Implant Stability of Osseodensification Drilling Versus Conventional Surgical Technique: A Systematic Review

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Purpose: This systematic review aimed to appraise the available evidence on the clinical characteristics produced by osseodensification drilling compared with the conventional drilling technique. ***Materials and Methods:*** Five databases (PubMed, Google Scholar, LILACS, EMBASE, and CENTRAL) were searched up to July 2020. Randomized clinical trials (RCTs) and nonrandomized studies of interventions (NRSIs) that compared osseodensification drilling with conventional drilling in humans were included. Random-effects meta-analyses of standardized mean difference (MD) with 95% confidence intervals (CI) and risk ratio were performed. ***Results:*** Three NRSIs fulfilled the inclusion criteria, and all were scored as low risk of bias. Meta-analysis showed that the osseodensification drilling technique presented higher average implant stability quotient (ISQ) scores at baseline (MD: 13.1, 95% CI: 10.0 to 16.1, $P < .0001$) than conventional drilling, with complete homogeneity ($I^2 = 0.0\%$). Furthermore, osseodensification drilling presented higher average ISQ scores at follow-up (MD: 5.99, 95% CI: 1.3 to 10.6, $P < .0001$) than conventional drilling, with high homogeneity ($I^2 = 73.0\%$). ***Conclusion:*** This systematic review showed that osseodensification presented consistently higher ISQ at baseline and at 4 to 6 months after implant placement compared with conventional drilling. However, these results should be carefully interpreted since only three studies were selected in this meta-analysis. In the future, RCTs will be necessary to confirm the consistency of these results. *Int J Oral Maxillofac Implants 2021;36:1104–1110. doi: 10.11607/jomi.9132*

Keywords: biomechanics, bone, conventional drilling techniques, implant site preparation, meta-analysis, osseodensification, systematic review

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Oral rehabilitation of partial or complete edentulism with endosseous titanium implants is a safe and predictable treatment option associated with high success rates.[1–3] Implant stability is a critical aspect for clinical success of rehabilitation[1] and includes primary stability (mechanical engagement that is achieved upon insertion in bone, holding the implant in place) and secondary stability (biologic stability that occurs due to new bone formation during healing, resulting in osseointegration).[4,5] Successful osseointegration depends on established primary stability, described as adequate contact between the implant and bone upon instrumentation.[6] It has been shown in the literature that implant micromotion exceeding 50 to 150 μm might induce peri-implant bone resorption or implant failure.[7,8] Therefore, high degrees of primary stability are associated in the literature with superior and higher probability of osseointegration.[9] Higher implant primary stability is particularly important with immediate and early loading protocols. Ottoni et al[10] showed a 20% reduction in the osseointegration failure rate of immediately temporized single implants for every 9.8-Ncm increase in insertion torque.

Numerous techniques have been described to increase bone quantity and quality and to enhance primary stability, especially in low-density bone. These

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include underpreparation drilling protocols,[11] use of osteotomes and condensers,[12] bicortical fixation,[13] or piezoelectric devices.[14] Although providing good success rates, all these techniques have downsides. Severe undersizing of implant site preparation may induce bone necrosis, potentially impeding secondary stability or osseointegration.[6,15] Conversely, the use of osteotomes creates a layer of compacted bone at the implant interface but has several limitations associated with it, namely, surgical trauma, patient vertigo, or accidental fracture, which may delay healing compared with conventional drilling protocols.[16–18]

More recently, to address these potential limitations, an innovative technique for implant site preparation, osseodensification, has been introduced.[19] Based on a nonsubtractive multistepped drilling process through specially designed burs to rotate in the counterclockwise direction, this technique promotes bone preservation by compacting bone along the osteotomy wall and plastically expanding the bony ridge.[20–22] Thus, counterclockwise drilling is indicated for densification in low-density bone, while clockwise regular motion is used for higher-density bone.[21] Osseodensification drilling is suggested to enhance implant primary stability due to the presence of residual bone chips associated with autografting compaction,[19,21] increasing bone-to-implant contact (BIC) after implant insertion. Additionally, nucleating osteoblasts on the instrumented bone may accelerate new bone formation,[21,23] thereby potentially shortening the healing period.[19] Recently, a number of systematic reviews appraised the potential characteristics of this surgical technique,[24,25] but none was able to synthesize results on implant clinical characteristics, and therefore, such analysis would be of great interest.

This systematic review aimed to appraise the available evidence on the clinical characteristics produced by osseodensification drilling compared with conventional drilling techniques. The following focused question was addressed: "Is the implant stability different between osseodensification drilling and the conventional surgical technique?"

