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SYSTEMATIC REVIEW

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Meta-analysis of randomized clinical trials comparing clinical and patient-reported outcomes between extra-short (≤6 mm) and longer (≥10 mm) implants

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Abstract

Aim: To compare the clinical outcomes of ≤6 mm extra-short implants (test group) versus ≥10 mm long implants (control group), with and without bone augmentation procedures.

Materials and Methods: A systemic literature search of randomized clinical trials was performed using the PubMed (MEDLINE) and EMBASE databases. A quantitative meta-analysis was conducted to compare all the outcome variables. Meta-regression analysis determined the effect of bone augmentation procedures and the influence of other clinical covariates on the results.

Results: Eighteen studies comprising 1,612 implants (793 extra-short and 820 long implants) were selected for the meta-analysis. No statistically significant difference in the survival rate was observed at 1 and 3 years ($p > 0.05$). Extra-short implants displayed less marginal bone loss (MBL) from both implant placement time points (1 and 3 years) and prosthetic placement (1 year), as well as less biological complications, surgical time and treatment cost ($p < 0.05$). Contrarily, a statistically significant small number of prosthetic complications were reported with long implants ($p < 0.05$).

Conclusions: Placement of extra-short implants (≤6 mm) presented as an equivalent option in the treatment of patients with an atrophic posterior arch up to 3-year follow-up. However, the long-term effectiveness of extra-short dental implants remains to be further studied.

KEYWORDS
atrophic maxilla, dental implant, meta-analysis, short implant

1 | INTRODUCTION

Edentulism can often limit patient's ability to perform routine daily tasks while presenting significant detrimental effects on one's aesthetic appearance and self-confidence (Misch, 2007). Dental implants have continually proven to present a positive long-term impact on a patient's quality of life by re-establishing a pleasant appearance, as well as restoring comfortable speech and masticatory function (Sargozaie, Moeintaghavi & Shojaie, 2017).

Following extraction, the bony socket undergoes significant horizontal and vertical reduction (Chappuis, Araújo & Buser, 2017). These dimensional alterations can prompt clinicians to rely on more complex and time-consuming techniques such as sinus lift in the maxilla or vertical guided bone regeneration procedures in the mandible (Boyne, 1980; Cucchi & Ghensi, 2014). Implants placed in

conjunction with sinus lift procedures exhibit high survival rates, increasing the ridge height up to 14 mm, and consequently, the bone-to-implant contact (Reinert, König, Bremerich, Eufinger & Krimmel, 2003). Similarly, implants placed after ridge augmentation in the mandible have displayed comparable results to those placed in native bone (Sbordone, Toti, Menchini-Fabris, Sbordone & Guidetti, 2009). However, despite the reliability of these techniques, they often seem to be accompanied by obstacles such as increased cost, high morbidity as well as intra- and post-surgical complications (Fontana, Maschera, Rocchietta & Simion, 2011; Thoma et al., 2015). Currently, these crucial elements of therapy encourage clinicians to consider less invasive procedures such as short (≤8 mm) or extra-short (≤6 mm) implants (Rossi et al., 2017; Slotte et al., 2015). The use of shorter dental implants has shown to be a plausible solution in cases of confined space, as well as those associated with unavoidable anatomical structures, such as lingual concavities (Chan et al., 2011) or the maxillary sinus (Gosau, Rink, Driemel & Draenert, 2009), which can be prone to surgical difficulties. However, they too are not exempt from possible complications due to their higher crown-implant ratio and prevalence of peri-implantitis; presenting a great concern, given their insubstantial length (Hingsammer, Watzek & Pommer, 2017).

Previous systematic reviews comparing short implants (≤8 mm) with long implants (>8 mm) placed after bone augmentation procedures found comparable survival rates, as well as less complications attributed to the short implants (Camps-Font et al., 2016; Fan, Li, Deng, Wu & Zhang, 2017). However, this could be imputed to the small difference in implant length between the test and control groups. Thus, the aim of the present review was to provide a more emphasized comparison between short and long implants comparing extra-short (≤6 mm) to long dental implants (≥10 mm) in both the mandible and maxilla, evaluating their survival rate, marginal bone loss, prosthetic and biological complications, as well as cost and duration of treatment.

Clinical Relevance

Scientific rationale for the Study: Implant placement following bone augmentation is considered the gold standard procedure for patients with posterior atrophy of the jaws. However, the use of extra-short implants is gaining popularity due to their favourable clinical performance, cost effectiveness and simple procedure.

Principal findings: Extra-short implants demonstrated less marginal bone loss, biological complications surgical time and cost at 1 and 3 years. However, long implants displayed smaller number of prosthetic complications and a higher long-term follow-up (5 years).

Practical implication: The use of extra-short implants can be considered an equivalent short-term option in the treatment of posterior atrophic jaws. However, the long-term effectiveness of extra-short dental implants remains to be further studied.

2 | MATERIALS AND METHODS

2.1 | Study registration

The review protocol was registered with the PROSPERO International Prospective Register of Systematic Reviews under the identification number CRD42018085966.

2.2 | Reporting format

The 27-item Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher, Liberati, Tetzlaff, Altman & PRISMA Group, 2009) were used in the summary and description of the search process results. The Assessment of Multiple Systematic Reviews guidelines (AMSTAR) (Shea et al., 2009) were abided by in achieving the predetermined standards of reporting systematic reviews.

2.3 | Patient, Intervention, Comparison, Outcome (PICO) question

The focused question was elaborated following the PICO format (Stone, 2002), where:

Patients (P): Patients receiving one or more extra-short dental implant(s) (≤6 mm) and one or more long implant(s) (≥10 mm) with or without bone augmentation procedure followed for ≥12 months.

Intervention (I): Extra-short (≤6 mm) dental implant placement in the mandible and/or the maxilla.

Comparison (C): Long dental implant (≥10 mm) placement with or without bone augmentation in the mandible and/or the maxilla

Outcome (O): Implant survival rate, prosthetic/biological complications and marginal bone loss between extra-short and long implants with or without bone augmentation procedures, cost and treatment time.

2.4 | Focused question

In systemically healthy patients with dental implants, do extra-short (≤6 mm) implants perform as well as long dental implants (≥10 mm) placed with or without bone augmentation procedures?

2.5 | Information Sources and Search Strategy

Electronic and manual literature searches were conducted by two independent reviewers (AR, HA), confined by no date or language restriction. A computerized, systematic literature search was performed using MEDLINE and EMBASE (until October 2017) using the following search terms: (a) MEDLINE: (short[All Fields] AND implants[All Fields]) AND (Randomized Controlled Trial[ptyp] AND

"humans"[MeSH Terms]); (b) EMBASE: short AND implants AND "randomized controlled trial".

Furthermore, a manual search of periodontics/implantology-related journals from January 2016 to May 2018 was performed to ensure a thorough screening process, in addition to an electronic screening of Medicine Gray Literature Report conducted to check for ongoing/unpublished trials. The level of agreement between the reviewers regarding study inclusion was calculated using k statistics. Additionally, previous systematic reviews assessing short implants were also examined for article identification (Al-Hashedi, Taiyeb Ali & Yunus, 2014; Alqutaibi & Altaib, 2016; Annibali et al., 2012; Atieh, Zadeh, Stanford & Cooper, 2012; Fan et al., 2017; Khouly & Veitz-Keenan, 2015; Kwon, Bain & Levin, 2014; Lee, Lee, Fu, Elmisalati & Chuang, 2014; Lemos, Ferro-Alves, Okamoto, Mendonca & Pellizzer, 2016; Mezzomo, Miller, Triches, Alonso & Shinkai, 2014; Monje et al., 2013; Neldam & Pinholt, 2012; Nisand, Picard & Rocchietta, 2015; Srinivasan et al., 2012; Sun, Huang, Wu & Shi, 2011; Telleman et al., 2011; Tong, Zhang & Yu, 2017).

2.6 | Eligibility criteria

Studies were deemed eligible if they met the following inclusion criteria: (a) Randomized clinical trials (RCTs) involving human subjects receiving one or more extra-short (≤6 mm) implant(s) as the test group and (≥8.5 mm) as the control group; (b) studies with a minimum follow-up period of ≥12 months; (c) studies in which the implants were restored with a fixed prosthesis. The exclusion criteria comprised (a) studies with a follow-up of <12 months after prosthetic loading; (b) prospective cohort study, case reports, case series, retrospective studies, systematic reviews; (c) preclinical animal studies.

2.7 | Data extraction & Statistical analysis

Initially, studies were excluded based on data from titles and abstract screening. The final stage of screening involved full-text reading by two reviewers (AR, HA) using a predetermined data extraction form to confirm the eligibility of each study based on the aforementioned inclusion and exclusion criteria. The data, such as patient characteristics, treatment covariates and clinical outcomes, were independently extracted by three reviewers (SB, HA, IW) and systematically meta-analysed by the statistician KS and the third reviewer (IW). A meta-analysis was conducted including only the studies that reported the same outcome measures using the specialized software *Comprehensive Meta-analysis* (version 3.3, Biostat, 2014). Implant survival rates were collected as primary outcome variables, and secondary outcome variables included marginal bone loss, as well as prosthetic and biological complication rates. To standardize the reporting of our results, risk ratios (RRs) and 95% confidence intervals (CI) were calculated from the absolute number of events reported in each clinical trial. By definition, weighted by the Mantel–Haenszel method, RR > 1 indicated a higher event rate of extra-short than long implants. Survival rates and peri-implant marginal bone loss were reported via 1-, 3- and 5-year subgroup analysis at the implant and patient level, respectively. Prosthetic/biological complication rates were analysed at the patient level from the reported results at the final follow-up year. A prior sensitivity analysis demonstrated minimal changes in the pooled estimated RR in including or excluding the both-arm-zero-event (BA0E) studies, and including the BA0E studies led to a more conservative, less biased estimate with a narrower CI, which was in accordance with previous findings (Friedrich, Adhikari & Beyene, 2007). A continuity correction of 0.5 inversely proportional to the relative size of the opposite arm was utilized in BAOE studies with imbalanced group size (Sweeting, Sutton & Lambert, 2004). Summary estimates of RR were obtained with the random-effects models if heterogeneity across trials tested with the χ^2 (Cochran *Q*) test ($p < 0.1$) and I^2 statistics >50% proved to be high (Higgins, Thompson, Deeks & Altman, 2003). Subgroup analysis and meta-regression were performed to test for categorical and continuous covariates, respectively, and the significance was set at $p < 0.05$. Additionally, the probability of publication bias was assessed with funnel plots and Egger tests.

Dichotomous variables such as screw/cement-retained prostheses, early/conventional loading and exclusion or inclusion of heavy smokers were analysed by meta-regression analyses. Among the total, only studies that adopted a single approach were included in the meta-regression, and immediate loading was combined with the early loading category (≤10 weeks) to analyse the possible predictors of the treatment outcome.

To analyse the potential influence of clinical crown/implant ratio (CI ratio) on the outcomes of extra-short and long implants, a ratio between the two CI ratios was calculated and expressed as a percentage to be used as the continuous moderator of "extra-short/long CI ratio" when performing the meta-regression analysis. Similarly, the total percentage of smokers and the ratio between the smoking percentage in the extra-short and long implant (S/L) groups were calculated and expressed as a percentage to investigate the impact of smoking habits on the outcome variables. The investigation of heterogeneity implementing subgroup analysis, meta-regression, sensitivity testing and exploration of publication bias were performed according to the recommendations of Higgins (Higgins et al., 2013).

2.8 | Risk of bias and qualitative assessment:

Quality assessment was based on the published full-text articles and was performed by two investigators (AR and HA) independently. All RCTs were assessed using the Cochrane Risk of Bias Tool for Randomized Controlled Trials (Higgins et al., 2011). The potential risk of bias was considered as low if a study provided detailed data on all the parameters. A study was considered to have a moderate risk if it failed to provide information on only one of the parameters; however, when a study lacked information regarding ≥2 parameters, it was outlined to have a high risk of bias.

