

Immediate versus Delayed Loading Protocols for Narrow Diameter Implant Supported Mandibular Overdentures: A Systematic Review and Meta-Analysis

Dr. Prathiyun Umashankar¹, Dr. Parthasarathy N^{2*}, Dr. Shanmuganathan N³, Dr. Madhan Kumar S⁴, Dr. Anushka Tripathi⁵, Dr. Chathurika G⁶

¹PG Resident, Department of Prosthodontics, Sri Ramachandra Dental College and Hospital, Sri Ramachandra Institute of Higher Education and Research (SRIHER), Chennai - 600116, Tamil Nadu, India.

^{2*}Associate Professor, Department of Prosthodontics, Sri Ramachandra Dental College and Hospital, Sri Ramachandra Institute of Higher Education and Research (SRIHER), Chennai - 600116, Tamil Nadu, India.

Email: parthasarathy.n@sriramachandra.edu.in

³Professor and Head, Department of Prosthodontics, Sri Ramachandra Dental College and Hospital, Sri Ramachandra Institute of Higher Education and Research (SRIHER), Chennai - 600116, Tamil Nadu, India.

⁴Professor, Department of Prosthodontics, Sri Ramachandra Dental College and Hospital, Sri Ramachandra Institute of Higher Education and Research (SRIHER), Chennai - 600116, Tamil Nadu, India.

⁵Dr. Anushka Tripathi

⁶Dr. Chathurika G

ABSTRACT

Purpose: To compare immediate loading (IL) versus delayed loading (DL) of narrow diameter implants (NDIs) supporting mandibular overdentures focusing on implant survival, peri-implant soft tissue health, marginal bone loss and implant stability.

Materials and Methods: Five databases which included PubMed, Scopus, Embase, Web of Science and the Cochrane Library were searched. Randomized controlled trials and comparative prospective studies evaluating IL versus DL with NDIs (3.0–3.75 mm) were included. Outcomes extracted were implant survival, Periotest values, probing depth, gingival index, marginal bone loss and implant stability quotient (ISQ). Risk of bias was assessed using ROB 2.0 (RCTs) and ROBINS-I (non-randomized). A random-effects meta-analysis was performed with heterogeneity assessed using I^2 .

Results: Twelve studies were included. Meta-analysis showed no significant IL–DL differences in Periotest values, gingival index, probing depth, marginal bone loss or ISQ across follow-up periods ($p > 0.05$). Implant survival at 36 months favoured IL (MD = 4.68, 95% CI: 1.16–8.19, $p = 0.01$). Heterogeneity ranged from low ($I^2 = 0\%$) to high ($I^2 > 85\%$) and varied widely based on outcome assessed.

Conclusion: IL of NDIs supporting mandibular overdentures provides clinical outcomes comparable to DL for soft tissue health, implant stability and bone preservation. When primary stability and case selection are adequate, IL is a viable option, though early maintenance may be higher. Longer-term multicenter trials with standardized protocols are needed.

Keywords: Narrow diameter implant, immediate loading, delayed loading, mandibular overdenture, implant stability, marginal bone loss, systematic review, meta-analysis.

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Introduction

Managing edentulous mandibles remains a major challenge in prosthodontics and geriatric dentistry.

With increased ageing trends in global population, complete mandibular edentulism is increasingly prevalent particularly in underserved and medically

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compromised groups [1]. Although conventional complete dentures (CCDs) remain common, mandibular dentures often provide inadequate retention and stability due to progressive ridge resorption and limited posterior support. These limitations impair mastication and speech, reduce patient satisfaction and adversely affect oral health-related quality of life (OHRQoL) [2, 3].

Implant-supported mandibular overdentures (ISMODs) are an established option to address these shortcomings. The McGill Consensus (2002) and York Consensus (2009) recommend a two-implant overdenture as the minimum standard of care for mandibular edentulism [4, 5]. Compared with CCDs, ISMODs improve retention and stability, enhance chewing efficiency and nutrition and yield better patient-reported outcomes [6].

Narrow diameter implants (NDIs) typically 3.0–3.75 mm in diameter, are increasingly used when ridge width is insufficient or when bone grafting is undesirable or contraindicated [7, 8]. Their minimally invasive placement, reduced healing demands and lower cost are advantageous for older adults and medically compromised patients [9]. Available evidence suggests NDIs can achieve survival and marginal bone loss outcomes comparable to standard implants, although biomechanical concerns remain because of reduced surface area and potential stress concentration [10–12].

