Outcome Difference between Short and Longer Dental Implants Placed Simultaneously with Alveolar Bone Augmentation: a Systematic Review and Meta-Analysis

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ABSTRACT

Objectives: This systematic review and meta-analysis aim to provide detailed insights into the clinical performance of short and longer dental implants placed simultaneously with bone augmentation.
Material and Methods: The search for literature was performed across MEDLINE (PubMed), ScienceDirect and the Cochrane Library databases, adhering to specific selection criteria and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Only articles published in English between 2014 and 2024 were considered for data collection. Primary outcomes were survival rate (SR), marginal bone loss (MBL) and complications. Clinical outcomes were as follows: bleeding on probing (BOP), periodontal pocket depth (PPD), and implant stability quotient (ISQ). Quality and risk of bias assessment were evaluated by the Critical Appraisal Checklist tool for randomized controlled trials developed by the Joanna Briggs Institute.
Results: A total of 14678 articles were screened, with 9 meeting the inclusion criteria and being utilized for this systematic review and meta-analysis. A total of 495 patients with 984 implants (491 short and 493 longer implants) showing a SR of 93.91% for the short implants and 91.83% for the longer implants. Meta-analysis revealed statistically significant difference between short implants and longer implants simultaneously placed with alveolar bone augmentation in relation to MBL (-0.513 mm, 95% CI = -0.93 to -0.096; P = 0.02), and in PPD (-0.247, 95% CI = -0.515 to 0.022; P = 0.07).
Conclusions: When comparing the results of treatment with short and longer dental implants combined with alveolar bone augmentation, short implants showed better clinical results regarding the parameters of survival rate, marginal bone loss and complications.

Keywords: alveolar bone loss; alveolar ridge augmentation; dental implantation; dental implants; meta-analysis; sinus floor augmentation.

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INTRODUCTION

With advancing age, the occurrence of tooth loss intensifies, and the greatest extent occurs at the age of 65. This loss leads to the alveolar bone's resorption, which is characterized by its progressive, cumulative, and irreversible nature [1]. Traditionally, dentures or bridges have been used to replace missing teeth and their supporting structures, thereby restoring the ability to chew, improving speech, and enhancing aesthetics. An alternative to these methods is dental implants, which are placed into the jawbone to anchor dental prostheses. The success of these implants lies in the close bond that forms as bone grows onto their surface, a phenomenon known as osseointegration. This process establishes a direct structural and functional linkage between the living bone and the surface of the implant [2]. Since their introduction by Brånemark [3], the insertion of dental implants is a widely practiced technique that yields outstanding outcomes [4]. The presence of anatomical boundaries, namely the proximity of the inferior alveolar nerve and the maxillary sinus in diminished jaws, could extend the scope of surgical intervention [5]. Introduced over four decades ago, the maxillary sinus floor elevation technique, utilizing the lateral window approach, boasts a success rate exceeding 90% for implantations into the augmented site. However, this procedure is not without significant risks, including infections, sinus membrane perforations, and necrosis of the bone graft, which continue to pose considerable complications [6,7]. Additionally, bone augmentation in the mandible presents an elevated risk of complications such as infection, graft exposure, and tissue necrosis [8]. Furthermore, the growing preference of patients for less invasive surgical methods, reduced complications, lower costs, and shorter treatment durations has led to numerous publications exploring the use of dental implants of smaller dimensions, both in diameter and length [9-11]. The biomechanical principle underlying the use of short implants posits that the load-bearing responsibility primarily resides with the implant's crest module, whereas the apical portion experiences lesser stress [12]. When an implant is placed in bone with sufficient density, the highest stress concentration occurs within the top 5 mm of the bone-implant interface. Consequently, the length of the implant might not be the critical element in dispersing the prosthetic loads across the bone-implant interface. Nonetheless, the diminished bone density of an atrophied jawbone, positioning towards the back of the dental arch, and a taller crown height for the restorations are significant risk factors for the utilization of short implants. These factors could potentially compromise the success of the implant placement [13,14]. The criteria for defining short implants varied widely among different studies and reviews, leading to a lack of universal agreement on their exact definition [15]. In the review by Renouard and Nisand [16], an implant is considered 'short' if its intended length within the bone is 8 mm or shorter, therefore for this review implants ≤ 8 mm were considered short.

The aim of this systematic literature review and meta-analysis is to examine existing research and assess if short implants serve as a viable substitute for longer implants placed simultaneously with bone augmentation.

MATERIAL AND METHODS

Protocol and registration

The review adhered to the guidelines outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement, which are standards for reporting systematic reviews [17]. The literature search for this review took place from March 1, 2023, to March 1, 2024, which signifies the completion of the final search.

Focus question

The focus question was created according to the Patient, Intervention, Comparison and Outcome (PICO) framework as described in Table 1.

Information sources

The information source was the MEDLINE (PubMed), ScienceDirect databases and the Cochrane Library. Reference lists of selected articles were manually searched for additional relevant publications. Grey literature, letters, editorials, doctoral dissertations, abstract case series, case reports, cross-sectional studies, reviews, unpublished literature were not included in the search strategy of this systematic review.

Literature search strategy

Research articles were sourced from March 1, 2014, to March 1, 2024, adhering to the PRISMA guidelines [17], through searches conducted in the MEDLINE (PubMed), ScienceDirect databases and the Cochrane Library utilizing their respective search functionalities. Selection of articles was guided by predefined

Table 1. PICO guidelines

Component	Description
Population (P)	Healthy adult patients with partially or completely lower or upper (or both) edentulous jaw requiring dental implant treatment
Intervention (I)	Short dental implants (≤ 8 mm) placement in native bone
Comparison (C)	Longer dental implants (> 8 mm) placement simultaneously with alveolar bone augmentation
Outcomes (O)	Short and longer implant treatment outcomes by evaluating following clinical parameters: survival rate, marginal bone loss, bleeding on probing, periodontal pocket depth, implant stability quotient, and complications.
Focus question	Are there any differences in treatment outcomes in short dental implants compared to longer implants simultaneously placed with alveolar bone augmentation?

inclusion and exclusion criteria. The different combinations of keywords were used (Table 2). The process began with an initial screening of titles and abstracts, followed by the segregation of full-text articles for detailed examination. Various keyword combinations were employed in the search strategy.

Selection of studies

This review's research process was carried out in several phases. Initially, articles were identified using the previously mentioned keywords by two reviewers (P.A. and R.S.) Subsequently, duplicates across databases were eliminated. Following this, the publications underwent a thorough evaluation to determine their relevance and adherence to the selection criteria based first on summary and finally on full-text analysis. Publications meeting these criteria were then incorporated into this systematic review. The reviewers independently checked the results, and disagreements were resolved by discussion with the senior investigator (G.J.). Reviewers were calibrated by calculating Cohen's kappa coefficient (κ) values to ensure inter-rater reliability of abstracts and titles on a sample of 10% of publications.

