RESEARCH PAPER

Comparing the implant stability of dental implants placed using osseodensification drills and conventional drilling: a systematic review and meta-analysis

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ABSTRACT

Background: Implant site preparation affects primary stability and early osseointegration of dental implants. Conventional subtractive drilling is widely used in routine clinical practice. Osseodensification has been introduced to compact bone and improve mechanical engagement, but comparative evidence remains inconsistent.

Purpose: To compare implant stability (ISQ) and insertion torque for implants placed with osseodensification versus conventional drilling across time points and anatomical sites.

Methods: Five electronic databases were searched from inception to June 2025. Human clinical and in vitro comparative studies were eligible when they reported ISQ and/or insertion torque for osseodensification and conventional drilling. Risk of bias was assessed using validated tools for randomized and non-randomized studies. Meta-analysis was performed in Stata 17 using a random-effects model. Mean differences with 95% confidence intervals were calculated, and heterogeneity was assessed with I^2.

Results: Six studies were included. Osseodensification produced higher ISQ values than conventional drilling immediately after placement (MD +5.96; 95% CI 2.78 to 9.13) and at six months (MD +4.45; 95% CI 1.17 to 7.74). Insertion torque values were also higher with osseodensification with the largest differences reported in posterior and maxillary sites. Heterogeneity was substantial across several comparisons.

Conclusion: Osseodensification improves mechanical stability compared with conventional drilling. Further trials with standardized drilling protocols and outcome assessment are required.

Clinical implications: Osseodensification may be considered to enhance primary stability particularly in low-density bone and posterior maxillary regions.

Keywords: Dental implants, osseodensification, systematic review, dental health, osteotomy

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Introduction

Dental implants are a predictable option for replacing missing teeth, providing functional and esthetic rehabilitation with high long-term success. Their clinical performance depends on achieving and maintaining osseointegration, defined as a direct structural and functional connection between the implant surface and surrounding bone. [1] Implant stability is central to this process and is closely linked to early healing and long-term outcomes.

Implant stability has two components. Primary stability reflects mechanical engagement of the dental implants at the time of placement. Secondary stability develops through bone remodelling during healing of the implant site. Bone quality and volume, implant macrodesign and surface and the osteotomy protocol all influence primary stability and can affect subsequent stability and survival. [2]

Osteotomy preparation has received increasing attention because it alters peri-implant bone preservation, density and early mechanical retention. Conventional drilling relies on sequential rotary subtraction of bone and remains the reference approach. [3] However, it may remove excessive bone, generate heat and reduce local density, such concerns that are more pronounced in softer bone (D3/D4 in the Lekholm and Zarb classification). [4, 5] These limitations encouraged the development of bone-preserving techniques such as osseodensification.

Osseodensification was introduced by Huwais (2015) as a non-subtractive method using densifying burs in counterclockwise rotation to compact bone laterally rather than excavate it. This “compaction autografting” concept has been associated with increased bone density, greater bone-to-implant contact and improved primary stability particularly in low-density bone. [6–8] A recent systematic review reported higher insertion torque and increased new bone formation with osseodensification compared with conventional drilling. [9]

Despite these proposed advantages, comparative studies have reported variable findings. Previous invitro studies showed higher primary stability and bone-to-implant contact with osseodensification than with conventional preparation in an animal model. [8] In contrast, clinical comparisons suggested benefits may be limited to sites with poor bone quality. [10] This inconsistency may relate to differences in anatomy, bone density, implant design, and study protocols.

Implant stability is commonly assessed using resonance frequency analysis, insertion torque, Periotest values and histomorphometry in animal studies. Resonance frequency analysis with devices such as Osstell® is widely used because it is non-invasive and provides reproducible Implant Stability Quotient values. [11]

Given the heterogeneity of available evidence, a systematic review and meta-analysis comparing osseodensification with conventional drilling is warranted to clarify effects on implant stability and clinical relevance. Therefore the current review aims to synthesize current evidence and determine whether osseodensification offer any clinically significant advantages over traditional methods.

Materials and Methods

This systematic was prospectively registered in the Open Science Framework (OSF) (https://osf.io/ua2fd).

Review question (PICO)

In patients undergoing dental implant placement (P), does osteotomy preparation using osseodensification (I) when compared with conventional rotary drilling (C) improve implant stability (O)? Implant stability was assessed using resonance frequency analysis (ISQ), insertion torque values or other validated clinical measures.

