Comparative Study of Immediate Loading on Short Dental Implants and Conventional Dental Implants in the Posterior Mandible: A Randomized Clinical Trial

Kritsada Weerapong, DDS1/Siripong Sirimongkolwattana, DDS, MSc2/Thanapat Sastraruj, PhD3/Pathawee Khongkhunthian, DDS, Dr Med Dent1

Purpose: Immediate dental implant loading has been investigated with favorable results. However, short implants have not been investigated in this treatment option. This study compared the clinical outcomes and survival rates of immediately loaded short and conventional-length dental implants in replacing mandibular molar teeth. Materials and Methods: Forty-six implants (23 short dental implants and 23 conventional dental implants) in 46 patients were included in the study. Provisional computer-aided design/computer-aided manufacturing (CAD/CAM) ceramic crowns were cemented to the abutments and immediately loaded. Several clinical parameters were recorded and statistically analyzed at 4-month and 1-year follow-up. Results: Two short implants lost integration, and one conventional implant failed. No statistically significant difference between the two implant types was found (P = 1.00). Minor complications were recorded; three provisional crown fractures were found in the short implant group and two provisional crown fractures in the conventional implant group. There was no significant difference in implant stability quotient values for short or conventional implants between baseline (short: 73.86 ± 2.38, conventional: 75.05 ± 3.26, P = .088), 4 months after loading (short: 72.37 ± 1.35, conventional: 72.89 ± 1.87, P = .165), and 1 year after loading (short: 74.60 ± 2.03, conventional: 75.35 ± 2.66, P = .296). The mean marginal bone level loss 4 months postloading was 0.28 ± 0.29 mm for short implants and 0.25 ± 0.25 mm for conventional implants (P = .73), and at 1 year postloading was 0.33 ± 0.47 mm for short implants and 0.26 ± 0.27 mm for conventional implants (P = .554); there was no statistical difference between the two implant types. Conclusion: The immediate loading of short implants is comparable to conventional-length implants in terms of implant survival, marginal bone level change, and implant stability quotient value. INT J ORAL MAXILLOFAC IMPLANTS 2019;34:141–149. doi: 10.11607/jomi.6732

Keywords: CAD/CAM, immediate loading, short implant, standard implant

The term osseointegration was defined by Brånemark et al to describe a direct connection between titanium implants and living bone without fibrous tissue encapsulation.1 Previously, titanium dental implants could be loaded after 3 to 4 months for the mandible and 6 to 8 months for the maxilla. That period of stress-free healing after implant placement was an essential requirement for osseointegration.2,3 Recently developed designs and improved implant surface characteristics enhance primary implant stability and biologic healing, immediate loading has become a better option.4 Immediate loading has elicited several advantages, for example, increased chewing function, better prosthetic stability,5 minimizing uncontrolled transmucosal loading, acceleration of bone remodeling, improvement of gingival contours, and better esthetics.6-8 Some posterior edentulous areas may present insufficient bone volume to place standard-length implants. Sinus elevation or vertical ridge augmentation procedures are selected to enable the placement of standard-length implants in such areas. However, these procedures are associated with additional surgical intervention, costs, surgical time, and patient morbidity. In particular, vertical augmentation bone graft
is associated with high numbers of complications and needs a high skill level of operator to achieve a successful outcome. An alternative therapy in these situations is the use of short dental implants, defined as implants with lengths of less than 8 mm. Recently, numerous manufacturers have improved their implants with surface modifications and rougher surfaces, leading to the development of shorter implants. However, clinical data using immediate loading protocols for short implants are still scarce.

Horwitz et al have suggested that the survival and success rates of immediately loaded implants are similar to those of the conventional protocol (loading implants 3 to 6 months after placement).

Buchs et al, in 2001, studied 142 one-piece implants in 93 patients to evaluate survival rates 2 years after immediate loading with a single crown. The implant survival rate was 93.7%, and implant failure occurred within 3 to 5 weeks of implant placement.

A prospective clinical study evaluated the performance of 30 ITI implants with a sandblasted and acid-etched (SLA) surface placed in first molar areas and immediately restored with single crowns. At the 1-year follow-up examination, the survival rate was 96.7%.

In a recent systematic review by Cordaro et al, a total of 580 implants were placed and immediately loaded in partially edentulous areas of the posterior mandible. The mean survival rate was 96.74%.

