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Original Article

Comparison of implant stability and marginal bone loss between osseodensification and conventional osteotomy at adjacent implant sites

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KEYWORDS
Osseodensification (OD);
Conventional drilling (CD);

Abstract *Background/purpose:* Osseodensification (OD) has been proposed to enhance implant stability, but the extent of stability and marginal bone changes is unclear. The aim of this study was to compare implant stability and marginal bone changes between osseodensification and conventional drilling (CD) osteotomy at adjacent implant sites.
Materials and methods: Forty partially edentulous patients requiring two adjacent implants

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Implant stability;
Implant stability quotient (ISQ);
Marginal bone loss (MBL)

(n = 80) were enrolled in this study. Each subject underwent one OD osteotomy and one CD osteotomy at adjacent implant sites in the posterior maxilla or posterior mandible. Insertion torque (IT) was recorded with a torque gauge during surgery. Implant stability quotient (ISQ) was measured using a resonance frequency analyzer immediately and at 3, 6, 9, and 12 months postoperatively, while marginal bone loss (MBL) was calculated from standardized periapical radiographs.

Results: OD showed significantly higher IT and primary ISQ than CD ($P < 0.05$), especially in the mandible. In the primary ISQ measurements of the maxilla and mandible, OD was 15.52 and 16.24 higher than CD, respectively. MBL in OD was significantly lower than CD in both maxillary and mandibular implants at 3, 6, and 9 months postoperatively ($P < 0.05$). No significant differences were detected in MBL between OD and CD 12 months postoperatively.

Conclusion: Implant stability was significantly higher in OD than in CD, implying the possibility of non-submerged healing or immediate/early provisionalization/loading protocols. MBL was lower in OD than in CD at 3, 6, and 9 months postoperatively but was similar at 12 months postoperatively.

Introduction

Adequate implant stability reduces the likelihood of fibrous encapsulation, thereby promoting osseointegration and even favoring immediate or early provisionalization/loading protocols to shorten treatment time. Many methods have been proposed to enhance implant stability, and one of the commonly used techniques is appropriate osteotomy.[1,2]

Conventional drilling (CD) applied to implant site osteotomy utilizes a series of drills with increasing diameters, rotating in a clockwise direction under adequate irrigation, to excavate bone for proper implant slots. Unlike OD, osteodensification (OD) is a novel, non-subtractive osteotomy technique that uses specially designed drills that rotates counterclockwise to condense bone during drilling, resulting in a tight fit between the implant and surrounding bone. Rather than removing bone during osteotomy, OD preserves bone by intruding autologous bone laterally and apically into the trabecular space, thereby increasing bone density implant stability.[3]

Currently, insertion torque (IT) and implant stability quotient (ISQ) are the most frequently used methods to measure implant stability. IT is a simple way to assess implant stability. Nevertheless, IT can only measure primary stability during implant installation and cannot evaluate secondary stability at other time points.[4] ISQ is a noninvasive and repeatable method for measuring implant stability at different time points using resonance frequency analysis. Studies have shown that IT assesses rotational stability while ISQ reflects axial stability. Combining these two measurements may improve objectivity and accuracy in determining implant stability.[4,5]

Marginal bone level is an important criterion for assessing peri-implant tissue status apart from implant stability. Various factors have been proposed to explain implant marginal bone loss (MBL), such as implant design, abutment design, surgical trauma, foreign body reaction, etc.[6–9] However, the main cause of MBL remains uncertain.[10]

Although OD has been suggested to improve implant stability in previous studies,[3,11,12] the extent of its impact on stability and marginal bone level requires further investigation. The purpose of this study was to compare changes in implant stability and marginal bone loss between OD and CD at the adjacent implant sites in a one-year longitudinal study.

