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Comparative analysis between extra-short implants (≤6 mm) and 6 mm-longer implants: a meta-analysis of randomized controlled trial

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ABSTRACT

The goal of this systematic study was to compare the survival rate (SR), marginal bone loss (MBL) and clinical complications between extra-short implants (≤6 mm) and 6-mm-longer implants in randomized clinical trials. A systematic electronic and manual search was performed using the PubMed, Web of Science, Scopus and DOAJ databases. A meta-analysis was conducted to compare the SR and MBL between both groups. We have selected 17 studies out of 1016 articles for qualitative and quantitative analysis. The data from 956 patients and 1779 implants were used with an overall mean clinical follow-up of 3.88 years ranging from 1 to 8 years. Overall, the SR of extra-short implants (93.12%) was lower than the observed in 6-mm-longer implants (95.98%); however, there was no statistical significance on these findings ($P > 0.10$). MBL analysis showed that extra-short implants and the 6-mm-longer group presented an average of −0.71 and −0.92 mm after 1-year respectively. Three years follow-up showed MBL of −0.42 mm (≤6 mm) and −0.43 mm (>6 mm); 5 years follow-up showed an MBL of −0.69 mm (≤6 mm) and −0.46 mm (>6 mm); and after 8 years of follow-up, it was found an MBL of −1.58 mm (≤6 mm) and −2.46 mm (>6 mm). Within the limitation of this study, the results indicated that SR of extra-short implants was similar to 6-mm-longer implants. In contrast, MBL and the presence of clinical complications were observed at a lessened rate on extra-short implants.

Keywords: Bone augmentation, dental implants, extra-short implants, sinus lift.

Abbreviations and acronyms: BIC = bone-to-implant contact; BOP = bleeding on probing; MBL = marginal bone loss; PD = probing in-depth; RCTs = randomized controlled trial.

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INTRODUCTION

The number of dental implants placed in recent years has indiscriminately increased due to the growing demand for oral rehabilitation. Such demand for oral rehabilitation is driven by the overall impact of oral health on quality of life, aesthetic, masticatory function, self-esteem and speech.[1]

Nevertheless, oral rehabilitation may be halted by tooth loss that takes place upon tooth extraction/loss. Furthermore, compromised periodontal apparatus results in bone ridge reduction, directly impacting the patient's horizontal and vertical dimensions of the patient.[2] It is estimated that two-thirds of the local tissue changes occur in the first 3 months,[3] with faster alveolar resorption observed in 6 months.[4,5] Beyond alveolar resorption, up to 50% of the crestal cortical thickness may be lost within 12 months (average of 6.1 mm of bone loss),[3] following a sequential average bone loss between 0.5% and 1.0% per year for the entire life.[6,7] A long-term study concluded that the alveolar bone dimensions reduce between 40% and 60% in height and width between 2 and 3 years after extraction.[7,8]

Bone loss constitutes an emerging issue in oral rehabilitation as it limits the repertoire of alternative treatments. This is the case of implant placement that requires the presence of good bone quality and quantity to achieve implant stability. Reduced bone mass leads to complex surgeries, such as vertical[9] and horizontal bone regenerations or sinus lift.[10] Even though systematic studies demonstrated high predictable and success rates[11] in the concomitant treatment of sinus

PROSPERO International Prospective Register of Systematic Reviews (CRD42021234135).

lift with immediate dental implant placement,[12,13] and mandibular ridge augmentation,[9,14] patients are often hit by an increased cost associated with complex surgical processes along with the increased risk of clinical complications and elevated chances of morbidity.[13,15]

Nonetheless, there are alternative strategies to manage patients presenting bone loss. Implementing extra-short implants (≤6 mm) for treatment[16,17] of sites with extremely limited bone dimensions that typically include the posterior regions of the maxilla and the mandible allow for less aggressive surgical procedures. Most importantly, the overall SR of extra-short implants are found to be similar to 6-mm-longer implants[11,12] after 12 months,[18,19] and even present a higher crown-to-implant (C-I) ratio, without overall impacting the marginal bone loss (MBL).[12,20] The use of extra-short implants reduced MBL compared with longer implants.[11,20] Moreover, extra-short implants had fewer biological complications[11,12] presenting predictable results[11] as demonstrated in a 3-year follow-up study.[21]

On the other hand, when analysed in the long term, Xu *et al*.[20] showed that extra-short implants (≤6 mm) had a poorer SR than implants greater than 6 mm ($P = 0.01$). Furthermore, there is a greater probability of complications, such as biological problems due to the C-I ratio, affecting the marginal bone level. Once the implant has already a very short length, it is raised the question involving SR in long term.[22]

Thus, after verifying some contradictions in the literature, this systematic review and meta-analysis aimed to compare extra-short implants (≤6 mm) and 6-mm-longer implants. Here we included all implants greater than 6 mm in the longer length group, differently from the systematic study published by Yu *et al*.,[23] who have chosen to exclude implants with 7-mm length. Moreover, these authors only include greater length implants when associated with bone augmentation procedures. Also, Malheiros Badaró *et al*.[24] reported only failures involving extra-short implants, one of the items (SR) observed in this study. The goal of this systemic review was to evaluate the SR, MBL and clinical complications comparing extra-short implants and long implants, thereby guiding clinicians on the selection of implants.

MATERIALS AND METHODS

Study registration and design

The review protocol was registered in the PROSPERO International Prospective Register of Systematic Reviews (CRD42021234135). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[25] were used to summarize and describe the search process results.

Focus question and PICOS strategy

The focussed question was elaborated following the PICOS format,[26] as follows: 'In healthy patients treated with dental implants (P), extra-short (≤6 mm) implants (I) when compared to 6-mm-longer implants (C) have better performance (O) (greater survival rate (SR) and reduced MBL and peri-implantitis/mucositis, in randomized controlled trials (RCTs)?'

Patients (P): Patients receiving one extra (super)-short dental implant (≤6 mm) with follow-up for at least 6 months; **Intervention (I)**: Extra-short (≤6 mm) dental implant placement in mandible and/or maxilla; **Comparison (C)**: Dental implant longer than 6 mm placed in the mandible and/or maxilla; **Outcome (O)**: Implant SR and MBL between the extra-short implant and in longer than 6 mm; **Study (S)**: RCTs.

Databases and search strategy

Two independent reviewers (G.V.O.F. and B.M.G.N.C.) conducted the searches on the literature, in duplicate, which were restricted to the English language and limited from January 01st, 2010 to August 31st, 2021. Four databases were accessed to perform a systematic search (PubMed/MEDLINE, Scopus, Web of Science and Directory of Open Access Journals—DOAJ), using the following search terms (short-implant[All fields] OR "dental implant"[All fields] OR "extra-short"[All fields] OR "extra short"[All fields] OR "super-short"[All fields] OR "super short"[All fields] OR "6 mm"[All fields] OR 6 mm [All fields]) AND ("survival rate*"[All fields]) AND ("randomized controlled trial"[All fields] OR RCT[All fields] OR "randomized clinical trial"[All fields]). Moreover, an additional manual search was performed on the references of included articles and Periodontics- and Implantology-related journals (*Journal of Periodontology, International Journal of Periodontics & Restorative Dentistry, Clinical Oral Implant Research, Journal of Clinical Periodontology, European Journal of Oral Implantology; The International Journal of Oral & Maxillofacial Implants*) to identify relevant publications.

Inclusion and exclusion criteria

Studies followed specific criteria of eligibility. Inclusion criteria: (i) RCTs involving at least one extra- or super-short (≤6 mm) implant for the test group and longer implant (>6 mm) in the control group; (ii) studies with a minimum follow-up of 6 months; (iii) the implants were restored with a fixed prosthesis; (iv) the article must have results involving at least one of the following parameters: SR, MBL, and/or peri-implantitis/mucositis. Only articles with the longest

follow-up were included in the case of multiple studies involving the same patient cohort (population).

The exclusion criteria comprised (i) studies with a follow-up <6 months after prosthetic loading; (ii) reports based on questionnaires, interviews, case reports/series, editorial letter, letter to the editor, systematic reviews; (iii) preclinical animal studies or laboratory study.

Risk of bias and qualitative assessment

The risk of bias and the methodological quality of the included RCTs were performed independently by two reviewers (G.V.O.F. and B.M.G.N.C.), through the Cochrane Risk of Bias Tool for Randomized Controlled Trials[27] focusing on the following issues: (i) Random sequence generation, (ii) Allocation concealment, (iii) Blinding of participants and personnel, (iv) Blinding of outcome assessment, (v) Incomplete outcome data, (vi) Selective reporting and (vii) Other bias. The potential risk of bias was considered low when a study provided detailed data on all parameters; a study was considered to have a moderate risk when it failed to provide information of one or two domains; however, when a study lacked information regarding ≥3 parameters, it was outlined with a high risk of bias.