3 | RESULT

3.1 | Study selection

Initial search involved a total of 520 articles, 267 via PubMed (MEDLINE) and 212 via EMBASE, while an additional 41 articles were collected through manual screening. Overall, 66 were selected after title and abstract evaluation, followed by the exclusion of 48 articles with further full-text assessment (Supporting information Table S1). Finally, 18 studies (Bechara et al., 2017; Bolle et al., 2018; Cannizzaro et al., 2015; Esposito, Pistilli, Barausse & Felice, 2014; Felice et al., 2015, 2018; Gastaldi et al., 2017, 2018; Gulje et al., 2013; Naenni et al., 2018; Pistilli, Felice, Cannizzaro, et al., 2013; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017; Romeo, Storelli, Casano, Scanferla & Botticelli, 2014; Rossi et al., 2016; Sahrmann et al., 2016; Thoma et al., 2015) remained eligible for examination (Figure 1). The *k* value for the inter-reviewer agreement for potentially pertinent papers was 0.85 (titles and abstracts) and 0.89 (full-text articles). Two articles, by Schincaglia et al. (2015); Thoma et al. (2015) reported data pertaining to the same cohort as a third article, by Pohl et al. (2017), but only to the 1-year follow-up mark. However, dissimilar to the other two, Thoma and coworkers evaluated parameters such as surgical time and cost. Furthermore, the article of Sahrmann et al. (2016) is the 3-year follow-up report of the recently published 5-year follow-up RCT by Naenni et al. (2018), while the publication by Felice et al. (2018) is a 3-year follow-up of the study of Pistilli, Felice, Cannizzaro, et al. (2013) and

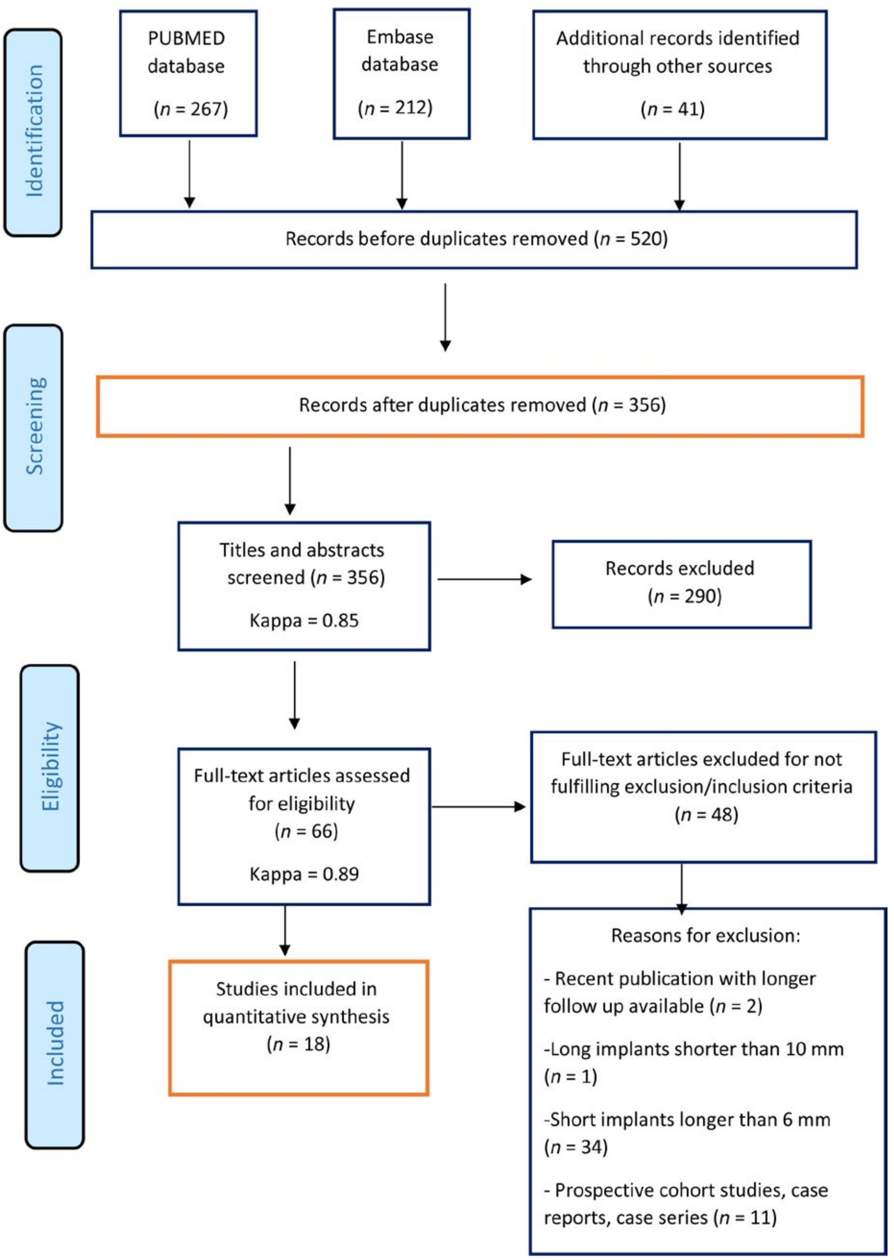


FIGURE 1 PRISMA flowchart of the screening process

another publication of the same author (Felice et al., 2015) is the 1-year follow-up of Gastaldi et al. (2017) (3 years). Finally, Bolle et al. reported the outcomes from implants placed in the upper and lower jaws, whereas in the present study, only maxillary implants were included due to six mandibular implants having been 8.5 mm long (Bolle et al., 2018).

3.2 | Quality assessment

The results of the risk of bias assessment for the included RCTs according to the recommendations of the Cochran Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011) are summarized in Supporting information Figure S1. One article was considered as having a low risk of bias (Gastaldi et al., 2017), eight articles were characterized by a moderate risk of bias (Bechara et al., 2017; Bolle et al., 2018; Esposito et al., 2014; Gastaldi et al., 2018; Gulje et al., 2013; Naenni et al., 2018; Romeo et al., 2014; Rossi et al., 2016) and four articles showed a high risk of bias (Cannizzaro et al., 2015; Felice et al., 2018; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017). Quality assessment of the article by Thoma et al. (2015), Schincaglia et al. (2015), Sahrmann et al. (2016), Felice et al. (2015) and Pistilli, Felice, Cannizzaro, et al. (2013) was not performed, as they report the results from the same cohort as the publication of Felice et al. (2018); Gastaldi et al. (2017); Naenni et al. (2018); Pohl et al. (2017).

3.3 | Characteristics of the included articles

Overall, 13 studies (Bechara et al., 2017; Bolle et al., 2018; Cannizzaro et al., 2015; Esposito et al., 2014; Felice et al., 2018; Gastaldi et al., 2017, 2018; Gulje et al., 2013; Naenni et al., 2018; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017; Romeo et al., 2014; Rossi et al., 2016) reported the outcome of 1,612 implants (793 extra-short and 820 long implants) in 793 patients. Among these, one study exclusively treated completely edentulous patients (Cannizzaro et al., 2015), whereas 11 included only partially edentulous posterior jaw areas (Bechara et al., 2017; Bolle et al., 2018; Esposito et al., 2014; Felice et al., 2018; Gastaldi et al., 2017, 2018; Gulje et al., 2013; Naenni et al., 2018; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017; Romeo et al., 2014; Rossi et al., 2016). Subgroups were created when implants placed in the maxilla or mandible were reported as separate analysis units in the original article (Cannizzaro et al., 2015; Esposito et al., 2014; Felice et al., 2018; Gastaldi et al., 2018; Pistilli, Felice, Piattelli, et al., 2013). Four studies exclusively investigated implants placed in the atrophic maxilla (Bechara et al., 2017; Bolle et al., 2018; Gastaldi et al., 2017; Pohl et al., 2017), while eight studies included maxillary and mandibular implants (Cannizzaro et al., 2015; Esposito et al., 2014; Felice et al., 2018; Gastaldi et al., 2018; Gulje et al., 2013; Naenni et al., 2018; Romeo et al., 2014; Rossi et al., 2016). Three out of 14 articles restored the implants with single-crown prostheses (Naenni et al., 2018; Pohl et al., 2017; Rossi et al., 2016), while five exclusively with splinted prostheses (Cannizzaro et al., 2015; Felice et al., 2018; Gulje et al., 2013; Pistilli, Felice, Piattelli, et al., 2013; Romeo et al., 2014) and the remaining studies with either a single-crown or 2–3 splinted prostheses (Bechara et al., 2017; Bolle et al., 2018; Esposito et al., 2014; Gastaldi et al., 2017, 2018). Three studies used only cement-retained prostheses (Esposito et al., 2014; Felice et al., 2018; Romeo et al., 2014), while three studies only screw-retained prostheses (Cannizzaro et al., 2015; Gulje et al., 2013; Naenni et al., 2018) and the remaining utilized both prosthetic retention techniques (Bechara et al., 2017; Bolle et al., 2018; Gastaldi et al., 2017, 2018; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017; Rossi et al., 2016). In terms of the loading protocol, in one study, implants were immediately loaded (Cannizzaro et al., 2015), four studies followed an early loading protocol (6–10 weeks) (Gulje et al., 2013; Naenni et al., 2018; Romeo et al., 2014; Rossi et al., 2016) and the remaining studies performed conventional loading methods (>4 months) (Bechara et al., 2017; Bolle et al., 2018; Esposito et al., 2014; Felice et al., 2018; Gastaldi et al., 2017, 2018; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017). In addition, eight studies included heavy smokers (≥10 cigarettes/day) (Bolle et al., 2018; Cannizzaro et al., 2015; Esposito et al., 2014; Felice et al., 2018; Gastaldi et al., 2017, 2018; Gulje et al., 2013; Rossi et al., 2016), whereas the remaining studies excluded or avoided the recruitment of heavy smokers (Bechara et al., 2017; Naenni et al., 2018; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017; Romeo et al., 2014).

Finally, three studies reported the clinical CI ratio at the final follow-up evaluation (Romeo et al., 2014; Sahrmann et al., 2016), two studies reported the anatomical CI ratio (Pohl et al., 2017; Romeo et al., 2014) and two studies reported the anatomical crown length allowing for the ratio calculation (Gulje et al., 2013; Rossi et al., 2016). The general characteristics of the included articles are outlined in Table 1.

3.4 | Publication bias

All the publication bias assessed by Egger test is presented in funnel plots in Supporting information Figure S2. In the total survival rate, there was no evidence of publication bias, according to the Egger's test, ($p = 0.30$) and confirmed by the symmetry noted in the funnel plot. Studies measuring the marginal bone loss from different baselines demonstrated publication bias in MBL (measured from implant placement) ($p = 0.003$) and did not report presence of publication bias at measurement from prosthesis delivery ($p = 0.053$). Egger's test, combined with funnel plots, showed that prosthetic ($p = 0.97$) and biological complications ($p = 0.92$) both failed to prove the presence of publication bias.

3.5 | Survival rate

The overall survival rate of the reported implants in different follow-up years throughout the studies was 97.1%, and the individual survival rate for the extra-short and long implants was 96.69% and 97.5%, respectively. The meta-analysis based on different follow-ups revealed a lack of statistical significance in the survival

TABLE 1 Characteristics of the included articles

(A) Articles and follow-up periods: Number (#) Main author (Publication Date) Study Design	Surgical procedures: Short	Surgical procedures: Long	Population characteristics (1. Total number of included patients (male; female) 2. Total number of patients in each group 3. Age (average, years) 4. Age (range, years)): Short	Population characteristics: Long	Implant locations (1. Maxillary 2. Mandibular 3. Premolar area 4. Molar area 5. Total): Short	Implant locations: Long	Implant characteristics (1. Company 2. Surface 3. Length (mm)): Short	Implant characteristics: Long
#1A Gastaldi et al. (2018) – Maxillary implants 3-year RCT	Implant placement	Lateral sinus floor elevation	1. *n* = 40 (15; 25) 2. *n* = 20 (5; 15) 3. 61.1 4. 45–70	1. *n* = 40 (15; 25) 2. *n* = 20 (10; 10) 3. 58.5 4. 45–75	1. *n* = 36 2. *n* = 0 3. N/R 4. N/R 5. *n* = 36	1. *n* = 37 2. *n* = 0 3. N/R 4. N/R 5. *n* = 37	1. MegaGen®,[g] 2. Sand blasted large grit acid-etched 3. 10, 11.5, 13, 15 mm	1. MegaGen®, [g] 2. Sand blasted large grit acid-etched 3. 10, 11.5, 13, 15 mm
#1B Gastaldi et al. (2018) Mandibular implants 3-year RCT	Implant placement	Vertical bone block augmentation	1. *n* = 39 (9; 30) 2. *n* = 20 (3; 17) 3. 58.6 4. 39–80	1. *n* = 39 (9; 30) 2. *n* = 19 (6; 13) 3. 52.8 4. 42–70	1. *n* = 0 2. *n* = 32 3. N/R 4. N/R 5. *n* = 32	1. *n* = 0 2. *n* = 31 3. N/R 4. N/R 5. *n* = 31	1. MegaGen®, [g] 2. Sand blasted large grit acid-etched 3. 5 mm	1. MegaGen®, [g] 2. Sand blasted large grit acid-etched 3. 10 mm or more
#2 Bolle et al. (2018, 4 mm Implants) – Maxillary Implants 1-year RCT	Implant placement	Lateral sinus floor elevation	1. *n = 40 (19; 21)* 2. *n = 20 (9; 11)* 3. 60.75 4. 25–77	1. *n = 40 (19; 21)* 2. *n* = 20 (10; 10) 3. 56.4 4. 36–71	1. *n* = 37 2. *n* = 0 3. N/R 4. N/R 5. *n* = 37	1. *n* = 41 2. *n* = 0 3. N/R 4. N/R 5. *n* = 41	1. Global D TwinKon Universal[e] 2. Sand blasted acid-etched 3. 4 mm	1. Global D TwinKon Universal[e] 2. Sand blasted acid etched 3. 10, 11.5, 13 mm
#3A Felice et al. (2018, 6 mm Implants)/Pistilli, Felice, Cannizzaro, et al. (2013) - Maxillary Implants 3-year RCT/1-year	Implant placement	Lateral sinus floor elevation	1. *n* = 40 (21; 19) 2. *n* = 10 3. N/A 4. N/A	1. *n* = 40 (21; 19) 2. *n* = 10 3. N/A 4. N/A	1. *n* = 39 2. *n* = 0 3. N/R 4. N/R 5. *n* = 39	1. *n* = 44 2. *n* = 0 3. N/R 4. N/R 5. *n* = 44	1. Southern Implants®,[b] 2. Roughened grit-blasted surface 3. 6 mm	1. Southern Implants®,[b] 2. Roughened grit-blasted surface 3. 10, 11.5, 13, 15 mm
#3B Felice et al. (2018)/Pistilli, Felice, Cannizzaro et al. (2013) -Mandibular Implants 3-year RCT/1-year	Implant placement	Vertical bone block augmentation	1. *n* = 40 (21; 19) 2. *n* = 20 3. N/A 4. N/A	1. *n* = 40 (21; 19) 2. *n* = 10 3. N/A 4. N/A	1. *n* = 0 2. *n* = 41 3. N/R 4. N/R 5. *n* = 41	1. *n* = 0 2. *n* = 47 3. N/R 4. N/R 5. *n* = 47	1. Southern Implants®,[b] 2. Roughened grit-blasted surface 3. 6 mm	1. Southern Implants®,[b] 2. Roughened grit-blasted surface 3. 10, 11.5, 13, 15 mm