Insufficient bone quantity and low bone density have been identified as the main risk factors for implant failure, as they are associated with excessive bone loss and impairment in the healing process compared with higher-density bone. Numerous studies agree on this point that the expected failure rate is higher in the maxilla than in the mandible because of low bone density.

In order to make a decision to proceed with immediate loading, initial stability is the key factor. The implant should be well anchored in the bone and able to tolerate a tightening torque of 35 Ncm without further twist, in order to load.

During the first European Association for Osseointegration (EAO) consensus conference, short implants were defined as devices with an intrabony length of less than 8 mm.

In a meta-analysis from Nisand et al in 2015, implant and prosthesis survival rates of short dental implants and standard implants were similar when placed in vertically augmented bone. In a meta-analysis from Lee et al in 2014, the 1-year and 5-year cumulative survival rates of short implants were 98.7% and 93.6%, respectively, while those of long implants were 98.0% and 90.3%, respectively. However, there were no statistically significant differences found between the two groups in success outcomes, failure, or complications.

Survival rates and biologic outcomes of short dental implants are independent of the crown/implant (C/I) ratio, but there is a higher incidence of technical complications in high C/I ratio prosthetic reconstructions. Short dental implants may be used as the treatment of choice in atrophic alveolar bone, as they are associated with decreased morbidity and lower biologic complications, costs, and surgical time.

Currently, immediate loading has become a more favored technique in implant treatment. The definitive prostheses should be created immediately after implant placement. There are also difficulties using traditional techniques due to blood and saliva contamination after the surgical stage. Moreover, patients require additional appointments to have prostheses placed.

Computer-aided design/computer-aided manufacturing (CAD/CAM) has gained popularity in dentistry over the past 25 years. CAD/CAM technology provides patients with one-day restorations. These techniques have been used widely by dentists and laboratories. For example, dentists can record a digital impression using an intraoral scanner and send these data to their computer or send it to a laboratory. Restorations are designed on the computer and sent for milling.

The option of chairside CAD/CAM restorative material is limited to solid blocks fabricated by manufacturers for the milling process. For one-visit treatments, the definitive restoration is delivered at the same appointment as that for surgical implant placement, so the material of restoration must be milled in less than 20 minutes to complete the chairside delivery. After the milling process, the definitive restoration should take a minimal amount of time to complete the chairside delivery.

Furthermore, dentists can use CAD/CAM technology to create a computer-generated surgical guide, which can help to place implants accurately, safely, and precisely into the prosthesis-driven position.

Other variables that are controlled by the clinician to potentiate the success or failure of dental implant placement include case selection, site selection, prosthesis design, and recall protocol. The experience and surgical skill of the clinician also play a significant role in the treatment success of dental implants. However, the most-reported criterion for successful implants is the survival rate, which means the implant is still physically in place.

Implant stability has been divided into primary stability and secondary stability. Primary implant stability is well-established as a key factor in osseointegration, as well as “secondary stability,” or “biologic stability,” which occurs during the healing period.

In 1996, Meredith et al introduced resonance frequency analysis (RFA) for primary implant stability measurement and long-term implant stability monitoring.
After that, the use of this evaluation technique has continuously increased. One year later, in 1997, he also found a correlation between crestal bone loss and implant stability loss.35 Tallarico et al, in 2011, suggested that the high initial ISQ value is one of the factors in following immediate loading protocol on dental implant placement. However, it is not possible to make the decision about immediate loading on only the ISQ value, because there are other parameters that have to be taken into consideration for the decision making.36

Following the conventional loading protocol, patients must make many visits for treatment. Without teeth in between the visits, patients also report that their speech, mental condition, and overall function are affected. Thus, an immediate loading protocol is expected to be a new development in treatment for patients’ benefit in the future. In addition, implant treatment in posterior regions commonly faces the problem of limited residual bone height (RBH). An alternative short dental implant to avoid the indications for additional surgical procedures, such as sinus elevation and bone grafting techniques, should decrease treatment time, patient morbidity, and cost.

CAD/CAM technology has been applied in implant dentistry; the use of this technology together with implant placement makes the immediate prosthesis connecting to the dental implant possible, and thus, after implant placement, the patients can immediately use the restoration on the implant.

