Primary and Secondary Stability of Extrashort (4-mm) Implants in the Edentulous Mandible: Preliminary Results of a Prospective Clinical Trial

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Purpose: To compare the primary and secondary stability of conventional (≥ 8-mm) and extrashort (4-mm) implants in edentulous patients using different methods of assessment. Materials and Methods: Patients underwent implant surgery and were randomly allocated into two groups: test, with two conventional implants in the anterior region and two extrashort (4-mm) implants in the posterior region; and control, with two conventional (≥ 8-mm) implants in the anterior region only. Primary stability (S1—implant placement) was assessed by insertion torque, implant stability quotient (ISQ, Osstell), and damping capacity (PTV, Periotest), while secondary stability (S221—21 days after S1; and S2clip—at prosthetic loading, ± 3 months after S1) was evaluated by ISQ and PTV. The statistical significance level was set at \( P < .05 \). Results: Fifty conventional implants and 24 extrashort implants were placed in 25 patients. The overall survival rate was 97.3%. There was no statistically significant difference between the insertion torque of conventional and extrashort implants (\( P > .05 \)). PTV values were significantly lower for conventional implants only at S2clip (\( P = .041 \)). ISQ values were significantly greater for conventional implants at S1 (\( P = .004 \)) and S2clip (\( P = .413 \) and \( P = .490 \), respectively). Damping capacity showed no significant differences between S1—S221 and S1—S2clip. ISQ values showed a significant increase of stability between S1—S2clip for conventional (\( P = .022 \)) and extrashort (\( P = .005 \)) implants, which was different from that observed between S1—S2clip. There was a moderate negative correlation between the PTV and ISQ variables (\( r = 0.5 \)) of extrashort implants, and between the PTV and insertion torque (\( r = −0.3 \)) of conventional implants. For extrashort implants, there was a null correlation between ISQ and torque (\( r = 0.0 \)). There was a moderately positive correlation between ISQ and torque (\( r = 0.3 \)) in the conventional implant group. Conclusion: The results suggest that extrashort and conventional implants present similar primary and secondary stability values and may similarly influence restorative protocols. Int J Oral Maxillofac Implants 2021;36:1173–1179. doi: 10.11607/jomi.8437

Keywords: bone-implant interface, bone remodeling, dental implants, dental implantation, osseointegration, resonance frequency analysis, torque

The success of dental implants is directly related to the healing process and bone remodeling that occurs directly in contact with the implant surface. For this to occur, criteria such as implant stability are assessed to obtain a more predictable prognosis. This feature has been assessed mainly in two different periods: at implant placement (primary stability)—related to mechanical locking, and at prosthetic loading (secondary stability)—related to bone healing.1

Implant stability can also be influenced by the quality and the quantity of bone available at the site of implant placement. Studies have shown that, in resorbed jaws, short (6-mm) and extrashort (4-mm) implants might be a viable option because they are less invasive, avoid bone graft surgery, and consequently, reduce the cost and time of the implant treatment.2–5

In the past, the option of short and extrashort implants was little explored because of the reduced implant length, and the sites where they were placed were related to failures of bone anchorage and osseointegration.6 With technologic advances, such as developments in the surface treatments, implant alloy composition and the implant topography itself have caused dramatic changes in this scenario.3,4,6–8

Dental implants with hydrophilic and chemically active surfaces have been introduced as an innovative alternative to conventional hydrophobic surfaces, since they are able to promote improved clot stabilization and
reduce the healing time to 3 to 4 weeks. These implants have a larger accessible surface area for better absorption of blood proteins and the formation of a fibrin network. Clinically, these implants are able to achieve secondary stability before implants with hydrophobic surfaces. Thus, short and extrashort implants with a hydrophilic and chemically active surface can achieve secondary stability in a few weeks, significantly modifying the restorative protocols. Furthermore, studies have shown positive results for extrashort implants (4 mm), with high survival rates (94% to 97.5%), in addition to a primary stability comparable to conventional implants. However, scientific evidence regarding the clinical performance and stability of these implants is still scarce.

Thus, the aim of the present study was to compare the primary and secondary stability of conventional (≥ 8 mm) and extrashort (4 mm) implants in edentulous patients using different methods of assessment.

**MATERIALS AND METHODS**

**Study Design**

The present study was designed as a double-blind randomized controlled clinical trial. The study was submitted to the Ethics Committee for Research with Human Beings at the Federal University of Santa Catarina and was approved in February 2016 (no. 1.452.492).