(Continues)

TABLE 1 (Continued)

(A) Articles and follow-up periods Number (#) Main author (Publication Date) Study Design	Surgical procedures		Population characteristics 1. Total number of included patients (male; female) 2. Total number of patients in each group 3. Age (average, years) 4. Age (range, years)		Implant locations 1. Maxillary 2. Mandibular 3. Premolar area 4. Molar area 5. Total		Implant characteristics 1. Company 2. Surface 3. Length (mm)	
	Short	Long	Short	Long	Short	Long	Short	Long
#4 Naenni et al. (2018) 1y/ Sahrmann et al. (2016) 5-year/3-year RCT	Implant place-ment	Transcrestal sinus lift or implant placement alone	1. n = 96 2. n = 41 (19; 22) 3. 52 4. 26–76	1. n = 96 2. n = 40 (17; 23) 3. 58 4. 36–81	1. n = 10 2. n = 31 3. n = 20 4. n = 31 5. n = 41	1. n = 15 2. n = 25 3. n = 16 4. n = 24 5. n = 40	1. Straumann®[,c] 2. Sand blasted large grit acid-etched 3. 6 mm	1. Straumann®[, c] 2. Sand blasted large grit acid-etched 3. 10 mm
#5 Gastaldi et al. (2017)/ Felice et al. (2015) 3-year/1-year RCT	Implant place-ment	Transcrestal sinus lift	1. n = 20 (8; 12) 2. n = 10 (3; 7) 3. 53.4 4. 43–67	1. n = 20 (8; 12) 2. n = 10 (5; 5) 3. 58.6 4. 48–70	1. n = 16 2. n = 0 3. n = 0 4. n = 0 5. n = 16	1. n = 18 2. n = 0 3. n = 0 4. n = 0 5. n = 18	1. Zimmer Biomet 3I®[,f] 2. Osseotite surface (micro textured) 3. 5 or 6 mm	1. Zimmer Biomet 3I®[, f] 2. Osseotite surface (micro textured) 3. 10 mm
#6 Bechara et al. (2017) 3-year RCT	Implant place-ment	Lateral sinus floor elevation	1. n = 53 (19; 34) 2. n = 33 (10; 23) 3. 47.5 4. 21–76	1. n = 53 (19; 34) 2. n = 20 (9; 11) 3. 49.2 4. 28–75	1. n = 45 2. n = 0 3. n = 3 4. n = 42 5. n = 45	1. n = 45 2. n = 0 3. n = 4 4. n = 41 5. n = 45	1. MegaGen®[, g] 2. Sand blasted large grit acid-etched 3. 6 mm	1. MegaGen®[, g] 2. Sand blasted large grit acid-etched 3. 10, 11.5, 13, 15 mm
#7 Pohl et al. (2017)/Thoma et al. (2015)/Schincaglia et al. (2015) 3-year/1-year/1-year Multicentric RCT	Implant place-ment	Lateral sinus floor elevation	1. n = 94 (49; 52) 2. n = 45 3. 50.5 4. 25–75	1. n = 94 (49; 52) 2. n = 49 3. 50.5 4. 25–75	1. n = 67 2. n = 0 3. N/R 4. N/R 5. n = 67	1. n = 68 2. n = 0 3. N/R 4. N/R 5. n = 68	1. Astra Tech®[,d] 2. Blasted fluoride-modified surface 3. 6 mm	1. Astra Tech®[, d] 2. Blasted fluoride-modified surface 3. 11, 13, 15 mm
#8 Rossi et al. (2016) 5-year RCT	Implant place-ment	Implant placement	1. n = 45 (24; 21) 2. n = N/R 3. 48.4 4. 30–74	1. n = 45 (24; 21) 2. n = N/R 3. 48.4 4. 30–74	1. n = 12 2. n = 18 3. n = 17 4. n = 13 5. n = 30	1. n = 15 2. n = 15 3. n = 18 4. n = 12 5. n = 30	1. Straumann®[, c] 2. Sand blasted large grit acid-etched 3. 6 mm	1. Straumann®[, c] 2. Sand blasted large grit acid-etched 3. 10 mm

(Continues)

TABLE 1 (Continued)

(A) Articles and follow-up periods: Number (#) Main author (Publication Date) Study Design	Surgical procedures: Short	Surgical procedures: Long	Population characteristics (1. Total number of included patients (male; female) 2. Total number of patients in each group 3. Age (average, years) 4. Age (range, years)): Short	Population characteristics: Long	Implant locations (1. Maxillary 2. Mandibular 3. Premolar area 4. Molar area 5. Total): Short	Implant locations: Long	Implant characteristics (1. Company 2. Surface 3. Length (mm)): Short	Implant characteristics: Long
#9A Cannizzaro et al. (2015) Maxillary Group 1-year RCT	Implant place-ment	Implant placement	1. n = 30 (15; 15) 2. n = 15 (7; 8) 3. 58.9 4. 44–78	1. n = 30 (15; 15) 2. n = 15 (9; 6) 3. 58.5 4. 43–72	1. n = 90 2. n = 0 3. N/R 4. N/R 5. n = 90	1. n = 91 2. n = 0 3. N/R 4. N/R 5. n = 91	1. Biomet 3I®, f 2. NanoTite™ Implant dual acid-etched 3. 5 mm	1. Biomet 3I®, f 2. NanoTite® 3D surface roughness of Sa 1.5 3. 11.5 mm
#9B Cannizzaro et al. (2015) Mandibular Group 1-year RCT	Implant place-ment	Implant placement	1. n = 30 (15; 15) 2. n = 15 (8; 7) 3. 62.9 4. 47–80	1. n = 30 (15; 15) 2. n = 15 (7; 8) 3. 58.8 4. 38–72	1. n = 0 2. n = 62 3. N/A 4. N/A 5. n = 62	1. n = 0 2. n = 60 3. N/A 4. N/A 5. n = 60	1. Biomet 3I®, f 2. NanoTite™ Implant dual acid-etched 3. 5 mm	1. Biomet 3I®, f 2. NanoTite® 3D surface roughness of Sa 1.5 3. 11.5 mm
#10 Romeo et al. (2014) 5-year RCT	Implant place-ment	Implant placement	1. n = 24 (12; 12) 2. n = 11 (6; 5) 3. 50 4. 37–75	1. n = 24 (12; 12) 2. n = 13 (6; 7) 3. 56 4. 32–75	1. n = 5 2. n = 21 3. N/R 4. N/R 5. n = 26	1. n = 7 2. n = 21 3. N/R 4. N/R 5. n = 28	1. Straumann®,‡ 2. Sand blasted large grit acid etched 3. 6 mm	1. Straumann®,‡ 2. Sand blasted large grit acid-etched 3. 10 mm
#11A Esposito et al. (2014) Maxillary 3-year RCT	Implant place-ment	Lateral sinus floor elevation	1. n = 15 (9; 6) 2. n = 15 (9; 6) 3. 56 4. 45–70	1. n = 15 (9; 6) 2. n = 15 (9; 6) 3. 56 4. 45–70	1. n = 34 2. N/R 3. N/R 4. N/R 5. n = 34	1. n = 38 2. N/R 3. N/R 4. N/R 5. n = 38	1. MegaGen®, g 2. Rescue® (Blasted with hydroxyapatite papers and cleaned with acid) 3. 5 mm	1. MegaGen®, g 2. EZ plus® (Blasted with hydroxyapatite Blasted fluoride-modified surface papers and cleaned with acid) 3. 10, 11.5, 13 mm
#11B Esposito et al. (2014) Mandibular 3-year RCT	Implant place-ment	Vertical bone block augmentation	1. n = 15 (4; 11) 2. n = 15 (4; 11) 3. 56 4. 37–69	1. n = 15 (4; 11) 2. n = 15 (4; 11) 3. 56 4. 37–69	1. N/R 2. n = 26 3. N/R 4. N/R 5. n = 26	1. N/R 2. n = 30 3. N/R 4. N/R 5. n = 30	1. MegaGen®, g 2. Rescue® (Blasted with hydroxyapatite papers and cleaned with acid) 3. 5 mm	1. MegaGen®, g 2. EZ plus® (Blasted with hydroxyapatite papers and cleaned with acid) 3. 10, 11.5, 13 mm

(Continues)

TABLE 1 (Continued)

(A) Articles and follow-up periods: Number (#) Main author (Publication Date) Study Design	Surgical procedures		Population characteristics: 1. Total number of included patients (male; female) 2. Total number of patients in each group 3. Age (average, years) 4. Age (range, years)		Implant locations: 1. Maxillary 2. Mandibular 3. Premolar area 4. Molar area 5. Total		Implant characteristics: 1. Company 2. Surface 3. Length (mm)	
	Short	Long	Short	Long	Short	Long	Short	Long
#12A Pistilli, Felice, Piattelli, et al. (2013), 5 mm Implants) - Maxillary Implants 1-year RCT	Implant place-ment	Lateral sinus floor elevation	1. n = 40 (15, 25) 2. n = 20 (5; 15) 3. 61.1 4. 45–70	1. n = 40 (15, 25) 2. n = 20 (10; 10) 3. 58.6 4. 45–75	1. n = 36 2. n = 0 3. N/R 4. N/R 5. n = 36	1. n = 37 2. n = 0 3. N/R 4. N/R 5. n = 37	1. MegaGen®, [g] 2. Rescue® (Blasted with hydroxyapatite papers and cleaned with acid) 3. 5 mm	1. MegaGen®, [g] 2. Rescue® (Blasted with hydroxyapatite papers and cleaned with acid) 3. 10, 11.5, 13, 15 mm
#12B Pistilli, Felice, Piattelli, et al. (2013) Mandibular Implants 3-year RCT	Implant place-ment	Vertical bone block augmentation	1. n = 40 (10; 30) 2. n = 20 (3; 17) 3. 58.6 4. 39–80	1. n = 40 (10; 30) 2. n = 20 (7; 13) 3. 52.8 4. 42–70	1. n = 0 2. n = 32 3. N/R 4. N/R 5. n = 32	1. n = 0 2. n = 31 3. N/R 4. N/R 5. n = 31	1. MegaGen®, [g] MegaGen®, [g] 2. Rescue® (Blasted with hydroxyapatite papers and cleaned with acid) 3. 5 mm	1. MegaGen®, [g] MegaGen®, [g] 2. Rescue® (Blasted with hydroxyapatite papers and cleaned with acid) mm
#13 Gulje et al. (2013) 1-year Multicenter RCT	Implant place-ment	Implant placement	1. n = 95 (48; 47) 2. n = 49 (21; 28) 3. 54.8 4. 26–69	1. n = 95 (48; 47) 2. n = 46 (27; 19) 3. 54.1 4. 34–70	1. N/R 2. N/R 3. N/R 4. N/R 5. n = 107	1. N/R 2. N/R 3. N/R 4. N/R 5. n = 101	1. Astra Tech®, [d] 2. Blasted fluoride-modified surface 3. 6 mm	1. Astra Tech®, [d] 2. Blasted fluoride-modified surface 3. 11 mm

(Continues)

TABLE 1 (Continued)

(B)