Data extraction and Statistical analysis

Data from the included studies were collected by two independent reviewers (G.V.O.F. and B.M.G.N.C.), in duplicate, using a data extraction table (Excel, Microsoft Office®, 2019, Redmond, Washington, DC, USA). Duplicate studies were excluded, and the remaining articles were screened initially by title and abstract for eligibility. Further examination regarding inclusion and exclusion criteria was subsequently made by full-text analysis. The full text of any title or abstract that did not provide enough information regarding the criteria was also obtained. In case of doubts in data collection, a third reviewer (J.C.H.F.) was involved in reaching a common agreement. Cohen's kappa test was adopted to evaluate reviewers' agreement for all selections.

Cumulative implant survival rates (%) and peri-implant MBL (mm) were collected as primary outcome variables, and the period (years) was inserted as a moderator in the statistical analysis. Secondarily, the following parameters were obtained: author(s), year of publication and study design (RCT); average period of evaluation; the number of patients and implants at the initial stage of the research, site of the implant placement (maxilla/mandible), the mean age of patients and age range; implant length; use of bone augmentation procedure; the last period of follow-up; the number of patients and implant dropouts, number of early and late implant failure; biological complications were analysed at the patient level from the report found, the influence of clinical C-I ratio on the outcomes of extra-short implants and a total percentage of smokers and the impact on the outcome.

The data were transferred to SPSS Statistical software (IBM®, v. 25.0, IBM Corp ©, Chicago, IL, USA) to verify the reliability statistics intergroup, the inter-item correlation matrix and the within-patient correlation coefficient to verify whether exist poor reliability (values from 0 up to 0.5), moderate reliability (between 0.5 and 0.75), good reliability (between 0.75 and 0.9), or indicates excellent reliability (any value above 0.9), according to Koo and Li.[28] Also, the meta-analysis involved the comparison of the data obtained for the MBL and implant survival rate. All analysis used a fixed effect model at a 5% significance level. A funnel plot was drawn to assess publication bias, and for studies outside the confidence interval area may indicate possible publication bias. Heterogeneity across the studies was quantified using the I^2 inconsistency test, which ranges between 0% and 100%, with lower values representing less heterogeneity, and values above 75% were considered an indication of substantial heterogeneity. Additionally, the probability of publication bias and heterogeneity was assessed through the funnel plots.

RESULTS

Study selection, characteristics, quality assessment and risk of bias

The selection of the studies is described in the flow diagram (Fig. 1), which found 1016 articles in all databases proposed. After removing the duplicated articles, it was found that 694 were analysed only by title. Afterwards, 142 abstracts were read, and 108 articles were excluded ($k_1 = 0.98$), passing 34 articles for full-text reading. Then, it was excluded 17 articles after reading, with justification described in Fig. 1. Then, 17 studies were included for analysis,[29–45] all RCT studies following the inclusion/exclusion criteria, published between 2010 and 2021 ($k_2 = 0.94$). All of them were included in the meta-analysis to evaluate the implant SR and assess MBL; only Bernardi *et al.*[34] study did not report MBL data and was not included in the statistical analysis.

The within-patient correlation coefficient found for the average measure was 0.813 (95% confidence interval (0.300–0.942)), using a two-way random-effects model where both individuals' effects and measures effects are random, and type-A intraclass correlation coefficients using an absolute agreement definition, which showed good reliability between the

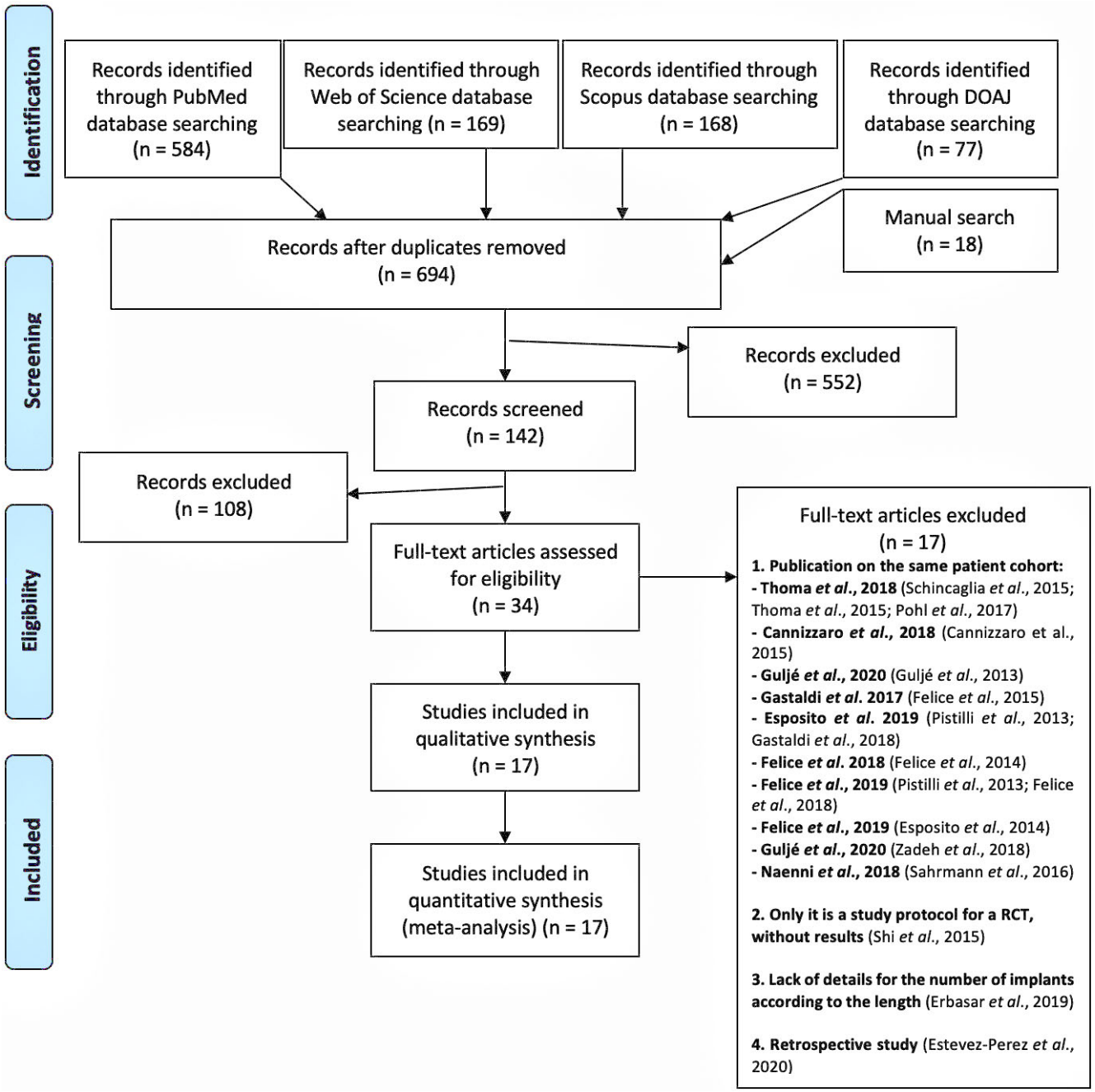


Fig. 1 Flow diagram for the search strategy and selection process for the included studies.

studies' data included. Also, the reliability statistics intergroup found was 0.868 for Cronbach's alpha and 0.869 for Cronbach's alpha based on standardized items, and the inter-item correlation matrix was 0.768 (between groups).

Moreover, the studies included a total of 956 patients (43.52% men and 56.48% women) which 475 patients received implants longer than 6 mm, and 481 patients were included in the extra-short group (≤6 mm), with a mean age of 55.20 (range: 21–80) years that were treated with and 1779 implants (900 longer than 6 mm and 879 extra-short), with an overall mean observation period of 3.88 years (between 1 and 8 years). The total dropout was 98 patients, but five studies[31,32,34,37,42] did not report it. It should be highlighted that the only study with more than 5-year follow-up was observed in Felice *et al.*'s study[44] (8 years). The implants were reported in 10 studies,[31,32,34–37,40,41,43,45] and these were distributed for mandible (602 implants) and maxilla (430 implants). The number of dropouts was 98 (10.25%), with a common justification that participants did not attend control visits, passed away, or moved to another place, or osseointegration failure. Five

studies[31,32,34] did not report any dropout. Seven out of 17 articles included were multicentre RCT.

Furthermore, all investigations described that the participants had a good healthy and accomplished direct comparison between 6-mm-longer implants and extra-short implants, sometimes named short implants. Nevertheless, Bolle and collaborators,[41] in their study design, considered initially to include two 6 mm implants in the longer-implant group. During the study, the authors considered including six implants of 4 mm (13%) and two implants of 6 mm (4.3%) in the 6-mm-longer implant group, justifying that there was not sufficient bone after vertical bone augmentation in the mandible to place the implants planned with 10 mm. Thus, there was a bias once a 6-mm-length implant was considered within the longer implant group.