Materials and methods

Subject selection

This study was approved by the Ethical Review Board of Kaohsiung Medical University Hospital Institutional Review Board (KMUHIRB–F(II)–20230145). It was conducted at the Department of Dentistry, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan. Each eligible patient must be missing two adjacent teeth in the posterior maxilla or posterior mandible and require two implant-supported crowns.

Forty subjects were recruited according to the following criteria: 1) age over 20 years, 2) missing at least two adjacent teeth in the posterior maxilla or posterior mandible, 3) no serious system diseases known to alter bone metabolism, 4) non-smokers, 5) controlled periodontal diseases and good oral hygiene, 6) sufficient bone and at least 2 mm of keratinized tissue at the scheduled implant sites. The exclusion criteria were: 1) acute infection at the implant sites, 2) bone metabolism disorders, 3) severe bruxism or parafunction, 4) uncontrolled periodontal diseases or poor oral hygiene, 5) evident bone deficiency requiring bone augmentation, and 6) pregnancy. Informed consent was obtained from each subject before performing this study. One OD osteotomy and another CD osteotomy for each patient were randomly assigned to the adjacent implant sites. A total of 80 implants were installed and followed for one year.

Preoperative radiographic examination

Digital periapical radiographs and cone beam computed tomography (CBCT) were collected preoperatively to examine the scheduled implant sites. Implametric software (NNT viewer®, NewTom, Verona, Italy) was used to assess bone volume, bone density, and plan implant size and position before surgery.

Surgical and prosthetic procedures

The mucoperiosteal flap was elevated and two osteotomy techniques were performed at the adjacent implant sites. OD was performed through a series of drills (Densah®, Versah, Jackson, MI, USA) using a counterclockwise motion. CD was done using the standard drilling protocol according to the recommended drilling scheme. Two identical implants (Seven®, MIS, Shlomi, Israel) with the same dimensions (diameter and length) were placed into the adjacent osteotomy sockets. All 80 implants were installed using the non-submerged method. Each implant was connected to a healing abutment after implant stability measurement. The subjects were advised to consume soft foods for at least two weeks postoperatively. The final implant-supported crowns were delivered 4 months postoperatively (Fig. 1).

Insertion torque measurement

The installation of implants was completed with a torque wrench (MIS, Shlomi, Israel), which allowed the final insertion torque value to be recorded. The implant platform was placed in the same position as the buccal crest.

Implant stability quotient measurement

Implant stability was measured immediately after surgery (primary ISQ) and at 3, 6, 9, and 12 months postoperatively (secondary ISQ) using a resonance frequency analyzer named Osstell® Mentor (Integration Diagnostics AB, Göteborg, Sweden). The operator performing ISQ measurements was blinded to which osteotomy technique was used. Each implant was measured from four directions (buccal, palatal/lingual, mesial, and distal) at a time, and the average of the 4 ISQ values was calculated.

Marginal bone loss

Standardized digital periapical radiographs were taken immediately postoperatively (baseline) and 3, 6, 9, and 12 months postoperatively to evaluate marginal bone loss (MBL). Radiographic magnification was determined by the

Figure 1 Procedures and measurements for this study. (A) Osseodensification osteotomy. (B) Conventional drilling osteotomy. (C) Insertion torque record. (D) Implant stability quotient measurement. (E) Periapical radiography was performed immediately after surgery. (F and G) Two final implant-supported crowns were delivered 4 months postoperatively. (H and I) Clinical and radiographic follow-up one year postoperatively.

image/actual length ratio of the installed implant fixture. The linear distance between the implant platform and the mesial and distal marginal bone was measured. Changes from baseline in mesial and distal peri-implant bone levels were calculated at different time points. The average of the mesial and distal values for each implant was considered the MBL.

Statistical analysis

SPSS Statistics 22.0 (SPSS Inc., Chicago, IL, USA) was used for data analysis. T-test and analysis of variance (ANOVA) for pairwise comparisons were performed to determine statistically significant differences. P values $\leq$ .05 were considered statistically significant.

