Evidence-Based Clinical Outcomes of Immediate and Early Loading of Short Endosseous Dental Implants: A Meta-analysis

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Purpose: Short dental implants serve as a valuable alternative for patients with limited bone height. Immediate or early provisionalization facilitates a more physiologic environment for the gingival tissues to be modeled. The purpose of this meta-analysis was to systematically review and evaluate the implant survival and marginal bone loss with immediate and early loading protocols of short dental implants (≤ 6 mm). ***Materials and Methods:*** A literature search (electronic and manual) was conducted to identify studies with a focused PICO question: "In patients with short dental implants, does loading time affect treatment outcomes?" Studies using an immediate or early loading protocol for restoration of short implants with a mean follow-up of at least 1 year, and refraining from the use of advanced surgical procedures (sinus floor elevation, bone augmentation), were included. After evaluating patient selection and outcome reporting biases, a meta-analysis was conducted to assess implant survival and bone loss for studies fulfilling the inclusion criteria. Bone loss differences between immediate and early loading protocols were evaluated by Student *t* test, and Spearman correlation analysis was used to analyze the trends between crown-to-implant (C/I) ratio and bone loss. ***Results:*** A total of 396 studies with patients receiving short implants (≤ 6 mm) with immediate or early prosthetic loading protocols were identified. For the 7 included studies, the pooled implant survival rate for 322 implants with a follow-up ranging from 1 to 10 years (5 years) was 91.63% (95% CI: 88% to 94%), with a mean bone loss effect estimate of 0.52 ± 0.1 mm ($z = 3.07$, $P < .002$). The differences observed in the mean bone loss for studies using immediate loading as opposed to early loading were not statistically significant. A moderate but significant positive correlation was observed between the C/I ratio and mean bone loss levels ($r = 0.67$, $P = .02$). ***Conclusion:*** Short implants with immediate or early loading protocols have satisfactory long-term treatment prospects with satisfactory implant survival rates and minimal bone loss. *Int J Oral Maxillofac Implants 2021;36:59–67. doi: 10.11607/jomi.8541*

Keywords: bone loss, dental implants, humans, short, success, survival

Tooth extraction accompanies a series of bone remodeling changes that engender attenuation of the buccolingual and apicocoronal bone tissue leading to alveolar ridge resorption.[1] Short endosseous implants have emerged as a minimally invasive alternative to complex corrective/regeneration surgeries for volumetric discrepancies of the alveolar bone.[2] Additional limiting factors such as proximity of the inferior alveolar nerve, pneumatization of the maxillary sinus, etc, impair direct rehabilitation via standard-length implants. Further, complex procedures such as bone augmentation, ridge expansion, and maxillary sinus floor elevation are often associated with increased cost and treatment times as well as higher risk of failure.[3]

Osseointegration at the bone-implant interface is collectively dependent on the cellular events occurring in response to the enhanced genetic expression of several factors involved in the healing phases following implant placement, eg, increased osteogenesis and fibrin remodeling owing to the increased expression of osteocalcin, osteoprotegerin, and transforming growth factor β.[4] Unfavorable bone topography and quality could greatly impact the peri-implant cell surface interaction, thereby affecting osseointegration and ultimately implant success. Immediate and early loading of dental implants could counteract the postextraction alveolar ridge bone catabolism.[5]

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Table 1 PICO Model and MeSH Terms Used for Electronic Search

Patient/ Population		Intervention/Comparison		Outcome
Clinical studies in which patients were missing one or more natural teeth, to receive at least one cylindrical short dental implant (≤ 6 mm) without bone augmentation	AND	Short dental implant (≤ 6 mm) with immediate (within 48 hours of implant placement) or early loading (no later than 3 months post–implant placement), with a mean follow-up of at least 1 year after prosthetic loading Comparison (whenever reported): traditionally loaded implants (or short implants with delayed loading)	AND	Implant survival and success; marginal bone loss (included: dental prosthesis failure, complications, radiographic bone loss, primary stability, and crown-to-implant ratio)

MeSH terms:
(1) Dental implants (MeSH term) AND short dental implant AND immediate dental implant loading (MeSH term) (178 articles)
(2) Dental implants (MeSH term) AND short dental implant AND early dental implant loading (218 articles)

The preliminary placement theories emphasized unperturbed healing intervals following implant placement.[6] Lately, there has been emerging evidence on the efficacious clinical outcomes of immediate and early loading protocols.[7] They can offer several advantages over delayed loading that accompany conserved bone and gingival architecture, such as improved treatment efficacy by accelerated bone remodeling, minimization of immoderate transmucosal loading, and the need for a provisional prosthesis.[7] Several studies have documented favorable implant survival with lower soft tissue/prosthetic complications with implants of shorter lengths.[8–12] The predictability of immediate and early loading of short dental implants is greatly underexplored. To the best of the authors' knowledge, a systematic review and a meta-analysis of the pertaining literature are not available.