Loading protocol is a key determinant of clinical success. Immediate loading (IL) usually delivers the prosthesis within 48–72 hours, whereas delayed loading (DL) allows weeks to months for osseointegration [13, 14]. IL can reduce treatment time and accelerate functional recovery, but it requires high primary stability (commonly ≥ 35 Ncm) and strict control of micromovements which may be more challenging to achieve with NDIs [15, 16].

Evidence comparing IL and DL remains mixed. Several studies report comparable survival and peri-implant outcomes with appropriate case selection and stability thresholds [17–19], whereas others describe greater early bone loss or maintenance demands with IL under suboptimal conditions such as poor hygiene or low-density bone [20]. A Cochrane review highlighted heterogeneity and cautioned against broad generalization of IL protocols [21]. Because many prior reviews pooled standard and narrow implants, NDI-specific guidelines remains limited [22]. There the current meta-analysis aims to compare IL and DL for NDIs in mandibular

overdentures in relation to implant survival, bone loss, complications and patient satisfaction.

Materials and Methods

Protocol and registration

This systematic review and meta-analysis was conducted in accordance with PRISMA 2020 guidelines [23]. The protocol was prospectively registered on the Open Science Framework (OSF) (<https://osf.io/7w2qa/>).

Research question and PICO

The review addressed the question: Do immediate loading protocols when compared with delayed loading result in comparable implant survival and clinical outcomes for completely edentulous patients rehabilitated with mandibular overdentures supported by narrow diameter implants? The PICO framework was: (1) Population—completely edentulous patients rehabilitated with mandibular overdentures supported by narrow diameter implants (NDIs); (2) Intervention—immediate loading (prosthetic loading within 72 hours of placement); (3) Comparison—delayed loading (conventional loading beyond 1-week post-placement); (4) Outcomes—primary: implant survival and marginal bone loss (MBL); secondary: prosthetic complications and patient satisfaction.

Eligibility criteria

Eligible studies were RCTs and prospective or retrospective comparative clinical studies directly evaluating immediate versus delayed loading for mandibular overdentures supported by NDIs (3.0–3.75 mm). Studies were required to include completely edentulous patients restored with at least two mandibular NDIs and to report implant survival and/or MBL with a minimum follow-up of 6 months. Exclusions included standard- or wide-diameter implants, fixed restorations, maxillary overdentures, non-comparative designs (case series) and inaccessible full texts.

Information sources and search strategy

MEDLINE (through PubMed), Scopus, Embase, Web of Science and Cochrane CENTRAL were searched for records published up to November 2025 without language restrictions. MeSH terms and keywords included “narrow diameter implants,” “implant-supported overdentures,” “mandibular edentulism,” “immediate loading,” “delayed loading,” “early loading,” and “implant loading protocols,” combined using Boolean operators (AND/OR). Reference lists of included studies and relevant systematic reviews were also hand-searched.

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Study selection

Records were imported into EndNote (version 27) and duplicates removed. Two reviewers independently screened titles/abstracts followed by full-text eligibility assessment. Disagreements were resolved by consensus or third-reviewer adjudication.

Data extraction and risk of bias

Two reviewers independently extracted data using a standardized, pilot-tested form, capturing study design, sample and demographics, implant characteristics (number, diameter, position), insertion torque, surgical approach, loading protocol, attachment system, follow-up and outcomes (implant survival, MBL, complications, satisfaction). Authors were contacted when needed. Risk of bias was assessed independently using RoB 2 for RCTs (five domains) [24] and ROBINS-I for non-randomized studies (seven domains) [25] with disagreements resolved through discussion or third-reviewer adjudication.

Meta analysis

All analyses were performed in Stata (StataCorp., College Station, TX, version 17). Meta-analyses used a random-effects model (REML) to account for between-study variability. For continuous outcomes, mean differences (MD) with 95% confidence intervals (CI) were calculated to compare immediate versus delayed loading across Periotest values, gingival index, probing depth, marginal bone loss (MBL) and implant stability quotient (ISQ) at multiple time points. Heterogeneity was assessed using Cochran's Q test ($p < 0.10$) and quantified with I^2 (25%, 50% and 75% indicating low, moderate and high heterogeneity). Between-study variance was additionally summarized using τ^2 and H^2 . Statistical significance of pooled effects was evaluated using a z-test ($p < 0.05$).

