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ORIGINAL RESEARCH

Evaluation of Short and Regular Implants after Prosthesis Placement in the Mandible: A Nonrandomized Controlled Clinical Trial

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ABSTRACT

Aim: The aim of this nonrandomized controlled preliminary clinical trial was to compare treatment using short and conventional implants in the posterior region of the mandible after prosthesis installation by means of clinical, resonance frequency, and radiographic analyses.

Materials and methods: A total of 10 patients with 40 dental implants already installed were included in this study. Four implants were installed for each subject, in which the length of the implants (short and conventional) was distributed according to the reminiscent alveolar bone in the left and right side of the mandible. All implants received splinted prosthesis after the osseointegration period. Analyses were performed immediately after prosthesis installation (T1), and 3 (T2) and 6 months (T3) after prosthesis placement.

Results: The 6-month survival and success rates were 100% for the short and conventional implants. Probing depths (PDs) after 6 months did not show statistical differences between short and conventional implants. All groups showed mean implant stability quotient (ISQ) values above 60 in all periods evaluated, demonstrating great implant stability, and no differences were found between groups at T3. Radiographic measurements showed an increased bone loss for conventional implants compared with short implants in all the three periods evaluated.

Conclusion: Our findings suggest that treatment of resorbed posterior regions in the mandible with shorter dental implants is as reliable as treatment with conventional implants after 6 months of splinted prosthesis installation.

Clinical significance: Short implants might be considered a predictable treatment alternative to bone augmentation or extensive surgical techniques in regions of restricted vertical bone height in the posterior region of the mandible.

Keywords: Alveolar bone loss, Bone resorption, Dental implants, Dental prosthesis, Implant supported.

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INTRODUCTION

Endosseous dental implants have provided predictable treatment outcomes and long-term high success and survival rates in cases of partial or total edentulism.[1,2] However, some factors, such as periodontal disease, early tooth loss, systemic diseases, infections, and use of ill-fitted dentures might cause alveolar bone resorption, making the installation of conventional implants particularly difficult to achieve. When there is vertical bone loss leading to a limited ridge height in the posterior region of the maxilla and mandible, the primary use of conventional implants >10 mm in length is a meticulous, difficult, and challenging procedure. In these situations,

surgical modification by the transposition of the inferior alveolar nerve,[3] bone graft harvesting techniques, sinus floor elevating procedure,[4] or alveolar distraction can allow the installation of wider and longer implants.[5] However, all these procedures are still little predictable, demand high surgical precision, and the increased risk for surgical complications and the morbidity to the patient are general drawbacks related to these approaches that decrease patient acceptance.

To overcome these disadvantages and to decrease the complication rate, the use of shorter implants could satisfy several indications where there is insufficient bone volume and may be considered a predictable treatment alternative to restore resorbed posterior alveolar ridge.[6] When properly designed and executed, shorter dental implants possess several advantages, such as (1) reduced number of interventions and treatment time, (2) reduced risks of paresthesia, (3) possibly lower cost, (4) reduced number and interval of office visits, (5) lower patient morbidity, and (6) increased patient acceptance.[7] Therefore, the indication for short implant placement in the posterior region of the maxilla and mandible has expanded with successful rates similar to conventional implants.[5,7-10]

Most recently, the success and survival rates of short implants (shorter than 10 mm length) installed in the posterior region seem to be similar to longer implants, according to recent systematic reviews.[11,12] This fact could be due to the scientific innovations in implant designs, alteration of the implant surface topography, enhancement in surgical techniques, and advancements on prosthetic rehabilitation.[8] The biomechanical rationale for the successful use of short implants is because most of the prosthetic forces involved in load bearing are distributed to the crestal portion of the implant body (the first two implant threads), while very slight stress is transmitted to the implant apical portion, as revealed by finite element analysis,[13] and the increase of implant length did not improve its anchorage considerably.[14] Thus, implant length might not be a main factor in spreading prosthetic loads to the implant/bone interface.[15] However, there are some risk factors that may increase stress and could result in a wide-ranging variation of the failure rate of short implants compared with conventional implants, such as increased ideal crown/implant ratio, higher masticatory forces, and bone mineral density in the region.