Eligibility criteria

Only human studies were eligible. We included randomized controlled trials, controlled clinical trials and prospective or retrospective cohort studies that directly compared osseodensification with conventional drilling for implant osteotomy. Studies were required to report quantitative stability outcomes (ISQ, insertion torque, or equivalent standardized metrics). Adult participants receiving implants in any maxillary or mandibular region were eligible. Articles in any language were considered when a complete English translation was available.

We excluded in vitro and animal studies, case reports, conference abstracts and narrative reviews. Studies without a comparator drilling group were excluded. Studies were also excluded when quantitative implant stability outcomes were not reported or when data could not be obtained.

Search strategy

A comprehensive search was undertaken in PubMed/MEDLINE, Scopus, Web of Science, Embase and Cochrane CENTRAL from database inception to October 30, 2025. No restrictions were applied for language or publication status. Search strategies combined controlled vocabulary and free-text terms related to dental implants, osseodensification, conventional drilling and stability outcomes. The PubMed strategy was: (“Dental Implants”[Mesh] OR “Dental Implantation” OR “Implant Dentistry”) AND (“Osseodensification” OR “Densah drill” OR “Bone compaction technique”) AND (“Conventional drilling” OR “Rotary drill”) AND (“Implant Stability” OR “Resonance Frequency Analysis” OR “ISQ” OR “Insertion Torque”). Equivalent strategies were adapted for each database.

To capture gray literature, the first 200 Google Scholar results were screened. Reference lists of included studies and relevant systematic reviews were manually searched.

Study selection and data extraction

Two reviewers independently screened titles and abstracts, followed by full-text assessment of potentially eligible reports. Data were extracted independently using a prespecified form. Extracted variables included study design, sample size, participant characteristics, indication for implant placement, perioperative medications and anesthesia, implant system and dimensions, anatomical site, surgical approach and osteotomy sequence, stability outcomes and time points, marginal bone level when available, surgical time, postoperative medication, complications, follow-up duration, and restoration timing and type. Disagreements were resolved by consensus or by consultation with a third reviewer.

Risk of bias assessment

Methodological quality was assessed independently by two reviewers. Randomized trials were evaluated using the Cochrane Risk of Bias 2.0 tool, and non-randomized comparative studies were evaluated using ROBINS-I.[13,14] Domains included the randomization process, allocation concealment, blinding of participants and outcome assessors, completeness of outcome data and selective reporting. Any disagreement was resolved through discussion or adjudication by a third reviewer.

Statistical analysis

All analyses were performed using Stata 17 (StataCorp., College Station, TX). Pooling was undertaken after assessment of clinical and methodological heterogeneity. A random-effects model was applied using restricted maximum likelihood estimation. Statistical heterogeneity was quantified using the I^2 statistic, with $I^2>50\%$ indicating substantial heterogeneity, and tested using Cochran's Q ($P<.10$). Continuous outcomes were summarized as mean differences with 95% confidence intervals. Meta-analysis was conducted only when at least two studies contributed data to the same comparison. For non-normally distributed data, means and standard deviations were estimated using the method described by Hozo et al. Subgroup analyses were performed by anatomical location (maxilla vs mandible; anterior vs posterior). Publication bias was not assessed because fewer than 10 studies were available for any outcome.

Results

Study selection

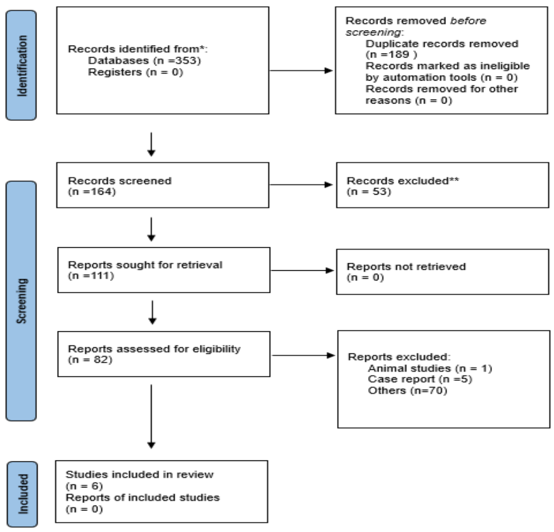
A total of 353 articles were retrieved from various databases, as detailed in **Table 1, Figure 1.** After the removal of 189 duplicate entries, 164 records were screened based on titles and abstracts. Of these, 53 records were excluded due to irrelevance or failure to meet the inclusion criteria. The remaining 111 articles were sought for full-text retrieval, all of which were successfully obtained. Subsequently, 82 full-text articles were assessed for eligibility. Among these, 70 articles were excluded—1 due to being an animal study, 5 as case reports, and 70 for other reasons such as methodological limitations or irrelevance to the review question. Ultimately, 6 studies met the inclusion criteria and were incorporated into the final systematic review.