Diameter of implants		Surgical parameters	Prosthetic parameters (*n*)	Risk factors included/assessed	Results	
1. Narrow (3.3–3.5 mm) 2. Regular (3.75–4.7 mm) 3. Wide (4.8–6.0 mm)		1. Time of implant surgery 2. Open flap 3. Implant placement (1- versus 2-stage) 4. Definition for success	1. Loading protocol 2. Prosthesis 3. Retention method 4. Implant-abutment junction	1. Systemic condition 2. Smoker patients (total %, excluded/ inclusion of heavy smokers) 3. Bruxism 4. History of periodontitis 5. Quality of bone 6. Primary stability 7. Anatomical Crown-to-implant ratio (mean) short/long	1. Number of patients lost to follow-up 2. Failure (early; late) 3. Biological complications 4. Marginal bone loss from implant placement to the last follow-up (mean, *SD*) 5. Marginal bone loss from prosthetic loading placement to the last follow-up (mean, *SD*) 6. Prosthetic complications	
Short	Long				Short	Long
1. *n* = 0 2. *n* = 36 3. *n* =	1. *n* = 0 2. *n* = 37 3. *n* = 0	1. Late 2. Yes 3. 2-stage 4. N/R	1. Conventional 2. Metal ceramic/ Metal-resin/Full zirconia 3. Screw/Cemented 4. External	1. Yes 2. 17.5%, excluded 3. No 4. Yes 5. No 6. No 7. No	1. *n* = 0 2. *n* = 1; *n* = 0 3. *n* = 0 4. 1.04 ± 0.35 mm 5. N/R 6. *n* = 3	1. *n* = 0 2. *n* = 0; *n* = 0 3. *n* = 5 4. 1.54 ± 0.53 mm 5. N/R 6. *n* = 1
1. *n* = 0 2. *n* = 32 3. *n* = 0	1. *n* = 0 2. *n* = 31 3. *n* = 0	1. Late 2. Yes 3. 2-stage 4. N/R	1. Conventional 2. Metal ceramic/ Metal-resin/Full zirconia 3. Screw/Cemented 4. External	1. Yes 2. 15.4%, excluded 3. No 4. Yes 5. No 6. No 7. No	1. *n* = 0 2. *n* = 0; *n* = 1 3. *n* = 9 4. 1.1 ± 0.25 mm 5. N/R 6. *n* = 2	1. *n* = 1 2. *n* = 1; *n* = 1 3. *n* = 17 4. 1.39 ± 0.4 mm 5. N/R 6. *n* = 2
1. *n* = 0 2. *n* = 37 3. *n* = 0	1. *n* = 0 2. *n* = 41 3. *n* = 0	1. Late 2. Yes 3. 2-stage 4. N/R	1. Conventional 2. Metal composite/ Metal-resin FPD 3. Screw/Cemented 4. External	1. Yes 2. 27.5%, Included 3. No 4. Yes 5. No 6. Yes 7. No	1. *n* = 1 2. *n* = 2; *n* = 1 3. *n* = 2 4. 0.63 ± 0.22 mm 5. N/R 6. *n* = 2	1. *n* = 1 2. *n* = 5; *n* = 2 3. *n* = 2 4. 0.72 ± 0.2 mm 5. N/R 6. *n* = 7
1. n = 0 2. n = 44 3. n = 0	1. n = 0 2. n = 44 3. n = 0	1. Late 2. Yes 3. 2-Stage 4. N/R	1. Conventional 2. Metal ceramic/ Metal-resin 3. Cemented 4. External	1. Yes 2. 15%, Included 3. No 4. Yes 5. Yes 6. No 7. No	1. *n* = 0 2. *n* = 0; *n* = 2 3. *n* = 0 4. 1.28 ± 0.37 mm 5. N/R 6. *n* = 1	1. *n* = 0 2. *n* = 0; *n* = 0 3. *n* = 4 4. 1.5 ± 0.37 mm 5. N/R 6. *n* = 1

(Continues)

TABLE 1 (Continued)

(B) Diameter of implants: 1. Narrow (3.3–3.5 mm) 2. Regular (3.75–4.7 mm) 3. Wide (4.8–6.0 mm) — Short	Diameter of implants — Long	Surgical parameters: 1. Time of implant surgery 2. Open flap 3. Implant placement (1- versus 2-stage) 4. Definition for success	Prosthetic parameters (*n*): 1. Loading protocol 2. Prosthesis 3. Retention method 4. Implant-abutment junction	Risk factors included/assessed: 1. Systemic condition 2. Smoker patients (total %, excluded/inclusion of heavy smokers) 3. Bruxism 4. History of periodontitis 5. Quality of bone 6. Primary stability 7. Anatomical Crown-to-implant ratio (mean) short/long	Results: 1. Number of patients lost to follow-up 2. Failure (early; late) 3. Biological complications 4. Marginal bone loss from implant placement to the last follow-up (mean, *SD*) 5. Marginal bone loss from prosthetic loading placement to the last follow-up (mean, *SD*) 6. Prosthetic complications — Short	Results — Long
1. $n = 0$ 2. $n = 41$ 3. $n = 0$	1. $n = 0$ 2. $n = 47$ 3. $n = 0$	1. Late 2. Yes 3. 2-Stage 4. N/R	1. Conventional 2. Metal ceramic/ Metal-resin 3. Cemented 4. External	1. Yes 2. 10%, excluded 3. No 4. Yes 5. Yes 6. No 7. No	1. $n = 0$ 2. $n = 0$; $n = 0$ 3. $n = 0$ 4. 1.25 ± 0.35 mm 5. N/R 6. $n = 0$	1. $n = 0$ 2. $n = 3$; $n = 0$ 3. $n = 8$ 4. 1.54 ± 0.14 mm 5. N/R 6. $n = 0$
1. N/R 2. N/R 3. N/R	1. N/R 2. N/R 3. N/R	1. Late 2. Yes 3. 1-Stage 4. Albrektsson and Isidor (1994); Ganeles et al. (2008)	1. Early 2. PFM[a] 3. Screw 4. Internal	1. Yes 2. 28.3%, excluded 3. Yes 4. Yes 5. Yes 6. Yes 7. Yes	1. $n = 7$ 2. $n = 0$; $n = 3$ 3. $n = 2$ 4. N/R 5. 0.43 ± 0.91 mm 6. N/R	1. $n = 9$ 2. $n = 0$; $n = 0$ 3. $n = 8$ 4. N/R 5. 0.35 ± 0.99 mm 6. N/R
1. $n = 0$ 2. $n = 0$ 3. $n = 16$	1. $n = 0$ 2. $n = 0$ 3. $n = 18$	1. Late 2. Yes 3. 2-Stage 4. N/R	1. Conventional 2. Metal-ceramic or metal-composite 3. Screw/Cemented 4. External	1. Yes 2. 55%, included 3. No 4. Yes 5. No 6. No 7. No	1. $n = 0$ 2. $n = 0$; $n = 0$ 3. $n = 0$ 4. 0.89 ± 0.25 mm 5. N/R 6. $n = 1$	1. $n = 2$ 2. $n = 0$; $n = 0$ 3. $n = 1$ 4. 1.08 ± 0.29 mm 5. N/R 6. $n = 0$
1. $n = 0$ 2. $n = 1$ 3. $n = 44$	1. $n = 0$ 2. $n = 20$ 3. $n = 25$	1. Late 2. Yes 3. 2-Stage 4. N/R	1. Conventional 2. PFM[a] 3. Screw/Cemented 4. Internal	1. Yes 2. 28.3%, N/A 3. Yes 4. Yes 5. Yes 6. Yes 7. No	1. $n = 1$ 2. $n = 0$; $n = 0$ 3. $n = 0$ 4. 0.2 mm[i] 5. N/R 6. $n = 0$	1. $n = 0$ 2. $n = 1$; $n = 1$ 3. $n = 18$ 4. 0.27 mm[i] 5. N/R 6. $n = 0$

(Continues)

TABLE 1 (Continued)

(B) Diameter of implants: 1. Narrow (3.3–3.5 mm) 2. Regular (3.75–4.7 mm) 3. Wide (4.8–6.0 mm) — Short	Long	Surgical parameters: 1. Time of implant surgery 2. Open flap 3. Implant placement (1- versus 2-stage) 4. Definition for success	Prosthetic parameters (*n*): 1. Loading protocol 2. Prosthesis 3. Retention method 4. Implant-abutment junction	Risk factors included/assessed: 1. Systemic condition 2. Smoker patients (total %, excluded/inclusion of heavy smokers) 3. Bruxism 4. History of periodontitis 5. Quality of bone 6. Primary stability 7. Anatomical Crown-to-implant ratio (mean) short/long	Results: 1. Number of patients lost to follow-up 2. Failure (early; late) 3. Biological complications 4. Marginal bone loss from implant placement to the last follow-up (mean, *SD*) 5. Marginal bone loss from prosthetic loading placement to the last follow-up (mean, *SD*) 6. Prosthetic complications — Short	Long
1. $n = 0$ 2. $n = 67$ 3. $n = 0$	1. $n = 0$ 2. $n = 70$ 3. $n = 0$	1. Late 2. Yes 3. 1-stage/2-Stage 4. N/R	1. Conventional 2. N/R 3. Screw/Cemented 4. Internal	1. Yes 2. 21%, N/A 3. Yes 4. Yes 5. No 6. Yes 7. 1.86/0.99	1. $n = 5$ 2. $n = 0$; $n = 0$ 3. $n = 2$ 4. 0.44 ± 0.56 mm 5. 0.1 ± 0.54 mm 6. $n = 10$	1. $n = 2$ 2. $n = 0$; $n = 0$ 3. $n = 9$ 4. 0.43 ± 0.58 mm 5. 0.25 ± 0.58 mm 6. $n = 3$
1. $n = 0$ 2. $n = 30$ 3. $n = 0$	1. $n = 0$ 2. $n = 30$ 3. $n = 0$	1. Late 2. Yes 3. 1-stage 4. N/R	1. Early 2. Gold–palladium alloy and porcelain 3. Screw/Cemented 4. Internal	1. Yes 2. 21.7%, included 3. Yes 4. Yes 5. Yes 6. Yes 7.1.21/0.73	1. $n = 0$ 2. $n = 1$; $n = 3$ 3. $n = 0$ 4. 0.52 mm[j] 5. 0.14 mm[j] 6. $n = 0$	1. $n = 0$ 2. $n = 0$; $n = 0$ 3. $n = 0$ 4. 0.54 mm[j] 5. 0.18 mm[j] 6. $n = 0$
1. $n = 0$ 2. $n = 0$ 3. $n = 90$	1. $n = 0$ 2. $n = 0$ 3. $n = 91$	1. Immediate 2. Flapless & Open flap 3. 1-Stage Surgery 4. N/R	1. Immediate 2. Metal-resin 3. Screw 4. External	1. Yes 2. 23.3%, included 3. No 4. Yes 5. Yes 6. Yes 7. No	1. $n = 0$ 2. $n = 2$; $n = 0$ 3. $n = 1$ 4. 0.15 ± 0.46 mm 5. N/R 6. $n = 0$	1. $n = 0$ 2. $n = 0$; $n = 0$ 3. $n = 0$ 4. 0.62 ± 0.46 mm 5. N/R 6. $n = 1$
1. $n = 0$ 2. $n = 0$ 3. $n = 62$	1. $n = 0$ 2. $n = 0$ 3. $n = 60$	1. Immediate 2. Flapless & Open flap 3. 1-Stage Surgery 4. N/A	1. Immediate 2. Metal-resin 3. Screw 4. External	1. Yes 2. 36.7%, included 3. No 4. Yes 5. Yes 6. Yes 7. No	1. $n = 0$ 2. $n = 0$; $n = 0$ 3. $n = 0$ 4. 0.08 ± 0.12 mm 5. N/R 6. $n = 1$	1. $n = 0$ 2. $n = 0$; $n = 1$ 3. $n = 0$ 4. 0.51 ± 0.39 mm 5. N/R 6. $n = 1$

(Continues)

TABLE 1 (Continued)

(B)

Diameter of implants: 1. Narrow (3.3–3.5 mm) 2. Regular (3.75–4.7 mm) 3. Wide (4.8–6.0 mm) — Short	Diameter of implants — Long	Surgical parameters: 1. Time of implant surgery 2. Open flap 3. Implant placement (1- versus 2-stage) 4. Definition for success	Prosthetic parameters (*n*): 1. Loading protocol 2. Prosthesis 3. Retention method 4. Implant-abutment junction	Risk factors included/assessed: 1. Systemic condition 2. Smoker patients (total %, excluded/inclusion of heavy smokers) 3. Bruxism 4. History of periodontitis 5. Quality of bone 6. Primary stability 7. Anatomical Crown-to-implant ratio (mean) short/long	Results: 1. Number of patients lost to follow-up 2. Failure (early; late) 3. Biological complications 4. Marginal bone loss from implant placement to the last follow-up (mean, *SD*) 5. Marginal bone loss from prosthetic loading placement to the last follow-up (mean, *SD*) 6. Prosthetic complications — Short	Results — Long
1. $n = 0$ 2. $n = 26$ 3. $n = 0$	1. $n = 0$ 2. $n = 28$ 3. $n = 0$	1. Late 2. Yes 3. Sutures 4. 1-Stage 5. "Prosthesis and implants free of any complications"	1. Early 2. PFM[a] 3. Cemented 4. Internal	1. Yes 2. 33.3%, excluded 3. No 4. Yes 5. No 6. Yes 7. 0.86/0.68	1. $n = 1$ 2. $n = 1$; $n = 0$ 3. $n = 1$ 4. N/R 5. 0.43 ± 0.34 mm 6. $n = 4$	1. $n = 1$ 2. $n = 0$; $n = 0$ 3. $n = 0$ 4. N/R 5. 0.24 ± 0.45 mm 6. $n = 3$
1. $n = 0$ 2. $n = 0$ 3. $n = 34$	1. $n = 0$ 2. $n = 0$ 3. $n = 38$	1. Late 2. Yes 3. 2-Stage 4. N/R	1. Conventional 2. Metal ceramic 3. Cemented 4. Internal	1. Yes 2. 10%, included 3. No 4. Yes 5. No 6. Yes 7. No	1. $n = 2$ 2. $n = 1$; $n = 2$ 3. $n = 4$ 4. 1.02 ± 0.47 mm 5. N/R 6. n = 0	1. $n = 2$ 2. $n = 1$; $n = 1$ 3. $n = 1$ 4. 1.54 ± 0.35 mm 5. N/R 6. n = 0
1. $n = 0$ 2. $n = 0$ 3. $n = 26$	1. $n = 0$ 2. $n = 0$ 3. $n = 30$	1. Late 2. Yes 3. 2-Stage 4. N/R	1. Conventional 2. Metal ceramic 3. Cemented 4. Internal	1. Yes 2. 10%, excluded 3. No 4. Yes 5. No 6. Yes 7. No	1. $n = 0$ 2. $n = 0$; $n = 1$ 3. $n = 4$ 4. 1.44 ± 0.44 mm 5. N/R 6. $n = 1$	1. n = 2 2. $n = 1$; $n = 0$ 3. $n = 10$ 4. 1.63 ± 0.52 mm 5. N/R 6. $n = 0$
1. $n = 0$ 2. $n = 0$ 3. $n = 36$	1. $n = 0$ 2. $n = 0$ 3. $n = 37$	1. Late 2. Yes 3. 2-Stages 4. N/R	1. Conventional 2. Metal ceramic or Zirconia 3. Screw/Cemented 4. External	1. Yes 2. 17.5%, excluded 3. No 4. Yes 5. No 6. No 7. No	1. $n = 0$ 2. $n = 0$; $n = 1$ 3. $n = 0$ 4. 0.87 ± 0.3 mm 5. N/R 6. $n = 0$	1. $n = 0$ 2. $n = 0$; $n = 0$ 3. $n = 5$ 4. 1.15 ± 0.52 mm 5. N/R 6. $n = 0$