Here, we aimed to compare treatment using short (5.5 mm length) and conventional (10 mm length) implants in the posterior region of the mandible after splinted prosthesis installation. The purposes of this clinical study were to compare PD alterations, by clinical assessments, dental implant stability, using resonance frequency analysis (RFA), and marginal bone-level alteration, by means of radiological assessments, immediately after prosthesis installation (T1), and 3 (T2) and 6 months (T3) after prosthesis placement.

MATERIALS AND METHODS

Experimental Design

This nonrandomized controlled preliminary clinical trial was conducted according to the principles outlined in the Declaration of Helsinki (last revised Fortaleza, Brazil, 2013) and was approved by the Ethics Committee on Human Research of the Dental School (Protocol #1302/11). The side of the mandible (left or right) in which the implants were installed was not randomized because the implant length was chosen according to the reminiscent alveolar bone crest height. In this context, short dental implants (5.5 mm length) were installed in patients with an alveolar bone crest height of <8 mm. For conventional implant installation (10 mm length), bone crest height above 12 mm should be present. Written informed consent to undergo all procedures was obtained prior to initial treatment from all patients.

Patient Characteristics

A total of 10 patients (7 female and 3 male subjects) from the Implantology Department were enrolled in this study. Patients were between 42 and 69 years of age, with mean age of 52.9 years at the start of the treatment. The inclusion criteria were as follows: Implant site free from infection, and patients who presented dental implants in the posterior mandibular regions and who needed prosthetic rehabilitation. All the ten patients included in this study presented with four implants (two implants from each side of the mandible) with a total of 40 implants. Moreover, patients were excluded if they had graft placement at the surgical site and compromised general health conditions or any condition known to modify bone metabolism that would primarily affect healing process, including chemotherapy and uncontrolled diabetes. Smokers or patients with bruxism were also excluded from the study.

Clinical Evaluations

All treatments were carried out at the Implantology Department in the Dental School and patients presented with 40 implants placed in the posterior region of the mandible as follows: 20 implants of 5.0 mm width x 5.5 mm length and 20 implants of 4.0 mm width x 10 mm length. All implants placed were double acid-etched, commercially available implants (MasterPorous®, Conexao Prosthesis System, São Paulo, Brazil) with external tapered connection, which received transepithelial healing abutments 4 months after implant installation.