The primary goal of this study was to evaluate the functionality of short dental implants that were loaded using immediate and early loading protocols by assessing implant survival and marginal bone level alterations. The secondary aim was to assess if the crown-to-implant (C/I) ratio could influence bone loss and whether there are any differences in bone loss estimates with immediate or early loading protocols. An adequate C/I ratio, in addition to the implant width, length, and size of the occlusal table are known factors that help in dissipating stress across the peri-implant bone.[13] Conversely, data from finite element analysis studies suggest that stress is governed more by the bone type and quality.[14,15] To shed light upon the matter, the impact of changes in the C/I ratio on bone loss was assessed from the studies included in the present analysis.

There is no well-defined concord for the cutoff length of short dental implants in the published literature, with studies considering < 10 mm-, 8 mm-, or ≤ 6 mm-length implants for their analysis.[9–12] For the purpose of this analysis, studies reporting the use of implant lengths ≤ 6 mm with immediate and early loading protocols were analyzed. Taking into account that the conglomeration of the outcome effects presented with the highest level of evidence, this meta-analysis would be instrumental in adding to the scientific rationale for future decision-making processes in clinical interventions using immediate or early loading of short endosseous dental implants.

MATERIALS AND METHODS

This meta-analysis was conducted in line with the PRISMA guidelines preferred for reporting systematic reviews and meta-analysis research.[16] An electronic search of MEDLINE (PubMed database), Embase, and Cochrane Library in combination with a hand search was conducted to identify relevant studies from January 1991 to March 2019. The focused PICO question[17] was "In patients with short dental implants, does loading time affect treatment outcomes?" The detailed criteria on the pertinent studies that were to be probed are shown in Table 1. In brief:

- Population: Studies in which patients were missing one or more natural teeth and received short dental implants (≤ 6 mm).
- Intervention: Short dental implant (≤ 6 mm) in the posterior maxilla/mandible with immediate (within 48 hours of implant placement) or early loading (no later than 3 months post–implant placement)[18] with a mean follow-up of at least 1 year after prosthetic loading.
- Comparison: Long endosseous dental implant (> 6 mm) or implants loaded with traditional (delayed) loading protocol. In cases where no comparison was reported, data from prospective clinical trials reporting the use of short implants with immediate or early loading were used, exclusively.
- Outcomes: Implant survival rates and marginal bone loss.

Eligibility Criteria and Search Strategy

The following literature search strategy was used in MEDLINE (PubMed):

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1. [Dental implants (MeSH term) AND short dental implant AND immediate dental implant loading (MeSH term)].
2. [Dental implants (MeSH term) AND short dental implant AND early dental implant loading]. The search terms applied for databases, EMBASE, and Cochrane were dental implants, short dental implant, immediate loading, or early loading.

Additionally, a manual journal search along with grey literature was employed pertaining but not limited to: *Clinical Oral Implants Research*, *International Journal of Oral & Maxillofacial Implants*, *Clinical Implant Dentistry and Related Research*, *International Journal of Oral and Maxillofacial Surgery*, *Journal of Periodontology*, *Journal of Oral Implantology*, *Journal of Oral and Maxillofacial Surgery*, *Journal of Dentistry*, *Journal of Clinical Periodontology*, etc.

The inclusion criteria were as follows: all types of clinical studies (except case series/clinical reports) in which dental implants ≤ 6 mm in length were loaded in the posterior maxilla or mandible using an immediate or early loading protocol, and with fixed prostheses involving single crown or fixed partial restorations; studies that reported details on the implant length and implant type (cylindrical) and at least 1 year of follow-up post–prosthetic loading; and literature in the English language. The parameters to be evaluated were as follows: implant survival rates and marginal bone loss amounts clearly indicated or calculable from reported data.

The exclusion criteria were as follows: studies with follow-up of less than 1 year, studies in which patients had undergone advanced surgical procedures such as sinus floor elevation or bone augmentation procedures, language not in English, animal studies, finite element analysis studies, case series, editorials, clinical reports, technical note, systematic reviews, critical reviews, and meta-analyses. Studies that had full-arch restorations in either the edentulous maxilla or mandible were also excluded. The PRISMA flow diagram with the specifics of the search strategy and the rationale for the final number of studies included is presented in Fig 1.

To evaluate the effect of potential sources of bias and heterogeneity of clinical resources for validating the applicability of the included evidence, the ROBINS-I tool, per the Cochrane Method guidelines (Fig 2) was used (Risk Of Bias In Non-randomized Studies of Interventions). Interexaminer agreement on the eligibility of the included studies was calculated as per the Cohen kappa statistics.

