Implant stability in posterior maxilla: bone-condensing versus bone-drilling: a clinical study

Aleksa Marković, DDS, PhD,a Dejan Čalasan, DDS, MSc,b Snježana Čolić, DDS, PhD,a Ljiljana Stojčev-Stajčić, DDS, PhD,a Bojan Janjić, DDS, MSc,b and Tijana Mišić, DDS,c Belgrade, Serbia
UNIVERSITY OF BELGRADE

Objective. The aim of this clinical trial was to compare primary and secondary stability of implants placed by bone condensing versus the standard drilling technique in the posterior edentulous maxilla.

Study design. Forty-eight SLA Straumann implants 4.1 × 10 mm (Institut Straumann AG, Waldenburg, Switzerland) were placed into edentulous maxillary posterior region in the same positions bilaterally, using the bone condensation technique for one and the standard technique for the other side. Implant stability measurements were performed immediately after implant placement, as well as every week for the next 6 weeks by use of resonance frequency analysis (RFA). Data were analyzed using Mann-Whitney U and Wilcoxon tests.

Results. After bone condensing, significantly higher implant stability was recorded immediately after surgery as well as during the whole observation period of 6 weeks compared with bone-drilling technique (Mann-Whitney U test, P < .000).

Conclusions. The bone-condensing technique can be recommended as an alternate surgical approach for implant site preparation in reduced bone density to achieve greater implant stability in the posterior maxilla. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:557-563)

Primary stability is one of the fundamental criteria for obtaining osseointegration. It depends on the implant design, surgical technique, bone density, and on the microscopic and macroscopic morphology of the implant used.1

In dense bone, high primary stability is easily obtained, thus providing contact osteogenesis. In low-density bone, it is often difficult to obtain satisfactory primary stability. The lack of initial stability can result in distant osteogenesis, a longer healing period, and a lower success rate.2

More or less dense trabecular bone surrounded by a thin layer of cortical bone is often present in posterior maxilla (class III and IV, Lekholm and Zarb).3 In this biologically challenged region for implant placement, it is often difficult to achieve good primary stability. It could be achieved by the undersized preparation technique, wider implant diameter, placement of conical implants or by condensing of the implant site.2

The bone-condensing technique was introduced to increase primary stability of dental implants in the posterior maxilla. This implant site preparation technique involves the use of implant-shaped instruments (bone condensers) by which the bone is compressed apically and laterally rather than removed. Bone condensing preserves as large a volume of existing maxillary bone as possible and increases its density so as to optimize the primary stability of implants in low-density bone.2

Compared with native trabecular bone, in compressed trabecular bone grafts, the increased amount of
new bone is formed and it is proportional to the degree of compression. This bone has enhanced density.

Animal studies showed that the bone-condensing technique would improve primary stability of implants and compared with standard drilling, accelerate bone healing. Condensation significantly increases bone density in apical peri-implant area in relation to standard surgical technique.

In contrast, Buchter et al. published that after bone condensing, microfractures in peri-implant bone have led to delayed bone recovery, impaired bone-to-implant contact and decreased implant stability. Also, longitudinal cracks and gap formation at the collar bone region, resulting in higher failure rates in cases of condensation techniques, have been reported.

As expected on the basis of theoretical considerations, the bone-condensing technique increased the success rate of implant therapy in the posterior maxillary region. It can be assumed that one of the causes of improved success rate is greater implant stability in such prepared implant sites. There are no data to support clinical evidence of the dynamics in implant stability for those placed in condensed bone. The aim of this clinical trial was to compare primary and secondary stability of implants placed by condensing versus the standard drilling technique in the posterior edentulous maxilla.

**MATERIAL AND METHODS**

Forty-eight sand-blasted, large grit, acid-etched (SLA) Straumann implants (Institut Straumann AG, Waldenburg, Switzerland) with the length of 10 mm and a diameter of 4.1 mm, were placed into edentulous maxillary posterior region of 8 nonsmoking and generally healthy patients (5 men and 3 women) between January and December 2009 at the Clinic of Oral Surgery, Faculty of Stomatologv, University of Belgrade. Patient ages ranged from 20 to 65 years (mean 47.6 years). Inclusion criteria for implantation were (1) bilateral subantral bone height 12 mm, (2) 6.2 mm or more bone width, and (3) jaw bone density D3 or D4 according to Lekholm and Zarb classification. Bone density assessment and implant planning were performed using Galileos cone beam CT Imaging (Sirona, Bensheim, Germany) (Fig. 1). Bone density was then once again tactile reaffirmed, during the preparation of pilot osteotomy.