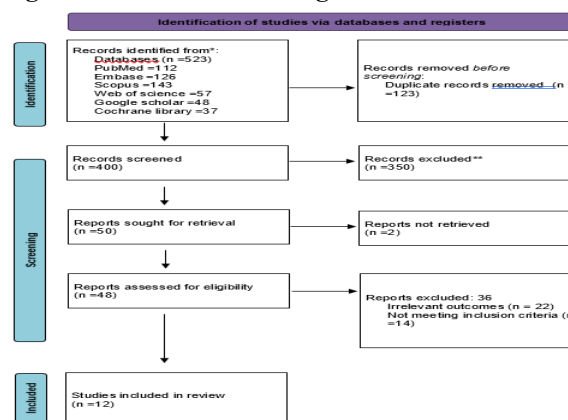
Results

Study selection

After identifying 523 records through database searches (PubMed: 112, Embase: 126, Scopus: 143, Web of Science: 57, Google Scholar: 48, Cochrane Library: 37), 123 duplicate entries were removed prior to screening. The remaining 400 records were screened based on titles and abstracts resulting in the exclusion of 350 records for not meeting relevance or inclusion criteria. Full texts of 50 records were sought of which 2 could not be retrieved. Consequently, 48 full-text articles were assessed for eligibility. Among these, 36 were excluded—22 due to irrelevant outcomes and 14 for not meeting the inclusion criteria. Finally, 12 studies

fulfilled the eligibility requirements and were included in the qualitative synthesis (systematic review) (Table 1, Figure 1).

Figure 1: PRISMA flow diagram



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

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Characteristics of included studies

Study characteristics are summarized in Tables 2 and 3. Of the 12 included studies, 9 were randomized controlled trials (RCTs) [20, 26, 27, 31-36] and 3 were non-randomized prospective clinical studies [28-30]. Participants were predominantly completely edentulous adults aged 50–85 years. Surgical techniques ranged from conventional flap elevation to minimally invasive flapless protocols. Flapless guided surgery or mucosa punch approaches were used by Fleury Curado et al. (2023), Gregory-Stephan et al. (2007), Elsyad et al. (2010, 2014), Maryod et al. (2014), Nikitas et al. (2017) and Mundt et al. (2022) mainly in the interforaminal/canine region [20, 26, 27, 30,31, 33,35]. Conventional mid-crestal flap elevation was utilised in Turkeyilmaz et al. (2007), Manesh Lahori et al. (2012),

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Reis et al. (2019) and Komagamine et al. (2018) [28,32, 34,36].

Insertion torque thresholds for loading eligibility were consistently reported most commonly ≥ 35 Ncm [20, 27, 30-36]. Fleury Curado et al. (2023) accepted ≥ 32 Ncm, while Turkyilmaz et al. (2007, 2010) required ≥ 45 Ncm [26, 28, 29]. Delayed loading typically followed 3 months of healing [20, 28-34, 36], whereas Fleury Curado et al. (2023) loaded at 6 weeks and Mundt et al. (2022) at 12 weeks [26, 35]. Gregory-Stephan et al. (2007) used immediate loading for test implants and 3-month delayed loading for controls [27].

All studies used narrow diameter implants (2.9–3.75 mm) from multiple systems (Ankylos, Straumann, BioHorizons, Brånemark TiUnite) with lengths typically 10–15 mm [26-28]. Immediate overdentures were delivered within 72 hours to 1 week [26, 27], while delayed delivery occurred after 6–12 weeks or 3 months [35, 30, 36]. Follow-up ranged from 6–36 months [20,26, 28-30, 33, 35].

Survival was 100% in most studies [20, 26-34, 36] with slightly lower rates in Mundt et al. (2022) [35]. MBL was comparable between protocols (Fleury Curado et al., 2023; Gregory-Stephan et al., 2007) [26, 27] with the lowest MBL in Komagamine et al. (2018) [36]. Radiographic assessment commonly used standardized periapical/digital methods [27-29, 36]. Overall, immediate loading appears predictable when adequate primary stability is achieved [26, 33].