Two[34,39] out of 17 articles did not register if there were smoker patients. However, 14 studies included this item, totalling 257 smokers (28.3%), and one study excluded smokers.[45] Four RCTs[30,32,33,40] stated the C-I ratio, using as reference the anatomic crown. Romeo *et al.*[40] reported the ratio in 1.64 ± 0.39 mm for the 6-mm-implant group and 1.02 ± 0.14 mm for the 10 mm-implant group, with statistical significance difference ($P < 0.001$). Thoma *et al.*[30] found the average ratio of 1.86 ± 0.23 for the test group and 0.99 ± 0.17 for the control group ($P < 0.001$). There were no statistical planning intergroups in Rossi *et al.*'s[32] study, which had a C-I ratio after 5 years of 1.55 (±0.39) for the test group and 0.97 (±0.21) for the control group; while Naenni *et al.*[33] analysed the median of the C-I ratio, which had 1.75 (IQR, 1.50–1.90) in the 6-mm group (test) and 1.04 (IQR, 0.95–1.15) in the 10-mm group (control), achieving a high statistical significance ($P < 0.001$).

Rossi *et al.*[32] was the most complete study when described the results, sorting the patients among bone type (I: 7, II: 24, III: 26, IV: 3), antagonist (opposite tooth) (44 natural, 14 ceramic, 1 acrylic and 1 metal), insertion torque (<15 = 29; 15 < × < 35 = 18; ≥35 = 13), and C-I ratio. Also, Cannizzaro *et al.*[36] reported the amount of quality bone found for the mandible, divided into hard bone quality (88), medium bone quality (32), soft bone quality (2) and immediate implant (post-extraction): 10 implants (16%, 7 patients); and for maxilla, respectively, hard (43), medium (121), soft (17) and immediate implant (post-extraction): 13 long (13%, 7 patients).

Gastaldi *et al.*[37] analysed the patient satisfaction 3 years after loading, and all patients treated with extra-short implants were completely satisfied. Otherwise, when compared with the 6-mm-longer group, seven patients completely and three partially were satisfied ($P = 0.067$), therefore, without statistical significance. On this hand, Felice *et al.*[43] also evaluated the satisfaction, and all individuals preferred extra-short implants compared to longer implants suffering bone augmentation ($P < 0.0001$).

Esposito *et al.*,[38] in 2019, published a RCT and detailed the torque of implant placement when torque was lower than 25 Ncm for longer implants (mandible = 6 (19%) and maxilla = 8 (22%) in 5 patients); and for extra-short implants (mandible = 1 (3%) and maxilla = 3 (8%), 3 patients). Likewise, Bolle *et al.*[41] described the torque when <25 Ncm, for longer group: mandible = 2 (10%) and maxilla = 11 (26.8%); extra-short group: mandible = 6 (14%) and maxilla = 11 (29.7%)). Felice *et al.*[43] also reported when the torque was ≤25 Ncm, finding it in 10 patients (16 longer implants) and in 14 patients (15 short implants).

Three articles assessed the resonance frequency analysis. Shah *et al.*[31] had as the outcome no significant difference between test and control group, either at baseline or 12 weeks. Likewise, Magdy *et al.*[45] also did not show a significant difference between the two treatment groups. Already Bechara *et al.*[42] evaluated the ISQ after 3 years. The changes from placement encountered for the test group at baseline the average was 68.2 ISQ (67.9–68.6) and after 3 years 71.6 ISQ (71.2–71.9); and for the control, at baseline, the mean was 67.8 ISQ (67.4–68.2) and after 3 years 72.4 ISQ (72.0–72.8).

From 17 studies, five[31,35,41,43,44] aimed to establish the control group with vertical bone augmentation, three[30,37,42] standardized the control associated with sinus lift procedure and one[34] accomplished alveolar ridge augmentation with osteogenic distraction, providing information about the bone grafting material adopted. Only one study[38] applied a modified implant surface with nanostructured calcium-incorporated titanium. Table 1 summarizes all data obtained.

According to the recommendations of the Cochran Handbook for Systematic Reviews of Interventions, the risk of bias of the RCTs included are summarized in Fig. S1. Ten articles had moderate risk[29,32–35,37,40,43–45] and seven had high risk of bias.[30,31,36,38,39,41,42]

Cumulative implant survival rate (SR) and implant failure

All 17 publications provided the cumulative implant survival rate (Table 1). Implant survival was defined as implants remaining *in situ* during the observation period, irrespective of their conditions. The survival rate is derived from the data of the included articles. From 1779 implants placed in 956 patients, the studies reported total failure of 97 implants (5.45%) due to peri-implantitis, loss of osseointegration, mobility, either before the crown installation or after rehabilitation (provisional or definitive crown). The overall

Table 1. Data from the included studies

Author	Year	Patients extra-short	Patients longer implants	Mean age (year)	Gender	n implants extra-short	n implants (>6 mm)	Survival rate extra-short (%)	Survival rate >6 mm (%)	MBL extra-short (SD), mm	MBL >6 mm (SD), mm
Guida *et al.*[29]	3	15	15	63 (±7.5 years)	17M:13F	75	75	100	100	−0.1 (0.24)	−0.02 (0.25)
Thoma *et al.*[30]	5	44	46	50.4 (20–77 years)	49M:52F	60	64	98	100	−0.54 (0.87)	−0.46 (1.0)
Shah *et al.*[31]	1	25	25	58.4 (±11.6) [32–87 years]	19M:31F	21	24	84	96	−0.97 (0.7)	−0.96 (1.2)
Rossi *et al.*[32]	5	30	30	48 (30–74 years)	24M:21F	26	29	86.7	96.7	−0.52 (0.03)	−0.54 (0.14)
Naenni *et al.*[33]	5	33	45	58.2 (±12.8 years)	39M:47F	40	46	91	100	−0.29 (0.69)	−0.15 (0.52)
Bernardi *et al.*[34]	1	18	18	62 (43–77 years)	18M:18F	86	84	94.19	84.52	NR	NR
Felice *et al.*[35] (A)	5	30	30	56 (37–70 years)	13M:17F	56	57	83.33	93.33	−1.49 (0.59)	−1.92 (0.56)
Cannizzaro *et al.*[36]	5	26	26	59.77 (±9.32 years) [38–80 years]	18M:42F	23	21	92.26	88.46	−0.26 (0.22)	−0.86 (0.39)
Gastaldi *et al.*[37]	3	10	10	56 (43–70 years)	8M:12F	16	18	100	100	−0.89 (0.25)	−1.08 (0.29)
Esposito *et al.*[38]	5	40	40	57.75 (39–80 years)	25M:55F	61	59	96.72	94.91	−1.23 (0.3)	−1.71 (0.4)
Guljé *et al.*[39]	5	46	39	54.5 (±9.5) [26–70 years]	48M:47F	100	87	96	98.9	0.01 (0.45)	−0.12 (0.93)
Romeo *et al.*[40]	5	9	9	53 (32–75 years)	12M:12F	26	28	90	100	−0.43 (0.34)	−0.24 (0.45)
Bolle *et al.*[41]	1	40	40	59.94 (36–77 years)	38M:42F	80	87	94.97	94.03	−0.57 (0.16)	−0.75 (0.23)
Bechara *et al.*[42]	3	33	20	48.1 (±15.1 years) [21–76 years]	19M:34F	45	45	100	95.6	−0.273 (0.078)	−0.201 (0.07)
Felice *et al.*[43] (B)	5	28	28	55.85 (42–80 years)	21M:19F	80	91	97.49	98.93	−1.44 (0.43)	−2.46 (0.8)
Felice *et al.*[44] (C)	8	30	30	55.5 (40–83 years)	22M:38F	60	61	90.9	94.44	−1.58 (0.46)	−1.96 (0.55)
Magdy *et al.* (2021)	1	24	24	42 (±9.7 years), 25–55 years	8M:40F	24	24	87.5	95.83	−0.81 (0.60)	−1.28 (0.62)