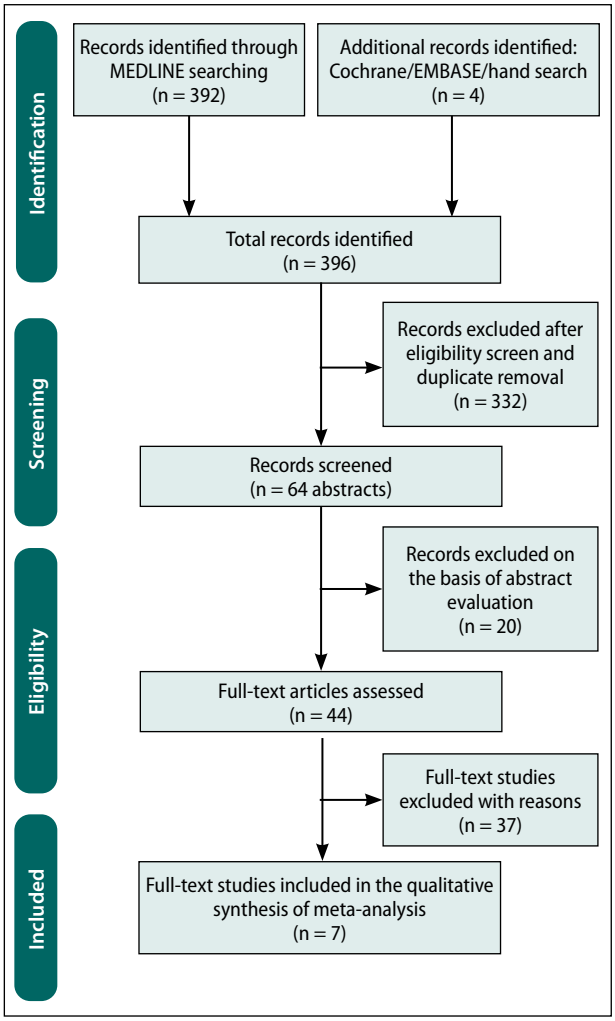


Fig 1 PRISMA flow diagram depicting the search strategy and screening process phases. It maps out the initial number of records identified along with the total included and excluded records with the reasons for exclusion.

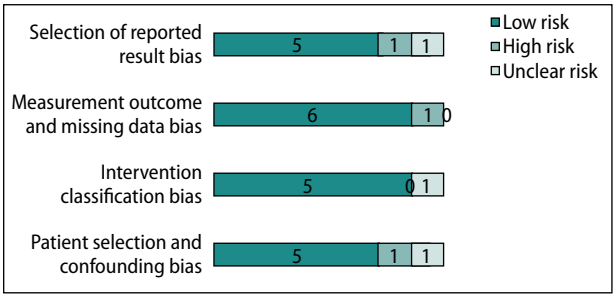


Fig 2 The ROBINS-I tool (Risk of Bias in Non-randomized Studies of Interventions) evaluating the potential biases for the seven (included) interventional studies in terms of randomized allocation, blinding of patients, and confounding domains in the measured variables.

Data Synthesis and Statistical Analysis

A meta-analysis was performed using the extracted data, applying a random-effects model weighted by the inverse variance method and meta-analysis of proportions. To account for the effect size variability across the included studies, while also incorporating the intrastudy sampling errors, a random-effects

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model was chosen for conducting the meta-analysis in order to estimate a functionally equivalent outcome. Pooled effects are presented in a forest plot with associated 95% confidence intervals (CI). Data were considered significant if $P < .05$ (two-sided α level of .05). MedCalc Statistical Software version 19.0.7 was used to conduct the meta-analysis (MedCalc Software). The Cochran Q test and I^2 inconsistency test were performed to evaluate the heterogeneity among the studies ($P < .001$/95% CI). The I^2 test analysis uses values ranging from 0% to 100%, with values ≥ 75% suggestive of a greater heterogeneity. To evaluate the potential presence of publication bias, the Egger test was used for each meta-analysis (funnel plot). All other statistical analyses were conducted in SPSS (24.0 software for Windows). The Student unpaired two-sample *t* test (assuming unequal variances) was used to evaluate the differences in the marginal bone loss for early and immediate loading protocols. The Spearman correlation analysis was used for assessing the trends between C/I ratio and bone loss.

RESULTS

Study Selection

The systematic search identified a total of 396 results from the PubMed (MEDLINE) database. The MeSH terms "Dental implants AND short dental implant AND immediate dental implant loading" yielded 178 articles. "Dental implants AND short dental implant AND early dental implant loading" showed 218 records. One additional study was identified from EMBASE, Cochrane Library database, and hand search, which added up to a total of 396 studies. Three hundred ninety-six studies were screened, and titles and abstracts were analyzed. The preliminary exclusion in the screening phase, accompanied with removal of duplicated references, led to elimination of 322 articles. Of the 64 articles assessed for eligibility, studies not meeting the mentioned inclusion specifications (Appendix Table 1; see Appendix in online version of this article at quintpub.com) were excluded in this phase (n = 20 abstracts followed by n = 37 full-text studies). Procedures that could possibly interfere with the implant survival rates, such as sinus floor elevation or bone augmentation, were excluded. Additionally, the analysis was restricted to exclude studies in which patients had full-arch restoration treatments since it may impact the differential results between early or immediate implant loading outcomes. Seven studies were included for the final qualitative and quantitative analysis, based on the inclusion criteria (Fig 1). Interexaminer agreement on eligibility of the included studies as per Cohen kappa statistics was high ($\kappa = 0.842$).