The purposes of this study were to compare the clinical outcomes and survival rates (failure rate) at 4 months and 1 year of immediately loaded short (6 mm) and standard (10 mm) implants in replacing single mandibular molar teeth.

**MATERIALS AND METHODS**

This study was designed as a prospective randomized clinical trial. Approval for the study was received from the Human Experimentation Committee (TCTR20170802003), and the study was conducted at the Center of Excellence for Dental Implantology, Faculty of Dentistry, Chiang Mai University.

Patients required single-tooth replacement for first or second mandibular molar teeth and had opposing den-

ition. Each patient received information about the study and was able to sign an informed consent. All patients were recruited according to the inclusion and exclusion criteria presented in Table 1. Smoking was recorded but not considered as a contraindication for treatment.

Dental implant treatments were performed by a single surgeon with flapless procedures. Preliminary screening was performed using an intraoral scanner, periapical radiographs, panoramic radiographs, and cone beam computed tomography (CBCT). A surgical template for guided implant surgery was fabricated.

Eligible participants were allocated equally to either of the two groups, standard dental implant (control group) and short dental implant (test group), using a simple randomization procedure by Microsoft Excel 2013 software. The nonduplicated random number table consisted of a list of patient numbers 1 to 46, and was created in three steps consisting of a list of patient numbers in order (1 to 46) in the first column, a second column filled (rows 1 to 46) with Microsoft Excel random formula (“RAND”), and the second column sorted from smallest to largest (expanding sorting to the first column); then, the patient numbers in the first column were shuffled. Finally, patient numbers 1 to 46 were classified using odd rows for the control group and even rows for the test group.

**Clinical Procedures**

Surgical procedures were done under local anesthesia. A dental implant system (PW+ Dental Implant System) was used in the study (Fig 1). It has been available on the market since 2007.

Following the flapless procedures, in the test group, 6-mm implants were placed following the
manufacturer’s guidelines. In the control group, similar procedures were performed to a depth of 10 mm. All implants were placed with an insertion torque > 35 Ncm. The final insertion torque and the resonance frequency analysis (RFA) values were recorded at the time of surgery. A titanium abutment was prepared and placed at the time of surgery (Fig 2). An intraoral scanner was used for digital impression at the abutment level. Provisional hybrid ceramic crowns (Shofu HC) were fabricated through a CAD/CAM milling machine using digital software. An occlusion between natural tooth and implant/prosthesis was designed for full centric occlusal contacts, whereas eccentric contacts were avoided. Oral antibiotics, oral analgesics, and antiseptic mouthrinse were prescribed. A soft diet was recommended for 2 to 3 weeks. Smokers were instructed to avoid smoking for 7 days postoperatively.

All patients were recalled for clinical assessment at 1-week, 2-week, 4-week, 2-month, 4-month, and post-1-year intervals after implant placement. Clinical examination including assessment of pain, mobility, probing depths, and complications were recorded. Implant failure was defined as an implant that should be, or already has been, removed.

Both biologic and technical complications were recorded. For peri-implant marginal bone level measurements, periapical radiographs using the paralleling technique were recorded immediately after implant placement and at the 4-month examination (Fig 3). The distances from the mesial and distal interproximal bone to the implant-abutment interface were measured. The mean of these two measurements was calculated for each implant.

Statistical Analysis
A reliability analysis of marginal bone level changes for the intra-examiner agreement and the inter-examiner agreement was conducted using intraclass correlation coefficient. The Fisher’s exact test was used instead of the chi-square test to compare the failure proportion of short vs standard-length implants due to the small sample sizes, and more than 20% of cells have expected frequencies < 5. The normal distribution of data consisting of the insertion torque, implant stability quotient (ISQ), and peri-implant bone level changes in each group were confirmed by the Shapiro-Wilk test. Independent sample t tests were used to compare the mean insertion torque and ISQ value at the time of surgery between the two groups. Differences in means for peri-implant bone level changes between the two groups were compared using independent sample t tests. Paired t tests were conducted to compare changes in the same group at each time point. All the comparisons were carried out using SPSS 17.0 software for Windows (SPSS). Statistical significance was tested at the .05 level. All values were presented as means ± standard deviations with 95% confidence intervals.

