

In Vitro Evaluation of the Primary Stability of Short and Conventional Implants

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The objective of this study was to evaluate the primary stability of short and conventional dental implants with different platform types at different site densities in vitro. One hundred twenty implants were placed in polyurethane blocks that simulate different bone densities (bone types I and IV). The implants were divided into 10 groups, with 12 implants each according to the type of prosthetic connections (external hexagon, EH; morse taper, MT) and size of the implants (conventional: 4 × 10 mm; short: 5 × 5, 5.5 × 5, 5 × 6, and 5.5 × 6 mm). Insertion torque and resonance frequency analyses were performed to evaluate the primary stability. The Kruskal-Wallis test complemented by Dunn's test and the Mann-Whitney test were used for statistical analysis. These tests were applied at the confidence level of 95% ($P < .05$). The implants installed in blocks with density type IV exhibited reduced insertion torque compared with implants placed in blocks with density type I. Short implants with EH exhibited increased insertion torque compared with short implants with MT in blocks with bone density type I. In general, implants installed in blocks with density type I exhibited greater primary stability. The short implants with EH with a 5.5-mm diameter and the short implants with MT with a 5-mm diameter exhibited reduced primary stability. No differences between short and conventional implants were noted. Short implants have primary stability and insertion torque at least equivalent to conventional implants irrespective of the platform type and density of the site.

Key Words: bone density, short implants, osseointegration

INTRODUCTION

The use of implants in the rehabilitation of edentulous and partially edentulous patients promotes a more conservative alternative in prosthetic treatment because the missing teeth can be replaced with great predictability, with no wear of adjacent teeth during the prosthetic procedures,¹ thus promoting greater patient satisfaction.² However, the installation of implants is dependent on bone tissue availability, which allows obtaining a suitable positioning of the dental implants without causing injury to noble structures present in the jaws.³

Some procedures have been indicated for the resolution of bone viability, such as the elevation of the maxillary sinus,⁴ the use of onlay graft blocks,⁵ the lateralization of the inferior alveolar nerve,⁶ and osteodistraction.⁷ However, these surgical procedures are complex and increase patient discomfort, the possibility of injuries of noble structures, and the time in the beginning of the prosthetic procedures.^{8,9}

Short implants have been cited as a less traumatic alternative

to the rehabilitation of areas with poor bone availability.^{8,10,11} Studies have demonstrated that the success rate of short implants is similar to that of conventional implants.^{8,11,12} However, the success of implants is highly dependent on obtaining primary stability,¹³⁻¹⁵ and factors such as the implant design,¹⁶ bone density,¹⁷ and insertion torque¹⁸ influence this parameter.

Given that short implants can be used in sites with low bone density, such as the posterior region of the maxillary, to avoid the sinus floor augmentation surgeries, it is important that the short implants present an appropriate design, which can improve the primary stability even in regions with low bone density. Thus, the objective of the study was to assess the primary stability through resonance frequency analysis and the insertion torque of conventional and short size implants with external hexagon or morse taper placed in polyurethane blocks with similar densities of bone types I and IV to answer the following questions. (1) Can the short implants provide primary stability at the same level of the conventional implants? (2) Can the type of platform and the different densities modify the primary stability of the short and conventional implants?

MATERIALS AND METHODS

Implants

One hundred twenty tapered implants were used in this study (Implacil de Bortoli, São Paulo, SP, Brazil). The implants

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were divided into 10 groups according to the type of prosthetic connection (external hexagon [EH] and morse taper [MT]) and implant size (conventional: 4×10 mm; short: 5×5 , 5.5×5 , 5×6 , and 5.5×6 mm). Six implants of each type were installed in polyurethane blocks of different densities (type I or type IV).

Implants placement

The implants were inserted into the specimens by a single operator following the sequence of surgical drills recommended by the manufacturer. To reproduce in vitro the evaluation of the primary stability of the implant in similar conditions to the bone tissue, blocks of polyurethane (Nacional Ossos, Jaú, Brazil) of 2 different densities simulating bone type I (40 per cubic foot [PCF]/ 0.64 g/cm^3) and type IV (15 PCF or 0.24 g/cm^3) were used. The blocks were generated in such a manner to have a length of 9.9 cm, width of 2.55 cm, and height of 2.02 cm. Each block received 5 implants. In total, 24 blocks were produced. Twelve of these blocks had a density similar to type I human bone, whereas the other 12 blocks had a density similar to type IV human bone (the Figure). The surgical drills were replaced every 5 perforations for implant placement.