Study Characteristics and Risk of Bias Assessment

Four prospective randomized controlled trials (RCTs) and three case controlled trials (CCTs) were included in the meta-analysis (Table 2). The included seven studies had a mean age of 51.9 years for the patients and data of at least 1 year of follow-up after the prosthetic loading. The total number of implants being evaluated across these studies was n = 322, primarily encompassed in the posterior region of both maxillary and mandibular segments. The detailed characteristics of these studies are summarized in Table 2. Since the final studies included in the present meta-analysis consisted of both prospective RCTs and CCTs, the ROBINS-I tool (Risk of Bias in Non-randomized Studies - of Interventions) was used for evaluating the internal validity of the studies.[19] Biases due to patient selection, confounders, intervention, measuring, and reporting outcome variables of the included studies were found to be at low risk (Fig 2).

Synthesis of Results

Implant Survival. To calculate the cumulative implant survival rate of short dental implants with immediate or early loading, a meta-analysis of proportion using the random-effects model was conducted. The total number of positive cases (ie, implants reported as having survived) was taken into consideration for every study. Heterogeneity tests were performed to evaluate publication bias for the outcome event, implant survival. The funnel plot (Fig 3a) was symmetrical (Cochran $Q = 6$, $I^2 = 0$) with no publication bias observed among the included studies. Proportion ratio corresponding to the percentage of surviving implants between the total number of implants evaluated was assessed. The cumulative implant survival rate for short dental implants with immediate and early loading was 91.63% (95% CI: 88.4% to 94.3%). The forest plot for the meta-analysis of implant survival rate is shown in Fig 3b. The average implant survival rates were 92.5% for the studies reporting immediate loading and 91.4% for the studies using early provisionalization, which did not differ statistically.

Marginal Bone Level Changes

A meta-analysis was performed using the generic inverse-variance method (random-effects model) to assess the mean bone loss as reported for every included study at the final follow-up, which was in turn evaluated by the peri-implant bone level changes over time. A forest plot with the weighted z scores of the pooled effect estimates is shown in Fig 4. Within the 95% CI, the pooled value estimates for mean bone loss reported in the studies were 0.19 to 0.96 mm (average: 0.53 mm), $z = 3.07$, $P < .002$. Likewise, a similar analysis

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Table 2 Implant Characteristics of the Included Studies (n = 7)

Study (year)	No. of short implants (n)	Implant length (mm)	Implant width (mm)	Implant system	Loading type and time	Prosthesis type	Follow-up duration	Location
Weerapong et al[20] (2019)	23	6	NR	PW+ Dental implant system	Immediate loading at the time of surgery	Provisional hybrid ceramic crowns	1, 2, 4 weeks; 2, 4 months; up to 1 year	MX, MD posterior region
Ayna et al[21] (2019)	63	6	5–6	LGI Plus, Hi-Tec implant	n = 48: immediate loading, n = 15: delayed loading	Single crown	Yearly, up to 5 years	MX posterior region
Rossi et al[8] (2018)	40	6	4.1 (n = 19), 4.8 (n = 21)	Straumann (SLActive)	Early loading after 6 weeks of healing	Single crown restorations	Yearly, up to 10 years	MX (n = 14), MD (n = 26) posterior region
Rossi et al[22] (2017)	40	6	4.1 (n = 29); 4.8 (n = 11)	Straumann (SLActive)	Early loading: 8 weeks of implant insertion	2/3 units fixed partial dentures	Yearly, up to 5 years	MX (n = 14), MD (n = 26) posterior region
Han et al[24] (2018)	95	6	4	OsseoSpeed, Dentsply	Early loading after 6 weeks healing	Splinted polymer ceramic crowns	Loading to 6 months; 1, 2, 3 years postloading	MX, MD posterior region
Villarinho et al[23] (2017)	46	6	4.1	Straumann (SLActive)	Early loading: 45 days of healing	Single crowns	Yearly, up to 45 ± 9 months	MX (n = 23), MD (n = 23) posterior region
Rossi et al[25] (2016)	30	6	4.1	Straumann (SLA modified surface)	Early loading: 6 weeks of implant placement	Single crown restorations	Yearly, up to 5 years	MX, MD posterior region SLActive = moderate surface modification; Nanotite = dual etched + calcium phosphate

n = number; MX = maxilla; MD = mandible; NR = not reported.