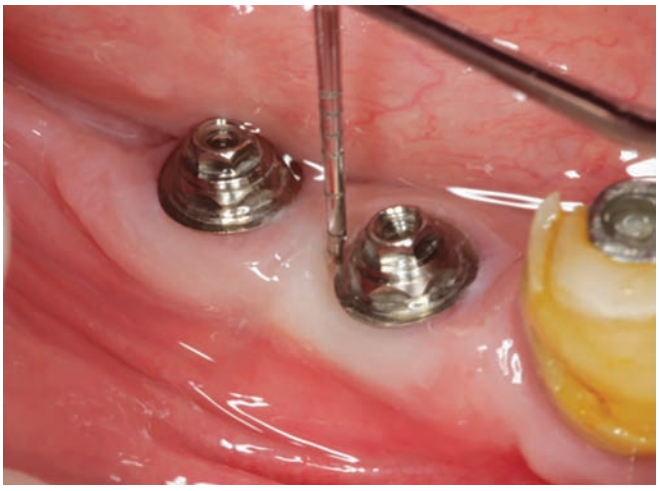


Fig. 1: Probing depth measurements after prosthesis removal

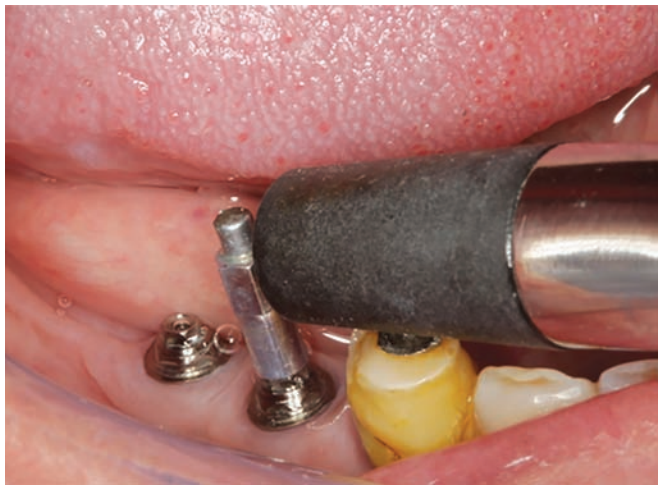


Fig. 2: Smart pegs installed and Osstell device to obtain the ISQ values

For all patients, the following information was recorded: Antagonist dentition, dental habits, general health conditions, missing teeth, number of implants placed, and implant length and diameter.[16]

Restorative Treatment

In all patients, the same prosthetic protocol was performed. Initially, abutments were placed (Micro Unit®, Conexao Prosthesis system, São Paulo, Brazil) on each implant and tightened to 20 Ncm with a torque controller. Impressions were taken (Impregum Penta®, 3M ESPE, Germany) as well as bite registration. A custom abutment overcast in cobalt-chromium (Conexao Prosthesis system, São Paulo, Brazil) was selected, and a screw-retained prosthesis was fabricated and installed. Each implant received an individual crown. There were no partial bridges, prosthetic pontic, or cantilever. For short dental implants, all prostheses were splinted due to unfavorable crown/implant ratio. The restorations were checked for satisfactory occlusal contacts and were carefully adjusted if necessary. All patients presented with natural dentition on the antagonist arch. Patients received oral hygiene instructions to maintain proper hygiene control around implants and prosthesis.

Follow-up Control

Patients were evaluated immediately after prosthesis installation (4 months after implant placement) (T1), and 3 (T2) and 6 months (T3) after prosthesis placement. For RFA, ISQ values were obtained from all patients immediately after surgical implant placement (T0) to allow comparisons among periods after prosthesis installation.

Clinical Examination

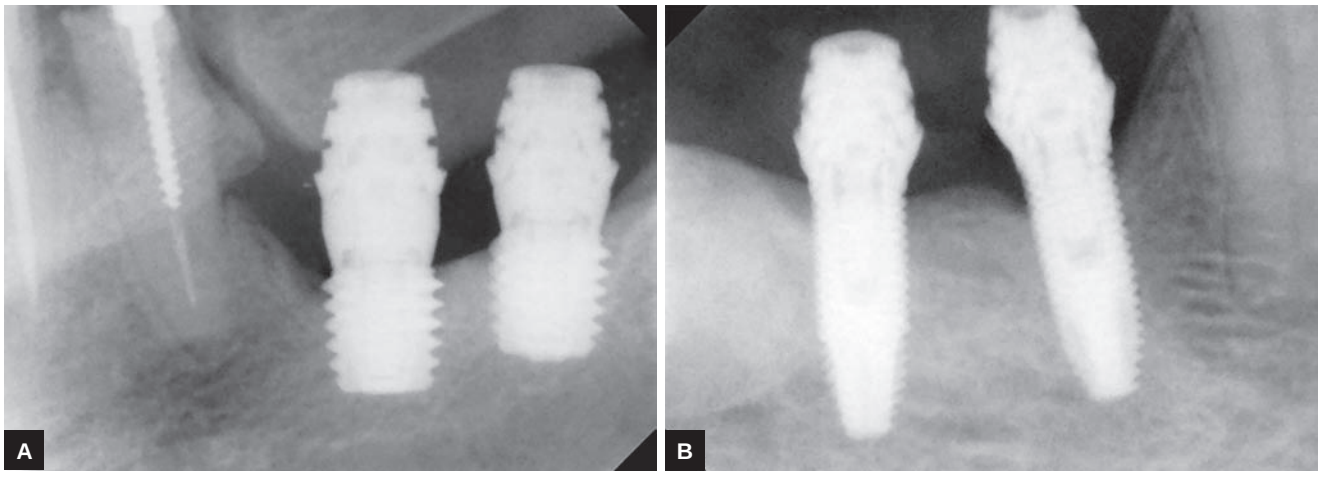
The PD at four aspects (buccal, lingual, mesial, and distal) around the implants was registered using a specific periodontal probe (Hu-Friedy®, Chicago, USA) (Fig. 1). For each implant, one PD value was obtained based on the four obtained values (average). The PD was evaluated after RFA analysis, in which prosthesis removal was accomplished to allow the ISQ measurements. The PD measurements were performed in a standardized manner by one experienced, blinded, and calibrated examiner, and masked to the original treatment protocol in all the three periods evaluated.