To facilitate the standardization of implant placement in the blocks, 2 surgical guides were prepared with resin acrylic. These surgical guides had the same width and length of the blocks, allowing the placement of the implants at the same position and equidistantly. A distance of 1 cm between the implants and the edge of the blocks was maintained. The EH implants were placed at the level of the blocks, whereas the MT implants were installed 2 mm below the end of the blocks (the Figure).

Evaluation of primary stability: insertion torque and resonance frequency analysis

The primary stability of each implant was assessed via insertion torque and resonance frequency analysis. Insertion torque was measured at the time of implant installation in the block until the implant reached the ideal position using the torque wrench (Implacil de Bortolli, São Paulo, Brazil). Resonance frequency analysis was performed with the Osstell (Osstell, Integration Diagnostic, Göteborg, Sweden). This machine uses a piezoelectric effect to produce a deflection of the implant on the transducer (smart peg), which was adapted directly over the implant and was stimulated to vibrate by means of sinusoidal waves. The stability measured by this device was measured on a scale from 1 (minimum) to 100 (maximum). The torque wrench and the Osstell were calibrated before and after the measurements of each implant. The measurements were repeated 3 times in each implant, and the average of this value was considered the value of the sample to eliminate the measurement bias.

Statistical analysis

The software GraphPad Prism 5 (San Diego, Calif) was used to perform statistical analyses of the study. The data obtained from insertion torque and resonance frequency analyses were assessed for a normal distribution using the Kolmogorov-Smirnov, D'Agostino-Pearson, and Shapiro-Wilk tests. These

tests revealed that data were not distributed according to the theorem of the central data distribution. The comparison of the subgroups was performed as follows: (1) the same implants were compared varying the block density (type I vs type IV) by the Mann-Whitney test; (2) the same implants placed in the same varying the implants platform (EH vs MT) by the Mann-Whitney test; (3) the comparison of 5 types of implants (conventional: 4×10 mm; short: 5×5 , 5.5×5 , 5×6 , and 5.5×6 mm) in the same block density and with the same type of platform was performed by the Kruskal-Wallis test complemented by the Dunn's test. The comparison of similar implant types installed in blocks with different densities was performed by the Mann-Whitney test. All tests were applied with a significance α level of 95% ($P < .05$).

RESULTS

The insertion torque of the implants installed in the blocks with a density similar to bone type I was consistently increased compared with the insertion torque of the implants installed in the blocks with a density similar to bone type IV ($P < .05$). The conventional EH implants presented lower insertion torque compared with short EH implants when the implants were placed in blocks with a bone type I density. In addition, the short MT implants presented lower insertion torque compared with short EH implants when these implants were placed in blocks with a bone type I density. No differences were noted between the implants placed in blocks with densities similar to bone type IV. Table 1 presents the mean (median) \pm SD of the insertion torque values in all the groups.

Regarding the data of resonance frequency analysis, reduced primary stability values were noted in implants installed in blocks with a density similar to bone type IV compared with implants placed in blocks with a density similar to bone type I, except the short EH implants (5×5 and 5×6 mm) and short MT implants (5.5×5 mm), which exhibited similar stability when installed in blocks with different densities. Regarding the implants placed in blocks with a density similar to bone type I, short implants with EH (5×6 mm) and MT (5.5×5 mm) exhibited increased primary stability compared with implants with MT (5×6 mm) and EH (5.5×5 mm), respectively. Regarding the implants placed in blocks with a density similar to bone type IV, short implants with EH and a 5-mm diameter presented increased primary stability compared with MT implants with the same diameter, whereas the short implants with MT with a 5.5-mm diameter exhibited increased primary stability compared with EH implants with the same diameter. Table 2 presents the mean (median) \pm SD of the resonance frequency analysis for all groups.