Smoker	Control (adjuvant surgical procedure)	Aim	Conclusion
Habitual: Heavy smokers (≥10 cig./day) = 7 Former smokers: 4	No	6-mm-short with 11-mm-long implants in the rehabilitation of totally edentulous mandible in a completely comparable clinical situation	6-mm-short implants may be a reliable option when used in the rehabilitation of total edentulous mandibles
Ex-smoker: 25 Occasional: 7 Habitual: 14	Sinus grafting	Extra-short implants and standard-length implants (11–15 mm) placed in combination with bone grafting	• Both treatment modalities were suitable for implant therapy in the atrophied posterior maxilla • No differences in terms of SR, MBL, patient-reported outcomes and biological complications
Current smoker: 3 Former smoker: 11	Vertical bone augmentation	Extra-short (6 mm) vs. standard implants (10 mm) placed with concomitant vertical bone augmentation	• Extra-short implants may offer an alternative for implant placement in an atrophic jaw • Extra-short implants should be used judiciously considering this potential predicament and alternatives assessed
Test group: 6 smokers Control group: 7 smokers	No	6-mm vs. 10-mm-long implants (SLA®) loaded within 7 weeks supporting single crowns in the posterior regions	• 6-mm-long implants supporting single crowns had a small MBL similar to that of 10-mm-long implants • There was more implant loss in the extra-short implants group
6 mm group: n = 11 (10–20 cig./day) 10 mm group: n = 10 (10–20 cig./day)	No	6 mm implants in the posterior jaw vs. 10 mm implants	6-mm single implants as a reasonable alternative to implants of standard length
NR	Vertical bone augmentation (osteogenic distraction)	6 mm implants vs. normal length implants placed in the vertical augmented atrophic posterior mandible	Extra-short implants can be the preferred choice to vertical bone augmentation for the placement of longer implants in the rehabilitation of edentulous posterior mandibles
mandible: 3 moderate maxilla: 2 moderate + 1 heavy	Maxillary sinus (particulate porcine bone via a lateral window) and Vertically augmented with interpositional equine bone blocks and resorbable barriers	6-mm-long implants vs. 10-mm-long implants placed in bone augmented with bone substitutes in posterior atrophic jaws	• 6-mm-long implants achieved similar results to longer implants placed in augmented bone • Short implants might be a preferable choice to bone augmentation, especially in posterior mandibles since the treatment was faster, cheaper and associated with less morbidity

(continued)

Table 1 (continued)

Smoker	Control (adjuvant surgical procedure)	Aim	Conclusion
mandible: Short = 6 (40%), 2 more than 10 cig. (13%); Long = 5 (33%), 2 more than 10 cig. (13%) maxilla: Short = 3 (20%), 1 more than 10 cig. (7%); Long = 4 (26%), 1 more than 10 cig. (7%)	No	5-mm-long vs. 11.5-mm-long implants placed flapless and immediately restored	Flapless-placed 5-mm-long implants achieved similar results as 11.5 mm long implants both in maxillae and mandibles
long group: 5 (50%) moderate + 2 (20%) heavyshort group: 1 (10%) moderate + 3 (30%) heavy	Crestal sinus lifting (Summers' technique) and grafting with anorganic bovine bone	5 or 6-mm-long implants vs. 10 mm or longer implants placed in crestally lifted sinuses	No differences were observed between 5- or 6-mm implants vs. 10-mm long in the posterior atrophic maxilla
mandible: long group = 5 (25%) (<10 cig.), short group = 1 (5%) (<10 cig.) maxilla: long group 1 (5%), short group = 6 (30%)	Augmented with bone substitutes (maxillary sinus, vertically augmented with interpositional bovine bone blocks covered with resorbable barriers)	5 × 5 mm implants with a *novel nanostructured calcium-incorporated titanium surface* vs. ≥10-mm long placed in bone augmented with bone substitutes in posterior atrophic jaws	• 5 × 5 mm implants achieved similar results to longer implants placed in augmented bone • Extra-short implants might be a preferable choice to bone augmentation especially in posterior mandibles since the treatment is faster, cheaper and associated with less morbidity
NR	No	6-mm vs. 11-mm implants placed in the posterior maxilla and mandible	Clinical and radiographic outcomes of 6-mm short and 11-mm length implants were not different
short-group: 3 lightlong group: 5 light	No	6-mm vs. 10-mm-long implants in partially edentulous posterior areas	Implant survival and success rates were similar between 6-mm or 10-mm-long implants
Moderate (up to 10 cig./day): 11 (55% long; 5 (25%) short; Heavy: (>10 cig./day): 4 (20%)–long group; 1 (5%) short	• Mandibles vertically augmented with inter-positional equine bone blocks and resorbable barriers • Maxillary sinuses were augmented with particulated porcine bone via lateral and resorbable barriers	4.0 mm (extra-short) implants vs. augmentation (xenografts) in the maxilla and placement of at least 10.0 mm implants	• 4.0-mm-long implants had similar results, if not better, than longer implants • Extra-short implants might be a preferable choice over bone augmentation (mandibles), since the treatment is less invasive, faster, cheaper and associated with less morbidity
15 patients (28.3%) (7 test, 21.2%; 8 control, 40%)	SFE	Extra-short (6-mm) implants vs. SFE and placement of ≥10 mm implants in the posterior maxilla	• Similar results for 6-mm implants and ≥10-mm • Short implants might be preferable to SFE, because is faster and less expensive
2 moderates/3 heavy	Mandibles were vertically augmented with interpositional bone blocks and maxillary sinuses with particulate bone via a lateral window	5-mm-short implants vs. augmentation with anorganic bovine bone and placement of ≥10-mm-long implants in posterior atrophic mandible and maxilla	• 5-mm-short implants achieved similar results to longer implants in augmented bone • Short implants might be preferable to vertical bone augmentation since the treatment is faster and cheaper
23 patients (38.33%) (11 moderate control; 11 moderate and 1 heavy test)	Vertically augmented posterior mandibles	6.6-mm implants vs. longer implants placed in vertically augmented atrophic posterior mandibles	6.6-mm extra-short implants are an interesting alternative to vertical augmentation since the treatment is faster, cheaper and associated with less morbidity
Were excluded	SFE	Investigate whether single standing ultrashort dental implants (5.5 mm) could provide a viable therapeutic alternative to standard-length dental implants (10 mm) in posterior maxillary rehabilitation with reduced bone height	Ultrashort implants appear promising as they are associated with a lesser postoperative discomfort, minimal invasiveness and lesser MBL

MBL = marginal bone loss; n = number; SD = standard deviation; Cig. = cigarette; NR = not reported; SR = survival rate; SFE = sinus floor elevation.
Data were obtained from each included study.

mean SR was 93.12% for the extra-short group and 95.98% for the control group (Fig. 2), respectively, achieving 0% for I^2 in both $P = 0.522$ and 0.959. The funnel plot (Fig. S2) shows a similar standard for both groups with a low risk of publication bias.

Two studies did not find the difference for SR between the groups, which achieved 100% of SR.[29,37] Five other articles found a greater SR for the extra-short implants. The results were sorted decrescent, from the highest to the lowest difference obtained

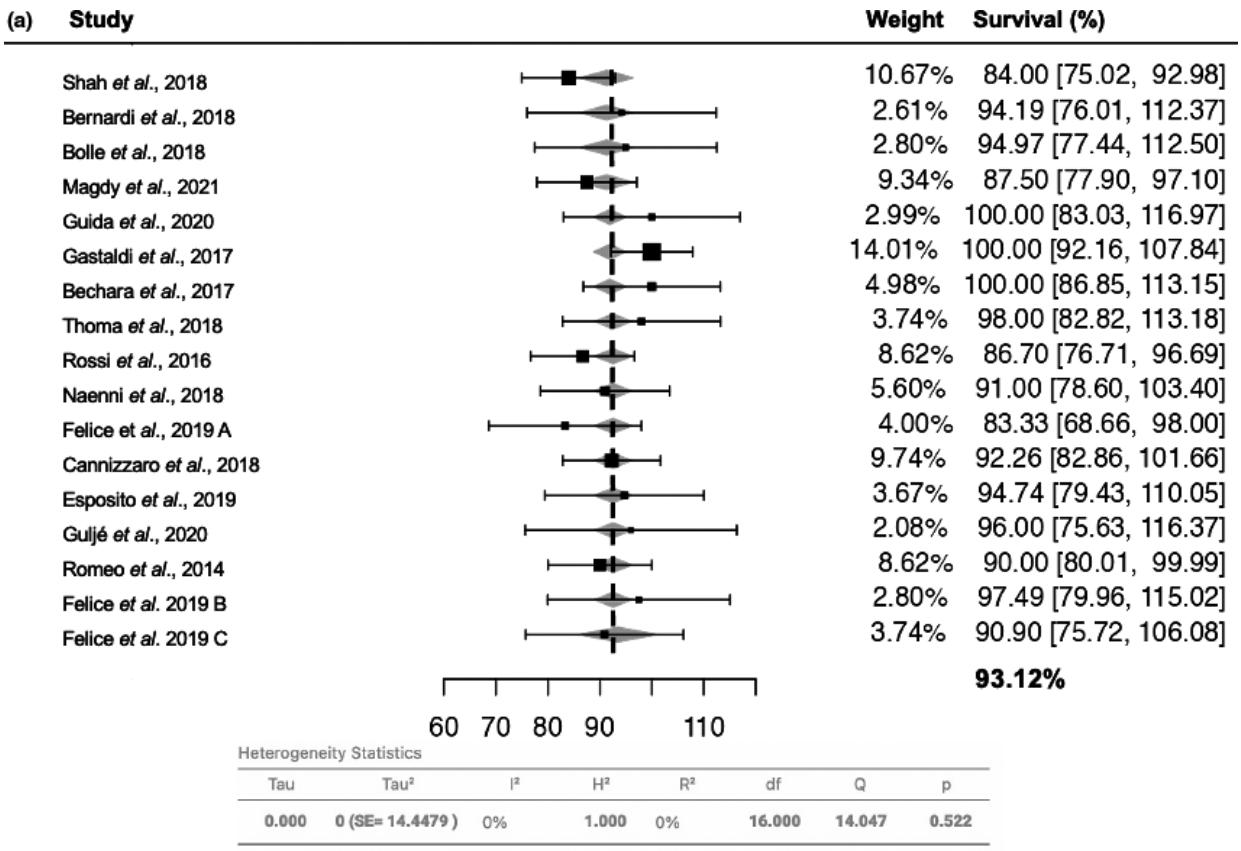


Fig. 2 Forest plot of the implant survival rate, comparing (a) survival rate of the extra-short implants with (b) survival rate of the longer than 6 mm-implants (FE Model: Fixed Effect Model).