Table 1: Search Strategy Table

Database	Search strategy	Articles
PubMed/MEDLINE	("Dental Implants" OR "Dental Implantation" OR "Implant Dentistry") AND ("Osseodensification" OR "Densah drill" OR "Bone compaction technique") AND ("Conventional drilling" OR "Rotary drill") AND ("Implant Stability" OR "Resonance Frequency Analysis" OR "ISQ" OR "Insertion Torque")	31
Scopus	TITLE-ABS-KEY("Dental Implantation" OR "Dental Implants" OR "Implant Dentistry") AND ("Osseodensification" OR "Densah Drill" OR "Bone Compaction Technique") AND ("Conventional Drilling" OR "Rotary Drill") AND ("Implant Stability" OR "Resonance Frequency Analysis" OR "ISQ" OR "Insertion Torque")	43
Web of Science	ALL=("Dental Implants" OR "Implant Dentistry" OR "Dental Implantation") AND ALL=("Osseodensifica	28

	tion" OR "Densah drill" OR "Bone compaction technique") AND ALL=("Conventional drilling" OR "Rotary drill") AND ALL=("Implant Stability" OR "ISQ" OR "Resonance Frequency Analysis" OR "Insertion Torque")	
Embase	('dental implant'/exp OR 'implant dentistry':ti,ab,kw OR 'dental implantation':ti,ab,kw) AND ('osseodensification':ti, ab,kw OR 'densah drill':ti,ab,kw OR 'bone compaction technique':ti,ab,kw) AND ('conventional drilling':ti,ab,kw OR 'rotary drill':ti,ab,kw) AND ('implant stability':ti,ab,kw OR 'resonance frequency analysis':ti,ab,kw OR 'ISQ':ti,ab,kw OR 'insertion torque':ti,ab,kw)	30
Cochrane CENTRAL	("Dental Implants" OR "Implant Dentistry" OR "Dental Implantation") AND ("Osseodensification" OR "Densah Drill" OR "Bone Compaction Technique") AND ("Conventional Drilling" OR "Rotary Drill") AND ("Implant Stability" OR "ISQ" OR "Resonance Frequency Analysis" OR "Insertion Torque")	21
Google Scholar	("Dental Implants" OR "Implant Dentistry" OR "Dental Implantation") AND ("Osseodensification" OR "Densah Drill" OR "Bone Compaction Technique") AND ("Conventional Drilling" OR "Rotary Drill") AND ("Implant Stability" OR "ISQ" OR "Resonance Frequency Analysis" OR "Insertion Torque").	200

Figure 1: PRISMA flow diagram



Characteristics of included studies

The included studies are summarized in Tables 2 and 3. The evidence base consisted of controlled clinical investigations with varied designs. One study was an in vivo comparative study. [15] The remaining studies were randomized clinical trials using either parallel-group or split-mouth allocation. [16-19] One multicenter prospective controlled clinical trial was also included. [20] Sample size ranged from 7 to 90 participants. The smallest cohort was reported by Mai Atef Hassan et al. [17] The largest cohort was reported by João Fontes Pereira et al. [16]

Most studies recruited adults receiving implants in healed edentulous ridges for prosthetic rehabilitation. [15–20] Posterior sites were most frequently treated, particularly in the posterior maxilla. [16-20] Several trials focused on low-density bone conditions (D3/D4). [15, 16-17, 20] Anjum Sultana et al.

evaluated healed anterior maxillary sites with D3/D4 bone. [15] Mello-Machado et al. assessed maxillary sites characterized as D3/D4. [18] Mai Atef Hassan et al. restricted inclusion to D4 posterior maxillary ridges. [17] João Fontes Pereira et al. included healed posterior ridges in both the maxilla and mandible. [16] Bergamo et al. placed implants in healed ridges across anterior and posterior maxillary sites and the posterior mandible. [20]

Antibiotic prophylaxis was routinely prescribed, most commonly amoxicillin or amoxicillin–clavulanate with differences in dose and duration between studies. [15-17, 20] Dexamethasone was used as an adjunct premedication in two trials. [15, 17] Local anesthetic reporting was inconsistent. Articaine 4% with 1:100,000 epinephrine was specified by João Fontes Pereira et al. [16] Lidocaine 2% with adrenaline was reported by Siddhant Aloorker et al. [19] Mepivacaine or articaine with epinephrine was reported by Bergamo et al. [20]