Types of publications

Present review included human studies that were published in English.

Types of studies

In this review were included randomized controlled trials (RCTs) published from March 2014 till March 2024. Literature reviews, meta-analyses, systematic reviews, letters to the editor, editorials, doctoral dissertations, and abstracts without full text were not considered.

Population

Adult patients in good health, experiencing either complete or partial tooth loss, who received treatment using either short dental implants or longer dental implants along with simultaneous bone augmentation.

Inclusion and exclusion criteria for the study selection

Inclusion criteria

- Studies published between March 2014 and March 2024.
- Full text studies written in English.
- Clinical RCTs.
- Minimum 20 patients in the study.
- Minimum of 15 implants in test and longer implants group (LIG).

Table 2. Summary of keywords combinations

Concept	Keywords
First concept	"dental implants"[MeSH Terms] OR short dental implants[Text Word]
Second concept	"sinus floor augmentation"[MeSH Terms] OR "alveolar ridge augmentation"[MeSH Terms]
Third concept	"dental implants"[MeSH Terms] AND "sinus floor augmentation"[MeSH Terms] AND short dental implant[Text work]
Fourth concept	"dental implants"[MeSH Terms] AND "sinus floor augmentation"[MeSH Terms] AND longer dental implant[Text work]
Fifth concept	"dental implants"[MeSH Terms] AND "alveolar ridge augmentation"[MeSH Terms] AND short dental implant[Text work]
Sixth concept	"dental implants"[MeSH Terms] AND "alveolar ridge augmentation"[MeSH Terms] AND longer dental implant[Text work]

- Simultaneous bone augmentation was done in LIG.
- Minimum follow-up 1 year.

Exclusion criteria

- Literature review.
- Studies conducted on species other than humans.
- Patient less than 18 years old.
- Controlled trials that registered only one length of implant.

Sequential search strategy

The systematic review was carried out in the following stages: 1) articles were identified using the specific keywords mentioned above; 2) found duplicates were removed; 3) screened titles and abstracts using the online screening tool Mendeley® Reference Manager v2.110.2 software (Elsevier; London, UK) 4) based on the analysis of the entire text, a detailed evaluation of each publication was carried out in order to assess its relevance and compliance with the established selection criteria. Publications that met the criteria were subsequently included in this systematic review.

Data extraction

In alignment with the objectives and specific tasks outlined for the review, data extraction from the articles was directly related to these goals and tasks. The data extracted included the following items, detailed below.

Data items

The following parameters were extracted when available: First author and publication year, country of origin, study design, mean age, total number of patients, total number of implants, implant characteristics (length and diameter), type of implant, alveolar bone augmentation technique and type of bone used, male to female ratio, last follow-up period, implant system, implant failure and implant survival outcomes, outcome measures namely marginal bone loss (MBL), bleeding on probing (BOP), periodontal pocket depth (PPD), implant stability quotient (ISQ) and complications.

The risk of bias assessment

The assessment of potential bias was conducted employing the Critical Appraisal Checklist tool for RCTs developed by the Joanna Briggs Institute (JBI) [18]. The specific questions evaluated are detailed in Table 3. Every criterion was given a rating of 'yes', 'no', 'unclear' or 'not applicable. Methodological quality was categorized as follows: "high risk of bias", when the study scored up to 49% of positive answers; "moderate risk of bias", when study scored between 50 and 69% of positive answers; "low risk of bias", when study reached more than 70% of favourable answers.

Synthesis of results

Relevant data on the mentioned items were gathered and systematically arranged in tables.

Table 3. The Joanna Briggs Institute Critical Appraisal Checklist for randomized controlled trials

Question number	Question definition
Q1	Was true randomization used for assignment of participants to treatment groups?
Q2	Was allocation to treatment groups concealed?
Q3	Were treatment groups similar at the baseline?
Q4	Were participants blind to treatment assignment?
Q5	Were those delivering treatment blind to treatment assignment?
Q6	Were outcomes assessors blind to treatment assignment?
Q7	Were treatment groups treated identically other than the intervention of interest?
Q8	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?
Q9	Were participants analysed in the groups to which they were randomized?
Q10	Were outcomes measured in the same way for treatment groups?
Q11	Were outcomes measured in a reliable way?
Q12	Was appropriate statistical analysis used?
Q13	Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

The first table are organized according to year of publication, country, number of patients, study design, male/female ratio and follow-up period. In the second table are summarized the implant type, implant length and diameter, jaw where the implants are placed, load time of the implants, type of bone used in the augmentation and type of prosthesis used. The last table provides information about the clinical outcomes.

Statistical analysis

Mendeley® Reference Manager v2.110.2 software (Elsevier) was used for article management. The level of agreement between the two raters in selecting abstracts and studies to be read in full text was measured using Cohen's kappa coefficient (κ). The meta-analysis was conducted in SPSS® Statistics version 29.0 (IBM Corp.; Armonk, NY, USA).

RESULTS

Study selection

Initial searches resulted in a total of 14678 articles. The remaining 13422 identified articles were then preceded once the 1256 duplicate records were eliminated. After the screening process, 13235 publications were eliminated due to them being older than 10 years, non-English language, animal studies, reviews or recorded one implant length. One hundred sixty-nine articles were then eliminated based on their title and abstract as they were irrelevant to the topic. The final decision was reached after 18 full-text articles in total were evaluated for inclusion and exclusion criteria. Finally, 9 records were included in the present systematic review after being thoroughly examined and meeting all the requirements (Figure 1). The level of agreement between two authors