(Continues)

TABLE 1 (Continued)

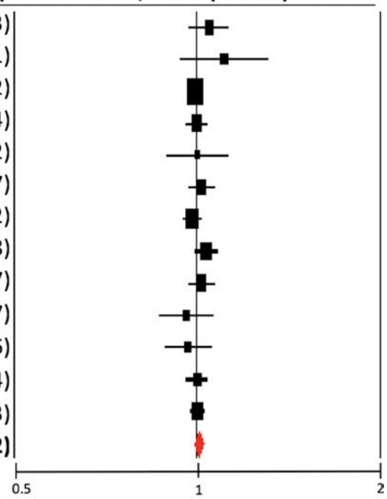
(B)

Diameter of implants		Surgical parameters	Prosthetic parameters (*n*)	Risk factors included/assessed	Results	
1. Narrow (3.3–3.5 mm) 2. Regular (3.75–4.7 mm) 3. Wide (4.8–6.0 mm)		1. Time of implant surgery 2. Open flap 3. Implant placement (1- versus 2-stage) 4. Definition for success	1. Loading protocol 2. Prosthesis 3. Retention method 4. Implant-abutment junction	1. Systemic condition 2. Smoker patients (total %, excluded/inclusion of heavy smokers) 3. Bruxism 4. History of periodontitis 5. Quality of bone 6. Primary stability 7. Anatomical Crown-to-implant ratio (mean) short/long	1. Number of patients lost to follow-up 2. Failure (early; late) 3. Biological complications 4. Marginal bone loss from implant placement to the last follow-up (mean, *SD*) 5. Marginal bone loss from prosthetic loading placement to the last follow-up (mean, *SD*) 6. Prosthetic complications	
Short	Long				Short	Long
1. $n = 0$ 2. $n = 0$ 3. $n = 32$	1. $n = 0$ 2. $n = 0$ 3. $n = 31$	1. Late 2. Yes 3. 2-Stages 4. N/R	1. Conventional 2. Metal ceramic or Zirconia 3. Screw/Cemented 4. External	1. Yes 2. 15%, excluded 3. No 4. Yes 5. No 6. No 7. No	1. $n = 0$ 2. $n = 0$; $n = 0$ 3. $n = 8$ 4. 0.94 ± 0.22 mm 5. N/R 6. $n = 0$	1. $n = 0$ 2. $n = 2$; $n = 0$ 3. $n = 17$ 4. 1.03 ± 0.52 mm 5. N/R 6. $n = 0$
1. $n = 0$ 2. $n = 107$ 3. $n = 0$	1. $n = 0$ 2. $n = 101$ 3. $n = 0$	1. Late 2. Yes 3. 1-Stage & 2-stage 4. N/R	1. Early 2. PFM[a] 3. Screw 4. Internal	1. Yes 2. 8%, included 3. Yes 4. Yes 5. Yes 6. Yes 7. 1.83/0.93	1. $n = 0$ 2. $n = 3$; $n = 0$ 3. $n = 0$ 4. 0.2 ± 0.22 mm 5. 0.06 ± 0.27 mm (bone gain) 6. $n = 7$	1. $n = 1$ 2. $n = 0$; $n = 1$ 3. $n = 0$ 4. 0.41 ± 0.46 mm 5. 0.02 ± 0.6 mm (bone gain) 6. $n = 8$

Notes. N/R, not reported; N/A, not available; RCT, Randomised controlled trial.
[a]Porcelain-fused to metal. [b]Southern Implants (Irene, South Africa). [c]Straumann AG (Basel, Switzerland). [d]Astra Tech® (Dentsply, Sirona Implants, Mölndal, Sweden). [e]TwinKon Universal SA2 (Global D, Lyon, France). [f]Zimmer Biomet® (Palm Beach Gardens, Florida, USA). [g]MegaGen Implant (Gyeongbuk, South Korea). [i]Only reported mean and 95% CI of radiographic marginal bone loss. [j]Only reported mean value of radiographic marginal bone loss; excluded from meta-analysis for MBL.

1-year Survival rate	Short implant		Long implant			Risk ratio
Study or Subgroup	Events	Total	Events	Total	Weight (%)	MH, Fixed (95% CI)
Bechara et al. 2017	45	45	43	45	**5.5**	1.05 (0.97, 1.13)
Bolle et al. 2018	34	37	34	41	4.1	1.11 (0.94, 1.31)
Cannizzaro et al. 2015	150	152	150	151	19.0	0.99 (0.97, 1.02)
Esposito et al. 2014	59	60	67	68	7.9	1.00 (0.96, 1.04)
Felice et al. 2015	16	16	18	18	2.1	1.00 (0.89, 1.12)
Gastaldi et al. 2018	67	68	66	68	8.3	1.02 (0.97, 1.07)
Gulje et al. 2013	104	107	100	101	13.0	0.98 (0.95, 1.02)
Pistilli et al. 2013 a	80	80	88	91	10.3	1.03 (0.99, 1.08)
Pistilli et al. 2013 b	67	68	66	68	8.3	1.02 (0.97, 1.07)
Romeo et al. 2014	25	26	28	28	3.5	0.96 (0.87, 1.07)
Rossi et al. 2016	29	30	30	30	3.9	0.97 (0.88, 1.06)
Sahrmann et al. 2016	47	47	47	47	5.9	1.00 (0.96, 1.04)
Schincaglia et al . 2015	63	63	69	69	8.3	1.00 (0.97, 1.03)
Total (95% CI)		**799**		**825**	**100%**	**1.01 (0.99, 1.02)**
Total events	786		806			

Risk ratio MH, Fixed (95% CI)

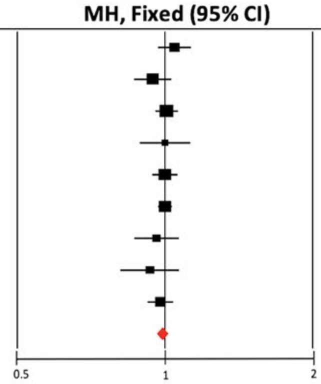


Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 8.83$, $df = 12$ ($p = 0.79$); $I^2 = 0\%$

(a) Test for overall effect: $Z = 0.13$ ($p = 0.90$)

3-year Survival rate	Short implant		Long implant			Risk ratio
Study or Subgroup	Events	Total	Events	Total	Weight%	MH, Fixed (95% CI)
Bechara et al. 2017	45	45	43	45	9.9	1.05 (0,97, 1.13)
Esposito et al. 2014	55	60	66	68	14.1	0.94 (0.87, 1.03)
Felice et al.2018	78	80	88	91	18.8	1.01 (0.96, 1.06)
Gastaldi et al. 2017	16	16	18	18	3.8	1.00 (0.89, 1.12)
Gastaldi et al. 2018	66	68	66	68	15.1	1.00 (0.94, 1.06)
Pohl et al. 2017	61	61	68	68	14.6	1.00 (0.97, 1.03)
Romeo et al. 2014	25	26	28	28	6.3	0.96 (0.87, 1.07)
Rossi et al. 2016	26	30	29	30	6.6	0.93 (0.81, 1.07)
Sahrmann et al. 2016	46	47	47	47	10.8	0.98 (0.92, 1.04)
Total (95% CI)		**433**		**463**	**100%**	**0.99 (0.97, 1.01)**
Total events	418		453			

Risk ratio MH, Fixed (95% CI)

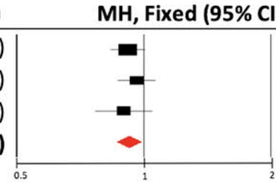


Heterogeneity: $Tau^2 = 0.000$; $Chi^2 = 5.57$, $df = 8$ ($p = 0.70$); $I^2 = 0\%$

(b) Test for overall effect: $Z = -0.40$ ($p = 0.69$)

5-year Survival rate	Short implant		Long implant			Risk ratio
Study or Subgroup	Events	Total	Events	Total	Weight (%)	MH, Fixed (95% CI)
Naenni et al.2018	43	47	47	47	44.8	0.92 (0.83, 1.01)
Romeo et al. 2014	25	26	28	28	38.2	0.96 (0.87, 1.07)
Rossi et al. 2016	26	30	29	30	17.0	0.90 (0.77, 1.05)
Total (95% CI)		**103**		**105**		**0.92 (0.86, 0.99)**
Total events	94		104			

Risk ratio MH, Fixed (95% CI)



Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.76$, $df = 2$ ($p = 0.69$); $I^2 = 0\%$

(c) Test for overall effect: $Z = -2.24$ ($p = 0.02$)

FIGURE 2 Forest plots (RR) of the survival rate comparing extra-short, with long implants group in (a) 1-year, (b) 3-year and (c) 5-year results. Mantel–Haenszel (MH)-weighted RR < 1 indicated a lower survival rate of extra-short implants than the long implants

rates between the extra-short and long implants at 1 (Figure 2a) and 3 years (Figure 2b; RR = 1.01, 95% CI: 0.99–1.02, $p = 0.90$ and RR = 0.99, 95% CI: 0.98–1.02, $p = 0.69$, respectively). However, extra-short implants revealed a statistically significant lower survival rate after 5 years (RR = 0.92, 95% CI: 0.86–0.99, $p = 0.02$; Figure 2c).

When a subgroup analysis dividing maxillary and mandibular arch was performed, after 1 year, a statistically significant

difference in favour of the extra-short implants was found in the mandible (RR = 1.04, $p = 0.04$), while no difference was noted for the maxillary counterpart (RR = 1.00, $p = 0.50$). Therefore, the arch had no impact on the risk ratio difference at 1 year ($p = 0.06$). At the 3-year follow-up mark, no significant differences were found between the test and control groups in the maxilla (RR = 1.00, $p = 0.67$) or mandible (RR = 1.03, $p = 0.31$). Finally, subgroup analysis (of only the maxilla/mandible independently) of the three studies with a 5-year follow-up (Naenni et al., 2018; Romeo et al., 2014; Rossi et al., 2016) was impossible to perform since they combined the data of both jaws.