Implant systems varied and reporting completeness differed. [15–20] Straumann Bone Level Tapered implants with an SLA surface were used in one trial. [16] Emfils implants with defined dimensions and subcrestal placement were used in another study. [18] ADIN Touareg S implants were used by Anjum Sultana et al., although surface characteristics were not described. [15] Implant brand or dimensions were incompletely reported in two studies. [17, 19] Bergamo et al. used several implant systems with grouped dimensions and sandblasted/acid-etched surfaces. [20]

Surgical protocols were comparable. Full-thickness flaps via crestal or mid-crestal incisions were commonly used. [15–20] All studies compared conventional subtractive drilling with osseodensification. [15–20] Osseodensification was performed using Densah or Versah burs in counterclockwise rotation with a pumping motion. [15–20] Conventional arms followed sequential drilling, often using manufacturer-specific kits. [16, 18, 20] Drilling sequences were described in detail in several studies. [15, 16, 18, 20]

Implant stability was most often assessed using resonance frequency analysis (ISQ). [15–18, 20] ISQ generally increased over time in both groups, and between-group differences were usually small. [15–18] Bergamo et al. reported higher short-term ISQ with osseodensification across most implant dimensions, except short implants. [20] One study did not measure ISQ and instead evaluated radiographic density and crestal bone level changes. [19]

Marginal bone level outcomes were reported in three studies, mainly using CBCT and showed no significant intergroup differences [15, 17, 19] Postoperative regimens typically included analgesics and chlorhexidine rinses, with low complication rates and uneventful healing. [15–20] Follow-up ranged from 6 weeks to 12 months. [15–20] Restoration timing was variably described with several studies initiating prosthetic procedures at 6 months. [16, 17]

Table 2: Study characteristics

First author & year	Study design	Sample size and sample characteristics	Diagnosis or clinical indication for implant placement	Premedication/local anesthetic used	Implant characteristics (manufacturer, dimensions)	Anatomical region of implant placement	Brief surgical procedure	Specific osteotomy sequence
Anjum Sultana et al. 2020 [23]	In vivo comparative study	20 implants in 20 patients with single missing tooth in the anterior maxilla and D3/D4	Implant-supported prosthesis in healed anterior maxillary sites.	Amoxicillin-clavulanate (625 mg), paracetamol (325 mg), and dexamethasone (0.75 mg); local anesthesia protocol not explicitly stated	ADIN Touareg S spiral implants of various diameters and lengths; surfaces were not described	Anterior maxilla	Standard two-stage placement with crestal incision, full-thickness flap, and site preparation using either traditional	Group I used Alpha Bio-DFI drills (up to D3.65); Group II used Versah burs in increasing size with final countercloc

		bone; mean age and gender not specified					or osseodensification technique.	kwise osseodensification.
João Fontes Pereira et al., 2024 [27]	Randomized controlled clinical trial	90 patients (mean age 48.7 years; 55 females, 35 males)	Partially edentulous patients with healed posterior ridges requiring at least two implants for prosthetic rehabilitation.	Amoxicillin/clavulanate 875/125 mg BID for 8 days starting 48 h pre-op; local anesthesia with 4% articaine + 1:100,000 epinephrine.	Strauman n Bone Level Tapered (BLT); diameters 3.3, 4.1, 4.8 mm; lengths 8–18 mm; SLA surface (sandblasted, large grit, acid-etched).	Posterior maxilla and mandible.	Full-thickness crestal flap; implants placed using either conventional subtractive drilling or osseodensification (Versah burs).	SD group used Straumann drill kits per standard RPMs; OD group used Densah burs in counterclockwise rotation with pumping motion.
Mai Atef Hassan et al., 2021 [28]	Split-mouth randomized clinical trial	7 female patients aged 40–59 years (mean 49.5)	Bilateral posterior maxillary edentulous ridges and low-density bone (D4).	Amoxicillin 1 g and dexamethasone 4 mg 1 hour pre-op; local anesthesia (not specified)	Brand and dimensions not specified.	Posterior maxilla	Full-thickness buccal and palatal flaps with conventional or osseodensification (Densah burs) drilling	Pilot drill for both, then sequential spiral drills (control) or Densah burs in reverse mode (test).
Mello-Machado et al., 2021 [30]	Prospective double-blind randomized controlled trial	30 patients (14 in OD group, 16 in control), mean age ~50 years, 24 females and 6 males	Maxillary implant placement in low-density bone (D3/D4).	Not explicitly stated; local anesthesia assumed standard	Emfils, 3.5 mm diameter, 10–13 mm length, placed 2 mm subcrestally.	Maxilla (central incisor to second premolar)	Full-thickness flap with placement using osseodensification or standard undersized drilling under saline irrigation	OD group used Densah burs (pilot to VT2838); control group used conventional drills up to 2.8 mm.
Siddhant Aloorker	Split-mouth study	10 patients ; mean age and	Bilateral implant placement in the	Prophylactic antibiotics per Misch's protocol; local	Threaded SLA implants; brand,	Bilateral posteri	Mid-crestal incision, full-	OD group used Densah burs in