Risk of bias (ROB) assessment

Using the Cochrane ROB 2.0 tool, RCTs were assessed across five domains. Most trials showed low risk in D2 (deviations from intended intervention), D3 (missing outcome data) and D4 (measurement of outcomes). Fleury Curado et al. (2023), M.A. Elsyad et al. (2014), Rita Reis et al. (2019), Torsten Mundt et al. (2022) and Yuriko Komagamine et al. (2018) had low risk across all domains and overall [26, 31, 34-36]. Gregory-Stephan et al. (2007), Manesh Lahori et al. (2012), Maryod WH et al. (2014) and Nikolaos Nikitas et al. (2017) showed some concerns in D1 (randomization) [20, 27, 32, 33] with additional concerns in D5 (selective reporting) for Gregory-Stephan et al. (2007), Maryod WH et al. (2014) and Nikolaos Nikitas et al. (2017) [20, 27,33]. No RCT was judged high risk (Figure 2a, b).

Using ROBINS-I, non-randomized studies showed greater bias. Turkyilmaz et al. (2007, 2010) had critical ROB due to confounding (D1) and moderate risks

in D2, D6, and D7 [28,29]. Elsyad et al. (2010) was overall moderate risk [30] (Figure 3a, b).

Meta analysis

Forest plots comparing immediate and delayed implant loading demonstrated largely comparable clinical outcomes. Periotest values at 12 months showed no significant difference between protocols (MD = -0.36, 95% CI: -1.81 to 1.09, $p = 0.63$) despite high heterogeneity ($I^2 = 85.90\%$) (Elsyad et al., 2010; Lahori et al., 2012) [30, 32]. Gingival index scores at 6 and 12 months were also non-significant (MD = 0.08 and 0.04; $p > 0.05$) with no heterogeneity ($I^2 = 0\%$) (Turkyilmaz et al., 2010; Elsyad et al., 2014) [29, 31] indicating similar peri-implant soft tissue health (Figure 4). Survival rate comparisons at 6, 12, 24 and 36 months favoured immediate loading across all intervals reaching statistical significance only at 36 months (MD = 4.68, 95% CI: 1.16 to 8.19, $p = 0.009$). Moderate heterogeneity was observed at 6 and 12 months, while analyses pertaining to later time periods showed none (Maryod et al., 2014; Mundt et al., 2022) [20, 35] (Figure 5). Probing depth assessments at insertion and at 6, 12 and 24 months revealed no significant differences ($p > 0.05$), though heterogeneity was high at early intervals (Gregory-Stephan et al., 2007; Turkyilmaz et al., 2010; Elsyad et al., 2014; Maryod et al., 2014) [20, 27, 29, 31]. At 36 months, a non-significant trend favoured immediate loading (MD = 0.31, $p = 0.23$) (Figure 6). Marginal bone loss showed no significant differences at any time point ($p > 0.05$) with pooled mean differences of 0.08–0.57 mm and heterogeneity limited to 6 months (Figure 7). Implant stability (ISQ) values were comparable at insertion and during follow-up with no statistically significant differences across time points despite occasional heterogeneity (Figures 8, 9).

Table 1: Search Strategy

| Database | Search Strategy | Articles |
|----------|---|----------|
| PubMed | ("narrow diameter implant" OR "narrow implant" OR "mini implant") AND ("overdenture" OR "implant-supported denture") AND ("immediate loading" OR "early loading" OR "delayed loading" OR "conventional loading") AND (mandible OR mandibular) | 112 |

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|------------------|--|-----|
| Embase | ('narrow diameter implant':ti,ab,kw OR 'mini implant':ti,ab,kw) AND ('overdenture':ti,ab,kw OR 'implant supported denture':ti,ab,kw) AND ('immediate loading':ti,ab,kw OR 'delayed loading':ti,ab,kw) AND (mandible:ti,ab,kw OR mandibular:ti,ab,kw) | 126 |
| Scopus | TITLE-ABS-KEY ("narrow diameter implant" OR "mini implant") AND TITLE-ABS-KEY ("overdenture" OR "implant supported denture") AND TITLE-ABS-KEY ("immediate loading" OR "delayed loading") AND TITLE-ABS-KEY (mandible OR mandibular) | 143 |
| Web of Science | TS=("narrow diameter implant" OR "mini implant") AND TS=("overdenture" OR "implant supported denture") AND TS=("immediate loading" OR "early loading" OR "delayed loading") AND TS=(mandible OR mandibular) | 57 |
| Google Scholar | ("narrow diameter implant" AND "overdenture" AND ("immediate loading" OR "delayed loading") AND mandibular) | 48 |
| Cochrane Library | ("narrow diameter implant" OR "mini implant") AND ("implant-supported overdenture") AND ("immediate loading" OR "delayed loading") | 37 |