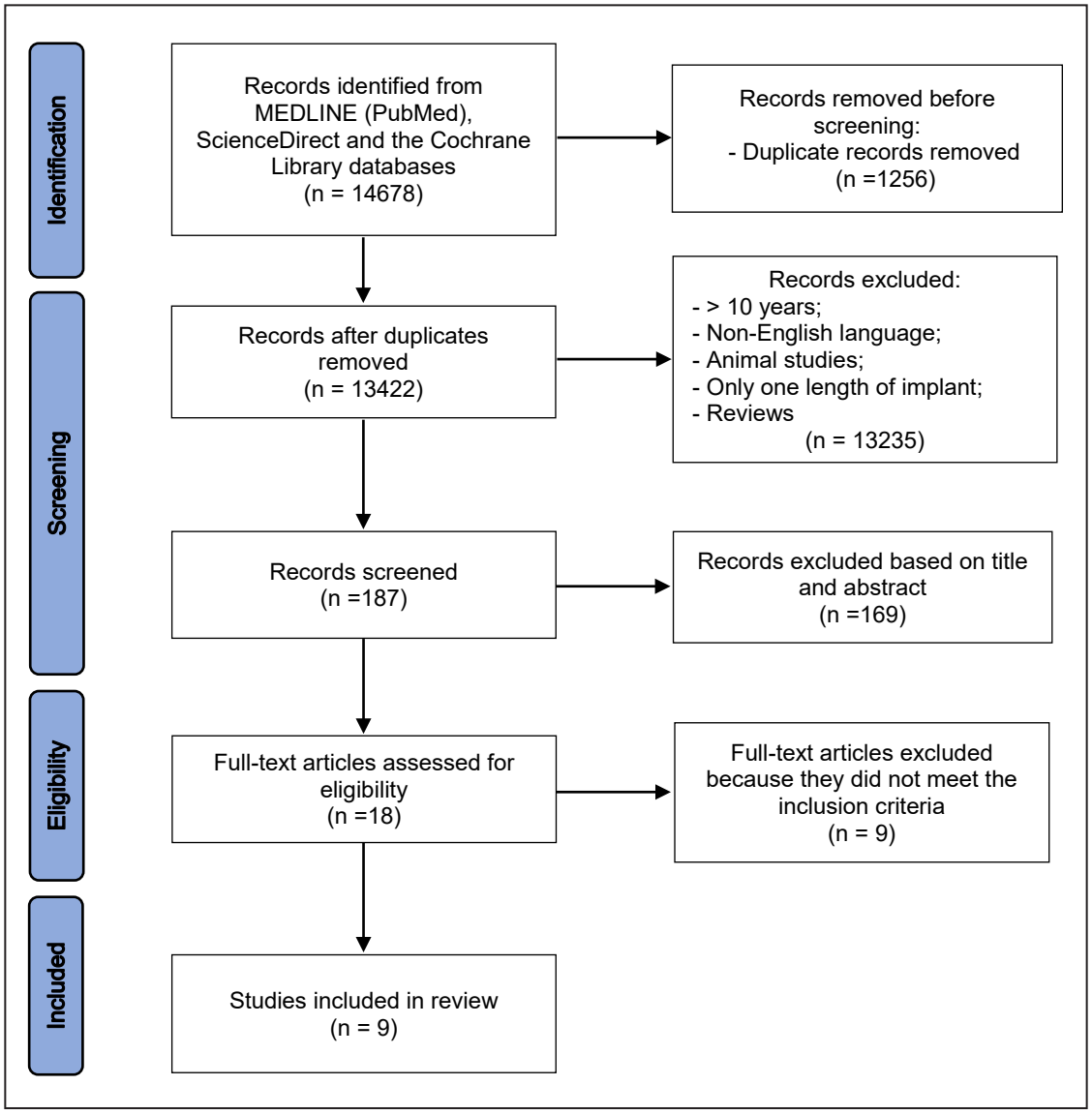

Figure 1. PRISMA flow diagram summarizing the search strategy and study selection.

(P.A. and R.S.) in the selection of abstracts was measured at κ = 0.89.

Study exclusion

After full-text review, 9 articles were excluded due to: retrospectives studies [19,20], no bone augmentation was done [21,22], have a sample size of less than 20 patients in the research [23], no bone grafting was done in the bone augmentation [24,25], checked short implants as distal support of full arch fixed dental prostheses (FDPs) [26], length of short implants were > 8 mm [27].

Quality assessment of the included studies

The methodological integrity of all RCTs was evaluated employing the JBI Critical Appraisal Checklist [18]. All RCTs studies were characterized as low risk of bias. The evaluations for each study are concisely presented in Table 4.

Study characteristics

Table 5 and Table 6 showcase the specifics and features of the studies included in this analysis. Present systematic review encompasses nine clinical trials, all of which were conducted with a prospective approach. The combined participant pool across these trials amounted to 495 patients, with a total of 68 individuals not completing the studies. In the aggregated data, it was noted that gender distribution specifics were omitted in two studies [28,29]. However, from the information available, it was documented that there were 180 males and 239 females in total.

A total of 984 implants were inserted, 491 short implants and 493 longer implants (Table 6). Research was conducted on the lower jaw in two instances [28,30], while four studies focused on the upper jaw [31,32-34] and three investigations encompassed both jaws [29,35,36].

Regarding the implants system used in the research, Felice et al. [30] used BIOMET 3i® (BIOMET 3i LLC; Palm Beach Gardens, Florida, USA), Shah et al. [35] used MIS Seven™ (MIS Implants Technology Ltd.; Misgav, Israel), Bernardi et al. [28] each group received a distinct type of implant, the short implants group (SIG) was fitted with the IM Macon® (MaCo Dental Care; Salerno, Italy), while the LIG received the Conical Active® (MaCo Dental Care). Bolle et al. [36] operated with twinKon® Universal® Profile implants (Global D; Lyon, France). Felice et al. [29] applied Southern Implants® pure titanium implants (Southern Implants; Irene, Centurion, South Africa), three studies Nielsen et al. [32], Guljé et al. [33], Thoma et al. [34] operated with Astra Tech Implant System™ (Dentsply Sirona; Mölndal, Sweden) and one research of Bechara et al. [31] did not report the company of the implants.

In the studies reviewed, the duration before loading the implants ranged from three to eight months. The shortest loading period reported was three months, noted in study Shah et al. [35], while the longest loading time of eight months was observed in two studies [29,30] (Table 6).

Implant survival rate

In total of 984 implants were inserted, 491 short implants and 493 longer implants, the total number of implants failed was 58, 27 in the SIG and 31 in the LIG. Resulting an overall implant SR of 93.91% within the SIG and 91.83% in the LIG (Table 6).

In the study of Felice et al. [30] there were a total of 8 implant failures, 3 in the SIG (SR = 81.4%) and 5 in the LIG (SR = 80%). Bechara et al. [31] had 2 lost implants, both in LIG (SR = 95.6%). Shah et al. [35] resulted in a total of 5 failed implants, 4 in the SIG (SR = 84%) and 1 in the LIG (SR = 96%).