MATERIALS AND METHODS

Protocol and Registration

This systematic review was structured following the Cochrane Handbook of Systematic Reviews of Interventions,[26] and reported according to the PRISMA guidelines.[27]

Eligibility Criteria

To address this PICO question (patients requiring implant placement [P: patients]; osseodensification surgical technique [I: intervention]; conventional surgical technique [C: comparison]; implant stability quotient [ISQ; O: outcome]), the following inclusion criteria were applied:

- Randomized clinical trials (RCTs) and nonrandomized studies of interventions (NRSIs)
- Studies comparing osseodensification drilling with conventional drilling
- Studies reporting implant stability (ISQ) through resonance frequency analysis (RFA)
- Studies with immediate outcome and follow-up of at least 3 months after placement of the dental implant

In addition, nonintervention studies, studies not reporting osseodensification drilling, studies without a conventional (control) group, studies not reporting the conventional drilling system, and studies in patients undergoing radiation treatment of the head and neck or with systemic pathologic conditions were not considered eligible for inclusion in the review.

Information Sources and Search

To streamline the identification of potentially eligible studies for inclusion in this systematic review, PubMed via MEDLINE (Medical Literature Analysis and Retrieval System Online), Google Scholar, CENTRAL (The Cochrane Central Register of Controlled Trials), LILACS, and EMBASE were searched up to, and including, July 2020 without language restriction. Keywords and subject headings were combined in accordance with the thesaurus of each database, and exploded subject headings were applied. The search strategy was based on the algorithm developed for MEDLINE: "(Osseodensification OR densification) AND (Dental implants [MeSH] OR dental implantation [MeSH] OR osseointegration [MeSH] or bone-implant interface [MeSH] OR stability OR survival rate [MeSH] OR success rate OR marginal bone loss OR bone density OR volume)." Moreover, the reference lists of relevant articles and reviews were manually searched. Gray literature was examined through proper registers and databases.

Study Selection, Data Items, and Data Extraction Process

Study selection was independently performed by two authors (J.G., J.B.), who assessed the titles and/or abstracts of selected studies. Interexaminer reliability after full-text screening was computed (kappa statistics). Any divergences were solved through debate with a third author (V.M.). Final study selection was based on the aforementioned inclusion criteria. Additionally, data extraction was independently conducted by one author (J.G.), through a predefined table, including the author's name, publication year, study design, number of participants, outcomes, and additional notes.

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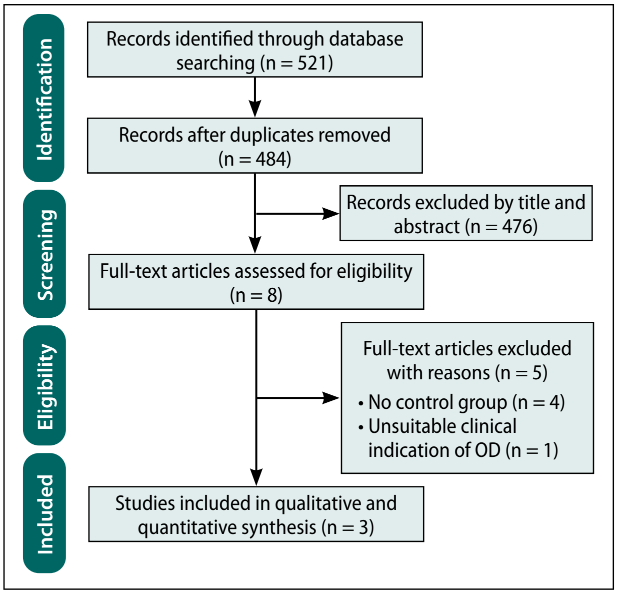

Fig 1 PRISMA flowchart representing the results of the workflow to identify eligible studies.

Risk of Bias in Individual Studies

The ROBINS-I tool (Risk of Bias in Non-randomized Studies - of Interventions) was used to appraise the risk of bias of the included NRSIs.[28] The risk of bias was appraised for each field and rated in its overall assessment as low, moderate, serious, or critical for all included studies.