The study was approved by the Ethics Committee at the Faculty of Stomatology, University of Belgrade (Number 36/20).

Patient history data, necessary for surgical procedure, were collected through a questionnaire, completed by patients themselves. The whole procedure was explained in detail to each patient and all surgeries were performed after patient written consent.

All surgeries were performed under local anesthesia (Ultracaine D-S Forte, Aventis, Frankfurt/Main, Germany). Antibiotic prophylaxis was applied in all cases with amoxicillin (1.5 g) or clindamycin (1.8 g) daily, divided in 3 doses, administered for 3 days.
To provide uniform conditions in both study groups, implant placements were made in the same positions bilaterally, using the bone condensation technique for one side and the standard technique for the other side of the maxilla. Jaw side for the bone condensation or standard technique was randomly selected.

A midcrestal incision with 2 vertical releasing incisions was made bilaterally. Full-thickness buccal and palatal mucoperiosteal flaps were reflected, exposing the alveolar ridge at the sites of implant placement.

Implant sites, at the “bone-condensation” side, were prepared by pilot drill, followed by condensers of increasing diameter (Osteotome Kit, Straumann) (Fig. 2). Each condenser remained at the implant site for 1 minute before the next diameter was used. Finally, implants were inserted with the same insertion torque, 35 N/cm, also without pretapping.

At the “standard technique” side, the implant sites were gradually enlarged to 3.5 mm in diameter, with pilot and spiral drills, according to the standard protocol of the manufacturer (Straumann GmbH, Waldenburg, Switzerland). Implants were placed using insertion torque of 35 N/cm, without pretapping.

After the implantation, at both sides, primary wound closure was achieved with single sutures.

Implant stability measurements were performed immediately after implant placement, as well as every week for next 6 weeks\(^1\)\(^3\) by use of resonance frequency analysis (RFA). The analysis of RFA was made using an Osstell Mentor apparatus (Osstell, Integration Diagnostics, Savadaled, Sweden) with a commercially available transducer (type 4) adapted to Straumann implants. The transducer was maintained perpendicular to the implant and was hand-screwed into the implant body as recommended by the manufacturer (Fig. 3). Measurements were shown in ISQ (implant stability quotient) units, on the scale from 1 to 100 (100 as maximum implant stability). Each measurement was repeated, until the same value was recorded twice, which was accepted as the authentic value. All implant stability evaluations were done by 1 researcher who was blinded to the technique used to prepare the implant sites so as to achieve objective measurement.

Control digital panoramic radiographs were made immediately after the implant insertion, as well as after 6 weeks. Data were analyzed in SPSS ver. 17 software (SPSS, Inc, Chicago, IL). Descriptive statistics were performed with measures of central tendency (mean and median), measure of dispersion (standard deviation), and 95% confidence interval. For statistical analysis of data, the following tests and methods were used depending on the nature of the data: Mann-Whitney U test and Wilcoxon test. The significance level was .05.

**RESULTS**

**Clinical observation**

At first, 10 patients fulfilled the criteria for inclusion in the study; however, in the bone-condensing study group...
the buccal lamella of the jaw was fractured during the implant site preparation in 1 patient. In the bone-drilling study group, the primary stability of implants in 1 patient was 42 ISQ. In both of these patients, implants were covered and 2-stage protocol was planned and patients were excluded from the study. Therefore, the study was conducted on 8 patients, ie, 48 implants. In all enrolled patients, the postoperative course was uneventful with minimal discomfort. Complications were not seen; implants from both study groups, bone-condensing as well as the standard technique, were clinically stable during the period of observation. Final prosthetic rehabilitation was performed for all implants 6 weeks after surgery when they were all eligible for early loading ISQ of greater than or equal to 65 (Fig. 4).

**Within-group results**

The recorded ISQ values and accompanying descriptive statistics for both study groups are presented in Table I.

Primary stability recorded after bone condensing was 74.03 ± 3.53 ISQ. In this study group, significantly smaller ISQ values were measured between the first and the sixth postoperative week than the values immediately after surgery (Wilcoxon test; \( P = .000 \)). In the sixth week, the ISQ values observed for implants placed after bone condensing were higher than those for primary stability only in some cases.