Results

This study consisted of 40 subjects (15 males and 25 females, mean age 57.58 $\pm$ 10.92 years). Overall 80 implants were installed in the 40 subjects, with one OD and one CD implant site per patient, including 46 and 34 implants placed in the posterior maxilla and posterior mandible, respectively. During the one-year follow-up period, no implant de-osseointegration or major complications (such as fixture or screw fracture) occurred, and the implant survival rate was 100 %. Implant distribution in the maxilla according to fixture size (diameter x length) was as follows: 4.2 $\times$ 10 mm (n = 10), 4.2 $\times$ 11.5 mm (n = 14), 5 $\times$ 10 mm (n = 14), and 5 $\times$ 11.5 mm (n = 8). Implant distribution in the mandible was as follows: 4.2 $\times$ 10 mm (n = 8), 4.2 $\times$ 11.5 mm (n = 10), 5 $\times$ 10 mm (n = 8), and 5 $\times$ 11.5 mm (n = 8).

The comparison of IT between OD and CD osteotomy of implants placed in the maxilla and mandible is shown in Table 1. OD demonstrated significantly higher IT than CD in both the maxilla and mandible ($P < 0.0001$). In addition, OD showed significantly higher IT in the mandible than in the maxilla ($P = 0.037$). However, there was no significant difference in IT between maxillary and mandibular implants using CD ($P = 0.214$).

The mean primary ISQ of OD was 74.75 $\pm$ 7.03 (maxilla: 70.39 $\pm$ 5.57; mandible: 80.65 $\pm$ 3.71) and that of CD was 58.93 $\pm$ 8.38 (maxilla: 54.87 $\pm$ 6.61; mandible: 64.41 $\pm$ 7.45).

Table 1 Comparison of insertion torque between osseodensification and conventional drilling osteotomy.

	Group		P value
	OD	CD	
	Mean $\pm$ SD	Mean $\pm$ SD	
Maxilla	46.74 $\pm$ 5.14 Ncm	31.30 $\pm$ 5.05 Ncm	<.0001*
Mandible	58.53 $\pm$ 8.06 Ncm	37.94 $\pm$ 6.39 Ncm	<.0001*
Maxilla + Mandible	51.75 $\pm$ 8.74 Ncm	34.13 $\pm$ 6.49 Ncm	<.0001*

OD, osseodensification osteotomy; CD, conventional drilling osteotomy; SD, standard deviation; Ncm, Newton centimeter; *, statistical significance ($P < 0.05$).

OD was 15.52 and 16.24 higher than CD in primary ISQ for maxillary and mandibular implants, respectively. Primary ISQ was significantly higher in OD than in CD for both maxillary and mandibular implants ($P < 0.0001$). As for secondary stability, OD showed significantly higher secondary ISQ than CD at 3, 6, 9, and 12 months postoperatively ($P < 0.0001$). Implants installed in the mandible using OD demonstrated the highest ISQ at all time points (Fig. 2).

MBL was assessed at 3, 6, 9, and 12 months after surgery, as shown in Fig. 3. The MBL of the mandible was higher than that of the maxilla in both OD and CD throughout the study period. MBL changes were greatest in OD and CD from implant placement to 3 months postoperatively. MBL was significantly lower in OD than in CD at 3, 6, and 9 months postoperatively ($P < 0.0001$). However, the difference in MBL between OD and CD was not significant at 12 months postoperatively ($P = 0.08$).