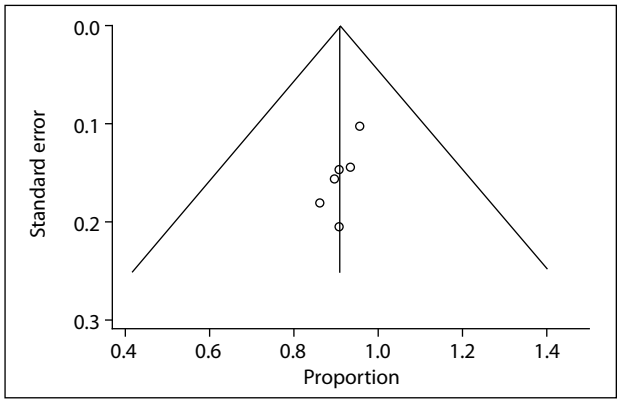


Fig 3a Publication bias assessment in the meta-analysis of proportion. Funnel plot representing the effect size on x-axis and standard error on y-axis.

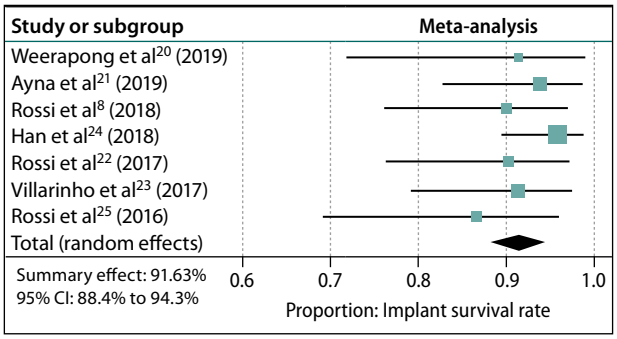


Fig 3b Forest plot for the meta-analysis of proportion with a total of seven studies. Central values of proportion marked as square markers with confidence intervals (95% CI) represented as horizontal lines. Variations in the size of the square markers correlate with study sample size. The pooled effects of the meta-analysis are shown with a diamond marker, representing the estimated effect size. The width of the diamond reflects the precision of the estimate.

was conducted for the cumulative bone loss estimates at 1 year postloading. The pooled value estimates for the mean bone loss reported 1 year postloading were 0.27 mm, z = 2.107, $P < .03$ (Fig 5). Slight asymmetry in the funnel plots assessing publication bias for mean bone loss and bone loss at 1 year was observed (Appendix Figs 1 and 2). However, Cochran Q and I^2 tests indicated a low heterogeneity for mean bone loss (Q = 9.5, $I^2 = 20.4\%$), and no heterogeneity for bone loss at 1 year (Q = 3.8, $I^2 = 0$), among the included studies. The publication bias for the mean bone loss outcome could be attributed to the variability in the reported outcomes and the effect sizes across the studies, albeit nonsignificant ($P > .14$). Taken together, the results indicated no significant differences in implant survival trends for the immediate loading group compared with early loading. However, the meta-analysis favored the early loading protocol when bone loss was accounted for.

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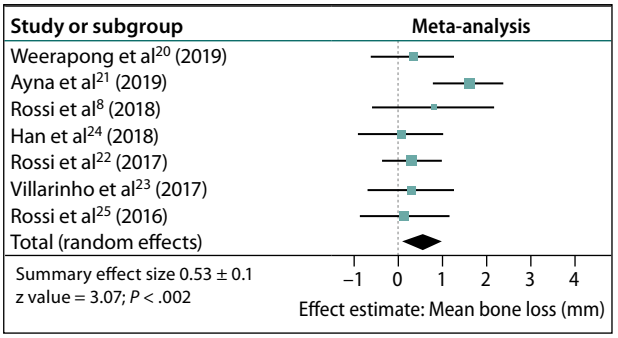


Fig 4 Forest plot with seven studies using the random-effects generic inverse variance meta-analyses for the mean marginal bone loss summary effect estimates and their confidence intervals (horizontal lines), calculated by weighted z scores and significance level ($P < .05$), for immediate and early loading of short implants. Diamond marker represents the pooled effects.

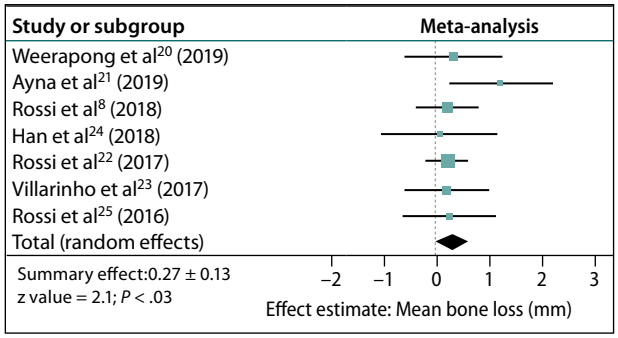


Fig 5 Forest plot with seven studies using the random-effects generic inverse variance meta-analyses for the mean marginal bone loss 1 year after loading for immediate and early loading of short implants. Summary effect estimates and their confidence intervals (horizontal lines) calculated by the weighted z scores and significance level ($P < .05$). Diamond marker represents the pooled effects.