Among the nine studies assessing the performance of both groups in the maxilla (Bechara et al., 2017; Bolle et al., 2018; Cannizzaro et al., 2015; Esposito et al., 2014; Felice et al., 2015, 2018; Gastaldi et al., 2018; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017), only one reported the outcomes of implants placed in sufficient bone height without an augmentation procedure (Cannizzaro et al., 2015). The mixed-effect subgroup analysis showed that the test and control group survival rate at the first year in the maxilla did not vary significantly between implant placement after augmentation and implant placement independent of an augmentation ($p = 0.34$) procedures, with individual non-significant results of RR = 1.00 for augmentation and RR = 0.98 for no augmentation. For studies with vertical bone augmentation in the mandible (Esposito et al., 2014; Felice et al., 2018; Pistilli, Felice, Cannizzaro, et al., 2013; Pistilli, Felice, Piattelli, et al., 2013), long implants showed a slightly lower survival rate (RR = 1.06) than the extra-short implants ($p = 0.03$) at 1-year follow-up. However,

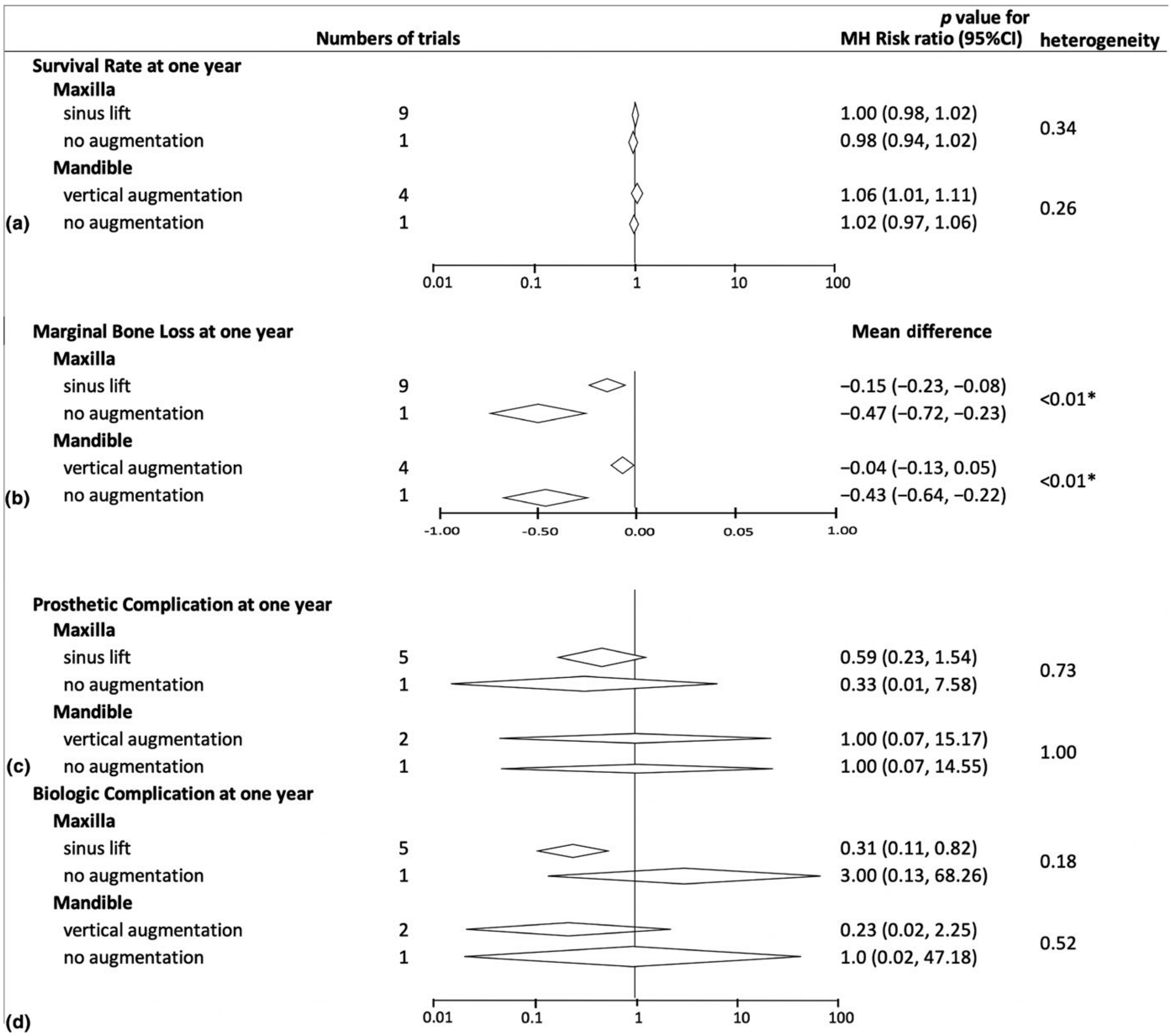


FIGURE 3 Subgroup analyses for the effects of augmentation on (a) survival rate at 1 year , (b) marginal bone loss at 1 year measured from implants placement in the maxilla and mandible, and (c-d) complication rate at 1 year. *$p < 0.05$: significant difference between augmentation and non-augmentation groups

the results of the mixed-effect analysis of augmentation versus no augmentation in the mandible demonstrated the absence of a statistically significant difference ($p = 0.26$) (Figure 3a). The effect of the bone augmentation at 3 and 5 years in both jaws was not attainable due to the only investigation that did not place implants in augmented bone (Cannizzaro et al., 2015) evaluating the included patients for only 1 year.

Furthermore, meta-regression analyses showed no significant differences in the 1-year survival rate between the extra-short and long implants for CI ratio ($p = 0.61$), smoking ratio ($p = 0.86$), total smoking percentage ($p = 0.54$), when heavy smokers were excluded ($p = 0.36$) and in separate jaw sub-analysis. Other categorical moderators, such as follow-up period, splinted/single crowns, cement/screw-retention, early/conventional loading, were not significantly associated with the survival rate differences in the between-group comparisons ($p > 0.05$). Similarly, non-significant influence was also found at 3- and 5-year recalls.

3.6 | Peri-implant marginal bone loss (MBL)

Baseline peri-implant marginal bone levels were measured at different times between studies. Eleven articles measured the baseline bone levels at implant placement (Bechara et al., 2017; Bolle et al., 2018; Cannizzaro et al., 2015; Esposito et al., 2014; Felice et al., 2015, 2018; Gastaldi et al., 2017, 2018; Gulje et al., 2013; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017), three of which also considered bone changes from the time of prosthetic loading (Felice et al., 2015; Gulje et al., 2013; Pohl et al., 2017). In contrast, two articles (Naenni et al., 2018; Romeo et al., 2014) reported marginal bone changes only from the time of prosthetic loading, and coincidentally, these were the only two studies that have reported the MBL at the 5-year follow-up. Therefore, the marginal bone level changes between test and control were compared based on these two different baseline criteria.

First, the results of the random-effects meta-analysis of the 10 studies after a 1-year measurement of MBL from implant placement (Bechara et al., 2017; Bolle et al., 2018; Cannizzaro et al., 2015; Esposito et al., 2014; Felice et al., 2015, 2018; Gastaldi et al., 2018; Gulje et al., 2013; Pistilli, Felice, Piattelli, et al., 2013; Pohl et al., 2017) showed significantly greater MBL in the long implant group with a difference in means of −0.16 (CI: −0.23 to −0.10, $p < 0.001$; Figure 4a). Similarly, 3-year results from six studies (Bechara et al., 2017; Esposito et al., 2014; Felice et al., 2018; Gastaldi et al., 2017, 2018; Pohl et al., 2017) also demonstrated significantly higher bone loss with a difference of −0.23 (CI: −0.34 to −0.13, $p < 0.001$; Figure 4b).

Subgroup analysis between the maxilla and mandible showed a significantly greater MBL at 1 year in the long implant group in the maxilla (mean difference = −0.19; 95% CI: −0.28 to −0.10, $p < 0.001$); however, its mandibular counterpart failed to reach significance in a random-effects model (mean difference = −0.12; 95% CI: −0.26–0.05, $p = 0.11$). Hence, jaw location was not found to have a significant impact on the difference in MBL ($p = 0.42$). Similarly, jaw location did not impact the results of the 3-year follow-up; nevertheless, the mean difference in both jaws reached statistical significance ($p = 0.002$ in maxilla, $p < 0.001$ in mandible).

Comparison of studies performed in the maxilla with sinus augmentation showed more MBL at 1-year in the long implant group (mean difference = −0.15; 95% CI: −0.23 to −0.08; $p < 0.01$) (Figure 3b). Similarly, this finding was also apparent in the only study (Cannizzaro et al., 2015) in which bone augmentation was not performed (mean difference = −0.47 mm; 95%CI: −0.72 to −0.23; $p < 0.01$). In the mandible, a higher degree of marginal bone loss was observed in the long implant group with and without (Cannizzaro et al., 2015) vertical ridge augmentation, reporting significant mean differences of −0.04 (95% CI: −0.13–0.05; $p < 0.01$) and −0.43 mm (95% CI: −0.64 to −0.22; $p < 0.01$), respectively. Hence, the augmentation procedure had a significant influence on the MBL difference in the maxilla ($p = 0.02$) and mandible ($p = 0.001$).

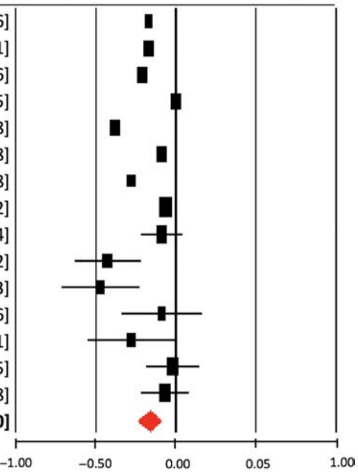
Meta-regression among the 1-year results showed early/conventional loading (coefficient: −0.22, $p = 0.002$) and screw/cement-retained (coefficient: −0.25, $p = 0.04$) was associated with more differences in means of MBL between the two groups (Figure 5a-b). In other words, early loaded long implants demonstrated more bone loss at 1 year compared with early loaded short implants. The same pattern was found in screw-retained prostheses, showing higher MBL than cement-retained prostheses. However, other covariates such as splinted/single ($p = 0.83$), smoking S/L ratio ($p = 0.24$), total smoking ratio ($p = 0.51$) or exclusion/inclusion of heavy smokers ($p = 0.15$) failed to reach statistical significance. All the parameters at 3 years did not contribute to a significant difference between the extra-short and long implants ($p > 0.05$).

The four studies that have considered prosthesis loading as the follow-up baseline (Felice et al., 2015; Gulje et al., 2013; Romeo et al., 2014; Schincaglia et al., 2015) failed to demonstrate a statistically significant difference between either groups at the 1- (mean difference = −0.08, CI: −0.18–0.03, $p = 0.15$), 3- ($p = 0.06$) and 5-year ($p = 0.4$) follow-up (Figure 4d-e). Among the 1-year studies, when both arches were combined, a bone augmentation procedure was not associated with the significant difference in MBL ($p = 0.17$). Meta-regression in the 1-year results also demonstrated that early/conventional loading protocols ($p = 0.15$), as well as the S/L smoking ratio ($p = 0.24$), total smoking percentage ($p = 0.88$), and the inclusion/exclusion of heavy smokers ($p = 0.09$) lacked a significant association with the differences in the study groups. Finally, a comparison of C/I ratio, splinting or screw- versus cement-retained was not possible due to a lack of data.

3.7 | Prosthetic/biological complication rate

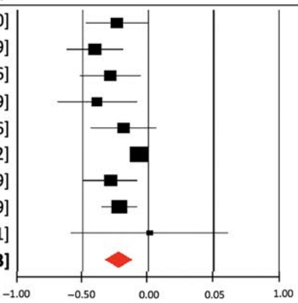
All the included trials reported biological complications, and all but two (Naenni et al., 2018; Sahrmann et al., 2016) also reported prosthetic (technical) complications. A subgroup meta-analysis according to the different follow-up years was performed based on the patient-reported incidence of complications. Although the 1-year prosthetic complication rate showed no significant differences between the

1-year MBL from IP		Short implant			Long implant				Mean difference
Study	Subgroup	Mean	SD	Total	Mean	SD	Total	Weight%	IV,Random,95% CI
Schincaglia et al. 2015	Mx	0.22	0.32	35	0.39	0.62	41	5.2	−0.17 [−0.40,0.06]
Felice et al. 2015	Mx	0.7	0.19	10	0.87	0.21	10	6.8	−0.17 [−0.35,0.01]
Gulje et al. 2013	Mx+Md	0.2	0.22	47	0.41	0.46	46	8.0	−0.21 [−0.36,−0.06]
Esposito et al. 2014	Md	1.2	0.49	15	1.20	0.47	15	7.6	0.001 [−0.15,−0.15]
Esposito et al. 2014	Mx	0.74	0.54	15	1.12	0.45	15	6.0	−0.38 [−0.58,−0.18]
Gastaldi et al. 2018	Md	0.94	0.22	20	1.03	0.31	18	7.2	−0.09 [−0.26,0.08]
Gastaldi et al. 2018	Mx	0.87	0.07	19	1.15	0.12	19	4.2	−0.28 [−0.55,−0.08]
Bechara et al. 2017	Mx	0.146	*	45	0.21	*	43	11.9	−0.06 [−0.11,−0.02]
Bolle et al. 2018	Mx	0.63	0.22	19	0.72	0.2	16	8.5	−0.09 [−0.22,0.04]
Cannizzaro et al. 2015	Md	0.08	0.12	15	0.51	0.39	15	5.8	−0.43[−0.64,−0.22]
Cannizzaro et al. 2015	Mx	0.15	0.15	15	0.62	0.46	15	4.8	−0.47 [−0.72,−0.23]
Pistilli et al. 2013 b	Md	0.94	0.22	20	1.03	0.52	18	4.7	−0.09 [−0.34,0.16]
Pistilli et al. 2013 b	Mx	0.87	0.3	19	1.15	0.52	19	4.2	−0.28 [−0.55,−0.01]
Pistilli et al. 2013 a	Md	1.05	0.26	19	1.07	0.25	18	7.3	−0.02 [−0.19,0.15]
Pistilli et al. 2013 a	Mx	1.02	0.27	20	1.09	0.22	20	7.7	−0.07 [−0.22, 0.08]
Total (95% CI)				**333**			**328**	**100%**	**−0.16 [−0.23,−0.10]**



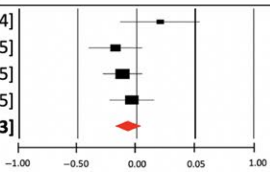
(a) Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 37.5$, $df = 14$($p = 0.001$); $I^2 = 62.7\%$
Test for overall effect: $Z = -4.7$ ($p < 0.001$)