Implant Stability Quotient

The ISQ, called RFA, was measured with RFA device (Osstell®, Diagnostics Integration, Gothenburg, Sweden).[16] Smart pegs fabricated for each implant were used to measure implant stability (Fig. 2). The RFA device establishes the resonance frequency of a peg, which can be attached to the dental implant abutment using a cylindrical holder. The Osstell apparatus measures contact-free through a range of frequencies, by exciting the SmartPeg that starts to oscillate where highest and the lowest resonance frequency takes place.[17] The measurements were performed in the buccolingual, lingual-buccal, mesiodistal, and distomesial regions, and the mean value was used.[18] The ISQ values range between 1 and 100,[16] where high ISQ values indicate great implant stability and low values a reduced integration between the implant and the adjacent bone. If an unstable osseointegration is observed, the oscillations will be high, and a low ISQ value will be recorded. The ISQ values were taken at T0, T1, T2, and T3.

Radiographic Examination

Digital periapical radiographs were obtained, at T1, T2, and T3 using a paralleling radiographic device. A custom acrylic resin guide particularly for occlusal registers was made for each patient intending to regulate the incidence



Figs 3A and B: Representative periapical images showing: (A) Short; and (B) conventional implants in position

of X-ray for the follow-up program. The periapical radiograph was taken perpendicular to the implant long axis, simulating a paralleling technique, exhibiting the whole implant and bone tissue around each implant side (Fig. 3). Exposures were performed with a digital dental X-ray unit (Gendex®, Hatfield, USA) operating at 65 kVp, 10 mA, and 0.115 s. Digital radiographs were imported to an image analysis software (ImageJ®, National Institutes of Health, Bethesda, Maryland, USA), and the contrast, brightness, and zooming of the images were regulated to accomplish ideal measuring conditions.[19,20] All periapical radiographs of the inserted implants were evaluated for proximal bone loss between the two groups and among periods. The distance from the implant shoulder on the mesial and distal aspects to the alveolar bone crest was measured for each implant. The same experienced and blinded examiner assessed all radiographs. The errors of the radiographic measurements were evaluated per patient by means of double recordings of one randomly selected implant. For this, after image acquisition, one randomly selected implant was measured two times, and the mean and standard deviation between recordings were registered in a spreadsheet. The measurements were repeated in all patients with 1 day of interval between analyses.

Statistical Analysis

GraphPad Prism Software 6.0 package (Graph-Pad®, California, USA) was used for statistical analysis and visualization of data. All results were expressed as mean ± standard error mean. The intraexaminer reproducibility considering the ISQ and PD measurements was accomplished at the baseline period. The analyses were repeated in four patients with 1 hour of interval between the examinations, and the data were submitted to Pearson's correlation test. The data obtained in each type of analysis were evaluated using the Shapiro–Wilk normality test. The ISQ and clinical data were analyzed by the non-parametric Mann–Whitney test for comparison between groups (short *vs* conventional implants). For radiographic analysis, data between groups were compared using Student's t-test. Repeated measures analysis of variance (ANOVA) followed by *post hoc* Bonferroni test was used for longitudinal analysis within each group. Differences were considered statistically significant at $p < 0.05$.