et al., 2022 [31]		gender not specified	maxillary posterior region	anesthesia with 2% lidocaine + 1:80,000 adrenaline.	diameter, and length not specified.	or maxilla	thickness flap, implant placement in both sites in one session.	counterclockwise (densifying) mode; control group used sequential extraction drilling.
T. P. Bergamo et al., 2021 [32]	Multicenter prospective controlled clinical trial	56 patients (30 females, 26 males; mean age 54.2 years)	Two implants in healed ridges (≥4 months post-extraction)	Amoxicillin 500 mg TID × 7 days starting 1 h pre-op; local anesthesia with mepivacaine or articaine + epinephrine 1:100,000	Strong SW Plus, Zimmer Biomet, IS-III Active (NeoBiotech); tapered, internal conical connection, sandblasted-acid etched; diameters: narrow (≥3 to <3.75 mm), regular, wide; lengths: short (>6 to <10 mm), regular, long (≥13 mm).	Anterior and posterior regions of maxilla and posterior mandible	Full-thickness flap; OD group used Densah burs in counterclockwise mode; SD group followed manufacturer-specific subtractive protocol; insertion torque recorded at 20–50 rpm with manual torque wrench.	OD vs SD following matched implant-specific drilling sequences.

Table 3: Data extraction

First author & year	ISQ measurements (baseline and follow-up)	Marginal bone level (MBL) evaluation (if applicable)	Surgical time	Postoperative medications prescribed	Occurrence of complications	Follow-up duration	Timing and type of implant restoration	Inference
Anjum Sultan	ISQ measured at baseline	MBL evaluated by	Total surgical	5-day antibiotic and analgesic course	No complicat	8 months	Standard prosthet	OD resulted in slightly higher ISQ

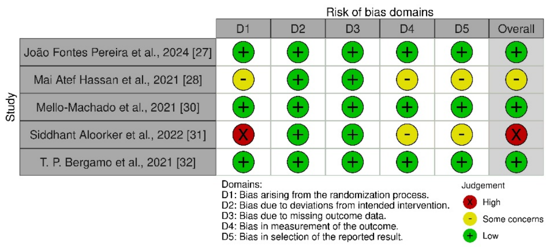
a et al. 2020 [23]	and 6 months using Osstell; OD group (65.6 → 66.0), traditional group (59.0 → 65.8); difference not statistically significant.	CBCT at baseline, 6, and 8 months; both groups showed positive gain, OD higher (36.9%) than traditional (29.8%) at 8 months; not statistically significant.	time not specified		ions were reported		ic protocol with implant-protected occlusion	and bone gain than traditional drilling but without statistical significance.
João Fontes Pereira et al., 2024 [27]	ISQ measured with Osstell IDX at baseline (T1), 6 months (T2), and 1 year (T3); all groups showed significant ISQ increases over time; no significant difference between SD and OD techniques.	Not assessed.	Not reported.	Naproxen 500 mg BID × 3 days, paracetamol 1 g TID, 0.12% chlorhexidine rinse TID × 2 weeks	None reported	1 year	Healing abutment placed at 6 months; zirconia crowns delivered post-impression.	OD is a safe technique yielding comparable primary and secondary implant stability to SD, with progressive ISQ increase in both groups.
Mai Atef Hassa	ISQ measured at baseline	Evaluated by CBCT	Not reported	Amoxicillin/clavulanate 375 mg + metronidazole	None reported	12 months	Prosthetic phase began at	Osseodensification enhanced

