IJCRM
International Journal of Contemporary Research In Multidisciplinary

Research Article

A Clinical and Radiological Comparative Evaluation of Osseodensification Technique and Rotary Bone Expansion Technique for Implant Placement in Low-Density Bone: A 16 Weeks Prospective Randomized Controlled Trial

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DOI: https://doi.org/10.5281/zenodo.14910959

Abstract

Background: Dental implants are highly effective for teeth replacement, with stability being crucial for success. Stability, defined by the absence of clinical mobility, includes primary and secondary stability. Primary stability is biomechanical, influenced by bone quality, implant design, surgical technique, and insertion torque. Secondary stability, a biological phenomenon, indicates osseointegration, the direct connection between bone and implant. Resonance Frequency Analysis (RFA) measures stability, recorded as the Implant Stability Quotient (ISQ) on a scale from 1 to 100, with higher values indicating greater stability. Techniques to enhance primary stability, especially in low-density bone, include bi-cortical fixation, under-preparation of the implant bed, osteotomes, and a new method called osseodensification, which increases bone density and improves stability.

Methods: Twenty-two single edentulous sites were selected for dental implant placement and divided into two groups of 11. Group A used the osseodensification technique, while Group B used rotary bone expanders. ISQ was recorded at 2, 4, 6, 8, 12, and 16 weeks, and IT and crestal bone levels were evaluated at baseline and 16 weeks.

Result: At baseline, Group A had significantly higher ISQ values than Group B. At 2 and 4 weeks, the ISQ difference was non-significant. Subsequently, Group B had higher ISQ values, but the difference remained non-significant. Insertion torque and crestal bone loss differences were also statistically non-significant between the groups.

Conclusion: Both osseodensification and rotary bone expander techniques showed statistically non-significant differences in ISQ, IT, and crestal bone loss, indicating equal efficacy for implant osseointegration.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 09-01-2025
- **Accepted:** 28-01-2025
- **Published:** 22-02-2025
- **IJCRM:**4(1); 2025: 151-155
- **©2025, All Rights Reserved**
- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Sinha A, Upadhyay P, Tripathi P, Pal M. A clinical and radiological comparative evaluation of osseodensification technique and rotary bone expansion technique for implant placement in low-density bone: A 16 weeks prospective randomized controlled trial. Int J Contemp Res Multidiscip. 2025;4(1):151-155.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Osseointegration, implant stability quotient, crestal bone level, osseodensification, Insertional torque

1. INTRODUCTION

For over 1500 years, the development of artificial tooth replacements remained elusive. Evidence of early attempts includes a 600 AD Mayan skull with an implanted tooth-shaped stone, as well as accounts from the Middle East and ancient Egypt. Interest in prosthetic teeth fixed to the jaws continued, culminating in the work of Per-Ingvar Branemark in 1952, who through extensive research introduced the concept of osseointegration—a direct structural and functional connection between bone and implant, using titanium.[1] This discovery revolutionized periodontics, shifting the focus from saving compromised teeth to extracting and replacing them with dental implants for better long-term outcomes. Implant stability is key to the success of dental implants, defined by the absence of clinical mobility and divided into primary and secondary stability. [2] Primary stability is the initial mechanical stability influenced by bone quality, surgical technique, and implant design. Secondary stability involves bone growth and remodelling at the implant-bone interface, influenced by the implant surface and healing time. Clinical assessment traditionally involved subjective methods like tapping the implant with mirror handles, but these lacked quantitative support.[3] Resonance Frequency Analysis (RFA) emerged as a reliable, non-invasive method to measure implant stability, recorded as the Implant Stability Quotient (ISQ) on a scale from 1 to 100. [4-6] Higher values indicate greater stability. RFA measures the stability of implants at various stages of the healing process. Early in vitro studies showed the device's ability to detect changes in interfacial stiffness, validating RFA for clinical use. The transducer used in RFA has piezoceramic components that generate and detect vibratory signals, determining the resonance frequency and thus the stability of the implant. [7-8]