RESULTS

Clinical Evaluation

The intraexaminer reproducibility for PD analysis was r = 0.89. The PD was performed at the mesial, distal, buccal, and lingual aspects of each implant, and the average of the four values was obtained. Short implants showed an increased PD at T1 (2.18 ± 1.15) compared with the conventional implants (1.7 ± 0.85), which were statistically significantly different ($p < 0.05$). However, at T2 (1.83 ± 1.01 and 1.82 ± 0.91) and T3 (1.7 ± 0.72 and 1.9 ± 0.93), significant differences were not found between short and conventional implants respectively. No differences were found among periods for both groups.

Implant Stability Quotient Analysis

The intraexaminer reproducibility for ISQ analysis was r = 0.93. The RFA was performed at T0, T1, T2, and T3 within each group. The ISQ values in T0 were not statistically significant between short (71.05 ± 8.47) and conventional implants (73.56 ± 10.06). The ISQ values for conventional implants (67.54 ± 9.92) were statistically significantly different ($p < 0.05$) at T1 compared with the short implant (62.6 ± 13.22). On the contrary, at T2 period, short implants (71.82 ± 5.92) showed higher ISQ values than conventional implants (66.81 ± 6.62), which were statistically different ($p < 0.05$). The ISQ values in T3 were not statistically significant between short

Table 1: Mean and standard deviation of ISQ values in the two groups evaluated in all the different periods

Groups	*T0*	*T1*	*T2*	*T3*
Short implants	710.05 ± 8.47[b]	0.6 ± 13.22*[,b]	71.82 ± 5.92*[,b]	63.77 ± 8.85[b]
Conventional implants	730.56 ± 10.06[a,b]	670.54 ± 9.92*[,a]	66.81 ± 6.62*[,a,b]	61.37 ± 8.92[a,b]

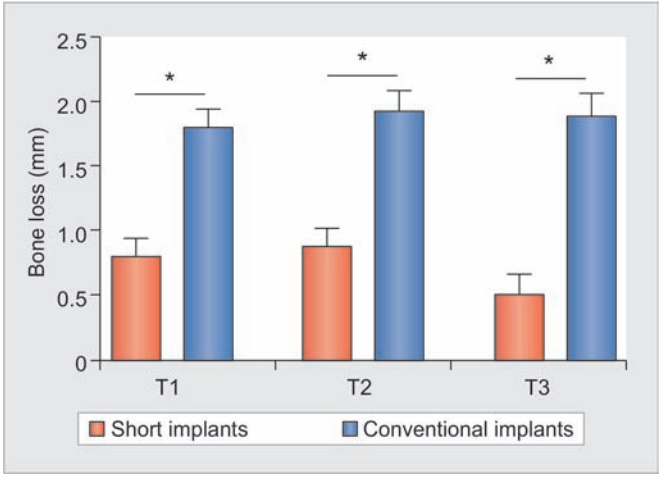
*Statistically significant different, $p < 0.05$, [a]Statistically significantly different, $p < 0.001$, [b]Statistically significantly different, $p < 0.0001$. Differences between groups were calculated by the nonparametric Mann–Whitney test. Differences among periods were evaluated by repeated measures ANOVA test

(63.77 ± 8.85) and conventional implants (61.37 ± 8.92), but both groups demonstrated lower ISQ values compared with T0.