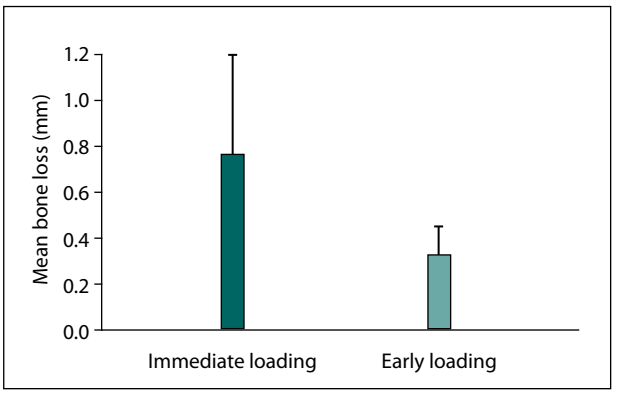


Fig 6 Unpaired two-sample *t* test used to evaluate differences in the mean bone loss (mm) reported for studies using immediate loading protocols (n = 2 studies) vs studies using early loading schemes (n = 5 studies).

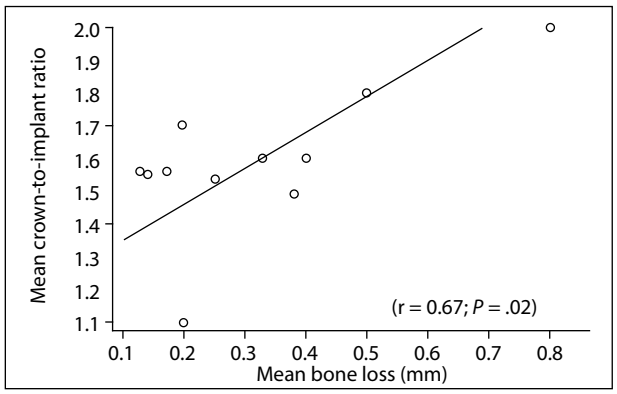


Fig 7 Scatter plot depicting the Spearman correlation analysis for the average crown/implant ratio and the mean marginal bone loss levels (reported in three studies), as calculated by the constant (rho) and significance level ($P < .05$). Each circle is representative of the mean bone loss noted at a follow-up time point in the respective study.

Clinical Outcome Comparison of Immediate and Early Loading

In order to assess if differences truly exist between immediate and early loading protocols, the mean bone loss across all the studies was compared with respect to the loading protocols used. Of the seven studies evaluated, one CCT[20] using short and conventional-length implants reported using an immediate loading protocol solely, while another compared clinical outcomes for immediate vs early loading.[21] Five studies including four prospective RCTs,[8,22–24] and one CCT[25] utilized an early loading protocol. The comparative bone loss estimates between the two protocols noted no statistically significant differences between the immediate and early loading protocols (0.76 ± 0.61 mm vs 0.32 ± 0.28 mm; $P < .21$, $t = -1.41$; Fig 6), although there was a trend for greater mean bone loss in the studies that had reported an immediate loading protocol in short dental implants.

Effect of C/I Ratio on Mean Bone Loss

It has been known that greater crown height induces greater moment of force, thereby transmitting stresses on the alveolar ridge.[26] Hence, the present meta-analysis aimed to assess the influence of the reported clinical C/I ratio on mean bone loss by correlation analysis, as described in three of the seven included studies.[8,23,25] Based on the Spearman correlation coefficient analysis, moderately positive significant correlation was observed between the average value of clinical C/I ratio and mean bone loss levels ([$r = 0.67$, $P = .02$] Fig 7). Greater bone loss was noted when the C/I ratio was approximately 1.8 to 2. The average C/I ratio and mean bone loss characteristics for each time point are summarized in Table 3.

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Table 3 Average Crown/Implant Ratio and Mean Marginal Bone Loss Characteristics (As Reported in Three Studies)

Study	Clinical crown/implant ratio (average ± SD)	Mean bone loss (mm), mean ± SD
Rossi et al[25] (2016)	At loading: 1.49 ± 0.36	0.38 ± 0.10
	1 year: 1.54 ± 0.37	0.25 ± 0.45
	2 years: 1.56 ± 0.4	0.17 ± 0.50
	3 years: 1.56 ± 0.4	0.13 ± 0.54
	4 years: 1.56 ± 0.4	0.12 ± 0.55
	5 years: 1.55 ± 0.39	0.14 ± 0.52
Villarinho et al[23] (2017)	At loading: 1.1 ± 0.5	0.2 ± 0.4
	3 years: 1.6 ± 0.3	0.33 ± 0.47
Rossi et al[8] (2018)	At loading: 1.6 ± 0.4	0.4 ± 0.9
	1 year: 1.7 ± 0.4	0.2 ± 0.3
	2 years: 1.8 ± 0.6	0.4 ± 0.5
	5 years: 2.0 ± 0.6	0.7 ± 0.6
	10 years: 2.0 ± 0.6	0.8 ± 0.5