In the control group (drilling), primary stability was 61.20 ± 1.63 ISQ. ISQ values measured from the first to third postoperative week in this group were significantly smaller than for the primary stability (Wilcoxon test, \( P = .000 \)). ISQ values in the fourth postoperative week in the control group were not significantly different from the primary stability values (Wilcoxon test; \( P = .230 \)), whereas values measured in the fifth and sixth weeks were significantly higher than the primary stability (Wilcoxon test; \( P = .000 \)). At the end of the analyzed period, all implants in this control group had a significantly greater stability in relation to their primary stability. However, this stability was still considerably less than those achieved in the bone-condensing group.

**Between-group results**

Implants placed after bone condensing had been performed achieved significantly higher stability immediately after surgery as well as during the whole observation period of 6 weeks compared with those placed following the conventional implant site preparation (Mann Whitney \( U \) test, \( P = .000 \); Table II).

From the first week postoperatively, there was a decline in stability of implants from both groups and the lowest ISQ values were observed in the third week: 66.70 ± 1.64 for bone condensing and 57.10 ± 1.45 for bone drilling. Implant stability started to increase in the fourth week postoperatively for both surgery techniques and it was continued until the sixth week (Fig. 5).

**DISCUSSION**

Excessive implant motion (between 50 and 150 \( \mu m \)) or poor implant stability results in tensile and shear motions, stimulating a fibrous membrane formation around the implant and causing displacement at the bone-implant interface, thus inhibiting osseointegration and leading to aseptic loosening and failure of the implant.\(^{14}\) Primary stability provides mechanical rest of implants after their insertion in the bone recipient site and thus creates the conditions for an undisturbed osseointegration. The bone condensation technique is recommended for increasing the stability of an implant placed in low-density bone, but its use is still controversial.

We noticed a significantly higher primary stability in the group where the bone condensation technique was performed compared with the standard technique. The result could be explained by changes in peri-implant trabecular bone micromorphology after its apicolateral condensation. Fanuscu et al.\(^ {15} \) noted that lateral bone condensation significantly increased trabecular thickness and reduced its separation. Also, they found significant increase in relative bone volume in a 1-mm circular vicinity of implants placed after bone condensation. Implant stability quotient values in their study on cadavers were higher for implants placed with the bone condensing than those for the standard technique, but were not statistically significant. This discrepancy with our results could be caused by the difference in the density of bone present in the maxilla “in vivo” and in the iliac crest from fresh cadavers that are used as an experimental model in their study.
Significantly higher primary stability after condensation, we have found, could be the result of an improved peri-implant bone density and increased bone-to-implant contact. The supporting results were published by Proff et al.\textsuperscript{16} in the cadaveric study. In spongy bone, following bone condensing, a significant histomorphometric increase of bone-to-implant contact supported by radiographic densitometry was found. That resulted in slight, yet not significant increase of primary stability after bone condensing (67.00 ± 3.32 ISQ) compared with the conventional technique (65.60 ± 3.29 ISQ). Within the compact area, the condensing technique has not achieved such a benefit.

Strietzel et al.\textsuperscript{17} highlighted the advantage of using the condensing technique in types 3 and 4 bone, as well as possible deleterious effect on osseointegration when it was performed in dense bone. Implant sites where the preparation cannot be achieved by force of less than 20 MPa are not suitable for condensation, because the stronger force damages osteocytes and bone microfractures appear that reduce mechanical competence of bone and stability of the implant.\textsuperscript{18,19} In clinical conditions, during bone condensing, defined force cannot be used and preoperative bone density assessment is important to achieve success outcome.

In accordance with our results, Kim et al.\textsuperscript{20} confirmed that the trabecular compaction technique should be an effective surgical technique to increase primary stability in soft bone regions. In their animal study, after placing an implant in the femur of dogs, the groups with trabecular compaction technique showed higher ISQ values than groups with the conventional drilling. Also Choi et al.\textsuperscript{21} observed higher primary stability for implants placed in the maxilla of fresh-frozen cadavers after bone condensing compared with conventional drilling. In contrast, Buchter et al.\textsuperscript{10} concluded that following bone condensing for implant placement, decreased implant stability was achieved because of microfractures in peri-implant bone. On the other hand, Stavropoulos et al.\textsuperscript{22} noted that minor cracks in the coronal portion of the alveolar ridge observed after condensation in the dog mandible have not prevented good primary stability of implants. Total separation of bone fragments was not detected.