Table 4. Quality assessment of all included randomized control trial (RCT) using the Joanna Briggs Institute Critical Appraisal Checklist

Study	Year of publication	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Bernardi et al. [28]	2018	+	+	+	-	-	+	+	+	+	+	+	+	+
Felice et al. [29]	2019	+	+	+	-	-	+	+	+	+	+	+	+	+
Felice et al. [30]	2014	+	+	+	-	-	+	+	+	+	+	+	+	+
Bechara et al. [31]	2016	+	+	+	-	-	?	+	+	+	+	+	+	+
Nielsen et al. [32]	2021	+	+	+	-	-	-	+	+	+	+	+	+	+
Guljé et al. [33]	2024	+	+	+	-	-	?	+	+	+	+	+	+	+
Thoma et al. [34]	2024	+	+	+	-	-	?	+	+	+	+	+	+	+
Shah et al. [35]	2018	+	+	+	-	-	?	+	+	+	+	+	+	+
Bolle et al. [36]	2018	+	+	+	-	-	+	+	+	+	+	+	+	+

Table 5. Description of studies included in the review

Study	Follow-up (years)	Study design	Population	Patients (n)			Age (years)	Gender (male/female)	
				Total	SIG	LIG	Mean	SIG	LIG
Bernardi et al. [28]	1	Randomized split mouth trial	Patients Presenting a posterior bilateral edentulous mandible, with bone height quantity less than 9 mm	36	18	18	62	NR	NR
Felice et al. [29]	5	Prospective RCT	Partially edentulous patient having bilateral edentulism in posterior jaws	40	NR	NR	Mandible 54.1; maxilla 57.6	NR	NR
Felice et al. [30]	5	Prospective RCT	Partially edentulous patients having 7 to 8 mm of residual crestal height and at least 5.5 mm thickness	60	30	30	55.5	7/23	15/15
Bechara et al. [31]	3	Prospective RCT	Patients with partial edentulism in the posterior atrophic maxilla at least 4 months after extraction with residual bone height ≥ 4 mm and width ≥ 5 mm under the maxillary sinus	53	33	20	48.1 (SD 15.1)	10/23	9/11
Nielsen et al. [32]	1	Prospective RCT	Patients with partial edentulism in the posterior part of the maxilla	37	20	17	52	9/11	6/11
Guljé et al. [33]	10	Prospective RCT	Patients, missing a premolar or a molar in the posterior maxilla and residual bone height underneath the maxillary sinus between 6 to 8 mm	38	20	18	49	7/13	11/7
Thoma et al. [34]	10	Prospective RCT	Patients with partial edentulism in the posterior maxilla	101	50	51	50.5	21/29	28/23
Shah et al. [35]	1	Prospective RCT	Patients had to have one or more missing teeth Residual ridge vertical bone height at the implant site had to be 6 to 8.5 mm	50	25	25	58.4 (SD 11.6)	9/16	10/15
Bolle et al. [36]	1	Prospective RCT	Partially edentulous patient who was missing teeth in the premolar and/or molar area	80	40	40	59.93	17/23	21/19

SIG = short implants group; LIG = longer implants group; RCT = randomized control trial; n = number; NR = not reported; SD = standard deviation.

Table 6. Data of the included studies

Study	Jaw	Type of implant	Implant length and diameter (mm)		Loading time	Implants (n)		Dropout (n)	Technique of augmentation	Type of bone graft	Prosthesis type
			SIG	LIG		SIG	LIG				
Bernardi et al. [28]	Lower	IM Macon® (SIG)/Conical Active® (LIG)	6 x 4.1	10 x 3.9	NR	86	84	-	Sandwich technique	OsteoBiol® Sp-Block (Tecnoss s.r.l.; Giaveno, Italy)	Single crown
Felice et al. [29]	Upper and Lower	Southern Implants® pure titanium	6 x 4	≥ 10 x 4	8 months	80	91	8 patients	Sandwich technique	Mandible: OsteoBiol® Sp-Block (Tecnoss s.r.l.) equine bone blocks	Single crown
									Lateral window technique	Maxilla: OsteoBiol® Gen-Os (Tecnoss s.r.l.) granules of porcine bone	
Felice et al. [30]	Lower	BIOMET 3i®	6.6 x 4	9.6, 11.2, 12.6 and 14.6 x 4	8 months	60	61	8 patients	Vertical augmentation	Particulate form bone graft autogenous Bio-Oss® (Geistlich Pharma AG; Wolhusen, Switzerland)	NR
Bechara et al. [31]	Upper	NR	6 x 4 to 8	10, 11.5, 15 or 15 x 4 to 8	4 months	45	45	1 patient	Lateral window technique	Xenograft bone graft, collagenated porcine particulate bone graft. OsteoBiol® Gen-Os® (Tecnoss Dental, Turin, Italy)	Single crown or fixed partial dentures
Nielsen et al. [32]	Upper	Astra Tech Implant System™	6	13	27 weeks	20	17	3 patients	Lateral window technique	Autogenous and xenograft (bovine) (Bio-Oss® - Geistlich Pharma AG)	Single crown
Guljé et al. [33]	Upper	Astra Tech Implant System™	6	11	16 weeks	21	20	8 patients	Lateral window technique	Autogenous and proteinized bovine bone mineral (Bio-Oss® - Geistlich Pharma AG)	Single crown
Thoma et al. [34]	Upper	Astra Tech Implant System™	6 x 4	11, 13, 15 x 4	6 to 7 months	67	70	30 patients	Lateral window technique	Particulated bovine bone material (Bio-Oss® granules - Geistlich Pharma AG)	Single crown
Shah et al. [35]	Upper and lower	MIS Seven™	6 longer	10 longer	3 or 6 months	25	25	7 patients	Vertical augmentation	Alloplastic bone graft composed of hydroxyapatite and β-tricalcium phosphate (4Bone® - Biomatlante - Advanced Medical Solutions; Vigneux de Bretagne, France)	NR
Bolle et al. [36]	Upper and lower	twinKon® Universal® Profile	4	≥ 10 x 4, 4.5	4 months	87	80	3 patients	Sandwich technique	Mandible: OsteoBiol® Sp-Block (Tecnoss s.r.l.) equine bone blocks	NR
									Lateral window technique	Maxilla: OsteoBiol® Gen-Os (Tecnoss s.r.l.) granules of porcine bone	

SIG = short implants group; LIG = longer implants group; n = number; NR = not reported.