Table 2: Study characteristics

| First author | Study design | Sample size | Sample characteristics | Intervention | Implant position | Surgical technique | Loading time of case |
|--------------|--------------|-------------|------------------------|--------------|------------------|--------------------|----------------------|
|--------------|--------------|-------------|------------------------|--------------|------------------|--------------------|----------------------|

| & year | | | | e value | | | group |
|-------------------------------------|--|--|--|---|--|--|--|
| Fleury Curado et al., 2023 [26] | Randomized controlled clinical trial | 296 implants placed in 74 patients | Adults aged 50–85 years with completely edentulous mandible | Minimum 32 mm was required for immediate loading. | Interforaminal region of the mandible. | Flapless guided surgery with stereolithographic surgical guide. | After 6 weeks |
| Gregory - Stephan et al., 2007 [27] | Prospective randomized controlled clinical trial | 26 patients - Experimental group (N=17); Control group (N=9) | Adults with edentulous mandible and functional maxillary dentures for at least 6 | Minimum 35 mm for immediate loading group; | Mandibular interforaminal region | Flapless (punch) technique using mucosal-supported stereolithographic surgical guide | Conventional loading performed after 3 months of healing |

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| | | | months. | not specified for delayed group | | | |
| I. Turkyilmaz et al., 2007 ^[28] | Prospective clinical study | 40 implants placed in 20 edentulous patients | Completely edentulous mandible with adequate bone volume and healthy systemic condition | Mini mum 45 Ncm for inclusion in both groups | Mandibular canine regions | Conventional two-stage surgery with mid-crestal incision and flap reflection | Loading after 3 months of healing period |
| I. Turkyilmaz et al., 2010 ^[29] | Prospective clinical study | 26 edentulous patients | Healthy, non-smoking patients with edentulous mandible and adequate bone | Mini mum 45 Ncm for implant placement | Mandibular canine regions | Flapless surgical technique with mucosa punch | Definitive prosthesis delivered after 3 months of healing |

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|--|--------------------------------------|--|--|--|---------------------------|--|---|
| | | | volume | | | | |
| M.A. Elsyad et al., 2010 ^[30] | Prospective clinical study | 36 completely edentulous patients (18 per group) | Healthy males aged 50–70 years with edentulous mandible and adequate bone volume | Mini mum insertion torque of 35 Ncm was required | Mandibular canine regions | Flapless approach using tissue punch technique | Overdenture inserted after 3 months of healing. |
| M.A. Elsyad et al., 2014 ^[31] | Randomized controlled clinical trial | 36 completely edentulous patients (18 per group) | Healthy males aged 50–70 years with edentulous mandible and sufficient bone volume | Mini mum insertion torque of 35 Ncm was required | Mandibular canine regions | Flapless surgical procedure using tissue punch | Overdenture delivered after 3 months of healing |

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|--|--|---|---|--|----------------------------------|--|--|
| Manesh Lahori et al., 2012 ^[32] | Prospective randomized clinical study | 20 implants placed in 10 edentulous patients | Healthy patients with edentulous mandible and adequate bone volume | Mini-implants on torque of 35 Ncm was required | Mandibular interforaminal region | Conventional flap elevation technique with mid-crestal incision. | Loading performed after 3 months of healing |
| Mar yod WH et al., 2014 ^[20] | Prospective randomized controlled clinical trial | 36 completely edentulous male patients (18 per group) | Healthy male patients aged 52–70 years with edentulous mandible and sufficient bone | Mini-implants on torque of 35 Ncm was required | Mandibular canine regions | Flapless surgical technique using tissue punch | Overdenture delivered 3 months after implant placement |
| Nikolas Nikitas et al., 2017 ^[33] | Prospective randomized clinical trial | 25 patients | Healthy patients with edentulous mandible and sufficient | Mini-implants on torque of 35 | Mandibular interforaminal region | Flapless surgical technique using mucosa punch | Definitive prosthesis delivered after 3 |

| | | | | | | | |
|---|--|---------------------------------------|--|--|----------------------------------|--|--|
| | | | cient bone volume for implant placement | Ncm was required | | | months of healing |
| Rita Reis et al., 2019 ^[34] | Prospective randomized controlled clinical trial | 24 edentulous patients (12 per group) | Healthy edentulous adults with sufficient bone volume in the anterior mandible | Mini-implants on torque of 35 Ncm was required | Mandibular interforaminal region | Conventional flap elevation with mid-crestal incision | Prostheses delivered after 3 months of healing |
| Tors ten Mundt et al., 2022 ^[35] | Multicenter prospective randomized controlled clinical trial | 76 edentulous patients (38 per group) | Completely edentulous adults with stable maxillary dentures and sufficient mandibula | Mini-implants on torque of 35 Ncm was required | Mandibular canine regions | Flapless surgical procedure using mucosa punch technique | Conventional loading performed after 12 weeks |