Discussion

Appropriate surgical instruments and techniques may greatly enhance implant stability under adverse bone conditions, thus promoting osseointegration. Osseodensification (OD) has been proposed to compensate for the potential limitations of conventional osteotomy. OD is a non-subtractive osteotomy technique that improves bone density and biomechanical interlocking between bone-to-implant contact through bone condensation, thereby increasing primary implant stability.[3,12]

Modern dental implant developments focus on improving efficiency, comfort, functionality, and esthetics. Several approaches to shorten treatment time have been proposed, such as immediate implant placement and immediate provisionalization.[13,14] Obtaining adequate implant stability is crucial for immediate/early provisionalization/loading of implants. One of the key prerequisites for immediate provisionalization/loading is sufficient primary implant stability (IT $\geqq$ 30 Ncm and/or ISQ $\geqq$ 60).[15,16] In this study, the mean IT was 51.75 $\pm$ 8.74 Ncm and the mean primary ISQ was 74.75 $\pm$ 7.03 in OD, both met the aforementioned stability requirements. However, the mean primary ISQ of CD was 58.93 $\pm$ 8.38, which was slightly lower than the recommended stability standard. Osteotomy using OD technique may facilitate non-submerged healing, thereby improving clinical efficiency. This is similar to the statement proposed by de Carvalho Formiga et al.,[17] who claimed that OD increased primary stability, enhanced faith and predictability during immediate implant placement.

The two osteotomy techniques had different effects on IT and ISQ. In this study, OD condensed the bone structure and increased engagement of the implant and bone, resulting in higher IT and ISQ values, which is consistent with the review by Tretto et al.[11] This condition might be due to OD using distinctive drills with many large negative rake angles as non-cutting edges to enlarge the implant sites and increase bone density.

In this study, mandibular implants showed higher IT and ISQ values than maxillary implants in OD and CD. Bone density might play an important role than osteotomy method in IT and primary ISQ determination. Implants placed at sites with denser bone quality (usually in the

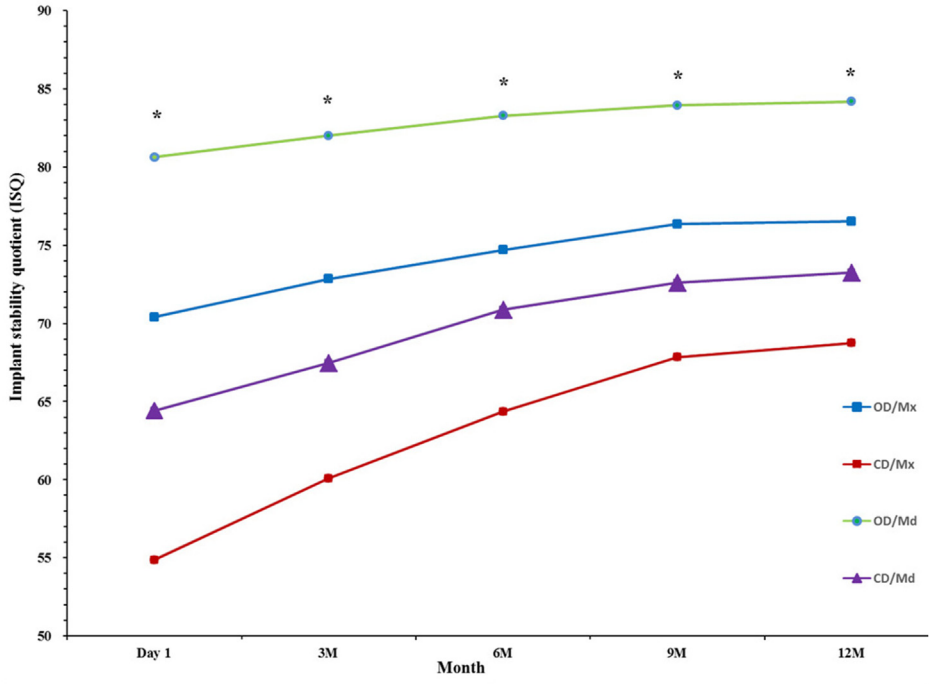

Figure 2 Implant stability quotient (ISQ) over time. OD: Osseodensification osteotomy, CD: Conventional drilling osteotomy, Mx: Maxilla, Md: Mandible, *: Statistical significance ($P < 0.05$).