**Screening and Enrollment**

Sample size calculation was based on the primary outcome of the main study (marginal bone loss) based on means and standard deviations from previous studies. The following parameters were considered for the analysis: 80% power test, standard deviation of 0.3, with alpha probability error of 5% (P < .05). The minimum required sample size was 17 participants per group. Seeking to compensate for expected dropout rates or loss of follow-up throughout the study and to ensure the generation of valid data for the assessment of future secondary outcomes (example: prosthetic complications), the sample size was increased to 25 patients per group, totaling 50 patients. The patients were screened at the Department of Dentistry between January 2017 and May 2019, with the following eligibility criteria.

The inclusion criteria were as follows: male and female patients with fully edentulous arches, with a minimum of 6 mm of bone height above the mandibular canal, from 40 to 75 years of age.

The exclusion criteria were as follows: previous episodes of failure of osseointegration in the region of interest for implant placement, bone augmentation sites, reduced interarch distance, heavy smoking (> 10 cigarettes/day), uncompensated type II diabetes, use of bisphosphonates, head and neck radiotherapy, immunodeficiency, presence of cyst or neoplasia in the region of interest for implant placement, and presence of bruxism, as assessed by the American Academy of Sleep Medicine (AASM 2014) questionnaire.

Included patients were asked to undergo digital panoramic radiography (second screening stage). Those with residual bone height of < 6 mm of bone above the mandibular canal in at least one of the sides of the mandible were excluded. Patients who met the eligibility criteria signed a written consent form and were enrolled in the study.

**Surgical Phase**

Implant surgery was planned using the coDiagnostix software (Dental Wings; Fig 1). Amoxicillin and piroxicam were prescribed as preoperative medication. In cases of allergy to penicillin, clindamycin was prescribed. The patient’s vital signs were assessed just before implant surgery, which took place at the university’s dental clinics.

The allocation of patients in each group remained confidential until implant surgery. A sealed and opaque envelope was chosen at random and opened by a person not participating in the study. Before implant placement, the group to which the patient was allocated was then disclosed to both the patient and the surgeon.

Patients were allocated into two experimental groups, according to the number of implants:

- Control group: Two conventional implants (≥ 8 mm) in the interforaminal region (mandibular left and right canine regions) only
- Test group: Two conventional implants (≥ 8 mm) in the interforaminal region (mandibular left and right canine regions), and two extrashort implants (4 mm) in the posterior region (mandibular left and right first molar regions), above the mandibular canal

Both implants had a cylindrical shape (4.1 mm) and a regular 4.8-mm-diameter neck with a prosthetic platform at the soft tissue level. However, the thread pitch was different between the conventional and extrashort implants, with 1.25 mm and 0.8 mm, respectively (Fig 2). The surgical procedure was performed using a conventional surgical guide according to the teeth setup obtained with the conventional complete denture. The drilling sequence followed the manufacturer’s recommendations (Tissue Level Standard Plus, Roxolid SLActive, Straumann Dental Implant System), and placement was performed according to the planned diameter (regular platform, 4.4.1 mm) and length of the implants (4 mm or ≥ 8 mm). No underpreparation of the recipient site was applied.

Implant stability data were collected at different times:
Primary Stability Assessment (S1)
The implant mount was placed on the implant. Three assessment tools were used:

- **Insertion torque** was measured using a manual wrench (Straumann Dental Implant System). The classification used, according to the manufacturer, was divided into three categories: < 15 Ncm, between 15 Ncm and 35 Ncm, and > 35 Ncm (Fig 3). The information was recorded using a digital form.

- **Periotest values (PTVs)** were obtained using the Periotest device. The tip was placed perpendicular to the implant mount, at a distance of 2 mm. From each implant, three measurements were obtained in the buccolingual direction and three measurements in the mesiodistal direction. The mean of the six measurements was calculated for comparisons (Fig 4).

- **Implant stability quotient (ISQ) values** were obtained using an Osstell device and a specific Smartpeg (Type IV) placed onto each implant. One measurement was recorded in each direction (mesiodistal and buccolingual) for each implant. The mean of the two measurements was used (Fig 5).

After S1, the healing abutments were screwed, and patients were given postoperative instructions, including a medical prescription. Patients were clinically evaluated approximately 10 to 12 days after surgery, analyzing possible discomfort in the region, pain, mobility...
of the implants, and temporary paresthesia. The suture was removed when the region was clinically healed.

Secondary Stability Assessment ($S2^{21}$)
Twenty-one days after implant placement, the healing abutments were removed, and the implant mounts were retightened. Secondary stability assessment ($S2^{21}$) was performed using Periotest and Osstell devices, using the same methodology as in $S1$.