Longitudinal evaluation of ISQ values in both groups demonstrated that short implants presented a higher ISQ values at T0 (71.05 ± 8.47) and T2 (71.82 ± 5.92), which were statistically different compared with T1 (62.6 ± 13.22) and T3 (63.77 ± 8.85), $p < 0.0001$. On the contrary, conventional implants showed a progressive reduction in ISQ values statistically significantly different among T0 (73.56 ± 10.06), T1 (67.54 ± 9.92), T2 (66.81 ± 6.62), and T3 (61.37 ± 8.92) ($p < 0.0001$). Differences were also noted between T1 and T3 ($p < 0.001$) as well as between T2 (66.81 ± 6.62) and T3 ($p < 0.001$). Table 1 shows the mean and standard deviation of the ISQ values using the Osstell® system as RFA in both groups for the different periods.

Radiographic Bone Loss Measurements

Periapical radiographs were taken at T0, T1, and T2 and were evaluated for proximal bone loss. Increased bone resorption was seen for conventional implants compared with short implants in all the three periods evaluated (Graph 1), which were statistically different ($p < 0.05$). Comparisons among periods showed no significant differences among T1, T2, and T3. All implants revealed the absence of peri-implant radiolucency.



Graph 1: Values of radiographic bone loss measurements between the two groups in all the three time intervals. *Statistically significantly different, $p < 0.05$. Differences between groups were calculated by Student's t-test followed by *post hoc* Dunn test

Survival and Success Rates

After the 6-month follow-up period, all implants and fixed prosthesis fulfilled strict success criteria, such as the absence of implant mobility, absence of bleeding on probing, and absence of suppuration and infection. Accordingly, 6-month survival and success rates were 100% for the two groups evaluated.

DISCUSSION

The present investigation was undertaken to evaluate the clinical performance of short dental implants after prosthesis installation in 10 consecutive patients. With the methodology employed, our results suggest that short dental implants are as reliable as treatment with conventional implants installed in the posterior region of the mandible. Short implants demonstrated similar ISQ values compared with conventional implants in all periods evaluated, and both groups presented with satisfactory implant stability (Table 1). Furthermore, PDs were not different between short and conventional implants in T2 and T3, and decreased bone loss was noted for short implants in all the periods evaluated when compared with conventional implants.

Here, the patients included in this preliminary clinical trial presented with dental implants already installed and were in the exact period for prosthetic rehabilitation. The scientific literature is still divergent in which period short implant failures occur. The current studies point to the initial period of osseointegration before prosthetic rehabilitation.[21-23] In this context, some studies made by Misch et al[13,15] demonstrated that most of the short implant failures occur after prosthetic rehabilitation in which implant is submitted to occlusal loads, and the success of rehabilitation is not related to the implant size but the proper prosthetic rehabilitation, which parallel observations made by Muftu and Chapman.[24] In addition, the association of two or more factors, such as patient habits (smoke, occlusal overload, and bruxism), implant insertion (primary stability and insertion torque), bone quality and quantity, peri-implantitis or periodontal disease, and systemic conditions[25] plays an important role in implant failure.[26] To reduce the chances of implant failure, the prosthesis was splinted due to the unfavorable ratio of crown/implant aiming to increase the functional

area when the occlusal load is applied, compensating for the reduced implant length and decreasing the stress concentration in the bone tissue.[15,27,28] Moreover, despite the short implants surpassing the ideal crown/implant ratio, this condition is reasonable since the orientation of forces, load distribution, and bruxism habits are strictly controlled.[27,28]

Conversely, the length of the implant might not positively affect the stress transferred to it, and the increase in diameter decreases the stress intensity along the implant length.[29] Accordingly, for each increase of 2 mm in the implant diameter, an increase of up to 67% in the surface area is achieved, which is equivalent to increasing 5 mm of the implant length.[30] Moreover, when the implant is placed under occlusal forces, the greatest stress is distributed in the first three threads of the implants, showing that implant width plays a pivotal role compared with the additional length.[14,15] Thus, shorter implants with larger diameters and a great surface area are indicated to compensate for limited length. For this reason, all short implants in the present study presented with 5 mm in diameter, whereas conventional implants presented with regular diameter of 4 mm.