n et al., 2021 [28]	and 6 months; values ~60 at both time points with no significant difference between groups.	at baseline, 7, and 12 months; both groups showed MBL increase, but maintained marginal bone integrity, with no significant intergroup difference		250 mg for 3 days, anti-inflammatory for 1 week, 0.1% chlorhexidine rinse for 2 weeks.			6 months with abutment placement.	bone density and maintained marginal bone better than conventional drilling, though ISQ and MBL differences were not statistically significant.
Mello-Machado et al., 2021 [30]	ISQ measured immediately and at 6 months; both groups increased significantly (OD: 67.1 → 74.0, Control: 65.5 → 73.3), no intergroup difference.	Not evaluated	Not reported	Ibuprofen 400 mg PRN, 0.12% chlorhexidine rinse BID × 2 weeks	None	6 months	Restoration with final ceramic prostheses after provisional	OD allowed wider osteotomy and healing chamber creation in low-density bone with higher insertion torque and comparable ISQ, supporting successful implant stability
Siddhant Aloorker et al., 2022 [31]	Not measured; instead, CBCT-based radiographic bone density (HU) and crestal bone level	Measured at baseline, post-op, and 3 months; changes not statistically	Not reported	Chlorhexidine rinse TID for 2 weeks	None reported	6 months	Restoration timeline not specified	Osseodensification significantly improved radiographic bone density but did not significantly alter crestal bone level compared to

	changes were assessed.	significant between groups.						conventional drilling
T. P. Bergamo et al., 2021 [32]	Recorded at baseline, 3 and 6 weeks using Osstell Mentor; OD consistently showed higher ISQ than SD, with OD group maintaining ISQ >68 throughout	Not assessed	Not reported	Nimesulide 100 mg BID and paracetamol TID × 3 days; chlorhexidine rinse.	None reported	6 weeks	Restoration protocol not detailed	OD significantly improved insertion torque and short-term ISQ across all implant dimensions and locations except short implants, indicating enhanced primary and secondary stability without compromising healing.

Risk of bias assessment

Most randomized trials showed low overall risk of bias supporting acceptable internal validity. Low risk was common for deviations from intended interventions (D2), missing outcome data (D3) and outcome measurement (D4). Concerns were mainly related to the randomization process (D1). Mai Atef Hassan et al. did not clearly describe allocation procedures resulting in some concerns for D1. [17] Siddhant Aloorker et al. was rated high risk for D1 and raised concerns in outcome measurement and selective reporting (D4–D5) leading to an overall high risk of bias. [19] In contrast, Bergamo et al. and Mello-Machado et al. were judged low risk across all domains. [18, 20] Overall, the ROB profile suggests generally robust trial quality **(Figure 2)**



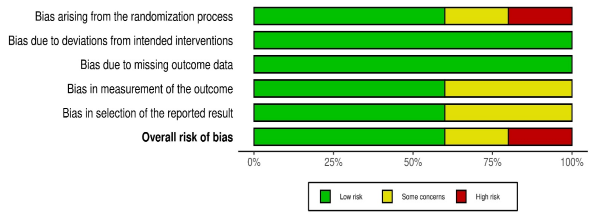


Figure 2 (a): Traffic plot –ROB 2.0 tool; (b): Traffic plot –ROBINS-I tool

The non-randomized comparative study was judged at critical risk of bias largely due to uncontrolled confounding with additional concerns in participant selection and reporting. [15]

Quantitative synthesis

The results of the meta-analyses and individual study estimates comparing implant stability between osseodensification and conventional drilling are presented in **Figure 3.** For immediate implant stability **(Figure 3A),** pooled data from five studies showed significantly higher ISQ values with osseodensification compared with conventional drilling (mean difference [MD] 8.81; 95% CI 4.40 to 13.22; P<.001). Heterogeneity was considerable (I^2=98.40%). The largest effect was reported by Bergamo et al., who observed a marked advantage for osseodensification in the posterior maxilla (MD 15.00; 95% CI 14.17 to 15.83). One study reported no meaningful difference between techniques, but the overall direction of effect consistently favoured osseodensification. The high between-study variance (τ^2=18.33) indicates substantial variability in effect size across studies, likely due to differences in bone quality, implant systems and drilling protocols.

At six months post-placement **(Figure 3B)**, no statistically significant difference in ISQ values was observed between the two techniques (MD −0.63; 95% CI −3.57 to 2.31; P=.67). Heterogeneity remained high (I^2=92.19%). Two studies reported slightly higher ISQ values with osseodensification, whereas one large trial reported lower ISQ values compared with conventional drilling. These findings suggest that although osseodensification improves primary stability, this advantage does not persist consistently over time, and both techniques appear to achieve comparable secondary stability by six months.