DISCUSSION

Based on the authors' knowledge so far, this is one of the first studies to systematically review and explore the functionality of short dental implants with immediate and early loading protocols by means of assessing implant survival and marginal bone level alterations. The use of conventional-length implants was recommended in the 1990s for adequate bicortical anchorage and to avoid imbalances in the C/I ratio due to short implants.[4,5] However, with the evolution of surface modifications and microreliefs of shorter implants, not only has the primary mechanical stability improved, but it has also aided in blood clot retention, thus instigating timely bone healing processes. The technical challenges and morbidity arising from ridge augmentation procedures, such as transient postoperative paresthesia or graft healing complications (eg, wound dehiscence), warrant the use of short implants as a highly favorable option over bone grafting for implant site development.[27] A study comparing the long-term outcomes for short implants (6 mm) with those for standard-length implants placed after vertical augmentation in posterior atrophic sites favored the use of short implants and found greater bone loss and insufficient remodeling, leading to inadequate vertical height gain of the grafted sites.[28] Two of the seven studies included[20,25] in the present meta-analysis compared the clinical outcomes for short and standard-length implants and found no significant differences between the two implant types. The overall implant survival rate was 91.6%. The lowest reported survival rate was 86.7%.[25] Upon probing the possibilities of decreased implant survival rate, the authors indicated fracture of the supporting bone leading to instabilities of the C/I ratio and needing an immediate prosthesis removal, rather than a progressive marginal bone loss, as the causative determinants.

Socket healing starts with plasma-derived fibrin networks granulating over the first few hours aided by perfusion of erythrocytes to form capillary networks that promote neoangiogenesis at the original defect in the following few days.[4] The fibrocartilaginous callous formed over the next 3 weeks by a complex interplay between capillary networks, fibroblasts, collagen, and osteogenic chondrocytes transitions into a bony callous over the next 3 to 4 months.[1] The anatomical harmony of bone marrow and implant directly impacts this remodeling process, which ultimately determines the osseointegration prognosis without pronounced complications.[14] Six of the seven studies included in this analysis[8,21–26] revealed minimal marginal bone loss with early loading, as recorded by the radiographic bone levels for 6-mm-long implants during the follow-up range of 1 to 10 years, indicating that 6 weeks is a suitable time window to allow loading of short dental implants. Studies have also documented that immediate and early loading of dental implants does not affect the mineralization of tissues and could possibly lead to a higher bone-to-implant contact percentage due to stimulation of bone apposition via functional loading vs classical implant loading.[29] There have been mixed reports on the marginal bone loss levels occurring between early and immediate loading protocols for single implant-supported crowns.[21,30] No statistically significant differences in the mean bone loss were found for studies that used immediate loading schemes (mean: 0.7 mm) as opposed to studies using early loading (mean: 0.3 mm) protocols. However, the

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present findings could be skewed because out of the seven included studies based on the inclusion criteria, only two reported using immediate loading, while five utilized an early loading protocol. Additionally, for the most part, the studies using an immediate bone loading protocol reported short-term follow-up data and had smaller sample sizes. Authors have favored immediate restoration by proposing a "one abutment at one time" protocol[30] in which the non-displacement of the abutment at the time of surgical implant placement was able to preserve bone levels to a certain extent, by avoiding compromised peri-implant mucosal and bone healing outcomes.

Predominantly, few postoperative complications and no relevant aftermaths were observed for short dental implants using immediate or early loading for the included studies. The relatively low failures that occurred were either before loading or 2 to 4 months postloading, reiterating the importance of primary stability in immediate and early implant placement. The mean peri-implant bone loss (0.53 ± 0.2 mm) remained within the practical realm of "success" characterized by the 2007 Pisa Consensus (< 2 mm).[31] A possible reason for bone loss being higher could be attributed to patients who had greater local factors (probing pocket depths, plaque accumulation, bleeding), which could have impacted the efficient oral hygiene status, as witnessed in one of the included studies.[21] A history of advanced periodontitis, poor bone quality, and systemic factors contributing to derailed wound healing mechanisms are crucial parameters to be taken into consideration while planning shorter-length implants with early and immediate loading protocols.[10,14,32]

Studies have expressed conflicting results for considering C/I ratio as a predictor of implant survival for short implants.[8,23,25] In the present analysis, significant positive (moderate) correlation was noted between the average value of C/I ratios and the mean bone loss levels, recorded at different follow-up time points. A trend for greater bone loss was noted if the reported clinical C/I ratio was approximately 1.8 to 2. The greatest leap in the C/I ratio was noted in the span within the first 2 years of function after prosthesis delivery.[8,33] One of the studies included in the present meta-analysis, utilizing a multi-regression model, demonstrated an increased clinical C/I ratio as a likely determinant for bone loss. The predicated bone loss of 0.1 mm was estimated for every 0.1-unit increase in the C/I ratio.[23] Theoretical models have hypothesized greater mechanical strain surrounding the dental implant with increased lever arm. This higher state of strain is believed to affect the marginal bone levels over time.[34] In summary, the use of short dental implants with immediate or early loading can be advocated over standard-length/conventional loading protocols in atrophic sites, to avoid challenging and less predictable vertical bone augmentation procedures, save overall treatment time, and preserve bone and gingival architecture. That being said, it is important to consider the confounding risk factors such as history of periodontitis, smoking, systemic conditions (diabetes mellitus), as well as anatomical considerations, eg, bone quality (type IV) and extraction site morphology while considering immediate or early loading protocols with short dental implants.