RESULTS
Twenty-five short implants (6 mm) and 25 standard-length implants (10 mm) were randomly placed as single-tooth replacement in the edentulous molar area of the mandible. However, four implants that had insufficient insertion torque (less than 35 Ncm) were excluded from the study (two short implants and two conventional implants). Therefore, 23 implants were investigated in each of the two groups (Table 2). No patients dropped out, and all were available for the 4-month follow-up.

Implant Survival and Complications
During the 3 months postloading, two short implants lost integration, and one conventional implant failed (Table 3). There was no significant difference between the two implant types (P = 1). All failed implants were taken out, and after a healing period of 2 months, conventional-length implants with delayed loading were provided to the patients (Table 4). One conventional implant (5.0 × 10 mm), placed with an insertion torque of 35 Ncm, positioned at the right first molar area in a male nonsmoker patient, was having mobility at 2 months after placement. No other symptoms were present. One short implant (4.2 × 6 mm), placed with an insertion torque of 35 Ncm, positioned at the right first molar area in a female nonsmoker patient, was having mobility at 2 months after placement. No other symptoms were present. One short implant (5.0 × 6 mm), placed with an insertion torque greater than 65 Ncm, positioned at the left first molar area in a
Weerapong et al

Fig 2  Treatment sequence of the patient requiring a single-tooth replacement of first molar: (a) flapless procedures in area of right first molar; (b) implant placement preparation; (c) placement of implant with insertion torque > 35 Ncm; (d) RFA values were obtained; (e) definitive abutment was placed with an insertion torque = 30 Ncm; (f) provisional crown was designed; (g) provisional crown in position; (h) periapical radiograph at delivery of the provisional crown.

Fig 3  (a) Periapical radiographs at 4 months after immediate loading. (b) The provisional prosthesis 4 months after immediate loading.
female nonsmoker patient, was removed at 4 months after placement because of mobility.

Minor prosthetic complications were found. Three provisional crowns in short implants fractured (two fractured at 2 months postloading and another at 3 months), and two fractured in conventional implants at 3 months. All failed provisionals were replaced with definitive restorations.

**Insertion Torque and ISQ Level**
The mean values of the insertion torque were 42.61 ± 7.52 in the short implant group and 45.22 ± 8.85 in the conventional implant group. The difference in insertion torque among the two groups was not statistically significant ($P = .287$).

The ISQ level at implant insertion was 73.91 ± 2.44 in the short implant group and 74.54 ± 3.27 in the conventional implant group. No statistically significant difference was found in ISQ value for short and conventional implants at baseline, 4 months, and 1 year postloading ($P > .05$).

**Marginal Bone Level Changes**
Reliability analysis using intraclass correlation coefficient for the intra-examiner agreement and the inter-examiner agreements was 0.98 and 0.95, respectively. The mean change in marginal bone level was analyzed for each implant by two independent examiners. The mean change in marginal bone level after 4 months of loading was 0.28 ± 0.29 for the short implant group and 0.25 ± 0.25 for the conventional implant group (Table 6). There was no statistically significant difference between the two implant types ($P = .73$). The mean change in marginal bone loss after 1 year of loading was 0.33 ± 0.47 for the short implant group and 0.26 ± 0.27 for the conventional implant group (Table 6). There was no statistically significant difference between the two implant groups ($P = .554$).

After 1 year, all patients came back for a regular check-up; all of the implants were still in good function, and no complications were found.
DISCUSSION

The preliminary outcomes of this randomized clinical trial supported the use of immediate loading of both short implants and standard-length implants in a single edentulous area. The survival rates of short and standard-length implants were 91.30% and 95.65%, respectively.

Numerous studies have reported high success rates of immediate loading with standard-length implants for a single edentulous gap.11–13 However, there are limited studies evaluating immediate loading of short implants. In 2012, Canizzaro et al reported the 4-year survival rate of immediate vs early loading of 6.5-mm short implants. The survival rate was 96.7% for both groups.37 The meta-analysis of Srinivasan et al in 2013 reported that 6-mm-short implants demonstrated favorable survival rates, and most of the failures occurred in the first 4 months.38 In the present study, the failures occurred within 3 months after immediate loading.

Primary stability is vital to the success of immediate implant loading. Various factors may contribute to primary implant stability. Some local factors, implant factors, patient characteristics, and surgical technique are related to primary stability after surgical implant placement.