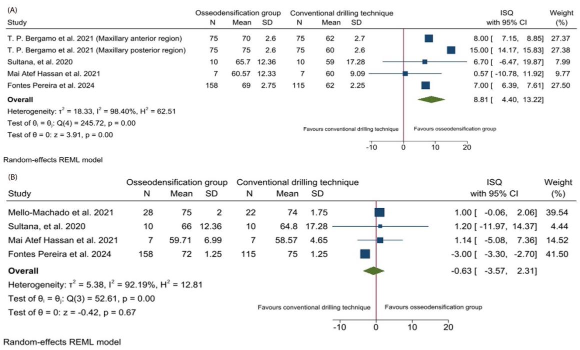


Figure 3 (a): ISQ values in osseodensification group vs conventional drilling technique (immediate) (b) ISQ values in osseodensification group vs conventional drilling technique (six months)

Subgroup analyses of immediate ISQ values, when implants were pooled irrespective of jaw location, one large study demonstrated significantly higher ISQ values with osseodensification (MD 7.00; 95% CI 6.39 to 7.61; P<.001). In the maxillary anterior region, two studies showed a significant overall pooled benefit for osseodensification (MD 7.99; 95% CI 7.15 to 8.84; P<.001). In the maxillary posterior region, one study reported a strong positive effect favouring osseodensification, whereas the pooled estimate from two studies was not statistically significant (MD 8.94; 95% CI −5.02 to 22.90; P=.21). Substantial heterogeneity was observed in this subgroup (I^2=83.81%). Despite this variability, the overall pooled estimate across all sites confirmed a significant advantage for osseodensification in relation to immediate implant stability (MD 8.81; 95% CI 4.40 to 13.22; P<.001). No significant differences between anatomical subgroups were detected (P=.17) indicating a broadly consistent early benefit across regions.

Subgroup analyses for ISQ values at six months, when both jaws were analyzed together, no significant difference was found between techniques (MD −1.03; 95% CI −4.95 to 2.89; P=.61). In the maxillary anterior region, one study showed a small, non-significant advantage for osseodensification (MD 1.20; 95% CI −11.97 to 14.37). A similar non-significant finding was observed in the maxillary posterior region (MD 1.14; 95% CI −5.08 to 7.36). Overall, there was no evidence of a sustained advantage for osseodensification at six months (MD −0.63; 95% CI −3.57 to 2.31; P=.67), and no subgroup differences were identified (P=.82).

Insertion torque outcomes are summarized in **Figure 4.** In the maxilla **(Figure 4A),** pooled data from two studies showed higher mean torque values with osseodensification, although the difference was not statistically significant (MD 9.81; 95% CI −7.66 to 27.61; P=.27). Heterogeneity was extreme (I^2=99.70%). Similar findings were observed in the mandible **(Figure 4B),** where osseodensification showed higher torque values without statistical significance (MD 18.99; 95% CI −20.21 to 58.19; P=.34; I^2=99.94%). In the anterior region **(Figure 4C),** a clinically relevant but non-significant improvement was observed (MD 9.48; 95% CI −1.30 to 20.26; P=.08). In the posterior region **(Figure 4D),** the pooled estimate again favored osseodensification numerically (MD 12.51; 95% CI −13.95 to 38.96; P=.35) with very high heterogeneity (I^2=99.95%).

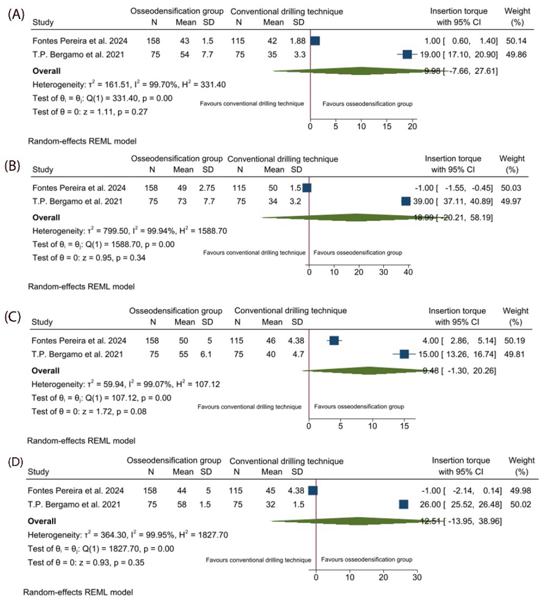


Figure 4 (a): Insertion torque osseodensification group vs conventional drilling technique (maxilla) (b) Insertion torque osseodensification group vs

conventional drilling technique (mandible) (C) Insertion torque osseodensification group vs conventional drilling technique (anterior) (d) Insertion torque osseodensification group vs conventional drilling technique (posterior)