DISCUSSION

Obtaining primary stability has been reported as an important factor for the osseointegration of implants,^{17,19,20} and this parameter has been used as a reference for determining the best time for application of occlusal loads on the dental implant.^{21,22} The density of the surgical sites influences the

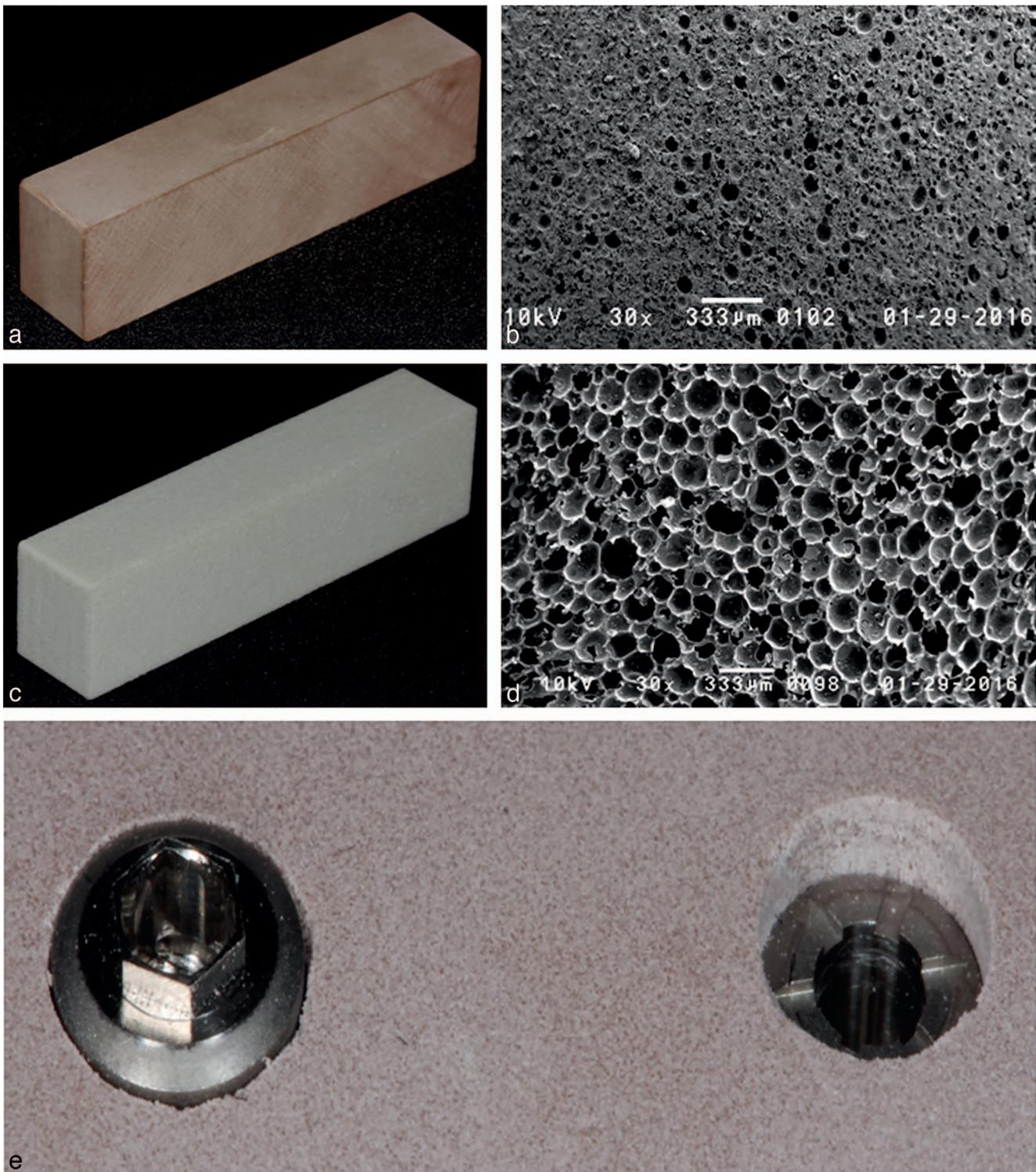


FIGURE. (a) The polyurethane block with a density similar to type I human bone. (b) The scanning electron microscopy (SEM) image of the block with density similar to type I human bone. Note that this block has a more massive structure. (c) The polyurethane block with a density similar to type IV human bone. (d) The SEM image of the block with density similar to type IV human bone. Note that this block has a more porosity structure. (e) Implants in the final position into the polyurethane blocks. The external hexagon implants were placed at the level of the blocks, whereas the morse taper implants were installed 2 mm below the end of the blocks.