Data Synthesis

Data were gathered into evidence tables. Mean values and standard deviations (SD) of ISQ measures for immediate and 4 to 6 months of follow-up after implant placement were used and evaluated with mean differences (MD) and 95% confidence intervals (CIs) using the DerSimonian-Laird random-effects model[29] in accordance with Schwarzer et al[30] in R version 3.4.1 (R Studio Team, 2018). To visualize the pooled estimates and 95% CIs, forest plots were rendered. The "meta" package was used to produce random-effects meta-analysis and forest plots.[30] The magnitude of the effect size (ES) dispersion was quantified with I^2, and the chi-square (χ^2) test appraised the homogeneity level.[26] All tests were two-tailed, with an alpha level set at .05, except for the homogeneity test, whose significance level cutoff was set at .10 due to the low power of the χ^2 test in the context of a reduced number of eligible studies. The 95% CIs were reported along with the pooled estimates.

RESULTS

Study Selection

The search method identified 521 possibly related publications. After duplicate exclusion, 484 studies were judged against the appropriateness criteria, and after title and/or abstract screening, 476 were rejected. Among the eight articles selected for full paper review, five articles were excluded, and the respective reasons for exclusion are specified in Fig 1. Thus, three NRSIs were included for qualitative analysis. Good interexaminer reliability at the full-text assessment was recorded (kappa score = 0.978, 95% CI: 0.963 to 0.992).

Study Characteristics

The three studies included comprised an overall sample of 54 patients (and 64 implants[31–33]; Table 1). These studies were derived from Asia, two from Egypt,[32,33] and one from India.[31] All implants were placed in the maxilla with the osseodensification technique and compared with conventional drilling.

In Sultana et al,[31] 20 patients were included and distributed in two groups (in group 1, 10 implants were placed using the traditional drilling technique, and in group 2, 10 implants were placed using the osseodensification drilling technique). Primary stability was measured by means of RFA (Osstell, Osstell) in both groups at baseline (immediately postoperative) and after 6 months, while crestal bone levels were measured at baseline and at 6 and 8 months postoperatively.

In Ibrahim et al,[32] 20 implants were placed in 10 patients (split-mouth design) with at least two teeth missing in the maxillary posterior region. ISQ was measured immediately and 4 months after implant placement.

In Arafat and Elbaz,[33] 24 patients requiring one to two implants in the posterior maxilla with at least 5 mm of residual bone height were included and randomly allocated into two groups. Group 1 (n = 12) received conventional osteotomy and osteotome technique to elevate the sinus membrane; group 2 (n = 12) received osseodensification for both implant site preparation and crestal sinus elevation. In both groups, simultaneous implant placement was performed. No bone graft was used in any group. ISQ was measured after implant placement (primary stability) and 6 months postoperatively (secondary stability).

Risk of Bias Within Studies

Overall risk of bias was considered low for the three included NRSIs, in terms of confounding, selection, classification, missing data, deviations from interventions, outcomes measurement, and selection of reported results (Table 2).

Synthesis of Results

Implant stability. In the present analysis, the osseodensification drilling technique presented higher average scores of baseline ISQ (MD: 13.1, 95% CI: 10.0 to 16.1, $P < .0001$) than conventional drilling, with complete homogeneity ($I^2 = 0.0\%$; Fig 2).

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Table 1 Characteristics of the Included Studies

Study	Methods	Participants	Interventions	Outcomes ISQ (mean ± SD)	Notes
Sultana et al[31] (2020)	NSRI	20	**Group I**—Conventional drilling 10 implants **Group II**—OD drilling 10 implants	**Immediate postoperative** Conventional drilling ISQ: 59 ± 17.28 OD ISQ: 65.7 ± 12.36 **6 mo** Conventional drilling ISQ: 65.8 ± 7.39 OD ISQ: 65.6 ± 5.23	India Swami Vivekanand Subharti University Funding: No
Ibrahim et al[32] (2020)	NSRI	10	**Split mouth design** **Conventional drilling (control):** 10 implants **OD drilling (test):** 10 implants	**Immediate postoperative** Conventional drilling ISQ: 59.65 ± 5.39 OD ISQ: 74.25 ± 4.95 **4 mo** Conventional drilling ISQ: 68.25 ± 5.14 OD ISQ: 76.9 ± 4.05	Egypt Alexandria University Funding: NA
Arafat and Elbaz[33] (2019)	NSRI	24	**Group 1**— Conventional drilling 12 implants **Group 2**—OD drilling 12 implants	**Immediate postoperative** Conventional drilling ISQ: 52.83 ± 6.29 OD ISQ: 65.17 ± 4.39 **6 mo** Conventional drilling ISQ: 67.83 ± 4.78 OD ISQ: 75.92 ± 2.94	Egypt MSA University Funding: NA