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|-----------------------------------|---|----------------------------------|--------------------------|------------------------|--|--|---|
| Gregory-Stephan et al., 2007 [27] | Replace Select Tapered TiUnite (Nobel Biocare, Sweden) | 3.5 mm diameter and 13 mm length | Two implants per patient | 1 year post-loading | Mean bone loss at 12 months (IL: 0.47 ± 0.33 mm, DL: 0.44 ± 0.31 mm, p > 0.05), implant survival 100% in both groups | Standardized digital periapical radiographs and clinical evaluation | Both Immediate and delayed loading showed similar success and minimal bone loss supporting the viability of both approaches |
| I. Turkylmaz et al., 2007 [28] | Replace Select Tapered TiUnite implants (Nobel Biocare) | 3.5 mm diameter and 13 mm length | Two implants per patient | 12 months post-loading | Marginal bone loss at 12 months (IL: 0.41 ± 0.16 mm, DL: 0.52 ± 0.24 mm), implant survival 100% in both groups | Standardized intraoral digital periapical radiographs with parallel | Both immediate and delayed loading protocols resulted in comparable |
| I. Turkylmaz et al., 2010 [29] | Nobel Biocare Replace Select Tapered TiUnite implants | 3.5 mm diameter and 13 mm length | Two implants per patient | 24 months post-loading | Marginal bone loss at 24 months (IL: 0.66 ± 0.37 mm, DL: 0.73 ± 0.46 mm), implant survival 100% in both groups | Standardized periapical radiographs with long-cone paralleling technique | Both immediate and delayed loading achieved excellent clinical success and minimal bone loss over 2 years |

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|--|--|----------------------------------|---------------------------|------------------------|---|--|---|
| M.A. Elsyah et al., 2010 ^[30] | Mini dental implants (Medical Dental Engineering, Germany) | 2.4 mm diameter and 13 mm length | Four implants per patient | 12 months post-loading | Marginal bone loss (IL: 0.56 ± 0.07 mm, DL: 0.64 ± 0.06 mm), implant survival 100%, no significant difference in probing depth or plaque and bleeding indices | Standardized peripheral radiographs, clinical evaluation, and digital caliper measurement. | Immediate and delayed loading of mini implants resulted in comparable bone loss and excellent clinical outcomes at 1-year follow-up |
|--|--|----------------------------------|---------------------------|------------------------|---|--|---|

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|--|--|----------------------------------|---------------------------|------------------------|--|---|---|
| M.A. Elsyah et al., 2014 ^[31] | Mini implants (MD E Medical Dental Engineering, Germany) | 2.4 mm diameter and 13 mm length | Four implants per patient | 12 months post-loading | Marginal bone loss at 12 months (IL: 0.57 ± 0.06 mm, DL: 0.64 ± 0.07 mm), peri-implant plaque index and bleeding index similar between groups, implant survival 100% | Standardized peripheral radiographs, clinical indices, and digital caliper measurements | Immediate and delayed loading of mini implants showed comparable peri-implant tissue health and bone preservation over 1 year |
|--|--|----------------------------------|---------------------------|------------------------|--|---|---|

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|---------------------------------------|---|-------------------------------------|---------------------------|------------------------|---|---|---|--|---------------------------|---|
| Manesh Lahori et al., 2012 [32] | Adin Touareg™ -S implants (Adin Dental Implant Systems, Israel) | 3.75 mm diameter and 11.5 mm length | Two implants per patient | 12 months post-loading | Mean marginal bone loss at 12 months (IL: 0.67 ± 0.13 mm, DL: 0.81 ± 0.12 mm), implant survival 100% in both groups | Standardized periapical radiographs with paralleling technique and clinical evaluation. | Immediate and delayed loading both showed high success rates, with slightly less bone loss in immediate loading group | 0.06 mm, DL: 0.69 ± 0.05 mm), implant survival 100% in both groups | ents and clinical indices | comparable peri-implant bone preservation and clinical success after 1 year |
| Nikolaos Nikitareas et al., 2017 [33] | Implant Direct Legacy 2 (Implant Direct Sybron, USA) | 3.7 mm diameter and 10 mm length | Two implants per patient | 12 months post-loading | Marginal bone loss at 12 months (IL: 0.43 ± 0.27 mm, DL: 0.45 ± 0.23 mm), implant survival 100% in both groups | Standardized periapical radiographs and clinical parameters | Immediate and delayed loading protocols both achieved excellent implant survival and comparable peri-implant bone preservation at | | | |
| Maryod WH et al., 2014 [20] | MDI mini implants (Medical Dental Engineering, Germany) | 2.4 mm diameter and 13 mm length | Four implants per patient | 12 months post-loading | Mean marginal bone loss at 12 months (IL: 0.60 ± | Standardized periapical radiographs with digital caliper measurement | Immediate and delayed loading of mini implants resulted in com | | | |