TABLE 1
Median (Q1, Q3) of the insertion torque values (N/cm²) in all groups*

Prosthetic Connection	Size	Block Density		
		Type I	Type IV	P
External hexagon	Conventional (4 × 10 mm)	25.00 (25.00, 25.00)†	10.00 (10.00, 10.00)	<.05
	Short (5 × 5 mm)	40.00 (40.00, 40.00)	10.00 (10.00, 10.00)	<.05
	Short (5.5 × 5 mm)	40.00 (40.00, 40.00)	10.00 (10.00, 10.00)	<.05
	Short (5 × 6 mm)	40.00 (40.00, 40.00)	10.00 (10.00, 10.00)	<.05
	Short (5.5 × 6 mm)	40.00 (40.00, 40.00)	10.00 (10.00, 10.00)	<.05
	P	<.05	NS	
Morse taper	Conventional (4 × 10 mm)	25.00 (25.00, 33.75)	10.00 (10.00, 11.25)	<.05
	Short (5 × 5 mm)	30.00 (30.00, 30.00)‡	10.00 (10.00, 10.00)	<.05
	Short (5.5 × 5 mm)	30.00 (27.50, 30.00)‡	10.00 (10.00, 10.00)	<.05
	Short (5 × 6 mm)	30.00 (30.00, 30.00)‡	10.00 (10.00, 10.00)	<.05
	Short (5.5 × 6 mm)	30.00 (30.00, 30.00)‡	10.00 (10.00, 10.00)	<.05
	P	NS	NS	

*Note the different variables tested in this study (implant size, prosthetic connection, and block density). NS indicates not significant.

†Lower insertion torque than the short implants placed in blocks with density similar to type I bone based on the Kruskal-Wallis test with Dunn's test.

‡Lower insertion torque of the short implants with external hexagon placed in blocks with a density similar to type I bone based on the Mann-Whitney test.

obtained primary stability.^{17,20,23} This statement was confirmed in this study, given that we verified increased insertion torque and resonance frequency values on implants installed in blocks with a density similar to bone type I compared with implants placed in blocks that simulated the density of bone type IV.

Another important finding from this study was that conventional implants with external hexagons had a reduced insertion torque compared with short implants placed in blocks with a density similar to bone type I. The diameters of the short implants in this study were 5 or 5.5 mm, whereas conventional implants were 4 mm in diameter. The increased diameter of the short implants may explain the increased primary stability of the short implants. It was previously reported that the diameter

of the implants has more influence on the primary stability than the length of the implant.^{16,24}

EH implants exhibited increased insertion torque compared with MT implants in blocks with a density similar to bone type I. Finite element studies revealed that EH implants exhibit increased concentrated stress in the cervical portion of the implant when subjected to the occlusal loads compared with MT implants.²⁵ It is possible that the distribution of forces during implant placement is similar to that observed during occlusal loads,²⁵ and this fact may explain the increased insertion torque of HE implants compared with MT implants. It is worth noting that despite this significant difference, the MT implants presented insertion torque values within the range of 28.33–30 N in the blocks that simulated the density of bone

TABLE 2
Median (Q1, Q3) of the resonance frequency analysis (RFA) in all groups*

Prosthetic Connection	Size	Block Density		
		Type I	Type IV	P
External hexagon	Conventional (4 × 10 mm)	27.75 (19.50, 38.13)	9.50 (7.18, 16.13) ^{a,b}	<.05
	Short (5 × 5 mm)	41.38 (20.38, 56.13)	28.88 (18.44, 41.44) ^{a,b}	NS
	Short (5.5 × 5 mm)	35.50 (25.38, 37.94)†	3.00 (1.87, 31.94) ^{a,b,‡}	<.05
	Short (5 × 6 mm)	34.75 (28.75, 40.63)	38.35 (25.81, 44.56) ^a	NS
	Short (5.5 × 6 mm)	20.75 (18.44, 30.13)	5.00 (3.12, 11.00) ^{b,‡}	<.05
	P	NS	<.05	
Morse taper	Conventional (4 × 10 mm)	20.50 (19.38, 50.38)	15.00 (12.25, 25.25) ^{a,b}	<.05
	Short (5 × 5 mm)	42.38 (13.50, 62.06)	1.25 (1.00, 20.19) ^{b,‡}	<.05
	Short (5.5 × 5 mm)	45.00 (36.50, 59.75)	45.75 (33.80, 50.13) ^a	NS
	Short (5 × 6 mm)	14.38 (12.63, 24.13)†	2.50 (2.00, 9.62) ^{b,‡}	<.05
	Short (5.5 × 6 mm)	14.50 (5.12, 37.13)	43.50 (31.19, 46.50) ^{a,b}	<.05
	P	NS	<.05	

*Note the different variables tested in this study (implant size, prosthetic connection, and block density). Different letters represent significant differences between the implants with the same prosthetic connections placed in blocks with the same density based on the Kruskal-Wallis test with Dunn's test. NS indicates not significant.