Past techniques to improve primary stability in low-density bone included bi-cortical fixation, under-preparation of the implant bed, and the use of osteotomes and condensers. While effective, these methods had drawbacks, such as patient discomfort and postoperative complications like benign paroxysmal vertigo. To address these issues, motor-driven bone expanders were developed, providing controlled ridge expansion and reducing surgical stress. These devices allow for precise application and direction of expansion pressures, enhancing implant site preparation, especially in types II, III, and IV bone. [9-10]

Osseodensification (OD) is a newer method for increasing osteotomy site density, introduced by Huwais in 2013. Unlike traditional drilling, which removes bone, OD uses specialized burs that condense bone by rotating in reverse at controlled speeds with saline irrigation. This process compacts and preserves bone, improving implant mechanical stability and peri-implant bone density during osteotomy preparation. The unique bur design facilitates bone compaction without cutting, promoting increased bone growth and plasticity. [11-12]

Primary stability in the low-density bone, such as the upper mandible, is influenced by the friction between the implant surface and the osteotomic walls. Secondary stability, achieved through osseointegration, involves new bone apposition on the implant surface. In low-density environments, insufficient bone around implants can adversely affect histomorphometric measures such as bone-to-implant contact (BIC) and bone volume (BV), impacting overall stability. [13-14] This clinical study aims to evaluate and compare the effectiveness of the osseodensification technique and the rotary bone expansion technique for implant placement in low-density bone. By assessing these methods, the study seeks to determine their relative efficacy in improving implant stability and osseointegration, ultimately contributing to better outcomes for patients with low bone density.

2. MATERIALS AND METHODS

The study, conducted in the Periodontology Department at Inderprastha Dental College, involved 22 subjects aged 25-55 needing implant-supported tooth restoration. Ethical approval was obtained from the institutional review board.

Inclusion criteria: Eligible patients were 25-55 years old with healed extraction sockets, adequate bone, good oral hygiene (plaque index ≤ 1.5), and cooperative.

Exclusion criteria: Medically compromised, immunosuppressive drugs, bleeding disorders, anticoagulants, physically challenged, smokers, bruxism, parafunctional habits, pregnant, or lactating.

Pre-Surgical Procedure: Dental implant treatment commenced 2 weeks after phase I therapy, which included full mouth scaling, root planing, and maintaining good oral hygiene with a plaque index score <1 throughout the study. An orthopantomogram or Radiovisiography was taken for the proposed implant site, followed by cone beam computed tomography scans to evaluate bone density. Routine blood investigations were conducted before surgery.

Surgical Procedure: Antibiotic therapy was administered one hour before surgery and continued for 5 days postoperatively. Patients performed a pre-surgical rinse with 0.2% chlorhexidine for 60 seconds. Local anesthesia (2% Lignocaine Hydrochloride with 1 in 80,000 adrenaline bitartrate) was used to anesthetize the area. A crestal incision was made on a healed residual ridge, raising a full-thickness mucoperiosteal flap. A small round bur marked the osteotomy site, which was prepared according to the technique employed and the size of the selected implant.

Group A: Osseodensification Technique

The pilot drill established the depth and aligned the implant osteotomy site. The narrowest osseodensification bur, with the drill motor set to reverse direction (800-1500 rpm with copious irrigation), was used in a densifying counterclockwise direction. The drilling sequence followed the manufacturer's instructions. If resistance was felt, pressure and the number of bouncing-pumping motions were increased to achieve the desired depth. The implant was placed using a torque wrench, and insertional torque value was recorded. If the minimum required insertional torque was achieved, healing abutments were placed; otherwise, a cover screw was placed, allowing the implant to heal as a submerged implant. The flap was approximated using non-resorbable sutures.[11]

Group B: Rotary Bone Expansion Technique

The pilot drill established the depth and aligned the implant osteotomy site. Rotary bone expanders of incrementally increasing diameters were used to prepare the osteotomy site, operating at a slow speed with torque values between 30-45N in a clockwise direction. The drilling sequence followed the manufacturer's instructions. The implant was placed using a torque wrench, and the insertional torque value was recorded. If the minimum required insertional torque was achieved, healing abutments were placed; otherwise, a cover screw was used, allowing the implant to heal as a submerged implant. The flap was approximated using non-resorbable sutures.[13]

Post-Surgical Procedure

Primary stability was measured using a Resonance Frequency Analysis (RFA) device. An implant-specific Multipeg™ was screwed into the implant, and the instrument's tip was held close to the top of the Multipeg™ to record ISQ readings. Measurements were repeated until three consistent values were obtained.