Clinical evaluation by means of PDs plays a key role for implant diagnosis and long-term prognosis because it allows the evaluation of clinical parameters, such as the presence of bleeding, exudation, and suppuration.[31] Our findings did not show any of these symptoms in the two groups evaluated during T1, T2, and T3 periods, indicating clinical success with the treatment employed. According to a previous study,[32] the success criteria of dental implants in the long-term follow-up depend on the sustained health of peri-implant hard and soft tissues and a correct distribution of forces on implants. Here, short implants presented with an increased PD at T1 statistically significant compared with the conventional implants. However, at T2 and T3, no differences were found between groups although 2.0 mm of PDs were found for short and conventional implants at T3. These results could potentially be attributed to the external prosthesis connection presented in all the implants installed. External hexagon connections offer less stability at the implant/abutment interface, and an average of 1.2 mm bone loss is expected in the first year.[33] However, an increased PD is not essentially associated with bone loss.[34] Implants are classically considered successful when they present PD of ≤3 mm,[35] which closely resemble our findings.

To study the progression of implant stability after prosthesis installation, the RFA analysis was employed to quantify ISQ of the bone–implant interface.[17] The ISQ values are influenced by some factors, such as (1) degree of osseointegration, (2) rigidity of the fixation, (3) stiffness of the bone, and (4) implant geometry (length and width).[36] The previous study suggested that levels of ISQ higher than 60 result in satisfactory implant stability.[16] In the present study, short and conventional implants presented mean ISQ values above 60 in all the periods evaluated. At the time of implant installation (T0), higher ISQ values were obtained for both groups. However, in the moment of prosthesis installation (T1), the ISQ values for conventional implants were statistically significantly superior compared with short implants. This finding could be attributed to the low bone quality in the posterior area of the mandibular bone in consequence of the deficient irrigation, which favored the conventional implants due to increased implant length.[16] On the contrary, at T2, short implants showed statistical increases in ISQ values, probably because of the locking being limited to the upper mandibular cortical bone, where the bone is denser,[16] decreasing the intensity of the stresses around the bone.[29] This fact suggests that those implants that produce more tension around the bone led to a higher bone remodeling. At T3, no significant differences were found between groups. These variations in ISQ values have been described earlier[37] and are considered normal, probably due to the mechanical primary stability being progressively substituted through biological stability. An interesting finding in this study is that secondary implant stability achieved after prosthetic loading did not increase the ISQ values after the follow-up period, suggesting that masticatory loads had no effect on the evolution of the secondary implant stability.

Radiographic bone loss analysis is one of the most used methods to evaluate osseointegration and implant follow-up.[38] Here, the results of the radiographic measurements showed a significant increase in bone loss for conventional implants compared with short implants in all periods evaluated, but no statistical difference was found among T1, T2, and T3. Potential explanations for this bone loss are that the external hexagon connection installed did not present a good bacterial seal at the abutment–implant interface,[37] as well as due to the largest diameter of the short implants which parallel observations with longitudinal studies, in which the success rate was higher in wide platform implants when compared with smaller diameter implants.[27,39] Furthermore, short implants had the same success rates comparable to conventional length implants, indicating that they are not more prone to bone loss over time.

Some considerations should be discussed when evaluating the results obtained in the present study. The short period of follow-up 6 months might limit the extrapolation of the results and conclusions, and more studies are needed to evaluate the clinical performance of short implants after prosthesis placement and the effects

of masticatory loads. Further evaluation of larger patient populations over longer periods will be necessary before more definitive conclusions can be drawn.

CONCLUSION

Within the limitations of this study, our findings suggest that treatment of resorbed posterior regions in the mandible with shorter dental implants is as reliable as treatment with conventional dental implants after 6 months of splinted prosthesis installation. Moreover, the survival and success rates of short dental implants were similar to conventional implants with 100% of clinical and radiographic success rates.

Clinical Significance

Short dental implants might be considered a predictable treatment alternative to bone augmentation or extensive surgical techniques in regions of restricted vertical bone height in the posterior region of the mandible.

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