Table 7. Clinical data of the included studies

Study	Survival rate (%)		Marginal bone loss (mm)		Bleeding on probing		Pocket probing depth (mm)		Implant stability quotient		Complications	
	SIG	LIG	SIG	LIG	SIG	LIG	SIG	LIG	SIG	LIG	SIG	LIG
Maxilla												
Felice et al. [29]	94.8	100	1.52 (SD 0.47)	1.85 (SD 0.51)	NR	NR	NR	NR	NR	NR	2	5
Bechara et al. [31]	100	95.6	0.201 (95% CI: 0.166; 0.236)	0.273 (95% CI: 0.232; 0.313)	NR	NR	NR	NR	68.2 to 72.4 (3 years)	67.8 to 71.6 (3 years)	0	19
Nielsen et al. [32]	100	100	0.28 (SD 0.17)	0.26 (SD 0.14)	24%	22%	2.4 (SD 0.5)	2.5 (SD 0.6)	NR	NR	2	17
Guljé et al. [33]	89.5	90.9	0.18 (SE 0.1)	0.26 (SE 0.12)	0.4 (SE 0.1)	0.6 (SE 0.2)	2.8 (SE 0.2)	3.3 (SE 0.3)	NR	NR	41.2% PIM	30% PIM 10% Peri-implantitis
Thoma et al. [34]	98.5	100	0.36 (SD 0.76)	0.65 (SD 1.28)	55.2%	28.1%	3.2 (SD 0.9	3.4 (SD 1.5)	NR	NR	53.3% PIM 3.3% peri-implantitis	45.5% PIM 16.3% peri-implantitis
Shah et al. [35]*	84	96	0.6 (SD 0.16)	0.86 (SD 0.2)	NR	NR	NR	NR	67.9 (SD 8.3) to 70.17 (SD 7.4) (3 months)	70.8 (SD 7.6) to 72.03 (SD 5.9) (3 months)	NR	NR
Bolle et al. [36]	91.8	82.9	0.63 (SD 0.15)	0.72 (SD 0.25)	NR	NR	NR	NR	NR	NR	4	12
Mandible												
Bernardi et al. [28]	94.1	84.5	NR	NR	NR	NR	NR	NR	NR	NR	8	22
Felice et al. [29]	95.1	93.6	1.34 (SD 0.35)	2.11 (SD 0.59)	NR	NR	NR	NR	NR	NR	3	14
Felice et al. [30]	81.4	80	1.49 (SD 0.4)	2.34 (SD 0.75)	NR	NR	NR	NR	NR	NR	6	25
Bolle et al. [36]	95.3	97.8	0.51 (SD 0.16)	0.77 (SD 0.21)	NR	NR	NR	NR	NR	NR	2	11

*This study did not separately assess the outcomes for the mandible and maxilla.
SIG = short implants group; LIG = longer implants group; NR = not reported; PIM = peri-implant mucositis; SD = standard deviation; SE = standard error.

Bernardi et al. [28] reported the highest number of implant failures, 5 were lost in SIG (SR = 94.1%) due to primary stability (1) and infections (4) while 13 were lost in the LIG (SR = 84.5%) due to primary stability (3) and infection (10). Bolle et al. [36] reported a total of 13 failed implants, 10 in the maxilla where 2 patients in SIG lost 3 implants (SR = 91.8%) and 4 patients in the LIG lost 7 implants (SR = 82.9%), while in the mandible 2 patients in the SIG lost 1 implant each (SR = 95.3%) and 1 patient in the LIG lost 1 implant (SR = 97.8%). Felice et al. [29] reported 7 implants failures, 4 in SIG due to peri-implantitis (2 in the maxilla [SR = 94.8%] and 2 in the mandible [SR = 95.1%]) and 3 in the mandible LIG due to infected graft (SR = 93.6%). Nielsen et al. [32] is the only research that didn't reports any implant failure (SR = 100%). Guljé et al. [33] resulted in 3 implant failures, 2 in SIG (SR = 89.5%) and 1 in the LIG (SR = 90.9%). Thoma et al. [34] reported 2 failed implants (SR = 98.5%), both in the shorter implant group (Table 7).

Marginal bone loss

Regarding the MBL parameter, seven of the included clinical trials conducted analyses on the MBL measurements (Table 6). Felice et al. [30] reported that at 1 year, short implants showed an MBL of 1 (SD 0.36 mm, 95% CI = 0.87 to 1.14), which increased to 1.24 (SD 0.36 mm, 95% CI = 1.1 to 1.39) at 3 years, and further to 1.49 (SD 0.4 mm, 95% CI = 1.33 to 1.66) at 5 years, as detailed in Table 6. In comparison, longer implants had an initial MBL of 1 (SD 0.31 mm, 95% CI = 0.88 to 1.11), which escalated to 1.76 (SD 0.72 mm, 95% CI = 1.48 to 2.04) at 3 years and reached 2.34 (SD 0.75 mm, 95% CI = 2.02 to 2.65) at 5 years. A statistically significant difference in MBL was observed between the groups at the 5-year mark following the application of an analysis of covariance ($P < 0.05$). Bechara et al. [31] observed that short implants had an MBL of 0.146 mm (95% CI = 0.117 to 0.175) at 1 year and 0.201 mm (95% CI = 0.166 to 0.236) at 3 years. The LIG displayed an MBL of 0.21 mm (95% CI = 0.176 to 0.244) at 1 year and 0.273 mm (95% CI = 0.232 to 0.313) at 3 years, with significant differences in MBL noted between the groups after a 3-year follow-up ($P < 0.05$) (Table 7). Shah et al. [35] after a 1-year follow-up, found the average MBL to be 0.6 (SD 0.16) mm in the SIG and 0.86 (SD 0.2 mm) in the LIG, indicating not significant difference between the two groups ($P > 0.05$). Bolle et al. [36] reported in the mandible 4 months post loading MBL of 0.4 (SD 0.12) mm for the short implants and 0.52 (SD 0.1) mm for the longer ones. One year post loading the results were 0.51 (SD 0.16) mm in the SIG and 0.77 (SD 0.21) mm in the LIG having a statistically significant difference ($P < 0.05$). In the maxilla the result for the SIG were 0.47 (SD 0.12) mm, 4 months post-loading and 0.63 (SD 0.15) mm, 1 year after loading showing not statistically difference between the groups ($P > 0.05$). Felice et al. [29] presented their findings for both the maxilla and mandible, detailing MBL at intervals of 1, 3, and 5 years. For short implants in the maxilla, MBL was recorded as 1.02 (SD 0.06, 95% CI = 0.9 to 1.14) at 1 year, 1.28 (SD 0.37, 95% CI = 1.1 to 1.47) at 3 years, and 1.52 (SD 0.47, 95% CI = 1.26 to 1.77) at 5 years. Longer implants in the maxilla showed MBL of 1.09 (SD 0.05, 95% CI = 0.99 to 1.18) after 1 year, 1.5 (SD 0.37, 95% CI = 1.32 to 1.68) after 3 years, and 1.85 (SD 0.51, 95% CI = 1.58 to 2.12) after 5 years. For short implants in the mandible, the MBL was 1.05 (SD 0.06, 95% CI = 0.93 to 1.17) at 1 year, 1.25 (SD 0.35, 95% CI = 1.05 to 1.45) at 3 years, and 1.34 (SD 0.35, 95% CI = 1.11 to 1.56) at 5 years. Conversely, longer implants in the mandible recorded MBL of 1.07 (SD 0.06, 95% CI = 0.95 to 1.19) after 1 year, 1.54 (SD 0.14, 95% CI = 1.46 to 1.63) after 3 years, and 2.11 (SD 0.59, 95% CI = 1.73 to 2.48) after 5 years. Across these observations, the differences in MBL were statistically significant, with a P-value of less than 0.05. Nielsen et al. [32] reported 1 year follow-up were the mean MBL for the short implants was 0.28 (SD 0.17) mm and for the longer implants 0.26 (SD 0.14) mm showing not statistically difference between both groups ($P > 0.05$). Guljé et al. [33] after 1 year registered 0.11 (SE 0.09) mm for short implants and 0.02 (SE 0.1) mm for longer implants, after 5 years he reported 0.14 (SE 0.08) mm for short implants and 0.12 (SE 0.08) mm for longer implants, after 10 years the results were 0.18 (SE 0.1) mm for the SIG and 0.26 (SE 0.12) mm for the LIG. The differences were not statistically different between the groups ($P > 0.05$). Thoma et al. [34] reported the mean MBL after 10 years of follow-up resulting 0.36 (SD 0.76) for the short implants and 0.65 (SD 1.28) for the longer. There wasn't a statistically significant difference ($P > 0.05$) (Table 7).