Table 2 Risk of Bias of Nonrandomized Studies of Interventions (NRSI)

	Domain							
	1	2	3	4	5	6	7	
Study	Confounding	Selection	Classification	Deviations from interventions	Missing data	Measurement of outcomes	Selection of reported result	τ Overall
Sultana et al[31] (2020)	Low	Low	Low	Low	Low	Low	Low	Low
Ibrahim et al[32] (2020)	Low	Low	Low	Low	Low	Low	Low	Low
Arafat et al[33] (2019)	Low	Low	Low	Low	Low	Low	Low	Low

Further, osseodensification drilling presented higher average scores of follow-up ISQ (MD: 5.99, 95% CI: 1.3 to 10.6, $P < .0001$) than conventional drilling, with high homogeneity ($I^2 = 73.0\%$; Fig 3).

DISCUSSION

Summary of Main Findings

To the best of the authors' knowledge, this systematic review is the first to investigate such clinical comparison through the means of meta-analysis; therefore, these results are novel. Overall, both individual study outcomes and pooled estimates identified that osseodensification presented consistently higher ISQ values at baseline and follow-up compared with conventional drilling.

Quality of the Evidence, Limitations, and Potential Biases in the Review Process

Overall, the quality of the evidence of this review is limited because there are some study limitations present, yet there is a large magnitude of effect that should be considered. The obtained result might be explained by the characteristics of the osseodensification counterclockwise drilling technique, where implant stability is hypothesized due to the spring-back effect,[34] and bone adaptation, which is why there is no need to undersize the osteotomy with these specially designed densifying burs.[19]

Comprehensively, the results of this systematic review point to a biologic rationale in which bone densification at the osteotomy walls along with the presence of residual bone chips results in an enhanced contact between the implant and surrounding bone. This will

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Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	MD	95% CI	Weight (%)
Sultana et al (2020)	10	65.700	12.3600	10	59.000	17.2800	6.700	[−6.468, 19.868]	5.4
Ibrahim et al (2020)	10	74.250	14.9500	10	59.650	5.3900	14.600	[10.064, 19.136]	45.2
Arafat et al (2019)	12	65.170	4.3900	12	52.830	6.2900	12.340	[8.000, 16.680]	49.4
Random effects model	32			32			13.060	[10.009, 16.110]	100.0

Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $P = .49$.

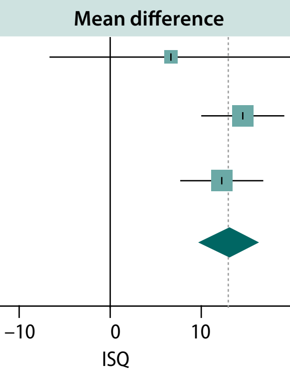

Fig 2 Meta-analysis results of baseline ISQ of osseodensification drilling versus conventional drilling.

Study	Experimental Total	Experimental Mean	Experimental SD	Control Total	Control Mean	Control SD	MD	95% CI	Weight (%)
Sultana et al (2020)	10	65.600	5.2300	10	65.800	7.3900	−0.200	[−5.811, 5.411]	27.7
Ibrahim et al (2020)	10	76.900	4.0500	10	68.250	5.1400	8.650	[4.594, 12.706]	34.2
Arafat et al (2019)	12	75.920	2.9400	12	67.830	4.7800	8.090	[4.915, 11.265]	38.1
Random effects model	32			32			5.989	[1.341, 10.637]	100.0

Heterogeneity: $I^2 = 73\%$, $\tau^2 = 12.1403$, $P = .02$.

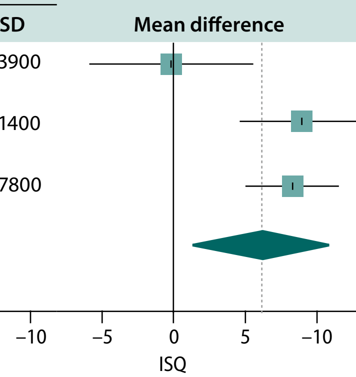

Fig 3 Meta-analysis results of follow-up ISQ of osseodensification drilling versus conventional drilling.

not only produce higher degrees of implant primary stability due to physical interlocking but also result in potentially improved and accelerated bone healing due to osteoblast nucleation on the instrumented bone.[21,23,35] In addition, osseodensification might induce alterations in the biomechanics of bone as previously described by Tretto et al.[36] In this review, the authors evaluated the influence of the instrument used for implant site preparation on the bone-implant interface. Among the tested instruments (conventional drills, osteotomes, Er:YAG LASER, piezoelectric device, and osseodensification), the osseodensification technique showed a substantial improvement in biomechanical properties in comparison to conventional drilling, with favorable and encouraging outcomes.