Post-Operative Evaluation Phase

Measurements were taken immediately after implant placement and at 2, 4, 6, 8, 12, and 16 weeks. Patients were followed for 16 weeks post-surgery, during which they were advised against wearing any provisional prosthesis or applying any load to the fixtures.

3. RESULTS

The study's outcome measures included Implant Stability Quotient (ISQ) values, insertion torque (IT), and crestal bone level (CBL). Implant Stability Quotient (ISQ Values) ISQ values were recorded immediately after implant placement (Day 0) and at 2, 4, 6, 8, 12, and 16 weeks. Group A showed a mean ISQ of 78.82±3.71 at baseline, decreasing to 69±3.60 at 4 weeks, then increasing to 77.00±3.44 at 16 weeks. Group B started with a mean ISQ of 75.91±2.77, decreased to 72.82±3.74 at 4 weeks, and increased to 76.91±1.70 at 16 weeks. Intragroup comparisons showed significant changes within both groups over time. Intergroup comparisons revealed Group A had significantly higher ISQ at baseline, but subsequent intervals showed non-significant differences.

Insertion Torque (IT) IT was measured at baseline, with Group A showing a mean value of 34.55±3.50 and Group B at 35.46±4.16. The intergroup comparison showed no significant difference in IT values between the two groups.

Crestal Bone Level (CBL) For Group A, 63.6% of sites showed changes in mesial CBL and 63.6% in distal CBL from baseline to 16 weeks, with statistically significant changes on both sides. In Group B, 54.5% of sites showed mesial CBL changes and 72.7% distal CBL changes, also with statistically significant changes on both sides. Intergroup comparisons indicated non-significant differences in CBL changes on both mesial and distal sides between the two groups.

4. DISCUSSION

Dental implantology has witnessed continuous advancements, especially in addressing challenges associated with implant placement in low-density bone. Misch defined four measures of bone density (D1–D4), with low-density bone often associated with poorer bone quality (e.g., Type III or IV). Such bone types are more prone to microfractures and achieving optimal bone-implant contact is challenging, influencing the bone's ability to withstand mechanical forces during implant placement. This indicates a high risk of early failure and the need for good primary and secondary stability. Currently, primary implant stability is considered a prerequisite for osseointegration. It is a static and purely mechanical parameter, determined at the time of implant placement and associated with resistance or friction between the bone and the implant upon insertion. [15-17]