Limitations and Future Directions

Given the heterogeneity of the included studies, in terms of their study design, implant systems, sample sizes, and the lack of availability of long-term prospective trials, future studies with greater sample sizes are needed to evaluate the long-term outcomes of short dental implants with immediate or early loading protocols.

Clinical Implications

It is not inappropriate to say that short dental implants with immediate or early loading schemes can be justifiably utilized for posterior atrophic rehabilitation to avoid the complications intrinsic to advanced bone augmentation procedures. Moreover, they also serve as an acceptable treatment modality for elderly or disabled patients for whom several treatment sessions may be impractical or cases where additional surgical procedures would risk important anatomical structures in the proximity (eg, maxillary sinuses, blood vessels, or existing implants). The net effect of shortening the treatment time with immediate or early loading protocols and the utilization of short dental implants have favorable outcomes and function.

CONCLUSIONS

Given the findings of this investigation and appraisal of the available studies, short dental implants with immediate or early loading protocols may be used when necessary, as they have fairly predictable treatment prospects with satisfactory implant survival rates and minimal marginal bone loss. The outcomes of this meta-analysis should be inferred keeping in mind the study limitations and the confounding uncontrolled variables in the included studies.

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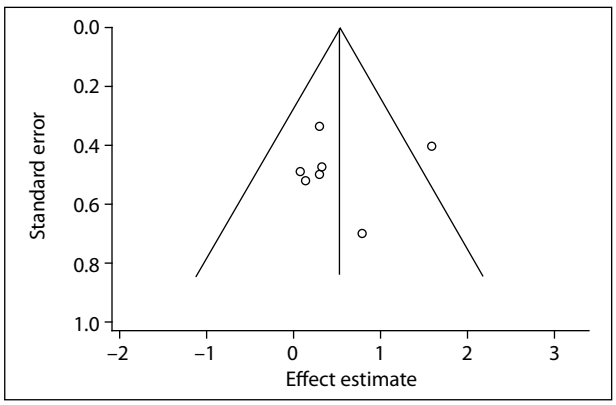
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APPENDIX

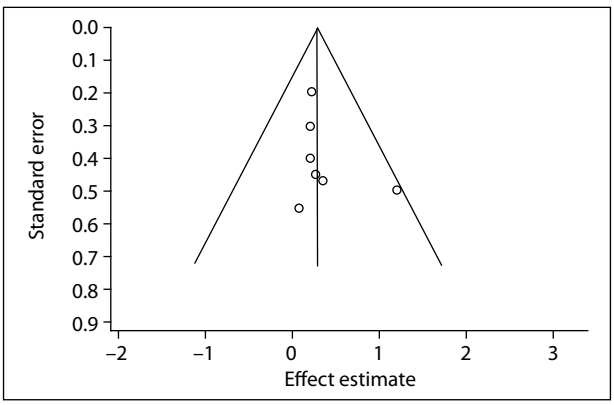
Appendix Table 1 Excluded Studies with Justifications (n = 37)

Reason for exclusion[a]	No of Studies	Study (year)
Delayed loading protocol	4	Davarpanah et al (2001), Gholami et al (2014), Hingsammer et al (2017), and Jiansheng et al (2012)
Longer-length implants used	16	Achilli et al (2007), Anitua et al (2018), Anitua et al (2016); Bömicke et al (2017), Calandriello et al (2003), Cannizzaro et al (2018), Cannizzaro et al (2012), Fischer et al (2009), Franchini et al (2011), Han et al (2016), Malo et al (2011), Norton (2004), Pozzi and Mura (2016), Rossi et al (2010), Sennerby et al (2008), and Vandeweghe et al (2013)
Data not clear for evaluation (location, follow-up duration, length)	14	Anand and Mehta (2012), Chow et al (2001), Dard et al (2016), Degidi et al (2007); Degidi et al (2006), Glauser et al (2007), Glauser et al (2005), Glauser et al (2003), Glauser et al (2001), Östman et al (2013), Ostman et al (2010); Pozzi et al (2012), Sullivan et al (2005), and Testori et al (2003)
Follow-up less than a year	2	Calandriello et al (2011) and Makowiecki et al (2017)
Case report	1	Sclesinger (2014)

[a]Studies excluded based on post-eligibility full-text assessment.



Appendix Fig 1 Funnel plot to evaluate publication bias for the outcome event mean marginal bone loss. Effect size is graphically represented in a funnel plot displaying effect size (x-axis) and standard error (y-axis).



Appendix Fig 2 Funnel plot to evaluate publication bias for the outcome event mean marginal bone loss 1 year after loading. Effect size is graphically represented in a funnel plot displaying effect size (x-axis) and standard error (y-axis).

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