between test and control group, respectively, 94.19% and 84.52%[34]; 100% and 95.6%[42]; 92.26% and 88.46%[36]; 96.72% and 94.91%[38]; and 94.97% and 94.03%.[41]

Ten studies, therefore, reported a higher SR for the control group (implants >6 mm). The comparison was organized according to the differences between groups. The lowest results and not significant statistically was found in four studies (test vs. control group), 1.44% (97.49% and 98.93%[43]), 2% (98% and 100%[30]), 2.9% (96% and 98.9%[39]), and 3.54% (90.9% and 94.44%[44]). Magdy *et al.*[45] found an 8.33% of the difference, with 87.5% for the ultra-short group vs. 95.83% for the standard-length group; Naenni *et al.*[33] obtained 9% of the difference for the SR (91% and 100%), whereas three studies had 10% as difference, Romeo *et al.*[40] with 90% SR for test group vs. 100% for long implant group; Rossi *et al.*[32] with 86.7% and 96.7%; and Felice *et al.*[35] with 83.33% and 93.33%.

The greatest SR (12% of difference) had an unfavourable result in the short term (after 1 year) for the extra-short implants, which was reported by Shah *et al.*,[31] with data for the extra-short group of 84% and longer implants of 96%. This study lost five implants (3 in the maxilla and 2 in the mandible) before the restoration, all in the posterior region (1 control and 4 test group), the fact that caused a lower SR in the extra-short implants group (84%) when compared to longer-implants group (96%).

Similar results also were found by Rossi *et al.*,[32] who had four implant losses in the extra-short group and one in control. The justification presented by the authors was related to two smoker patients (mean 49.25 years, test group), with bone type I (1), III (2) and IV (1), and three out of them reaching a low initial torque (<15 Ncm). In the control group, there was no smoker (mean age was 41 years), the bone status was type III and the initial torque was between 15 and 35 Ncm.

Naenni *et al.*[33] lost 4 implants only in the test group without any previous detectable radiographic peri-implant bone loss, where one patient was classified as a moderate smoker and two presented periodontitis. Bernardi *et al.*[34] obtained a better result for extra-short implants, with five implant losses due to lack of primary stability (n = 1) and infections (n = 4), compared to the control group had 13 implant losses also for lack of primary stability (n = 3) and site infection (n = 10).

Felice *et al.* (2019), in three studies published in the same year, reported (A)[35] two long implants failed vs. five for extra-short implants, where there were no statistically significant differences in implant failures ($P = 1.00$); (B)[43] there was implant failure of three in the longer implant group and four in the extra-short implant group; (C)[44] in the most significative long-term of evaluation (8 years), the authors obtained three implants failed in the longer implant group (3 patients) vs. five extra-short implants failure in three patients.

For Bechara and collaborators,[42] no implant failure occurred in the test group, whereas two implant failures were observed in the same patient of the control group, which was a 55-year-old male, smoker and with periodontal disease (2 months after surgery – there was no rehabilitation). In Cannizzaro *et al.*'s[36] study, three patients were involved with implant loss (6 extra-short implants), and three other patients lost four longer implants. However, there was no statistically significant difference.

For Esposito *et al.*,[38] 33 patients experienced complications. More patients had complications at maxillary augmented sites than in patients receiving extra-short implants, but the difference was not statistically significant, respectively, seven patients vs. two patients ($P = 0.128$). Three longer implants failed in the same patient vs. two extra-short implants (one in a patient who lost one extra-short implant 2 years after loading; and another failed with its provisional crown 3 months post-loading, this last one in the maxilla).

Comparing SR between both groups, there was no observed heterogeneity ($I^2 = 0\%$) with no statistical difference ($P = 1.000$) found (Fig. 3).

Peri-implant MBL

All the selected studies considered the distance between implant shoulder or base of abutment and most coronal level of bone-to-implant contact (BIC) on both mesial and distal surfaces as references for the MBL measurement. Excepting one article,[34] which did not report any marginal bone level, all other studies (n = 15) assessed this aspect and described the peri-implant MBL for all analysis periods (Table 1), normally performing periapical radiographs using the paralleling technique. Esposito *et al.*[38] reported that longer implants showed a greater MBL up to 5 years after loading than extra-short implants, both in the maxilla ($P = 0.024$) and in the mandibles ($P = 0.004$).

For the extra-short group, the overall mean of MBL encountered was −0.70 mm (±0.39 mm), whereas for the control group (>6 mm) was −0.64 mm (±0.52 mm). For 1-year follow-up, two studies[31,41] evaluated the mean MBL and the average found was −0.77 mm (±0.43 mm) for extra-short and −0.85 ± 0.71 mm for control group; three studies[29,37,42] assessed during 3 years and reported −0.42 mm (±0.19 mm) and −0.43 ± 0.20 mm respectively; for 5 years, nine articles[30,32–36,38–40,43] were considered and the average for MBL found was −0.69 mm (±0.44 mm) for test group and