DISCUSSION

This systematic review and meta-analysis compared implant stability and insertion torque outcomes after osseodensification (OD) versus conventional drilling (CDT). Pooled analyses showed higher primary stability with OD reflected by significantly greater ISQ values immediately after placement. Evidence for sustained superiority at later follow-up was less consistent, and clinically meaningful differences beyond early stability could not be confirmed.

The higher baseline ISQ in the OD groups indicates improved initial mechanical engagement between the implant and the osteotomy walls. The effect appeared most relevant in low-density bone particularly in the posterior maxilla, where trabecular architecture predominates and compaction may increase peri-implant density. [34] However, differences in ISQ at later time points including 6 months were often not statistically significant. High heterogeneity further limited the certainty of these findings. This pattern is consistent with the broader implant literature where early mechanical advantages do not necessarily predict superior long-term osseointegration or survival. [35–37]

Insertion torque values were numerically higher with OD across anatomical sites, but pooled comparisons did not reach statistical significance. The trial by Bergamo et al. reported markedly higher torque values. [32] In contrast, the results of Fontes Pereira et al. were more modest. [27] Differences in bone density distributions, implant macrodesign, drilling sequences and operator technique could have led to this divergence of results. These findings emphasize the need for standardized torque measurement protocols and clearer reporting of drilling parameters.

Experimental and histomorphometric studies provide mechanistic support for OD. Lahens et al. reported higher bone-to-implant contact and improved primary stability with OD in low-density bone. [43] Trisi et al. described trabecular compaction and more favorable load distribution along the implant surface which might explain higher torque and early stability reported in some clinical trials. [44] Huwais and Meyer documented increased ISQ and torque resistance in cadaver models after OD which could have led to enhanced mechanical interlocking during early healing. [45] Collectively, these studies suggest that OD preserves native bone and may improve primary stability at placement. [46] Nevertheless, conclusions on longer-term biologic performance remain limited because key outcomes such as crestal bone preservation and secondary stability were inconsistently reported in the existing trials.

High heterogeneity (often I^2>90%) was a major constraint. Variations in implant systems, OD protocols, bone quality and the timing of ISQ assessment could have contributed to the high heterogeneity observed across the included studies. Differences in RFA devices, transducer positioning and healing intervals may also have introduced measurement bias. Only a few studies reported marginal bone level changes which have limited the clinical interpretation beyond stability measurements. [23, 31]

Additional limitations included variation in surgical expertise and study design (split-mouth versus parallel arms). Surgical time and patient-reported outcomes were seldom reported which limits assessment of procedure-related burden. Despite these constraints, this review provides an updated quantitative synthesis of OD versus CDT and includes subgroup analyses by time point and anatomical site.

CONCLUSIONS

Based on the current systematic review and meta-analysis:

1. Osseodensification significantly improves immediate implant stability (ISQ) compared with conventional drilling, particularly in low-density bone, although this advantage may not persist at six months.
2. Insertion torque values were generally higher in the osseodensification group, but not statistically significant across most comparisons due to high inter-study variability.
3. There is insufficient evidence to suggest a consistent long-term clinical advantage of OD over conventional drilling, emphasizing the need for standardized protocols and longer follow-up periods in future trials.
4. Future studies should include uniform ISQ assessment intervals, radiographic bone loss metrics and patient-centered outcomes such as pain, healing time, and implant success rates.

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Figure legends:

Figure 1: PRISMA flow diagram

Figure 2 (a): Traffic plot –ROB 2.0 tool; (b): Traffic plot –ROBINS-I tool

Figure 3 (a): ISQ values in osseodensification group vs conventional drilling technique (immediate) (b) ISQ values in osseodensification group vs conventional drilling technique (six months)

Figure 4 (a): Insertion torque osseodensification group vs conventional drilling technique (maxilla) (b) Insertion torque osseodensification group vs conventional drilling technique (mandible) (C) Insertion torque osseodensification group vs conventional drilling technique (anterior) (d) Insertion torque osseodensification group vs conventional drilling technique (posterior)