Over time, the primary mechanical stability of the implant is transformed into a secondary biological stability, which reflects regeneration and remodeling in bone-implant interface.\textsuperscript{23} Results of this clinical trial presented significantly higher mean stability levels for implant sites prepared by bone condensing compared with bone drilling at all time points during the observation period of 6 weeks. This result could be a consequence of different bone regeneration patterns present after the use of 2 surgical techniques. Unlike the

<table>
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<th>Parameter</th>
<th>Evaluation time</th>
<th>Technique</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
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<td>74</td>
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<td>73</td>
<td>3.20</td>
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<tr>
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<td>1.40</td>
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<td>1.41</td>
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<td>65.07-65.39</td>
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Values expressed as implant stability quotient (ISQ).

<table>
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<th>Evaluation time</th>
<th>Implant stability</th>
<th>P value*</th>
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<tr>
<td>Primary stability</td>
<td>Condensing</td>
<td>74.03 ± 3.53</td>
</tr>
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<td>1st week</td>
<td>Condensing</td>
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<td>2nd week</td>
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<td>3rd week</td>
<td>Condensing</td>
<td>66.70 ± 1.64</td>
</tr>
<tr>
<td>4th week</td>
<td>Condensing</td>
<td>68.37 ± 1.65</td>
</tr>
<tr>
<td>5th week</td>
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<tr>
<td>6th week</td>
<td>Condensing</td>
<td>70.33 ± 1.21</td>
</tr>
</tbody>
</table>

Values are given in implant stability quotient (ISQ), expressed as mean ± standard deviation of the mean; *Mann-Whitney U test; all values are statistically significant.
usual process of bone regeneration in the control group, the trauma-dependent repair mechanism known as “regional acceleratory phenomena” is expected after bone condensing. Mechanical stimuli could accelerate the formation of trabecular bone. The local bone remodeling can be intensified up to 50 times. In the animal study, local trauma caused by the osteotome technique has led to improved bone-to-implant contact ratio, over time. It is also found that comparing bone drilling and condensing, the latter generated significantly smaller amounts of heat, which potentially creates improved conditions for osseointegration. Previously, enhanced osseointegration of dental implants in trabecular bone following bone condensation compared with standard technique was reported.

The results of this clinical study indicate a significant decrease in implant stability in the third week in both study groups. This decline is in agreement with previous findings and could be explained by necrotic bone remodeling, which means the activity of osteoclasts that decrease the initial mechanical stability of the implant when the formation of new bone has not yet occurred to the level required to maintain implant stability. Indeed, in the second week, Berlundh et al. noticed ongoing bone remodeling in pitch regions of the implant, responsible for primary mechanical stability in their dog animal model. With respect to the interspecies differences in healing time, this phenomenon corresponds to the third week of healing in humans.

The interesting finding of our study is that even in the critical third week, regardless of the present fractured bone trabeculae noted in previous histologic studies, the stability of the implant after the condensation had not dropped below 60 to 65 ISQ as a suggested value for the immediate loading of implants. In the control study group, significantly lower ISQ values were measured. One could speculate that the increase in implant stability after bone condensation creates the conditions for its earlier loading. This suggests the need to revise the existing loading protocols in low-density bone dealing with bone condensation technique. Successful outcome of immediate loading of implants placed following the condensing technique was published in a few clinical reports.

In the present study, implant stability started to increase from the fourth week as the result of woven combined with lamellar bone formation and in the sixth week implants from both groups obtained ISQ values suggested for the early loading protocol. However, significantly higher ISQ values were recorded for bone-condensing compared with standard technique.

The variety of data present in the literature on the impact of bone condensing on the implant stability could be derived from differences in density and healing time between the different experimental animal models, as well as between animal models and maxillary bone. The applied biomechanical test could also have an impact. Resonance frequency analysis was used to evaluate the implant stability in this study. In the literature, it is proposed as the most acceptable clinical method for determination the primary and secondary implant stability as well as a valuable indicator for implant success and early failure.

In conclusion, the bone-condensing technique can be recommended as an alternate surgical approach for implant site preparation in reduced density bone so as to achieve greater implant stability. According to the results of this study, implants inserted in the bone after bone condensing had been performed met the criteria for im-
mediate loading as opposed to those placed after the standard technique, which fulfilled this requirement later in the healing period. More years of observation are needed to prove that the increased stability of dental implants provided by bone condensing will be preserved.

REFERENCES


Reprint requests:
Aleksa Markovic, DDS, PhD
Clinic of Oral Surgery
Faculty of Stomatology
University of Belgrade
Dr Subotica 4
11000 Belgrade, Serbia
maleksa@sbb.rs