Prosthesis Delivery
Approximately 3 months after implant placement, a mandibular bar-retained overdenture was fabricated for each patient (conventional loading protocol). In both groups, prosthetic abutments (synOcta, Straumann Dental Implant System) were tightened with a 35-Ncm torque to the implants. An egg-shaped, distal extension–free Dolder bar, fabricated in chromium-cobalt, was tightened with a 15-Ncm torque splinting either the two- or the four-implant–retained overdentures (Fig 6). After a period of mucosal adaptation to the new denture, one single retention clip, regardless of the number of implants placed, was attached to the intaglio surface of the overdenture at the midline, and the implants were finally loaded.

Table 1  Comparison of Insertion Torque Between Conventional and Extrashort Implants at Placement ($S1$)

<table>
<thead>
<tr>
<th>Insertion torque (Ncm)</th>
<th>Conventional</th>
<th>Extrashort</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>14% (n = 7)</td>
<td>12.5% (n = 3)</td>
<td>.954*</td>
</tr>
<tr>
<td>Between 15 and 35</td>
<td>56% (n = 28)</td>
<td>54.2% (n = 13)</td>
<td></td>
</tr>
<tr>
<td>&gt; 35</td>
<td>30% (n = 15)</td>
<td>33.3% (n = 8)</td>
<td></td>
</tr>
</tbody>
</table>

*P value for chi-square test. Significant correlation at a .05 significance level.

Secondary Stability Assessment ($S2^{clip}$)
At clip capture, implant stability measurements with both Periotest and Osstell devices were repeated, using the same methodology as in $S1$.

Statistical Analysis
The Mann-Whitney $U$ test was used for between-group comparisons (conventional vs extrashort implants) at each assessment period. The Wilcoxon test was used for longitudinal within-group comparisons (primary and secondary stability of either conventional or extrashort implants). The chi-square test was used to compare the categorical variables. Correlation between assessment tools was performed using the Pearson test. The statistical significance level was set at $P < .05$.

RESULTS
A total of 74 implants were placed in 25 patients (17 women, mean age 61 ± 9.84 years; 8 men, mean age 64 ± 10.62 years; 12 from test group and 13 from control group)—50 conventional implants (≥ 8 mm) and 24 extrashort implants (4 mm). Two 4-mm-long implants were lost before prosthesis placement (extrashort implant survival rate: 91.7%) and replaced by new implants of the same length, in an adjacent position. No conventional implant was lost (conventional implant survival rate: 100%). The overall survival rate was 97.3%.

Between-Group Comparisons
The results of insertion torque values are shown in Table 1. There was no statistically significant difference between implant lengths ($P > .05$). PTV values were significantly lower (greater stability) for conventional implants only at $S2^{clip}$ ($P = .041$). ISQ values were significantly greater for conventional implants at $S1$ ($P = .004$), whereas at $S2^{21}$ and $S2^{clip}$, no differences were found ($P = .413$ and $P = .490$, respectively; Table 2).
who received supported screw-retained fixed complete implants (10-mm and 4-mm implants) in 10 patients between S1 and S2clip for both conventional and extrashort implants showed a significant increase of implant stability irrespective of the implant length. On the other hand, ISQ values did not linearly depend on its length, since damping capacity (PTV values) showed no significant differences between S1–S221 and S1–S2clip, irrespective of the implant length. The role of implant stability as a predictive factor for the success of dental implants is well-documented.11–16 In the present study, optimistic results were found for conventional and extrashort implants related to primary and secondary stability, which can optimize restorative protocols in rehabilitation treatments of edentulous patients.

The implant insertion torque at the time of placement does not linearly depend on its length, since there was no association between the insertion torque and the implant length. Similar results were reported by Calvo-Guirado et al (2015),3 who placed 60 dental implants (10-mm and 4-mm implants) in 10 patients who received supported screw-retained fixed complete dentures. No difference was found between the insertion torque of both implant types.

This study found no significant differences between primary and secondary stability (at 21 days and at prosthetic loading) of conventional and extrashort implants, as assessed by the Periotest device. This finding is in agreement with another clinical study that compared PTV values of 6-mm-long implants supporting single crowns in the posterior region, at the moment of surgery and at 3 months.17 It is noteworthy that there are factors that may directly interfere with Periotest measurements, such as the horizontal distance and angulation between the tip of the handpiece and the implant.1 Particularly with the Loxim mount, which is screwed to the internal implant connection, a micromovement is expected to occur at the connection level, thus possibly compromising the measurements. Therefore, the responses of this implant mount to the tip of the device must be interpreted with caution.