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|--|---|-----------------------------------|--------------------------|------------------------|--|--|---|
| | | | | | | | 1 year |
| Rita Reis et al., 2019 ^[34] | VEGA® implants (Klockner Implant System, Spain) | 3.5 mm diameter and 10 mm length | Two implants per patient | 1 year post-loading | Mean bone loss at 12 months (IL: 0.32 ± 0.24 mm, DL: 0.34 ± 0.29 mm), implant survival 100% in both groups | Standardized periapical radiographs and clinical evaluation | Immediate and delayed loading protocols showed comparable clinical and radiographic success with minimal marginal bone loss |
| Torsten Mundt et al., 2022 ^[35] | ICX Active Master implants (medentis medical GmbH, Germany) | 3.75 mm diameter and 10 mm length | Two implants per patient | 12 months post-loading | Marginal bone loss at 12 months (IL: 0.52 ± 0.46 mm, DL: 0.51 ± 0.47 mm), implant survival 99.4% (IL) and 98.7% (DL) | Standardized periapical radiographs with software-based measurement and clinical examination | Immediate and delayed loading protocols both provided high implant survival and similar marginal bone preservation after 1 year |
| Yuriko Komagamine et al., 2018 ^[36] | Nobel Replacet Select TiUnit implants (Nobel Biocare,) | 3.5 mm diameter and 10 mm length | Two implants per patient | 12 months post-loading | Mean marginal bone loss at 12 months (IL: 0.19 | Standardized periapical radiographs and clinical evaluations | Both immediate and delayed loading protocols achieved excel |

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|--|---------|--|--|--|--|--|
| | Sweden) | | | | ± 0.24 mm, DL: 0.33 ± 0.40 mm) , implant survival 100 % in both groups | lent implant survival with minimal and comparable bone loss over 1 year |
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Discussion

Rehabilitation of completely edentulous mandibles using narrow diameter implants (NDIs) is increasingly accepted in geriatric and medically compromised patients because it is minimally invasive, cost-effective and often avoids grafting [37]. This systematic review and meta-analysis evaluated NDIs (2.4–3.75 mm) supporting mandibular overdentures and compared immediate loading (IL) with delayed loading (DL). Across 12 studies with 6–36 months of follow-up, implant survival was consistently high for both protocols commonly exceeding 98%. Fleury Curado et al. (2023) reported no failures in the assessed groups at 12 months in a large RCT (296 implants) with low marginal bone loss (MBL) (0.38 mm IL; 0.43 mm DL) indicating stable peri-implant conditions [26]. Other trials similarly reported 100% survival for IL and DL supporting the predictability of IL when clinical prerequisites are met (Gregory-Stephan et al., 2007; Turkyilmaz et al., 2007, 2010; Komagamine et al., 2018) [27-29, 36].

Primary stability emerged as a consistent requirement for IL. Most studies used insertion torque ≥ 35 Ncm as an eligibility threshold (Maryod et al., 2014; Elsyad et al., 2010, 2014; Lahori et al., 2012; Reis et al., 2019) [20, 30, 32, 34], while Turkyilmaz et al. (2007, 2010) required ≥ 45 Ncm with stable 12–24 month outcomes [28, 29]. In keeping with biomechanical principles, controlling micromovements appears particularly critical for reduced-diameter implants.