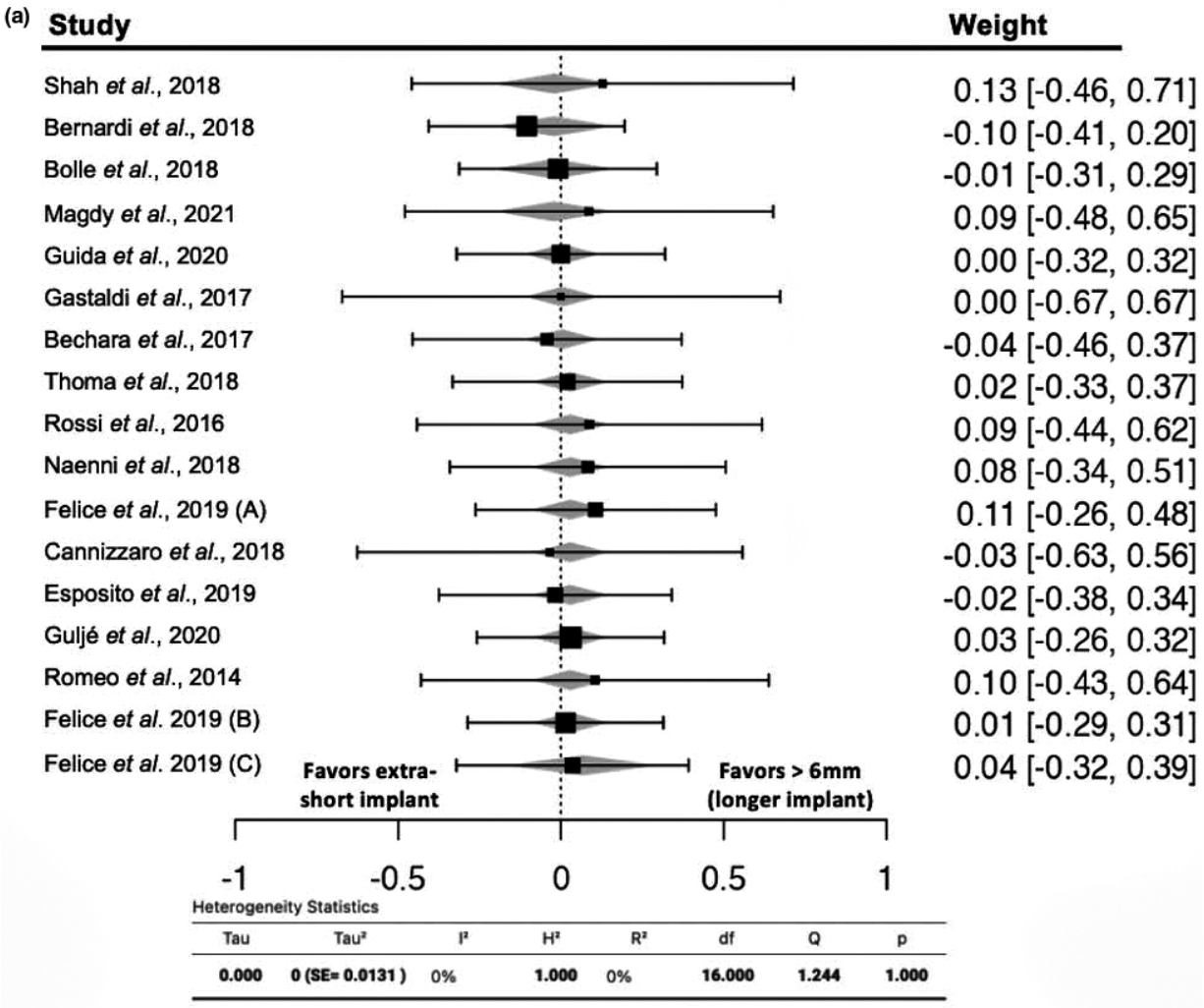
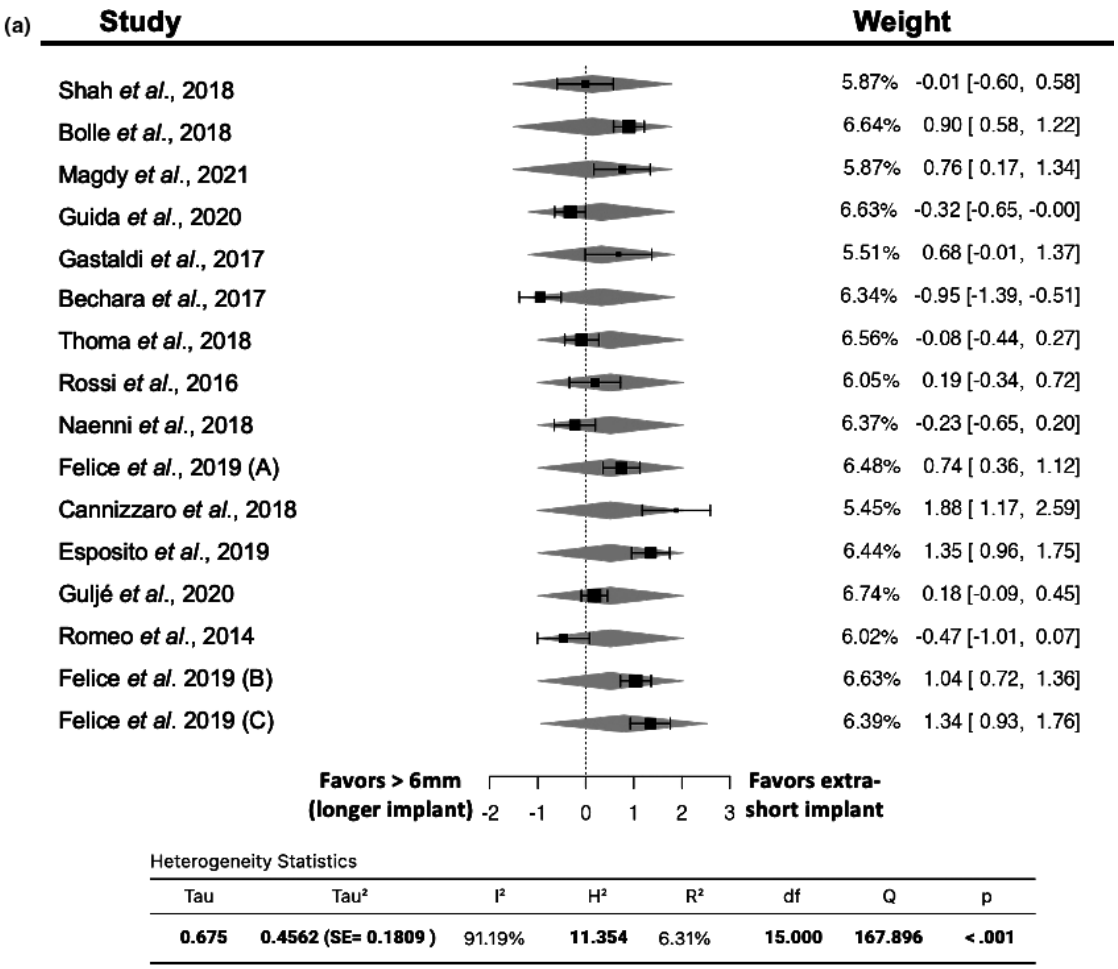


Fig. 3 (a) Forest plot for SR of each group (FE Model: Fixed Effect Model). (b) Funnel plot analysing the heterogeneity in the SR found for the included studies.



Heterogeneity Statistics

Tau	Tau²	I²	H²	R²	df	Q	p
0.675	**0.4562 (SE= 0.1809)**	91.19%	**11.354**	6.31%	**15.000**	**167.896**	**< .001**

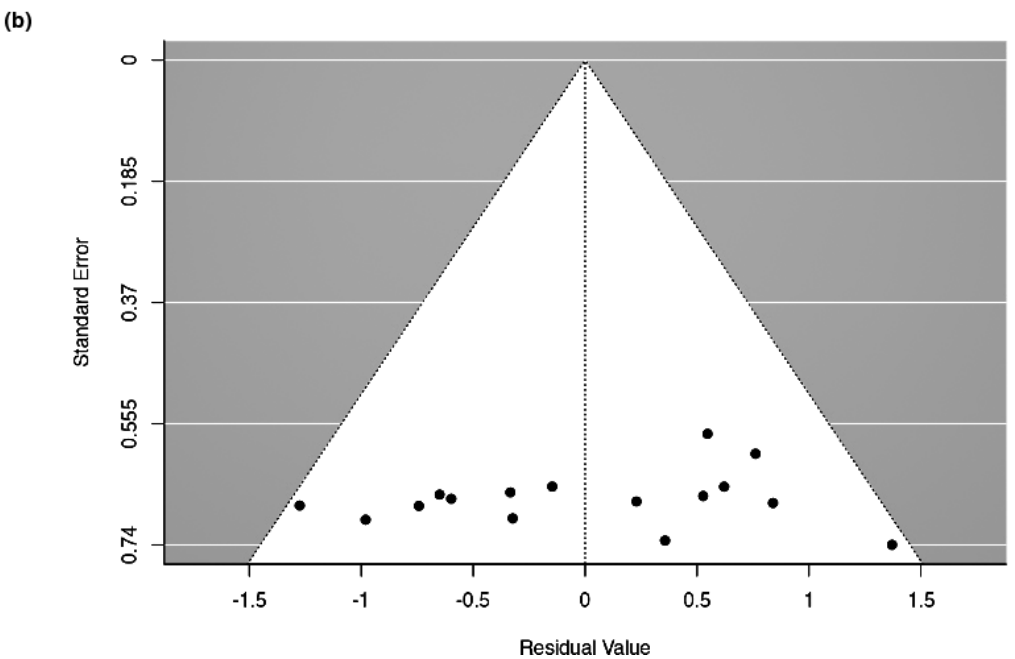


Fig. 4 (a) Forest plot for MBL of each group (RE Model: Paule-Mandel Model). (b) Funnel plot analysing the heterogeneity in the MBL found for the included studies.

−0.46 ± 0.55 mm for >6-mm-long implants; only one study[44] evaluated in long term (8 years) with mean MBL of −1,58 mm (±0.46 mm) and −2.46 ± 0.8 mm, respectively.

The extra-short group ranged values between +0.01 mm[39] with bone gain and −1.58 mm.[44] For the control group (implants >6 mm), the average ranges between −0.02 mm[29] and −2.46 mm.[42] Guljé *et al.*'s[39] study was the only one that had a marginal bone gain, and Felice *et al.*[44] found the worst (the lowest) and greater MBL for both groups.

The greatest results for MBL were obtained by Felice *et al.*[35,43,44] in three studies published, which can be justified due to having the greatest period of analysis[44] (8 years) and the others[35,43] were included among the nine studies with the greater follow-up (5 years). Otherwise, Guljé *et al.*[39] also evaluated for 5 years and achieved marginal bone level with positive results, considered a bone gain (+0.01 mm), becoming questionable the highest result found by Felice and collaborators in the follow-up period. For 1-year MBL post-loading analysis, the data obtained by Shah *et al.*[31] was −0.97 ± 0.7 mm (test) and −0.96 ± 1.2 mm (control), for Bolle *et al.*[41] was −0.57 ± 0.16 mm (test) and −0.75 ± 0.23 mm (control), and for Magdy *et al.*[45] was −0.81 ± 0.60 mm (test) and −1.28 ± 0.62 mm (control). For 3-year of analysis, three studies were obtained: Guida *et al.*[29] (test: −0.1 ± 0.24 mm; control: −0.02 ± 0.25 mm), Gastaldi *et al.*[37] (test: −0.89 ± 0.25 mm; control: −1.08 ± 0.29 mm) and Bechara *et al.*[42] (test: −0.273 ± 0.078 mm; control: −0.201 ± 0.07 mm).