### Table 2 Mean ± SD Stability Values (PTV and ISQ) of Conventional and Extrashort Implants at Different Follow-up Assessments

<table>
<thead>
<tr>
<th></th>
<th>PTV</th>
<th>ISQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional (≥ 8-mm) implants</td>
<td>Conventional (≥ 8-mm) implants</td>
</tr>
<tr>
<td></td>
<td>Extrashort (4-mm) implants</td>
<td>Extrashort (4-mm) implants</td>
</tr>
<tr>
<td>Primary stability</td>
<td>+6.1 ± 5.9 (n = 50)</td>
<td>+8.2 ± 6.0 (n = 24)</td>
</tr>
<tr>
<td>Secondary stability</td>
<td>+8.5 ± 4.3 (n = 26)</td>
<td>+11.4 ± 10.2 (n = 12)</td>
</tr>
<tr>
<td></td>
<td>+10.0 ± 5.3 (n = 12)</td>
<td>+11.4 ± 10.2 (n = 12)</td>
</tr>
<tr>
<td>S1–S221</td>
<td>+5.8 ± 4.9 (n = 24)</td>
<td>+11.4 ± 10.2 (n = 12)</td>
</tr>
<tr>
<td>S1–S2clip</td>
<td>+7.6 ± 1.0 (n = 24)</td>
<td>+8.2 ± 6.0 (n = 24)</td>
</tr>
<tr>
<td>Secondary stability</td>
<td>+7.6 ± 1.0 (n = 24)</td>
<td>+8.2 ± 6.0 (n = 24)</td>
</tr>
</tbody>
</table>

*P value for Mann-Whitney U test; **P value for Wilcoxon test. Significant correlation at a .05 significance level.

**Within-Group Comparisons**

Damping capacity (PTV values) showed no significant differences between S1–S221 and S1–S2clip, irrespective of the implant length. On the other hand, ISQ values showed a significant increase of implant stability between S1 and S2clip for both conventional and extrashort implants (P = .022 and P = .005, respectively), but this tendency was not observed in the first days of bone healing (S1–S221; Table 2).

**Correlation Between Methods**

There was a moderate negative correlation between the PTV and ISQ variables (r = −0.5) of extrashort implants, and between the PTV and insertion torque (r = −0.3) of conventional implants. For extrashort implants, there was a null correlation between ISQ and torque (r = 0.0). In contrast, there was a moderately positive correlation between the variables ISQ and torque (r = 0.3) in the conventional implant group (Table 3).

### Table 3 Correlation of Different Implant Stability Assessment Tools Using Pearson Correlation Test

<table>
<thead>
<tr>
<th>Implants/Comparison</th>
<th>Pearson correlation coefficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extrashort</td>
<td></td>
</tr>
<tr>
<td>PTV × ISQ</td>
<td>Moderate −0.5*</td>
</tr>
<tr>
<td>PTV × insertion torque</td>
<td>Weak −0.1</td>
</tr>
<tr>
<td>ISQ × insertion torque</td>
<td>Null 0.0</td>
</tr>
<tr>
<td>Conventional</td>
<td></td>
</tr>
<tr>
<td>PTV × ISQ</td>
<td>Weak −0.2</td>
</tr>
<tr>
<td>PTV × insertion torque</td>
<td>Moderate −0.3*</td>
</tr>
<tr>
<td>ISQ × insertion torque</td>
<td>Moderate +0.3*</td>
</tr>
</tbody>
</table>

Pearson correlation (r): 0.1–0.3: weak; 0.3–0.5: moderate; 0.5–1.0: strong; “−” = inverse and “+” = direct.

Significant correlation at a .05 significance level.

**DISCUSSION**

The role of implant stability as a predictive factor for the success of dental implants is well-documented.11–16 In the present study, optimistic results were found for conventional and extrashort implants related to primary and secondary stability, which can optimize restorative protocols in rehabilitation treatments of edentulous patients.

This study found no significant differences between primary and secondary stability (at 21 days and at prosthetic loading) of conventional and extrashort implants, as assessed by the Periotest device. This finding is in agreement with another clinical study that compared PTV values of 6-mm-long implants supporting single crowns in the posterior region, at the moment of surgery and at 3 months.17 It is noteworthy that there are factors that may directly interfere with Periotest measurements, such as the horizontal distance and angulation between the tip of the handpiece and the mount.1 Particularly with the Loxim mount, which is not screwed to the internal implant connection, a micromovement is expected to occur at the connection level, thus possibly compromising the measurements. Therefore, the responses of this implant mount to the tip of the device must be interpreted with caution.
The initial stability of conventional implants was statistically higher when compared with extrashort implants, as seen with the mean ISQ values. This corroborates a study that compared the ISQ values of implants with different lengths in edentulous mandibles. However, the result obtained in the present study might not be clinically detrimental for the decision regarding loading protocols, since both groups of implants revealed ISQ mean values greater than 60 each. According to the literature, with these values, the implants would even be capable of receiving immediate loading. Since in the present study, a conventional loading protocol (≥ 3 months) was chosen, the potential of extrashort implants to receive loading in shorter intervals requires further investigation. Although at the time of surgery, the ISQ values of extrashort implants were significantly lower than those of conventional implants, they have achieved osseointegration within 21 days as well as conventional-length implants, within the healing patterns proposed by the manufacturer. Likewise, SLActive implants tend to increase ISQ values between the third and fourth week after placement, as shown at the time clip capturing for this study and also in the study by Schätzle et al.