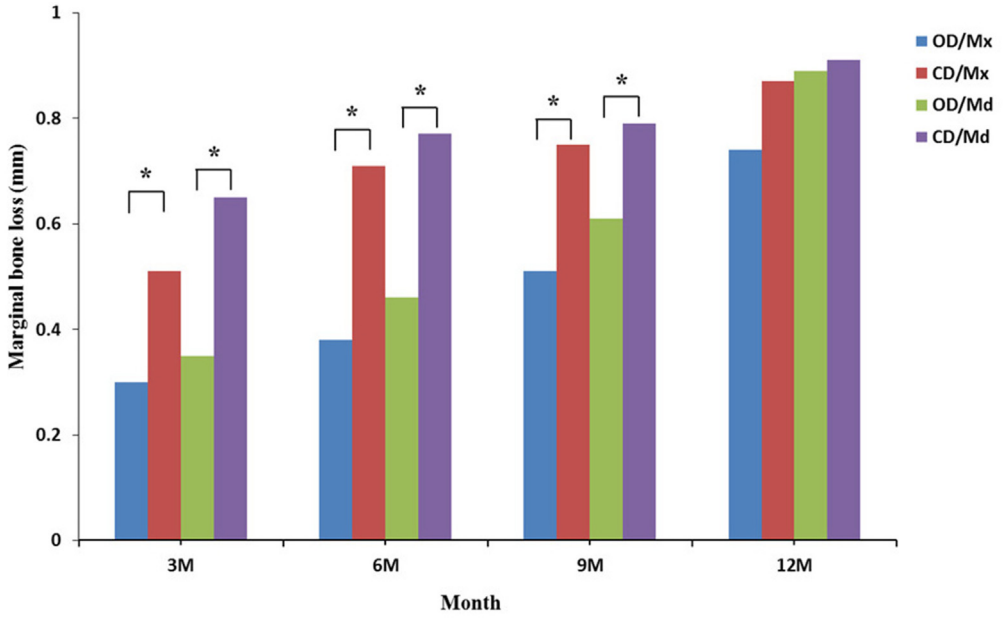

Figure 3 Marginal bone loss (MBL) over time. OD: Osseodensification osteotomy, CD: Conventional drilling osteotomy, Mx: Maxilla, Md: Mandible, *: Statistical significance ($P < 0.05$).

mandible) generated more friction between the fixture and surrounding bone and therefore exhibited higher IT and primary ISQ. This is in agreement with the study by Sim and Lang,[18] who found that ISQ values were influenced by bone structure and implant length.

Conventional drilling often takes advantage of the dimension discrepancy between the drill and the implant fixture to create undersized osteotomy for tighter engagement, which is especially true with wider implants. However, the substantial excavation of bone in CD may result in more strain, microcacks, bone remodeling, and subsequent MBL.[2] In this study, MBL was significantly lower in OD than in CD at 3, 6, and 9 months postoperatively. This favorable bone remodeling phenomenon was similar to the findings of Witek et al.[19] and Mullings et al.[20] Briefly, OD compacts bone fragments into the trabecular space during

osteotomy rather than removing bone, which contributes to high implant stability. The unique drilling technique may minimize strain, reduce microcracks, and limit bone remodeling when operated correctly.[21]

Strengths of this study included the random application of the two drilling techniques to adjacent implant sites and ISQ measurements by an operator blinded to the osteotomy technique to avoid possible bias. Furthermore, the use of two identical implants at adjacent implant sites might minimize the potential effects of various implant sizes (diameter/length) and bone density on IT, ISQ, and MBL, thus highlighting the impacts of different osteotomies on these parameters. Limitations of this study were the small sample size and the selection of specific implant sites should be interpreted with caution.

This study demonstrated the advantages of OD over CD on IT, ISQ, and MBL. However, further studies with larger sample sizes, various bone densities, and different loading protocols are needed to better elucidate the impacts on these parameters.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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