†Lower RFA than implants with similar dimensions but different prosthetic connections placed in blocks with a density similar to the type I bone using the Mann-Whitney test.

‡Lower RFA than implants with similar dimensions but different prosthetic connections placed in blocks with a density similar to type IV bone based on the Mann-Whitney test.

type I, and these values represent good primary stability of the implant during the clinical procedures.²²

An important finding of this study was that resonance frequency analysis data for short implants were generally similar to the data recorded for conventional implants. Changes in the short implants design (eg, increase of the diameter, modification of the implants surfaces)^{16,26} provided an improvement in clinical outcomes for these implants, inducing increased primary stability¹² and promoting clinical outcomes similar to the conventional implants.^{10–12}

In our study, the statistically significant differences that occurred in the insertion torque and resonance frequency analyses were not coincidental. Both tests analyze the primary stability, and their values are influenced by similar parameters (eg, bone density). A positive correlation was noted between these data; however, the result is not statistically significant.^{27,28} This effect occurs because the insertion torque measures the compression induced by implant placement into the surgical site, whereas the resonance frequency analysis evaluates the micro-movements of the implant in the final position into the jaws.²⁹

This in vitro study has limitations that should be taken into consideration when interpreting the results. Although the blocks exhibited density characteristics similar to bone, these blocks exhibited homogeneous density, which is not observed in bone tissue. The implants were also installed under optimum conditions, with no conditions that hinder access to the surgical site. Thus, although the preliminary data are important for the knowledge regarding the effect of the short implant design on primary stability, clinical studies assessing the primary stability of short implants are needed to confirm the findings of this study.

CONCLUSION

In conclusion, the short implants tested in this study exhibited primary stability and insertion torque at least equivalent to conventional implants irrespective of the platform type and density of the site.