Primary stability can be affected by multiple factors, including recipient bone density, implant design, surgical technique, and operator experience. Numerous techniques have been proposed over the years to measure primary stability; currently, implant insertion torque and resonance frequency analysis (RFA) measurements are the most commonly accepted biomechanical parameters used for this purpose.[16] Resonance frequency analysis (RFA) is a method developed by Meredith et al. in 1998 [17] to determine the stability of dental implants. The stability is presented as an implant stability quotient (ISQ) value, which is dependent on the stiffness of the implant/tissue interface and the distance from the transducer to the first bone contact. RFA can detect the overall stiffness of the implant/bone complex (a summation of mechanical and biological stability at the observation time). It has been widely accepted as the standard implant stability detector used to assess the stability of the implant immediately after placement and to monitor the development of implant stability during the healing phase. This, in turn, shortens the healing phase and allows patients the benefit of earlier-loading implant restorations. Gupta *et al.* [19] noted that primary implant stability is a mechanical phenomenon related to local bone quality and quantity, implant type, surgical techniques used, and installation. The application of a simple, clinically applicable non-invasive tool to evaluate changes in implant stability and osseointegration over time is highly desirable. Therefore, the clinical applicability of RFA should be encouraged as a tool to test implant suitability for immediate loading protocols (ISQ ≥70), dictate biologic prognosis, and monitor the short- and long-term behavior of implants. Barewal *et al.* in 2003 [20] conducted a study utilizing RFA to determine the changes in stability as a reflection of early healing around single-stage, roughened-surface implants in humans. Numerous innovative techniques have been employed to enhance the primary stability of an implant. Bi-cortical fixation significantly increases implant primary stability but has a higher fracture rate due to increased stress and bending forces. Under-preparation of the osteotomy site is another technique to enhance implant insertion torque, where the diameter of the final drill is kept smaller than the implant's diameter by about 10%. However, this may result in slower woven bone formation and delayed osseointegration. In 1994, Summer [13] introduced the use of osteotomes to enhance the density of prepared osteotomy sites using specially designed condensers and expanders for low-density bone condensation. However, this technique has drawbacks, such as a limited increase in bone density primarily in the periapical area, difficulty in controlling the technique, and the potential for unintentional displacement or fracture. The traumatic condensation technique may also cause trabecular microfractures, prolonging the healing period due to bone resorption and delaying osseointegration. To address the shortcomings of previous methods, Huwais developed osseodensification in 2015. This technique involves the use of densah burs rotating counterclockwise at 800 to 1500 rpm, allowing bone preservation and condensation through compaction autografting during osteotomy preparation. This increases peri-implant bone density and mechanical stability. Millan *et al.* conducted an in vitro study comparing osseodensification (OD) to the conventional under-drilling (UD) method, particularly in low-density bones. The results indicated that OD significantly improves primary stability compared to UD, with mean insertion torque for OD implants at 21.72±17.14 Ncm versus 8.87±6.17 Ncm for UD implants, and mean RFA for OD implants at 69.75±6.79 ISQ versus 65.16±7.45 ISQ for UD implants. The study concludes that OD enhances primary stability in low-density bones, highlighting its potential advantages over the conventional UD method.[21] This study involved 22 patients with at least one missing tooth, who were otherwise healthy. The patients were randomly assigned to Group A (osseodensification technique) and Group B (rotary bone expansion technique) to enhance implant stability and success in low-density bone environments by evaluating implant stability quotient (ISQ), insertional torque, and crestal bone levels.

ISQ Values in Group A, the mean ISQ values at baseline, 2 weeks, 4 weeks, 6 weeks, 8 weeks, 12 weeks, and 16 weeks were 78.82±3.71, 71±4.65, 69.82±3.60, 72.91±2.17, 74.18±3.06, 76.46±3.17, and 77±3.44, respectively. High ISQ values at baseline were due to the densification of bone by densah burs, increasing peri-implant bone density and mechanical stability. A dip in ISQ at 4 weeks was observed due to remodeling of the osteotomy site, followed by an increase in ISQ until 16 weeks, reflecting the transition from primary to secondary stability.

In Group B, the mean ISQ values at the same intervals were 75.91±2.77, 73±2.23, 72.82±3.74, 73.64±2.69, 75.46±2.66, 75.91±2.07, and 76.91±1.70, respectively, showing a similar pattern. Rotary bone expanders compact the bone against the osteotomy wall, creating a higher-density environment and achieving higher primary stability. The dip at 4 weeks and subsequent increase until 16 weeks was consistent with the pattern observed in Group A.

On intergroup comparison, Group A showed significantly higher ISQ values at baseline due to bone densification. At 2, 4, 6, 8, 12, and 16 weeks, the ISQ values of both groups showed no significant difference, although Group B showed higher ISQ values post-baseline due to less thermal necrosis from manual rotary bone expansion.

Insertion Torque (IT) The mean IT values for Group A and Group B were 34.55±3.50 Ncm and 35.46±4.16 Ncm, respectively, showing no significant difference. High IT values indicate good primary stability and positive correlation with initial ISQ values, supporting the survival rate of implants in low-density bone environments.

Crestal Bone Level (CBL) In Group A, mesial and distal crestal bone level changes were seen in 63.6% of sites after 16 weeks. In Group B, 54.5% of mesial sites and 72.7% of distal sites showed changes. Intergroup comparison showed no significant differences in CBL changes. Crestal bone level maintenance is essential for functional and aesthetic outcomes, with both techniques showing similar results in maintaining CBL.

5. CONCLUSION

Both techniques were well tolerated without adverse tissue reactions, infections, or impaired healing. Statistical analysis using SPSS version 26.0 showed that osseodensification and rotary bone expansion techniques had comparable outcomes in terms of ISQ, IT, and CBL, indicating both methods are effective for implant placement in low-density bone.

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