further studies should be carried out to ratify or refute the present discussion.

The versatility of hybrid/conical implant against various bone densities found favors in the practice of immediate loading and allows the dental surgeon to reduce the number of implant designs in his professional practice.

CONCLUSIONS

Within the limitations of this study, it is suggested that the macrostructure of the implant, as well as the bone instrumentation technique, influenced the insertion torque. Therefore, some considerations can be described:

Hybrid/conical implants with oversized instrumentation showed similar behavior to control group for high density bone; Hybrid/conical implants with undersized instrumentation showed similar behavior to control group for low density bone. This result was not achieved with regular instrumentation.

Clinical relevance

Implants with different macrogeometries placed in synthetic bone with different types of instrumentation showed that there are differences in behavior between them. The type of bone-dependent instrumentation and the macrogeometry of the implant are important, considering primary stability and osseointegration of the implant as well as preparation of an immediate provisional prosthesis, this is observed in the two cases reported with a 12-month follow-up.

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Conflict of Interests: The authors work at Neodent and present conflicts of interest. The authors had no influence on the results.

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