3-year MBL from IP		Short implant			Long implant				Mean difference
Study	Subgroup	Mean	SD	Total	Mean	SD	Total	Weight%	IV,Random,95% CI
Esposito et al. 2014	Md	1.44	0.44	13	1.63	0.52	14	10.1	−0.24 [−0.48,−0.00]
Esposito et al. 2014	Mx	1.02	0.47	13	1.54	0.35	14	11.2	−0.41 [−0.63,−0.19]
Gastaldi et al. 2018	Md	1.1	0.25	17	1.39	0.40	14	10.4	−0.29 [−0.52,−0.06]
Gastaldi et al. 2018	Mx	1.04	0.35	17	1.43	0.53	17	7.5	−0.39 [−0.69,−0.09]
Gastaldi et al. 2017	Mx	0.89	0.25	10	1.08	0.29	8	9.6	−0.19 [−0.44,−0.06]
Bechara et al. 2017	Mx	0.2	*	44	0.27	*	43	20.8	−0.07 [−0.13,−0.02]
Felice et al. 2018	Md	1.25	0.35	15	1.54	0.14	14	11.7	−0.29 [−0.50,−0.09]
Felice et al. 2018	Mx	1.28	0.37	18	1.5	0.37	18	16.0	0.22 [−0.36,−0.09]
Pohl et al. 2017	Mx	0.44	0.56	52	0.43	0.58	52	2.6	0.01 [−0.59,0.61]
Total (95% CI)				**199**			**194**	**100%**	**−0.23 [−0.34,−0.13]**



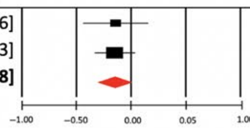
(b) Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 20.6$, $df = 8$($p = 0.01$); $I^2 = 61.7\%$
Test for overall effect: $Z = -4.43$ ($p < 0.001$)

1-year MBL from PL		Short implant			Long implant				Mean difference
Study	Subgroup	Mean	SD	Total	Mean	SD	Total	Weight%	IV,Fixed,95% CI
Romeo et al. 2014	Mx+Md	0.18	0.32	10	0.04	0.24	13	9.5	0.2 [−0.14,0.54]
Schincaglia et al. 2015	Mx	−0.02	0.3	33	0.16	0.62	41	20.5	−0.18 [−0.41,0.05]
Felice et al. 2015	Mx	0.39	0.19	10	0.51	0.19	10	39.3	−0.12 [−0.29,0.05]
Gulje et al. 2013	Mx+Md	−0.06	0.27	47	−0.02	0.6	46	30.7	−0.04 [−0.23,0.15]
Total (95% CI)				**100**			**110**	**100%**	**−0.08 [−0.18,0.03]**



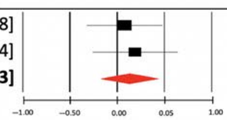
(c) Heterogeneity: $Tau^2 = 0.003$; $Chi^2 = 3.74$, $df = 3$($p = 0.29$); $I^2 = 19.79\%$
Test for overall effect: $Z = -1.45$ ($p = 0.15$)

3-year MBL from PL		Short implant			Long implant				Mean difference
Study	Subgroup	Mean	SD	Total	Mean	SD	Total	Weight%	IV,Fixed,95% CI
Sahrmann et al. 2016	Mx+Md	0.19	0.62	40	0.33	0.71	38	27.6	−0.14 [−0.44,0.16]
Pohl et al. 2017	Mx	0.1	0.54	50	0.25	0.58	50	72.4	−0.15 [−0.33,0.03]
Total (95% CI)				**90**			**88**	**100%**	**−0.15 [−0.30,0.08]**



(d) Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.03$, $df = 1$($p = 0.96$); $I^2 = 0\%$
Test for overall effect: $Z = -1.86$ ($p = 0.06$)

5-year MBL from PL		Short implant			Long implant				Mean difference
Study	Subgroup	Mean	SD	Total	Mean	SD	Total	Weight%	IV,Fixed,95% CI
Naenni et al. 2018	Mx+Md	0.43	0.91	40	0.35	0.99	46	55.3	0.08 [−0.32,0.48]
Romeo et al. 2014	Mx+Md	0.43	0.34	9	0.24	0.45	9	44.7	0.19 [−0.26,0.64]
Total (95% CI)				**49**			**55**	**100%**	**0.13 [−0.17,0.43]**



(e) Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.13$, $df = 1$($p = 0.72$); $I^2 = 0\%$
Test for overall effect: $Z = 0.84$ ($p = 0.40$)

FIGURE 4 Forest plots (Difference in means) for marginal bone loss comparing extra-short and long implant groups at 1, 3 and 5 years considering baseline at implant placement and implant prosthesis loading. Negative value in difference in means indicates more MBL in the long implant group. *effect size calculation based on the *p*-value and mean difference

extra-short and long implant groups (RR: 0.68, 95% CI: 0.37–1.25, $p = 0.26$; Figure 6a), the 3-year prosthetic complications showed a significantly higher rate in the short implant group with RR = 2.29 (CI: 1.08–4.85, $p = 0.04$; Figure 6b). At the 5-year follow-up, there was no statistically significant difference between the two groups (RR: 1.49, 95% CI: 0.45–4.96, $p = 0.5$) (Figure 6c).

During 1- and 3-year follow-up recalls, extra-short implants showed a significantly less biological complication rate compared to their long counterparts (RR = 0.32, 95% CI: 0.19–0.54, $p = 0.04$; RR = 0.28, 95% CI: 0.19–0.43, $p = 0.003$, respectively; Figure 6d,e). At 5 years, no statistically significant difference was found (RR = 1.79, 95% CI: 0.25–12.78, $p = 0.6$; Figure 6f).

Subgroup analysis showed no significant difference between the maxilla and mandible for prosthetic and biological complication rates ($p > 0.05$). When comparing studies with and without bone augmentation procedures in both jaws, similar non-significant differences were found ($p > 0.05$; Figure 3c). The influence of bone augmentation on prosthetic and biological complications was not significant when the incidences of complications from different follow-up years were combined ($p = 0.52$ & 0.11, respectively).

Biological complications were significantly higher in the maxillary sinus augmented sites compared to the extra-short group (RR: 0.31, 95% CI: 0.11–0.82, $p = 0.02$). However, in vertically augmented mandibular arches receiving long implants (RR: 0.23, 95% CI: 0.02–2.25, $p = 0.21$), a statistically significant difference was not demonstrated. Similarly, the impact of augmentation procedures on the biological complication rate in both jaws was not significant ($p > 0.05$; Figure 3d).

A meta-regression analysis showed no significant correlation between any covariates and prosthetic or biological complications. A subset meta-regression analysis in different jaw positions was performed to investigate any association between explanatory covariates and complication risks. The results showed smoking S/L ratio had a positive correlation to biological complications in the maxilla in all studies (coefficient = 3.48, $p = 0.057$), although the p value did not reach statistical significance ($p < 0.05$). This indicates that the

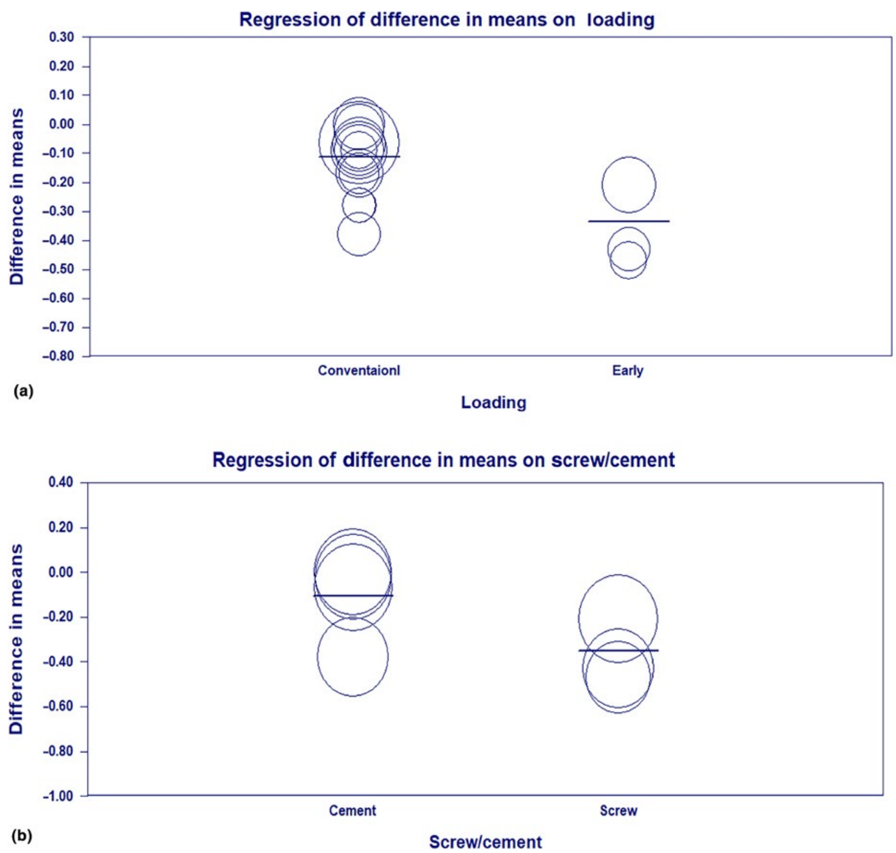
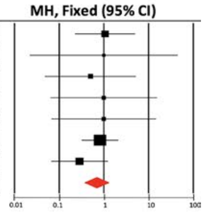


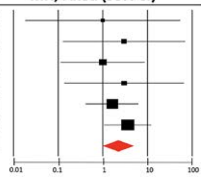
FIGURE 5 (a) Meta-regression (analysed based on maxillary subgroup) of the difference in mean of 1-year MBL from implant placement. Early loading group showed more difference in mean of MBL between short and long implants as reference to conventional loading (coefficient: −0.22; $p = 0.002$); goodness of fit: $\tau^2 = 0.004$; $\chi^2 = 20.9$, $df = 13$ ($p = 0.07$); $I^2 = 37.9\%$. (b) Meta-regression (analysed based on maxillary subgroup) of the difference in mean of 1-year MBL from implant placement. Screw retained group showed more difference in mean of MBL between short and long implants as reference to conventional loading (coefficient: −0.25; $p = 0.04$); goodness of fit: $\tau^2 = 0.02$; $\chi^2 = 14.67$, $df = 5$ ($p = 0.02$); $I^2 = 65.9\%$

1-year Prosthetic Complications	Short implant		Long implant			Risk ratio
Study	Events	Total	Events	Total	Weight (%)	MH, Fixed (95% CI)
Thoma et al. 2017	3	47	3	50	12.8	1.06 [0.23,5.01]
Felice et al. 2015	0	10	0	10	2.2	1.00 [0.02,45.64]
Cannizzaro et al. 2015	1	30	2	30	8.8	0.50 [0.05,5.23]
Pistilli et al. 2013 b	0	40	0	39	4.4	1.00 [0.06,15.44]
Pistilli et al. 2013 a	0	20	0	20	4.4	1.00 [0.06,14.9]
Gulje et al. 2013	7	49	8	46	36.4	0.82 [0.32,2.08]
Bolle et al 2018	2	20	7	20	30.9	0.29 [0.07,1.21]
Total (95% CI)		**216**		**215**	**100%**	**0.68 [0.37,1.25]**
Total events	13		20			



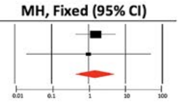
(a) Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.12$, $df = 6$ ($p = 0.91$); $I^2 = 0\%$
Test for overall effect: $Z = -1.13$ ($p = 0.26$)

3-year Prosthetic Complications	Short implant		Long implant			Risk ratio
Study	Events	Total	Events	Total	Weight (%)	MH, Fixed (95% CI)
Bechara et al. 2017	0	33	0	20	5.3	1.00 [0.02,54.60]
Esposito et al. 2014	1	30	0	30	5.6	3.00 [0.13,70.74]
Felice et al 2018	1	20	1	20	16.9	1.00 [0.11,8.82]
Gastaldi et al. 2017	1	10	0	10	5.6	3.00 [0.14,65.90]
Gastaldi et al. 2018	5	40	3	39	34.2	1.63 [0.42,6.34]
Pohl et al. 2017	10	45	3	49	32.3	3.63 [1.07,12.36]
Total (95% CI)		**178**		**168**	**100%**	**2.29 [1.08,4.85]**
Total events	18		7			



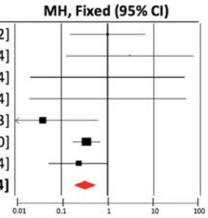
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.56$, $df = 5$($p = 0.91$); $I^2 = 0\%$
(b) Test for overall effect: $Z = 2.03$($p = 0.04$)

5-year Prosthetic Complications	Short implant		Long implant			Risk ratio
Study	Events	Total	Events	Total	Weight (%)	MH, Fixed (95% CI)
Romeo et al. 2014	4	11	3	13	84.6	1.58 [0.45,5.57]
Rossi et al. 2016	0	30	0	30	15.4	1.00 [0.02,48.78]
Total (95% CI)		**41**		**43**	**100%**	**1.49 [0.45,4.96]**
Total events	4		3			



Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.05$, $df = 1$($p = 0.83$); $I^2 = 0\%$
(c) Test for overall effect: $Z = 0.67$(p = 0.5)

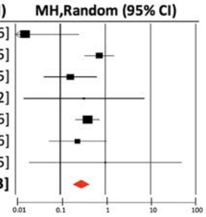
1-year Biologic Complications	Short implant		Long implant			Risk ratio
Study or Subgroup	Events	Total	Events	Total	Weight%	MH,Fixed (95% CI)
Bolle et al 2018	2	20	2	20	4.3	1.00 [0.16,6.42]
Cannizzaro et al. 2015	1	30	0	30	1.1	3.00 [0.13,70.74]
Felice et al. 2015	0	10	0	10	1.1	1.00 [0.02,45.64]
Gulje et al. 2013	0	49	0	46	1.1	1.00 [0.02,49.64]
Pistilli et al. 2013 a	0	20	12	20	26.6	0.04 [0.03,0.63]
Pistilli et al. 2013 b	8	40	22	39	47.4	0.36 [0.18,0.70]
Thoma et al. 2017	2	47	9	50	18.6	0.25 [0.05,1.04]
Total (95% CI)		**216**		**215**	**100%**	**0.32 [0.19,0.54]**
Total events	13		45			



Heterogeneity: $Tau^2 = 0.07$; $Chi^2 = 6.48$, $df = 6$($p = 0.37$); $I^2 = 7.51\%$
(d) Test for overall effect: $Z = -2.91$ ($p = 0.004$)

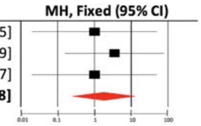
3-year Biologic Complications	Short implant		Long implant			Risk ratio
Study or Subgroup	Events	Total	Events	Total	Weight (%)	MH, Random (95% CI)
Bechara et al. 2017	0	33	18	20	29.0	0.02 [0.00,0.26]
Esposito et al. 2014	8	30	11	30	14.0	0.73 [0.34,1.55]
Felice et al. 2018	2	20	12	20	15.23	0.17 [0.04,0.65]
Gastaldi et al. 2017	0	10	1	10	1.9	0.33 [0.02,7.32]
Gastaldi et al. 2018	9	40	22	39	28.3	0.40 [0.21,0.76]
Pohl et al. 2017	3	45	9	49	10.9	0.24 [0.05,1.06]
Sahrmann et al. 2016	0	47	0	47	0.6	1.00 [0.02,49.35]
Total (95% CI)		**225**		**215**	**100%**	**0.28 [0.19,0.43]**
Total events	22		73			

(e)



Heterogeneity: $Tau^2 = 0.43$; $Chi^2 = 12.13$, $df = 6$($p = 0.06$); $I^2 = 50.54\%$
Test for overall effect: Z = −3.00 ($p = 0.003$)

5-year Biologic Complications	Short implant		Long implant			Risk ratio
Study	Events	Total	Events	Total	Weight (%)	MH, Fixed (95% CI)
Naenni et al.2018	0	47	0	47	34.2	1.00 [0.02,49.35]
Romeo et al. 2014	1	11	0	13	31.6	3.50 [0.16,78.19]
Rossi et al. 2016	0	30	0	30	34.2	1.00 [0.02,48.77]
Total (95% CI)		**88**		**90**	**100%**	**1.79 [0.25,12.78]**
Total events	1		0			



(f) Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.35$, $df = 2$ ($p = 0.84$); $I^2 = 0\%$
Test for overall effect: Z = 0.52 ($p = 0.60$)

FIGURE 6 Forest plots (RR) for prosthetic (a-c) and biologic (d-f) complication rate comparing extra-short implant with the long implant groups at 1-, 3- and 5-year follow-up. RR > 1 indicated a higher complication rate of extra-short implants than the long implants

higher the number of smokers in the short implant group the higher the tendency of biological complications occurring in short compared to long implants.

3.8 | Surgical time and treatment cost

Only two articles (Bechara et al., 2017; Thoma et al., 2015) reported a difference in surgical time and cost between the two study groups. In the first study, the mean time undergone in the placement of one implant in the extra-short group amounted to 52.6 min, while in the long implant group, the average time amounted to 74.6 min. In the test group of Bechara et al. (extra-short implants), the mean time required for the placement of a single implant was 19.1 min, whereas in the control group (sinus floor elevation with long implants), the mean time was 32.2 min. The calculated ratio (extra-short implant/sinus grafting with long implant) was 50% in the former article and 59% in the latter. Both differences were statistically significant ($p < 0.05$ and $p < 0.01$, respectively).

When the cost of both procedures was compared, Thoma et al. (2015) reported the mean price for an extra-short implant (without prosthesis) to be 941 EUR, while in the grafted group, it was totalled to 1,946 EUR. Similarly, Bechara and coworkers (Bechara et al., 2017) reported the average cost for the placement of a single extra-short implant to be 700 EUR, whereas in the long implant group, this was at 1,322 EUR (Bechara et al., 2017). Hence, in both studies where sinus floor elevation was performed, the cost of the procedure was nearly doubled ($p < 0.01$).

4 | DISCUSSION

The current use of extra-short implants is becoming a popular alternate treatment option in the management of the vertical ridge deficiencies of the posterior maxilla and mandible. This may be a result of the positive outcomes reported in previous prospective studies restoring implants with single or splinted prostheses (Rossi et al., 2015, 2016; Slotte et al., 2015).

To the best of our knowledge, this is the first meta-analysis comparing the clinical outcomes of extra-short (≤6 mm) and long implants (≥10 mm). The peculiarity of this study lies in the marked difference in the implant length between the test and control groups, namely a minimum of 4 mm. Preceding investigations comparing short implants to long implants, being either ≤8 mm versus >8 mm (Camps-Font et al., 2016; Lee et al., 2014) or ≤8 mm versus ≥9.3 mm (Tong et al., 2017), may not have been able to distinguish the variations or common treatment impacts across different studies. Additionally, the recent publication of several RCT's (Bechara et al., 2017; Bolle et al., 2018; Felice et al., 2018; Gastaldi et al., 2017, 2018; Naenni et al., 2018; Pohl et al., 2017; Rossi et al., 2015; Sahrmann et al., 2016) has allowed for a more efficient analysis of the scientific evidence in the existing literature.

The lack of a statistically significant difference in survival rate at 1 and 3 years between the test and control implants resembles the reports of previous meta-analyses (Lee et al., 2014; Tong et al., 2017). Instead, the higher survival rate demonstrated by long implants after 5 years is a novel finding not previously reported by meta-analyses comparing these two groups over shorter observational periods. However, this result should be interpreted with caution, since it is extrapolated from the analyses of only two articles placing long implants in native bone (Romeo et al., 2014; Rossi et al., 2016) and a third article (Naenni et al., 2018) in which bone augmentation (sinus lift) was performed when indicated. Thus, a long-term comparison between short implants versus long implants placed in augmented bone remains non-applicable. We believe that this comparison is essential in order to formulate a final judgment, since the primary advantage of short implants is to avoid bone augmentation procedures. The lack of heterogeneity among all the studies for the survival rate (I^2 = 0%), together with the limited dispersion of the forest plot, indicated highly consistent findings across studies as a result of the short-term follow-up in a large majority of the selected articles.

In the present article, the higher bone loss in the control group when baseline measurements were taken from implant placement could be attributed to bone remodelling prior to prosthetic loading as it is known to occur with the formation of an adaptive biological width following the second stage of implant surgery (Abrahamsson, Berglundh & Lindhe, 1997). Moreover, significant resorption is likely to follow vertical augmentation, especially in the mandible (Mertens et al., 2013). This higher MBL in the long implant group is corroborated in the reports of preceding meta-analyses on the same topic (Lemos, Ferro-Alves, et al., 2016; Tong et al., 2017). Furthermore, the heterogeneity in the meta-regression analysis for MBL indicated that the majority of the observed variance values stem from a real difference between studies and as such can potentially be explained by study-level covariates (Higgins et al., 2003). The heterogeneity found at the 1- and 3-year follow-up times (59.7% and 61.7%, respectively) for the MBL could be attributed to different surgical approaches in maxillary augmentation (transcrestal or lateral sinus lift), varying prosthetic designs and the inclusion of heavy smokers. In the meta-regression analysis, an early loading protocol (<10 weeks) was associated with more differences in means of MBL when compared with conventional loading (≥4 months). The result implies that earlier implant loading causes greater MBL, especially in the long implant group mostly after bone augmentation. Thus, earlier loading may have a detrimental effect on the new bone level. This conflicts with the concept of functional adaptation of bone to stimuli, manifesting as increased bone density (Sahrmann et al., 2017). Results also differ from the observations of previous meta-analyses that reported a lack of a statistically significant difference between the two loading protocols (Esposito, Grusovin, Willings, Coulthard & Worthington, 2007; Helmy, Alqutaibi, El-Ella & Shawky, 2017; Suarez, Chan, Monje, Galindo-Moreno & Wang, 2013).

Similarly, the difference in MBL around test and control groups was higher when implants were restored with screw-retained compared to cement-retained prostheses. Despite being considered as

a risk indicator for peri-implantitis (Wilson, 2009), the presence of cement has previously been described as a contributing factor of decreased misfit between the implant and the abutment, as well as an aid in balancing occlusal force distribution (Guichet, Caputo, Choi & Sorensen, 2000; Pietrabissa, Gionso, Quaglini, Martino & Simion, 2000). The results of a recent meta-analysis, including 9,000 implants, reflect our findings, that is, for bone loss in cement- as opposed to screw-retained prostheses (Lemos et al., 2016).

Prosthetic and biological complications were reported and compared at the patient level, rather than the implant level. Two previous meta-analyses failed to distinguish between these categories, merely combining both into "complications" (Fan et al., 2017; Lemos, Ferro-Alves, et al., 2016), while similarly to this study, two other meta-analyses (Lee et al., 2014; Tong et al., 2017) evaluated each category of complications independently. However, despite the similarity in the methodology, Tong and coworkers (Tong et al., 2017) failed to find statistically significant differences in both biological and prosthetic complications. It is possible that the increased sample size of the present article has increased the statistical power of the analysis, thus enhancing the chance of finding significant difference between groups. Surprisingly, the difference in biological complications between test and control has been caused by the higher number of negative episodes registered in the maxilla (Bechara et al., 2017; Pohl et al., 2017) during sinus lift procedures, which are known to be less operator-dependent than vertical bone augmentation in the mandible. On the contrary, the rates of prosthetic complications were higher in the short implant group, particularly due to the employment of non-splinted short implants (Pohl et al., 2017). Biomechanically, the increased number of prosthetic complications with higher C/I ratio could be explained by the increased microrotation/rocking, due to the longer occlusal height arm caused by the large prosthesis (Bidez & Misch, 2008) and/or by the higher resistance to prosthetic complications that accompanies the splinted crowns, particularly due to their resistance to rotational movements enhancing their stability to eccentric forces (Faucher & Bryant, 1983). Although the Egger's test failed to prove the publication bias in studies reporting both complication rates, most were plotted towards the bottom of the funnel plot and presented with a wide confidence interval. In this way, the estimated effect of treatment may be less accurate due to the relatively small sample size being calculated on a patient-based number. Furthermore, similar to what can be observed for the MBL, a sensitivity test showed that the heterogeneity (50%) for the 3-year biological complications came from covariates such as the type of prosthesis and time of loading.

Despite the presence of 18 different studies, the majority of them comprised short follow-ups (1–3 years), with only 3 of 12 articles reporting a 5-year follow-up, which set the primary limitation of this meta-analysis. A second limitation could be identified in the results of the mixed-effect analysis where the difference of MBL between augmentation and no augmentation groups reached significance. These results should be interpreted with caution since only one study (Cannizzaro et al., 2015) included in the present meta-analysis had not performed augmentation procedures in both jaw locations.

Furthermore, given the post hoc observational nature of the meta-regression, the results of potential associating clinical variants should be interpreted as hypothesis generating, suggesting the direction for future research rather than serving as proof of causality (Baker et al., 2009).

Thus, the results of the present review remain reliable for a short-term comparison. Further studies with a longer follow-up period are necessary to evaluate the performance of extra-short implants and confirm their clinical reliability in being used as clinical substitutes for longer implants.

5 | CONCLUSIONS

The results of the present article suggest that the placement of extra-short implants (≤6 mm) is a viable option in treating patients with an atrophic posterior arch for up to 3 years. In fact, during the first 3 years of placement, short implants have not only shown comparable survival rates but also reduced bone loss, biological complications, cost and surgical time compared to long implants (>10 mm). However, prosthetic complications were higher with extra-short implants. After a 5-year timeframe, long implants showed a higher survival rate than extra-short implants. Nonetheless, this result should be interpreted with caution as only three articles reported 5-year survival rates. In addition, most failures occurred within the first 3 years, with only one study (Naenni et al., 2018) reporting increased failure rates between the third and the fifth year. Hence, the long-term effectiveness of extra-short dental implants remains to be further investigated.

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CONFLICT OF INTEREST

The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

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SUPPORTING INFORMATION

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