In this study, the RFA values and insertion torque were used to measure implant stability. The ISQ level at placement time was slightly lower in the short implants compared with the conventional length; no statistically significant differences were found. Winter et al found that the varying lengths of implants were insignificant to ISQ values in cases of a high level of bone quality. On the other hand, an increased implant length could provide greater implant primary stability in patients with an inadequate bone quality.39

After 4 months and 1 year postloading, the RFA values of the short implants and the group of conventional implants showed a trend toward a slight increase. No significant difference was found between the short and standard implants in the time interval. Accordingly, the study by Tirachaimongkol et al demonstrated a reduction in ISQ values within the first 3 weeks after implant placement, and it eventually increased and attained the initial value up to/within 12 weeks.40

The difference in mean insertion torque among short implants and conventional-length implants was not statistically significant. An optimum insertion torque can alleviate implant micromovement, which jeopardizes the osseointegration of implants. Besides, several factors contribute to insertion torque, such as thickness of cortical bone, bone quality, implant bed preparation, and implant thread design.41

A tapered thread design for an implant provides a considerably high mechanical retention, leading to an increase in implant primary stability.42 To achieve primary stability, implant placement preparation is the most intricate procedure, since different systems have their own drilling techniques. For this reason, a modified drilling technique, such as underpreparation, will be selected in type III or IV bone quality. However, using a countersink technique in bone type I may compromise the insertion torque despite the advantages in reducing thermal effect and excessive friction toward bone. Hence, the skill and experience of practitioners are important.43

However, very high insertion torque may cause excessive trauma and thermal injury during implant insertion. In the present study, one of three failed implants had an insertion torque over 65 Ncm. These may be factors that cause implant failure.44

The mean value of peri-implant bone loss in both groups after 4 months and 1 year postloading was less than 1 mm, and there was no significant difference among groups. These conform with the previous studies.43

Both implant groups in this study were immediately loaded with hybrid ceramic provisional crowns that were fabricated using a CAD/CAM device. Using a CAD/CAM device to make the provisional crown can reduce chair time, surgical trauma, and postoperative complications. Moreover, the restorations that were processed by the CAD/CAM device have high accuracy, which reduces prosthetic misfit.45,46 The misfit of restorations distributes an uneven occlusal force to the

### Table 5

<table>
<thead>
<tr>
<th>ISQ</th>
<th>Short implant (n = 23)</th>
<th>Conventional implant (n = 23)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>73.91 ± 2.44</td>
<td>74.54 ± 3.27</td>
<td>.47</td>
</tr>
<tr>
<td>4 months</td>
<td>74.79 ± 2.31</td>
<td>75.04 ± 2.20</td>
<td>.607</td>
</tr>
<tr>
<td>1 year</td>
<td>74.60 ± 2.03</td>
<td>75.35 ± 2.66</td>
<td>.296</td>
</tr>
</tbody>
</table>

P value between baseline and 1 year

ISQ = implant stability quotient.

### Table 6

<table>
<thead>
<tr>
<th>Marginal Bone Level Changes (mm) from Baseline to 4 Months and 1 Year of Loading Between Two Implant Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>Short implant (n = 23)</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Conventional implant (n = 23)</td>
</tr>
<tr>
<td>Mean</td>
</tr>
</tbody>
</table>
implant, which results in increasing stress to the implants. Therefore, an appropriate provisional restoration, good contact and occlusion, as well as passive fit, may be essential steps to success in immediate loading of implants. 47,48

According to an investigation by Abrahamsson et al, as the prosthetic components were repeated and reconnected, this was able to compromise the peri-implant mucosal barrier, thus leading to an apical migration of the connective tissue and underlying bone. The “one abutment at one time” protocol was recently introduced. A definitive abutment is placed at the time of surgical implant placement to avoid its displacement/removal during healing. 49 The nonremoval of an abutment placed at the time of surgery can significantly reduce the marginal bone remodeling around the immediate restoration. 50 Thus, another advantage from immediate loading implant placement is preserving bone level due to the “one abutment at one time protocol”.

CONCLUSIONS
Due to the small sample size of the study, it can be concluded that, with the optimum bone quality and primary stability of dental implant placement, CAD/CAM technology together with the immediate loading protocol, the immediate loading of short implants is comparable to conventional-length implants in implant survival rate, marginal bone loss, and ISQ value.

ACKNOWLEDGMENTS
This trial was partially funded by Chiang Mai University. The authors reported no conflicts of interest related to this study.

REFERENCES