Bleeding on probing

Only three studies showed information about the BOP (Table 7). Nielsen et al. [32] revealed that the evaluation for the short implants was 24% while for the longer implants was 22% showing not statistically significant difference ($P > 0.0.5$). Guljé et al. [33]

assessed BOP at several intervals following crown placement on dental implants. Initially, two weeks post-crown placement, the short implants exhibited no bleeding (0.0 [SD 0.1]) while the longer implants had minimal bleeding (0.4 [SD 0.1]). At a 12-month follow-up, short implants showed a slight increase in bleeding (0.3 [SD 0.1]), as did the longer implants (0.5 [SD 0.0]). This pattern was consistent at the 60-month evaluation, with short implants at a mean of 0.3 (SD 0.1) and longer implants at 0.5 (SD 0.1). The final evaluation conducted 120 weeks after crown placement, recorded bleeding scores of 0.4 (SD 0.1) for short implants and 0.6 (SD 0.1) for longer implants. Throughout these periods, the observed differences in bleeding between the short and LIGs did not reach statistical significance ($P > 0.05$). Thoma et al. [34] after a period of 10 years, an evaluation of BOP revealed that longer implants exhibited a 28.1% incidence of bleeding, whereas short implants showed a higher rate of 55.2%. Despite the apparent difference in bleeding rates between the two types of implants, statistical analysis indicated that this discrepancy was not significant ($P > 0.05$).

Periodontal pocket depth

Only three articles included measurements of PPD (Table 7). Nielsen et al. [32] found, one-year post-implant, an average PPD of 2.4 (SD 0.5) mm for short implants and 2.5 (SD 0.6) mm for longer implants, with the difference not reaching statistical significance ($P > 0.05$). After 120 months post-crown placement, Guljé et al. [33] observed a PPD of 2.8 (SE 0.2) mm for the SIG and 3.3 (SE 0.3) mm for the LIG, with this difference being statistically significant ($P < 0.05$). Thoma et al. [34] reported PPDs of 3.2 (SD 0.9) mm in the SIG and 3.4 (SD 1.5) mm in the LIG, indicating that the variation was not statistically significant ($P > 0.05$).

Implant stability quotient

Only two studies assessed a specific ISQ parameter (Table 7). Bechara et al. [31] observed that in the LIG, the ISQ value was 67.8 (95% CI = 67.4 to 68.2) at the time of implant placement, which rose to 72.4 (95% CI = 72 to 72.8) after three years. For the SIG, the initial ISQ measurement was 68.2 (95% CI = 67.9 to 68.6), which increased to 71.6 (95% CI = 71.2 to 71.9) over the same period, without showing a statistically significant difference ($P > 0.05$). Shah et al. [35] recorded baseline ISQ values and re-evaluated after three months, noting that the SIG's ISQ values changed from 67.9 (SD 8.3) to 70.17 (SD 7.4), while the LIG's values changed from 70.8 (SD 7.6) to 72.03 (SD 5.9), also without a significant statistical difference between the groups ($P > 0.05$).

Complications

For the complication parameter seven studies presented results, Bechara et al. [31] reported no complications within the SIG, whereas the LIG experienced 19 complications (Table 7). Specifically, 3 patients encountered intraoperative bleeding, 1 patient had pain and swelling, 14 patients suffered from swelling alone, and there was one instance of a chronic sinus infection leading to total graft loss (Table 7). The disparity in complication rates between the groups was statistically significant ($P < 0.05$). Felice et al. [30] observed a statistically significant difference in complication rates between the groups ($P < 0.05$), noting 6 complications in the SIG compared to 25 in the LIG. However, the specific nature of the complications within each group was not detailed by the authors. Shah et al. [35] didn't report any complication in the research. Bernardi et al. [28] noted that within the SIG, paraesthesia was observed in 3 patients. In contrast, the LIG reported complications including infection and paraesthesia across 22 patients, though the breakdown of each complication was not specified. The observed differences in complication rates between the groups reached statistical significance ($P < 0.05$). Bolle et al. [36] observed than in the mandible nine augmented patients suffered 11 complications versus two patients in the SIG were affected by 2 complications showing statistically significant difference ($P < 0.05$). In the maxilla 9 sinus lifted patients had 12 complications vs 4 SIG patients with 4 complications showing not statistically significant difference ($P > 0.05$). Felice et al. [29] reported that in the mandible, there were 14 complications among nine patients who received grafts, and 3 complications among three patients with short implants. In the maxilla, five grafted patients experienced five complications, compared to one patient who had two complications with short implants. The study found no statistically significant difference between the groups ($P > 0.05$). Nielsen et al. [32] categorized complications into biological and mechanical. In the case of biological complications, none were reported in the SIG, whereas the LIG experienced 11 complications, including three instances of Schneiderian membrane perforation and one case of permanent neurosensory disturbance, with these differences being statistically significant ($P < 0.05$). Regarding mechanical complications, the group

with short implants reported two instances, compared to six in the LIG; however, this difference did not reach statistical significance (P > 0.05). After a 10-year evaluation period, Guljé et al. [33] found that the incidence of peri-implant mucositis was 41.2% in the SIG compared to 30% in the LIG. While no cases of peri-implantitis were observed in the group with short implants, a 10% incidence rate of peri-implantitis was reported in the group with longer implants. Thoma et al. [34] observed that peri-implant mucositis affected 53.3% of the SIG and 45.5% of the LIG. Additionally, peri-implantitis occurred in 3.3% of cases involving short implants, in contrast to 16.3% for those with longer implants. In examining the outcomes related to complications in the research conducted by Guljé et al. [33] and Thoma et al. [34], it is noted that neither study provides specific P-values associated with these outcomes (Table 7).