When observed MBL greater than 1 mm, in the extra-short implants, four studies achieved the following result: Esposito *et al.*[38] (−1.23 ± 0.3 mm), Felice *et al.*[35] (−1.49 ± 0.59 mm), Felice *et al.*[43] (−1.44 ± 0.43 mm) and Felice *et al.*[44] (−1.44 ± 0.43 mm); whereas the same authors also presented the greatest value for the control group, respectively, −1.71 ± 0.4 mm, −1.92 ± 0.56 mm, −1.96 ± 0.55 mm and −2.46 ± 0.8 mm (Fig. 4).

A low heterogeneity among the studies was observed (I^2 = 0%) in the SR outcomes. Oppositely, there was a high heterogeneity for MBL (I^2 = 91.19%) with $P < 0.001$. The forest plot was adjusted with the moderator 'year' due to the variance. After statistical analysis, the result obtained was interestingly and slightly in favour of the extra-short implants.

Risk of bias

The risk of bias and the study's quality was performed independently by two reviewers, using the Cochrane Risk of Bias Tool,[28] which revealed no RCT study with a low risk of bias, mainly due to the blinding participations and personnel. Conversely, all studies followed the randomization criterium. The included articles did not report the calibration of surgeons concerning the surgical procedure for implantation, mainly when the study was multicentric, which may elevate the level of bias in 'other bias'.[29,30,32,37–39,41]

Biological complications

Thoma *et al.*,[30] Naenni *et al.*[33] and Guljé *et al.*'s[39] studies presented a higher quantity of biological information. Only two observed and performed the plaque control record,[30,39] in 44 patients with 86.4% (P = 0.31) and 98 extra-short implants 16.3% contrasting with 86 longer implants with 7% (P = 0.068).

Also, only two studies[30,33] measured specifically the bleeding on probing (BOP). Thoma *et al.*[30] considered BOP on implants as peri-implant mucositis and observed in 44 patients the mean of 40.9% (test group) vs. 50.0% (control group), with no statistically significant difference (P = 0.41). Within Naenni *et al.*'s study,[33] BOP was measured, at least, in three sites per implant, and there was also no statistical difference.

Regarding peri-implant mucositis, Guida *et al.*[29] reported that two patients (one test and one control) and two implants per patient presented during the first year of function. The disease was resolved by professional cleaning and 1% chlorhexidine gel application (every week for 1 month). At the same time, Cannizzaro *et al.*[36] and Romeo *et al.*[40] found one mucositis each in the extra-short implant group. For Guljé *et al.*,[39] the mucositis findings were more remarkable, with 44% of the implants in the test group (6 mm group) and 33% of the implants in the control group (11-mm group) but with no significance (P = 0.131). Bechara *et al.*[42] was the only study that did not have a case of mucositis. Moreover, Gastaldi *et al.*[37] reported that one patient had discomfort and bleeding when brushing teeth, which had the implant debrided. The recommendation was to apply chlorhexidine gel (3 times a day for 21 days).

Concerning peri-implantitis, Romeo *et al.*[40] and Bechara *et al.*[42] did not report compromised patients. Moderate/severe level of peri-implantitis (MBL >2 mm from implant platform), after 5 years, had a rate of 0% (test group) and 2% (control) (P = 1.00).[30] Naenni *et al.*[33] declared that no implant displayed peri-implantitis (pocket depth >5 mm) in combination with suppuration and/or progressive MBL, while Cannizzaro *et al.*[36] reported one case in the control group (long implant). Already Guljé *et al.*,[39] similar to those presented for mucositis control, had the highest percentual, with 6% in the 6 mm group (test) and 7% in the 11 mm group (control), but with no statistical significance (P = 1.000). No other study described peri-implantitis.

The probing in-depth (PD) was also analysed and described in four studies. Thoma *et al.*[30] showed in 44 clinical cases the mean of 3.0 ± 1.0 mm (ranging between 1.3 and −5.5 mm), with no statistical difference between test and control groups ($P = 0.74$). Already for Naenni *et al.*,[33] a total of 20 implants had considerable probing depth (≥5 mm of PD), 12 implants from the 6 mm group (7 with one site; 5 with two sites), and eight implants in the 10 mm group (7 with one site, 2 in two sites and 1 implant with 3 sites). Magdy *et al.*[45] reported probing depth between 4 and 12 months with statistically significant mesial, distal and buccally ($P = 0.0199$, $P = 0.0068$ and $P = 0.0146$ respectively) for the standard group, whereas, in the ultra-short group, it was statistically significant at mesial and distal ($P = 0.046$ and $P = 0.0126$ respectively). Therefore, the most significant numbers were found in Guljé *et al.*'s study,[39] with 98 extra-short implants with 2.0 ± 0.8 mm (PD) and in the long implants group, 86 implants with 2.6 ± 0.7 mm, therefore, with no statistical difference ($P = 0.298$).

Another parameter analysed was the previous history of periodontitis, which is considered a confounder factor. Therefore, only two studies noted and reported this topic. Naenni *et al.*[33] reported that 36 patients (n = 22 in the test group (6 mm) and n = 14 in the control group (10 mm)) had a previous history of periodontitis. In contrast, Bechara *et al.*[42] verified 18 patients with the same situation, nine in the test group (27.3%) and nine in the control group (45%).

Other considerations

Within the Guljé *et al.*'s study,[39] one patient (control) had a chronic sinus infection with intraoperative bleeding ($P = 0.049$) and a more significant swelling ($P < 0.0001$) when compared to the test group. Another critical data collected by Bernardi *et al.*[34] was three patients experienced transient paraesthesia on the side of the short implant was placed, whereas 22 patients had this complication on the side that suffered vertical ridge augmentation ($P < 0.05$).

Thoma *et al.*[30] reported 14 complications, five in the extra-short group and nine in the control group (fistula, swelling, infection and implant failure). For Felice *et al.*,[35] 11 patients presented 16 complications at extra-short implants (abscesses/peri-implantitis, mucositis and abutments loosening), six of them in one patient and 12 patients had 14 complications at longer implants. In addition, it was reported no permanent paraesthesia on the inferior alveolar nerve (the most prolonged period lasting 3 days).

Cannizzaro *et al.*[36] found five complications in the longer implants group (19.23%) and four in the extra-short group (15.38%). Esposito *et al.*[38] reported multiple complications in two grafted patients (in the mandibles) who were not prosthetically rehabilitated. Already Bolle *et al.*,[41] it was observed a total of 23 complications in 39 patients for the longer group and six in 40 patients for the short group ($P = 0.003$), and a significative statistical difference for the mandible ($P = 0.010$) when compared to the maxilla (no statistical significance).

For Felice *et al.*,[43] there were 19 complications for the more extended implant group and five for the extra-short group in 35 patients analysed. Within another work published by Felice *et al.*,[44] 27 complications in 22 patients were observed for the augmented vertical group and nine in eight patients for the extra-short implant group. Moreover, in a third study published by Felice *et al.*,[35] in five vertically augmented mandibles with planning to place 10-mm-longer implants, it was impossible and not performed, which was implemented shorter implants (7.0 and 8.5 mm).

Magdy *et al.*[45] reported three ultra-short implants were lost (early implant failure) with one of these implants with infection and purulent exudate. Only one standard implant was lost due to an infection (early failure). Furthermore, the authors reported that one case in the longer implant group showed postoperative complications (benign paroxysmal positional vertigo), which improved within 6 weeks.

Finally, Naenni *et al.*[33] reported that four implants lost were removed by hand. Shah *et al.*[31] concluded that extra-short and short implants request significantly less time to do the procedure (51.6 ± 23 min) than 68.5 ± 35 min when vertical augmentations are performed.

DISCUSSION

Currently, there is a greater preference for the use of short and extra-short implants over advanced-reconstructive therapies needed to manage patients with compromised bone volume and anatomical restrictions that requires the placement of larger implants.

Within this scenario, the selection of extra-short implants[46] (≤6 mm) has been indicated as a feasible and reliable alternative approach presenting lower morbidity, reduced levels of complications[29–45] while being more cost-effective.[42] Short-implants have also been used in either case of atrophic posterior maxilla and posterior mandible, thereby avoiding advanced surgeries,[11,13,47] with a comparable survival rate, a lesser MBL, and biological complications,[11] and with favourable long-term outcomes compared with 6-mm-longer implants.[9]

Thus, 12 articles included in this review [29–35,37,39,40,42,44,45] used 6-mm-length extra-short

implants in the test group, four[36–38,43] used 5-mm-length implants and only one[41] applied 4 mm. For implants longer than 6 mm, all reports used at least 7 mm implants, with the majority measuring 10 mm or more. Furthermore, there was a tendency for a higher incidence of clinical complications upon advanced-surgical procedures. Such complications are mainly associated with vertical bone gain (augmentation procedures) and lesser adverse events for extra-short implants.