Preclinical studies in sheep have demonstrated the biologic potential of osseodensification. In one study, osseodensification drilling enhanced the osseointegration of machined implants to values equivalent to surface-textured implants placed with traditional subtractive osteotomy in low-density bone.[37] In another study in the same animal model, implant site preparation with osseodensification was able to compensate the osteoconductive disadvantage from the absence of surface treatment of the machined-surfaced implants, suggesting that nontreated implant surfaces associated with osseodensification drilling may achieve comparable levels of osseointegration to surface-treated implants placed with conventional drilling methods.[38]

On the other hand, a study in a murine model by Wang et al assessed the effect of condensation on peri-implant bone density and remodeling.[39] According to their results, although condensation was able to increase bone density, it caused marginal bone resorption and excessive strains rather than improvement in implant stability. The authors extrapolated their findings to the osseodensification technique. However, caution is recommended in the interpretation and extrapolation of the results since conventional osteotomes instead of osseodensification drills were used to prepare 0.5-mm-wide osteotomies in mice. The bone structure in rats and humans has significant biochemical dissimilarities, which suggests that bone research data originating from this animal model should be transferred to the clinical situation with extreme precaution.[40] In another study in a murine model, Coyac et

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al[41] reported that excessive osseodensification can lead to osseodestruction. However, the authors did not use osseodensification drills for implant site preparation. Instead, they used conventional drills to undersize the osteotomy in relation to the diameter of the implants, thereby creating a misfit between both, which led to peri-implant compression and a high insertion torque.

Human clinical studies have demonstrated favorable and predictable outcomes of osseodensification. Huwais et al,[42] in a retrospective multicenter study of 261 implants with an up-to-5-year follow-up, concluded that osseodensification represents an effective method to facilitate crestal sinus elevation, with a 97% implant survival rate in a wide range of residual bone heights. Gaspar et al[43] conducted an observational study with 97 implants to evaluate the outcome of osseodensification in four different groups: ridge expansion, crestal approach sinus elevation, immediate implant placement, and full-arch cases with immediate loading. The results were favorable for all clinical situations, namely, in terms of bone expansion capacity of osseodensification, which may be clinically significant in reducing peri-implant bone fenestrations or dehiscences.[43]

This systematic review respected a thorough protocol with up-to-date international reporting guidelines and a comprehensive literature review, and all the articles included were considered as low risk of bias. However, several shortcomings are worth mentioning. The results are derived from NRSIs, which may limit the interpretation of these conclusions. In addition, the follow-up interval was not standardized, which may explain the heterogeneity in that particular result. Even so, the results of the first meta-analysis presented complete homogeneity, though the low number of included studies may explain this optimistic result. Another limitation is the sample size included; nevertheless, this result may be key in sample size calculation for future investigations. Finally, the present study was only able to provide estimates regarding ISQ values, so in the future, it would be important to broaden to other clinical characteristics.

Agreements and Disagreements with Previous Reviews and Studies

Concerning the agreement with previous reviews, this study was the first to analyze data from exclusively human subjects. Until now, several systematic reviews have provided important insights; however, they have either analyzed only animal studies or combined data from animal preclinical and human clinical studies.[24,25,36,44] Current histologic evidence in animal studies indicates an increase in BIC and bone-area fraction with osseodensification.[25] Moreover, a significant improvement in the biomechanical properties is observed with osseodensification that shows encouraging results to be further investigated in clinical research.[36,44] However, well-designed human studies are necessary to fully determine the clinical advantages of this promising technique.[24,25,36,44,45]

CONCLUSIONS

This systematic review demonstrated that osseodensification presented consistently higher ISQ at baseline and at 4 to 6 months after implant placement compared with conventional drilling. However, these results should be cautiously interpreted since only three studies were selected in this meta-analysis. Nevertheless, within the limitations of the results of this study, the osseodensification technique for implant site preparation might be particularly useful in low-density bone and when immediate temporization is intended. It is also important to mention that none of the studies reported inferiority of clinical outcomes of osseodensification compared with conventional drilling methods.

Future studies should expand to RCT designs to evaluate the potential of this technique in maxillary sinus elevation, ridge expansion, postextraction sites, and its behavior within guided bone regeneration comparing clinical follow-ups with conventional drilling.

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