Meta-analysis

The forest plot in Figure 2 displays the effect sizes of eight studies on marginal bone loss (MBL), with an overall effect size of -0.51 (95% CI = -0.93 to -0.1, P = 0.02) using a random-effects model. Significant heterogeneity is present (I^2 = 87%, P = 0.00). Each blue square represents an individual study's effect size, with horizontal lines indicating the 95% CI. The overall effect size estimate is shown as a diamond. The plot indicates variability among the studies, with the combined effect suggesting a moderate negative effect.

Figure 3 shows the forest plot of the effect sizes of three studies on periodontal pocket depth, with an overall effect size of -0.25 (95% CI = -0.52 to 0.02, P = 0.07) using a random-effects model. There is no significant heterogeneity (I^2 = 0%, P = 0.7), indicating consistent findings across studies.

DISCUSSION

This systematic review and meta-analysis assess the clinical performance and effectiveness of short dental implants compared to longer implants that necessitate alveolar bone augmentation. The study specifically evaluates primary outcomes such as SR, MBL, and the incidence of complications. Notably, short implants tend to have higher SRs in the mandible due to better bone density, whereas longer implants may perform better in the maxilla where bone density is typically poorer. These findings are pivotal in addressing the debate within dental implantology regarding the optimal implant length for maximizing functional efficacy and patient satisfaction.

The SR from the data collected ranged from 81.4% [30] to 100% [32] for the short implants and 80% [30] to 100% [32] in the longer implants. Nielsen et al. [32] reported 100% SR in both groups however, the interpretations of these results should be approached with caution due to the limited sample sizes, with only 20 short implants placed and 17 longer implants. Concerns regarding the use of short dental implants often focus on the crown-to-implant ratio,

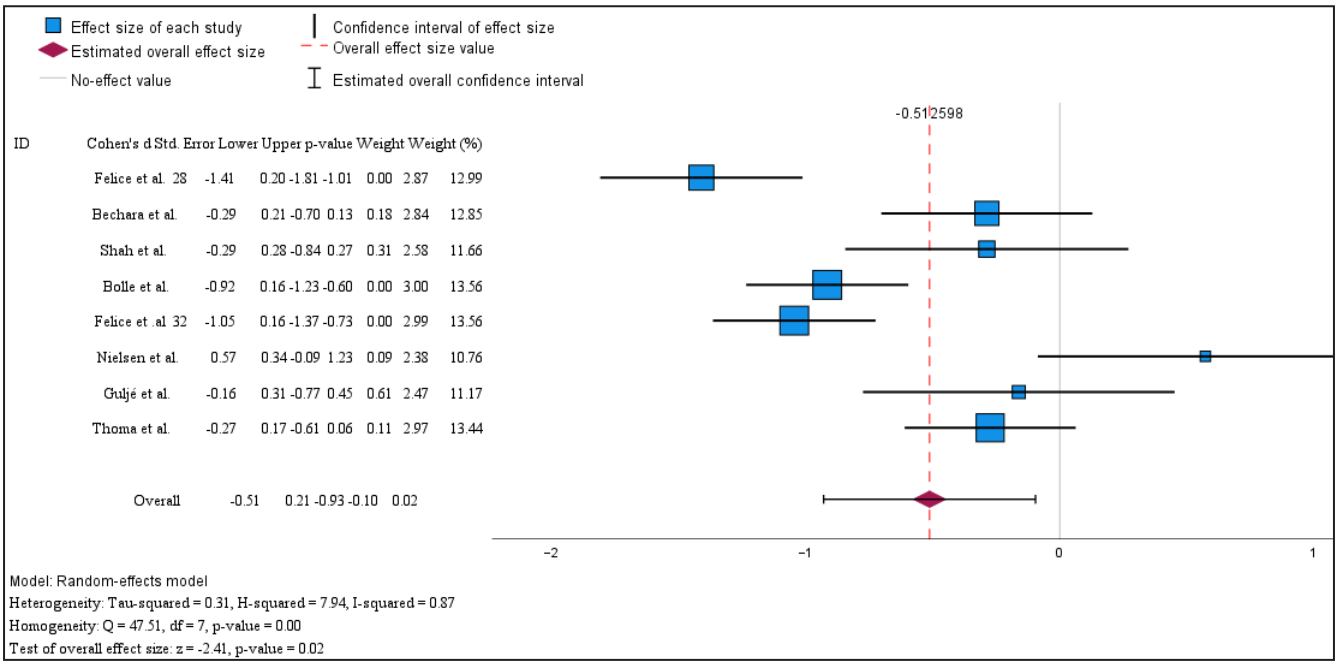

Figure 2. The forest plot displays the effect sizes of eight studies on marginal bone loss (MBL), with an overall effect size of -0.51 (95% CI = -0.93 to -0.1, P = 0.02) using a random-effects model.

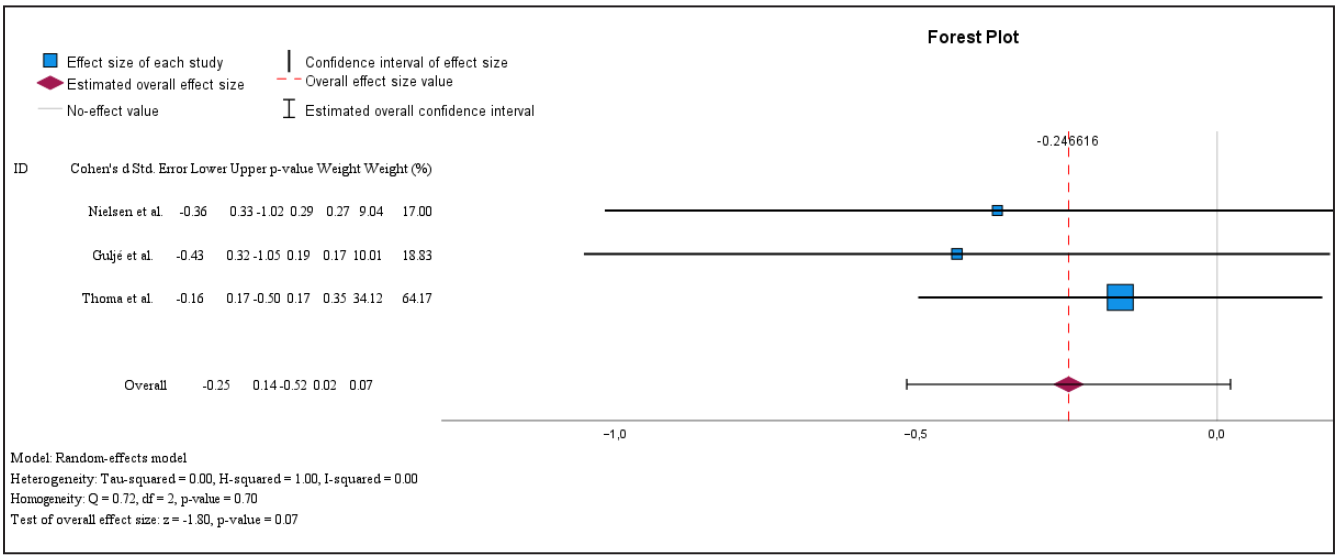

Figure 3. The forest plot shows the effect sizes of three studies on periodontal pocket depth, with an overall effect size of -0.25 (95% CI = -0.52 to 0.02, P = 0.07) using a random-effects model.