As a patient-related factor, bone density at the implant placement site often differs between different patients or in different regions in the same individual, which may directly influence its stability. However, the different sites for placement of conventional (> 10-mm) and extrashort (4-mm) implants adopted in this study are justified by the difference in bone availability between the anterior (Type I/II) and posterior (Type III/IV) of the mandible, respectively, seeking to dispense with the necessary invasive surgical procedures that would allow the placement of implants of conventional sizes in severely resorbed regions. In addition, strict eligibility criteria were followed during the screening stage of patients, excluding individuals with systemic conditions and/or unfavorable locations for this assessment, thus seeking greater sample homogeneity for its randomization between the control and test groups (50% chance for each group).

Only the comparison of ISQ value between primary and secondary stability (at clip capture) showed a significant difference for both groups of implants. This difference suggests that the implant stability over time is a dynamic process and tends to increase according to the evolution of osseointegration. However, this study reinforces the hypothesis that a lower ISQ value at implant placement would not be enough to contraindicate extrashort implants, as these implants also present clinically acceptable values for different restorative protocols.

In the present study, only two aspects related to the implant were different between the groups: the length and the thread pitch. The length of the implant favors the stability of conventional implants by promoting greater intrasosseous anchorage. The thread pitch, on the other hand, favors the stability of extrashort implants, since conventional tissue-level implants have a thread pitch of 1.25 mm, while extrashort implants have undergone topographic changes to 0.8 mm of distance between threads, assuming a bone-level implant body. This is supposed to enhance the stability of the implant thanks to the greater number of threads per implant length.

When the measurement tools were correlated, the comparison of the means of PTV and ISQ, and PTV and insertion torque showed moderately negative correlations (r = –0.5 and –0.3, respectively), which shows a predictable proportion and inverse value: While ISQ increases in value, PTV decreases by almost the same proportion. The comparison between the insertion torque and the mean ISQ for implants of conventional length showed a moderately positive correlation, which shows that the increase in one measure is correlated with the increase in the other. This same result was also obtained in a study that evaluated single crowns supported by short 6-mm implants. This specific finding of implants of conventional lengths may have been achieved due to their larger sample size, resulting from the study design that evaluated the conventional implants placed in participants of both groups (control and test).

Despite the implant stability values measured by three different methods having been predictive of success, it should be highlighted that they cannot be analyzed in isolation. Factors related to the implant (implant length, implant diameter, surface treatment, implant shape, and thread pitch), to the patient (bone changes, metabolic changes, bone quality in the implant region, anatomy of the alveolar residual ridge), and to the operator (experience and obedience to strict surgical protocols) should also be evaluated. Only two extrashort implants failed during the healing period, even though they have shown clinically acceptable primary stability values, compatible with other implants in this study. Thus, these failures can be attributed to other biologic factors, such as bone quality (types III/IV), and mechanical factors, not excluding the possibility of error at the time of placement. These failing implants were successfully replaced by others with the same characteristics, but in an adjacent position with better bone quality and obtaining optimal primary stability values. Similar data were reported in a study that revealed a loss of an extrashort 4-mm-long implant before prosthetic loading, followed by subsequent replacement with another implant of the same length. Although the preliminary results of the stability of extrashort implants are encouraging, a larger
sample size with survival data is necessary to confirm the results of the present study.

In this study, the small sample size, short follow-up period, and nonusage of double-blind examiners could be considered as important limitations. Besides these, not considering the difference in bone densities between the anterior/posterior region of the mandible and not calculating the intrarater and interrater variability (Kappa-values) between the independent examiners could be other meaningful limitations.

CONCLUSIONS

Within the limitations of this study, it is suggested that extrashort and conventional implants have comparable primary and secondary stability values and may similarly influence restoration protocols. Although the assessment tools showed moderate correlations with each other, there is not enough evidence to support the safe replacement of Osstell by the manual key or by Periotest.

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REFERENCES