ABBREVIATIONS

EH: external hexagon
MT: morse taper
PCF: per cubic foot

REFERENCES

- Al-Quran FA, Al-Ghalayini RF, Al-Zu'bi BN. Single-tooth replacement: factors affecting different prosthetic treatment modalities. *BMC Oral Health*. 2011;21:11–34.
- Zembic A, Wismeijer D. Patient-reported outcomes of maxillary implant-supported overdentures compared with conventional dentures. *Clin Oral Implants Res*. 2014;25:441–450.
- Arlin ML. Short dental implants as a treatment option: results from an observational study in a single private practice. *Int J Oral Maxillofac Implants*. 2006;21:769–776.
- Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. *J Oral Surg*. 1980;38:613–616.
- Misch CM. Ridge augmentation using mandibular ramus bone grafts for the placement of dental implants: presentation of a technique. *Pract Periodontics Aesthet Dent*. 1996;8:127–135.
- Friberg B, Ivanoff CJ, Lekholm U. Inferior alveolar nerve transposition in combination with Brånemark implant treatment. *Int J Periodontics Restorative Dent*. 1992;12:440–449.
- Chiapasco M, Zaniboni M, Rimondini L. Autogenous onlay bone grafts vs. alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: a 2–4-year prospective study on humans. *Clin Oral Implants Res*. 2007;4:432–440.
- Felice P, Pistilli R, Piattelli M, Soardi E, Corvino V, Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 5 × 5 mm implants with a novel nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. Preliminary results from a randomised controlled trial. *Eur J Oral Implantol*. 2012;5:149–161.
- Vasco MA, Hecke MB, Bezzon OL. Analysis of short implants and lateralization of the inferior alveolar nerve with 2-stage dental implants by finite element method. *J Craniofac Surg*. 2011;22:2064–2071.
- Anitua E, Orive G, Aguirre JJ, Andía I. Five-year clinical evaluation of short dental implants placed in posterior areas: a retrospective study. *J Periodontol*. 2008;79:42–48.
- Schincaglia GP, Thoma DS, Haas R, Tutak M, Garcia A, Taylor TD, Hämmerle CH. Randomized controlled multicenter study comparing short dental implants (6 mm) versus longer dental implants (11–15 mm) in combination with sinus floor elevation procedures. Part 2: clinical and radiographic outcomes at 1 year of loading. *J Clin Periodontol*. 2015;42:1042–1051.
- Calvo-Guirado JL, López Torres JA, Dard M, Javed F, Pérez-Albacete Martínez C, Maté Sánchez de Val JE. Evaluation of extrashort 4-mm implants in mandibular edentulous patients with reduced bone height in comparison with standard implants: a 12-month results. *Clin Oral Implants Res*. 2016;27:867–874.
- Javed F, Romanos GE. Role of implant diameter on long-term survival of dental implants placed in posterior maxilla: a systematic review. *Clin Oral Invest*. 2015;19:1–10.
- Moraschini V, Velloso G, Luz D, Barboza EP. Implant survival rates, marginal bone level changes, and complications in full-mouth rehabilitation with flapless computer-guided surgery: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg*. 2015;44:892–901.
- Queiroz TP, Aguiar SC, Margonar R, de Souza Faroni AP, Gruber R, Luvizuto ER. Clinical study on survival rate of short implants placed in the posterior mandibular region: resonance frequency analysis. *Clin Oral Implants Res*. 2015;26:1036–1042.
- Möhlhenrich SC, Heussen N, Elvers D, Steiner T, Hölzle F, Modabber A. Compensating for poor primary implant stability in different bone densities by varying implant geometry: a laboratory study. *Int J Oral Maxillofac Surg*. 2015;44:1514–1520.
- Martinez H, Davarpanah M, Missika P, Celletti R, Lazzara R. Optimal implant stabilization in low density bone. *Clin Oral Implants Res*. 2001;12:423–432.
- Trisi P, Perfetti Q, Baldoni E, Berardi D, Colagiovanni M, Scogna G. Implant micromotion is related to peak insertion torque and bone density. *Clin Oral Implants Res*. 2009;20:467–471.
- Albrektsson T, Brånemark PI, Hansson HA, Lindström J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. *Acta Orthop Scand*. 1981;52:155–170.
- Bilhan H, Bilmenoglu C, Urgan AC, Ates G, Bural C, Cilingir A, Geckili O. Comparison of the primary stability of two implant designs in two different bone types: an in vitro study. *Int J Oral Maxillofac Implants*. 2015;30:1036–1040.
- Bischof M, Nedir R, Szmukler-Moncler S, Bernard JP, Samson J. Implant stability measurement of delayed and immediately loaded implants during healing. *Clin Oral Implants Res*. 2004;15:529–539.
- Barewal RM, Stanford C, Weesner TC. A randomized controlled clinical trial comparing the effects of three loading protocols on dental implant stability. *Int J Oral Maxillofac Implants*. 2012;27:945–956.
- Oliscovitz NF, Shimano AC, Marcantonio Junior E, Lepri CP, Dos Reis AC. Analysis of primary stability of dental implants inserted in different substrates using the pullout test and insertion torque. *Int J Dent*. 2013;2013:194987.
- Maiorana C, Farronato D, Pieroni S, Cicciu M, Andreoni D, Santoro F. A four-year survival rate multicenter prospective clinical study on 377 implants: correlations between implant insertion torque, diameter, and bone quality. *J Oral Implantol*. 2015;41:e60–e65.
- Dayrell AC, Noritomi PY, Takahashi JM, Consani RL, Mesquita MF,

dos Santos MB. Biomechanical analysis of implant-supported prostheses with different implant-abutment connections. *Int J Prosthodont*. 2015;28:621–623.

26. Urdaneta RA, Daher S, Leary J, Emanuel KM, Chuang SK. The survival of ultrashort locking-taper implants. *Int J Oral Maxillofac Implants*. 2012;27:644–654.

27. da Cunha HA, Francischone CE, Filho HN, de Oliveira RC. A comparison between cutting torque and resonance frequency in the assessment of primary stability and final torque capacity of standard and

TiUnite single-tooth implants under immediate loading. *Int J Oral Maxillofac Implants*. 2004;19:578–585.

28. Valente ML, de Castro DT, Shimano AC, Lepri CP, dos Reis AC. Analysis of the influence of implant shape on primary stability using the correlation of multiple methods. *Clin Oral Invest*. 2015;19:1861–1866.

29. Herekar M, Sethi M, Ahmad T, Fernandes AS, Patil V, Kulkarni H. A correlation between bone (B), insertion torque (IT), and implant stability (S): BITS score. *J Prosthet Dent*. 2014;112:805–810.