Short, extra-short implants and 6-mm-longer implants

Among many systematic reviews published between January 2010 and August 2021 involving short- (7 and 8 mm) and extra-short (or super-short/ultra-short) implants (6 mm or lesser), only five reviews used the nomenclature extra-short accordingly to the classification proposed for the length of the implant.[16] This observation exposes the current lack of standardization found in the literature. The classification proposed by Al-Johany and colleagues[16] considered the length of 6 mm or lesser as extra-short; between 6 and 10 mm as short; 10–13 mm as regular length; and implants greater than 13 mm as long implants.

In another study published in 2020,[48] there was no differentiation between short and extra-short implants. Therefore, the focus was reporting results of single vs. splinted-short implants (up to a 9-year follow-up). The authors of this study[48] concluded that was similar clinical outcomes (single vs. splinted implants) for implants lengthening <10 mm, in sites that suffered sinus lift treatment. Nonetheless, non-splinted crowns supported by extra-short implants in posterior regions should be carefully used.[20] Another recent study[49] showed similar SR for extra-short implants compared to standard lengths, for single crowns installed in the posterior region (1-year follow-up), which is a predictable treatment for single rehabilitation posterior tooth loss.

Ravidà *et al*. published three sequential, systematic reviews, (i) in 2018/2019,[50] a (ii) consensus (2019)[21] and (iii) other in 2019,[51] which were (i and ii) a meta-analysis comparing extra-short implants (≤6 mm) with ≥10 mm of length up to 3-year follow-up, concluding that extra-short implants are a predictable option to treat patients with maxillary atrophy; (iii) and a systematic study without meta-analysis including articles up to 2018 that concludes that extra-short implants are a viable treatment option with satisfactory SR and low level of biological complications across 5-year follow-up. Moreover, this study reported that splinted extra-short implants had a lower implant failure rate than non-splinted implants.

Gonçalves *et al*.[52] published a meta-analysis study that explored critical aspects in favour of using extra-short implants. However, currently, the literature lacks consensus on overall implant outcome after 5 years of follow-up. Another study published by Iezzi *et al*.[19] limited the evaluation to 6-mm-longer implants placed on only vertically augmented bone and partially edentulous posterior patients, beyond to state and consider <7-mm-length implant as a short implant. All these studies mentioned above have shown a preference for using extra-short implants instead of deploying regenerative surgical procedures to install longer implants.

MBL and C-I ratio

The statistical results analysing MBL, in our systematic review, slightly favourable to extra-short implants compared to 6-mm-longer implants. These findings are in concordance with the study from Esposito *et al*.,[9] who found that after 5 years of follow-up, higher MBL of longer implants are associated with vertical augmentation in mandibles. Interestingly, even though short implants presented a higher C-I ratio,[20] they did not affect MBL.

As observed in this present systematic study, there was no statistical difference for MBL between the group of extra-short implants or control (−0.70 mm (±0.39 mm) and −0.64 mm (±0.52 mm) respectively). Yet, it persists a greater risk for implants with reduced length, mainly whether there was MBL, which reduces the percentual of BIC. Thus, after a 1-year of follow-up, the average MBL found was −0.77 mm for extra-short and −0.85 mm for control group[31,41]; after 3 years[29,37,42] was reported −0.42 and −0.43 mm, respectively; for 5-year follow-up, the average for MBL[30,32–36,38–40,43] found was, respectively, −0.69 and −0.46 mm; and only one study[44] evaluated after 8 years, with a mean MBL of −1.58 and −2.46 mm respectively.

Notably, although the included studies employed different implant systems, the internal connection was preferably used. This type of connection exhibited a lesser MBL compared to the observed with external counterparts.[53,54] Moreover, the influence of screw-retained vs. cement-retained restorations cannot be evaluated. Therefore, there are two biological hypotheses to explain the existence of this phenomenon (MBL): firstly, it can be considered a tissue rearrangement to achieve an adequate space for maintaining the supracrestal attached tissues (formerly named as biological width)[55]; and secondarily, an inflammatory zone involving abutment/crown connection and alveolar crest.[56]

Implant characteristics

The surface treatment of implants may play a key role in the osseointegration of extra-short implants, as

observed within Sun *et al.*'s study.[57] In their study, most failures were attributed to poor bone quality (in the maxilla) and the use of machined-surface implants. The study from Esposito *et al.*[38] highlighted using different implant surfaces (nanostructured calcium-incorporated titanium) and obtaining an SR for extra-short and longer implants of 94.74% and 97.37% after 5 years respectively. These values are adequate and are within the interval accepted for SR, independently of the implant surface treatment. This observation was confirmed by Atieh *et al.*,[58] who stated a higher SR for extra-short implants in the posterior region while not directly related to the implant surface, design or width. However, the question involving width, mainly in the posterior region, must be carefully observed once this region undergoes higher masticatory forces. Usually, the recommendation was the use of regular or wide platforms.

Conversely, a long-term follow-up indicated that extra-short implants have a poorer SR than standard implants ($P = 0.01$).[20] Nonetheless, the term 'poorer' used by the authors is somewhat incisive because, in this meta-analysis, the SR values for extra-short and longer implants were, respectively, 93.34% and 96.14%, which obtained values around $P > 0.100$ (not significant), demonstrating no statistical significance between the groups ($P = 0.1649$; (−1.094 to 6.126) 95% confidence interval), what reduced the negative impact. Conversely, several studies had positive results for the extra-short implants regarding the SR.[34,36,38,41,42,50] However, after adjusting the forest plot with the moderator time, the overall SR in this study was more significant for the control group (6-mm-longer implants) than for the extra-short group (Fig. 2). Therefore, no heterogeneity and statistical difference were found when directly compared both groups (Fig. 3).

Extra-short implants applied in full-arch restorations and after vertical bone augmentation

An interesting systematic study[59] evaluated the findings for full-arch restorations supported by extra-short and short implants, including 291 implants with lengths between 5 and 8 mm, inserted in atrophic edentulous mandibles. It concluded to be a viable treatment option, with minimal MBL and implant failure in the short term.

In the option to surgically augment the bone vertically, Nisand and collaborators[60] in 2015 already reported similar implant SR between implants placed in vertically augmented bone (95.09%) and short implants (96.24%), with follow-up ranging from 1 to 5 years. Therefore, more complications were reported for the implant group placed in vertically augmented bone (56 patients) than short implants (18 patients respectively).

Risk of bias

Regarding the methodological aspect for analysing the risk of bias, the included studies had a relatively homogeneous risk, none of them being at low risk, 10 with moderate and seven with high risk. Indeed, some of the items of the Cochrane tools for RCTs were difficult to address, such as blinding of participants and operators might sometimes be impossible during surgical procedures and radiographic assessment, whereas the surgeons knew the type of implants during the treatments. On this hand, blinding outcome assessment in some situations might be difficult. Furthermore, this study was the only systematic review that evaluated the within-patient correlation coefficient, finding good reliability between the studies' data included (81.3%) beyond the reliability statistics intergroup (86%) and the inter-item correlation matrix (76.8%).

Limitation of this systematic study

The limitations inherent to this study were the type of cementation or if the crown was screw-retained; the professional ability according to the personal experience (mainly in multicentre studies); the number of internal and external implant connections, There is a lack of information in some studies; and the lack of uniformity between the studies regarding the sample size and implants dimensions prevented the correct comparison.

Nonetheless, the use of extra-short implants is currently a popular alternative option for rehabilitating the maxilla and the mandible, with predictable results found in the literature highlighted mainly by RCTs, which reported implants with single or splinted prostheses. Thus, to the best of our knowledge, this is the most robust study assessing the outcomes of extra-short (≤6 mm) implants. Moreover, although there are methodological limits, the studies included in this systematic review were homogeneous. The quality of evidence was estimated to be majority moderate, thereby somewhat limiting the strength of recommendations.

CONCLUSION

Within the limitations of this study and focusing on the variables analysed, the results indicated that SR of extra-short implants was similar to 6-mm-longer implants. In contrast, MBL was lower, and there was lesser biological complications for the extra-short group, suggesting predictable results as observed for longer implants. Therefore, the main cause of complication associated with longer implants in the studies evaluated was matched to augmentation procedures. Future research is suggested evaluating extra-short implants within a more significant follow-up period.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

GVO and BMGNC **carried out concept/design of the article.** GVOF, BMGNC and JCHF carried out **data analysis/interpretation.** GVOF and JCHF **carried out drafting of the article.** GVOF, HFT, RMC and JCHF were involved in **critical revision of the article.** GVOF, RMC and HFT carried out a**pproval of the article.** GVOF also carried out **statistics.** GVOF, BMGNC, HFT and JCHF **were involved in data collection.**

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Figure S1. Reviewers' judgements for each risk of bias parameter evaluated for each of the 16 studies assessed in the meta-analysis (it was considered the lack of calibration when the study was multicentre); The plot of percentage distribution of the reviewers' judgements on each risk of bias parameter across the evaluated studies.

Figure S2. Funnel plot of the implant survival rate, comparing (a) distribution standard of the results of the extra-short implant with (b) the longer than 6 mm implants (FE Model: Fixed Effect Model).

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