largely due to beliefs rooted in Ante's law. However, it is critical to recognize that implants differ fundamentally from natural teeth, notably in their lack of a periodontal ligament. Research by Nedir et al. [37] involving a 7-year life table analysis of both long and short rough-surface implants with varying crown-to-implant ratios revealed a high cumulative success rate of 99.4%. Their findings indicated that short implants were not at a higher risk of failure compared to longer ones, even though they exhibited greater crown-to-implant ratios. Similarly, a retrospective study by Schulte et al. [38] which assessed the crown-to-root ratios of 889 implants with ratios ranging from 0.5 : 1 to 3 : 1, concluded that the traditional guidelines applicable to the crown-to-root ratios of natural tooth single crown restorations do not correlate with the crown-to-implant ratios in single implant restorations. These studies collectively suggest that the traditional concerns regarding crown-to-implant ratios may be less critical in implantology than previously assumed. It was not possible to conduct a meta-analysis on the SR data due to the absence of information about confidence intervals and standard deviations in the studies included.

MBL was assessed as a primary outcome, revealing that the research results showed notable differences between the two groups. Albrektsson and Isidor [39] posited that an implant can be considered successful if it exhibits less than 1.5 mm of bone loss during the first-year post-functional loading, followed by annual bone loss of less than 0.2 mm. This indicates that some degree of MBL is inevitable. Early manifestations of MBL represent an adaptive, non-infective response influenced by various factors. Surgical elements such as trauma, overheating of the bone, excessive implant tightening, and crestal width are contributory. Prosthetic factors also play a role, including occlusal overload, implant design, the presence of a microgap, abutment height, and the biological response to residual cement [40-42]. Galindo-Moreno et al. [43] discovered that initial MBL of 0.44 mm at six months post-loading was a strong predictor of further MBL exceeding 2 mm by 18 months. Consequently, the six-month measurement could serve as a reliable indicator for forecasting long-term bone loss. Despite the inevitability of MBL, certain methodologies can mitigate its extent. Research conducted by Lee et al. [44] demonstrates that implants with taller prosthetic abutments are associated with reduced MBL. It is advised that the height of the abutment be maintained at or below 4 mm to minimize bone loss. Furthermore, the adoption of Morse taper connection implants has been validated as an effective strategy for the rehabilitation of both partially and completely edentulous arches, as noted by Mangano et al. [45]. The elimination of the implant-abutment interface, or microgap, correlates with minimal crestal bone loss. Additionally, the high mechanical stability provided by this design substantially decreases the likelihood of prosthetic complications, enhancing the overall efficacy of the treatment. The meta-analysis demonstrated a statistically significant difference between the groups (SMD = -0.513 mm, 95% CI = -0.93 to -0.096; df = 7; Q = 0.4751; P = 0.02).

The adoption of short dental implants has been primarily driven by the need to address limited bone volume and specific anatomical limitations that prevent the placement of standard implants. To manage these challenges, advanced surgical

procedures such as bone augmentation and nerve transposition have been developed. Despite their potential benefits, these procedures carry inherent risks and complications which are critical to consider in treatment planning. Felice et al. [33] note that bone augmentation techniques are technically more complex than the placement of short implants, and had increased postoperative morbidity, a higher rate of complications, extended treatment times, and the necessity for additional surgeries. Similarly, Bolle et al. [32] highlight the technical challenges, particularly in rehabilitating the posterior mandible with interpositional bone grafts, where in 30% of cases, the necessary bone height to place implants of at least 10 mm was not achieved. Furthermore, the systematic review indicated that the LIGs undergoing bone grafting tended to experience more complications. This comparative analysis suggests significant considerations in choosing between straightforward short implant placements and the more invasive, albeit sometimes necessary, bone augmentation procedures.

Regarding the evaluation of BOP and pocket depth (PD), only a few studies have reported data on these parameters. The existing evidence does not definitively conclude whether short or longer implants are associated with higher, lower, or comparable levels of BOP or PD, primarily due to the small sample sizes of the studies involved. The meta-analysis, which included three studies on probing pocket depth (PPD), found no statistically significant difference between both groups (SMD = -0.247, 95% CI = -0.515 to 0.022; df = 2; Q = 0.72; P = 0.07).

A multitude of research has assessed the clinical effects of short versus longer dental implants, particularly in scenarios involving bone augmentation. In their systematic review and meta-analysis, Bitinas and Bardijevskyt [46] scrutinized the clinical performance of both short and longer implants. They observed significant differences in outcomes such as implant failure rates, MBL, and complication rates among the groups. Their findings suggest that short dental implants could be a viable option compared to standard-length implants following bone augmentation, potentially offering a reduced risk of complications due to the elimination of the need for bone augmentation.

Overall, it is evident that both short and longer dental implants have their respective merits and drawbacks. Short implants are advantageous due to less invasive procedures and reduced need for bone augmentation, making them a practical choice for areas with limited bone volume. On the other hand, longer implants, typically used in conjunction with bone augmentation, are traditionally favoured in cases requiring deeper anchorage in the jawbone. When selecting the appropriate implant length, it is crucial to consider the specific anatomical and clinical needs of the patient, as well as the dentist's expertise with each implant type. The decision should be tailored on a case-by-case basis, factoring in the patient's anatomical constraints, clinical requirements, and overall health profile. While the clinical outcomes of short and longer implants might be comparable in various contexts, each type offers unique benefits and limitations. Thus, a detailed discussion between the dentist and the patient is essential to determine the most suitable implant length for the patient's particular situation.

CONCLUSIONS

1. Longer implants with bone augmentation had lowest survival rate compared to short implants.
2. Marginal bone loss has the highest result in the longer implants.
3. More complications were reported in the longer implants than in the short ones.
4. Longer implants have better result than shorter in bleeding on probing and periodontal pocket depth.

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The authors report no conflict of interest related to this study.

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