Pooled analyses from the current review showed no significant differences between IL and DL in MBL at 6, 12, 24 or 36 months (mean differences 0.08–0.57 mm) indicating that IL does not compromise crestal bone preservation under appropriate conditions. Komagamine et al. (2018) reported especially low MBL (0.19 ± 0.24 mm IL vs. 0.33 ± 0.40 mm DL) suggesting favourable bone maintenance in well-controlled IL protocols [36]. Studies using mini-implants (2.4 mm) also reported no adverse bone outcomes with IL (Elsyad et al., 2010, 2014; Maryod et al., 2014) [20, 30, 31].

Soft tissue outcomes including Periotest values, gingival index and probing depth were broadly comparable between IL and DL across studies (Elsyad et al., 2010; Lahori et al., 2012; Turkyilmaz et al., 2010; Elsyad et al., 2014; Gregory-Stephan et al., 2007; Maryod et al., 2014) [20, 27, 29-32]. Transient early inflammation or remodelling observed in some IL cohorts (Maryod et al., 2014) was not clinically meaningful by 12 months [20]. Resonance frequency analysis showed similar implant stability quotient (ISQ) trajectories between protocols with any baseline IL advantages generally small and not statistically sustained (Gregory-Stephan et al., 2007; Turkyilmaz et al., 2010; Elsyad et al., 2014; Mundt et al., 2022) [27, 29, 31, 35].

Patient-centered outcomes often favoured IL with earlier functional improvement, higher satisfaction and better OHRQoL (Fleury Curado et al., 2023; Elsyad et al., 2010) [26, 30]. Some studies reported slightly higher prosthetic maintenance in IL groups such as attachment wear/loosening emphasizing the need for structured follow-up (Elsyad et al., 2014; Maryod et al., 2014) [20, 31]. IL protocols frequently used flapless or mucosa-punch approaches potentially improving comfort and preserving vascularity [38]. While biomechanical concerns for NDIs persist, resilient attachments and optimized occlusion likely reduce risk (Reis et al., 2019; Mundt et al., 2022) [34, 35, 39]. Caution is warranted in poorer bone quality or low compliance, where early remodelling or complications may be more likely (Maryod et al., 2014; Nikitas et al., 2017) [20, 33].

Overall, IL of NDIs for mandibular overdentures appears clinically predictable when primary stability, precise technique and appropriate patient selection are ensured, thereby offering shorter treatment time and earlier functional benefit than DL.

Strengths: This review provides a focused analysis specifically on narrow diameter implants (NDIs),

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minimizing confounding from pooled outcomes that include standard-diameter implants. The inclusion of both randomized controlled trials and prospective clinical studies strengthens the evidence base by combining higher internal validity with greater clinical generalizability. In addition, the meta-analysis of key clinical outcomes adds quantitative rigor and supports more defensible comparisons across immediate and delayed loading protocols.

Limitations: Interpretation of pooled findings is limited by moderate-to-high heterogeneity in certain outcomes, likely reflecting variability in implant systems, surgical techniques, attachment designs and follow-up schedules. Reporting of secondary outcomes such as prosthetic maintenance, patient-reported outcome measures (PROMs) and cost-effectiveness was inconsistent restricting more comprehensive synthesis. Moreover, most studies enrolled predominantly systemically healthy participants limiting applicability to medically compromised populations. Follow-up durations were also generally short (commonly 12–24 months) constraining assessment of long-term complications and maintenance demands.

Future scope: Future research should prioritize long-term (≥ 5 years), multicenter randomized controlled trials to clarify comparative stability, complication rates and maintenance profiles of immediate versus delayed loading in NDIs. Standardization of critical variables including insertion torque thresholds, attachment systems and radiographic assessment protocols is needed to reduce heterogeneity and improve comparability across trials. Broader inclusion criteria should be adopted to incorporate patients with systemic disease, smokers and individuals with compromised bone quality to enhance external validity. Finally, routine integration of PROMs, prosthetic maintenance frequency and economic evaluations would support more patient-centered and cost-informed clinical decision-making.

Conclusion

This systematic review and meta-analysis supports the use of immediate loading protocols for narrow diameter implants supporting mandibular overdentures when clinical prerequisites such as adequate primary stability and appropriate case selection are met. Across most clinical parameters including implant survival, marginal bone loss, soft tissue indices and implant stability, immediate loading showed comparable outcomes to delayed loading protocols with

a slight advantage in survival at 36 months. However, variability in methodology and follow-up duration across studies necessitates a cautious, individualized approach. Until more robust and standardized long-term evidence is available, clinicians should consider patient-specific risk factors, bone quality, systemic health and prosthetic requirements when choosing the appropriate loading strategy.

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