Failures in Single Extra-Short Implants (≤ 6 mm): A Systematic Review and Meta-analysis

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Purpose: The aim of this systematic review with meta-analysis was to compare the survival rate of single crowns supported by extra-short implants (≤ 6 mm) to those supported by conventional implants, with or without previous maxillary sinus augmentation. The proportion of failures was described according to the type of complication and follow-up periods. ***Materials and Methods:*** Randomized and prospective clinical trials were selected from six databases and gray literature. The risk of bias was evaluated by Joanna Briggs Institute Critical Appraisal Checklist, and the certainty of the evidence was analyzed with Grading of Recommendations Assessment, Development, and Evaluation. Meta-analyses were processed with RevMan and MedCalc Statistical Software. ***Results:*** Single crowns supported by extra-short implants had a similar risk of failure to those supported by conventional implants, regardless of previous maxillary sinus augmentation ($P > .05$). Overall failure proportion of extra-short implants was 5.19%, but it varied according to follow-up (1.18% before loading, 1.56% at 12 months, 1.20% at 24 months, 2.10% at 48 months). Biologic failure complications were 37.90% for bleeding on probing, 22.45% for peri-implantitis, and 11.29% for infection. Prosthodontics failure complications were 14.88% for abutment failures and 14.73% for prosthetic screw loosening. Considering the risk of bias, most studies were classified at moderate risk. ***Conclusion:*** The risk of failure of single crowns supported by extra-short implants is similar to those supported by conventional implants, regardless of previous maxillary sinus augmentation or follow-up period. The most frequent biologic and prosthetic complications were bleeding on probing and abutment failures, respectively. *Int J Oral Maxillofac Implants 2021;36:669–689. doi: 10.11607/jomi.8689*

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The use of short or extra-short implants can be a relevant option to avoid major surgery, such as maxillary sinus augmentation, bone graft, guided bone regeneration, distraction osteogenesis, or inferior alveolar nerve displacement.[1,2] The placement of extra-short implants also requires less clinical time, interventions, costs, and patient morbidity, allowing the rehabilitation of the majority of patients.[2–4] Another advantage is the absence of complications related to augmentation procedures, including partial or total rejection of bone grafting, perforation of the maxillary sinus membrane, and/or postoperative sinusitis, inherent to the maxillary sinus elevation procedures.[5]

Several studies,[6–8] including systematic reviews,[9,10] reported survival rates of extra-short implants close or similar to conventional implants (> 8 mm). However, most of these studies refer to the use of splinted extra-short implants[6,8] or extra-short implants splinted to a conventional-size implant.[7] On the other hand, according to biomechanical tests, increasing the ratio between the crown and implant could enlarge the risk fracture during stress, especially for single crowns.[11] Occlusal loads have also been described as a factor that could increase the stress transmitted to the peri-implant bone, leading to biologic and prosthetic complications.[12]

Biologic complications can ultimately result in loss of osseointegration,[13] but a variety of clinical signs such as inflammation, mucositis, bleeding on probing, suppuration, and soft tissue dehiscences are commonly observed before the implant loss.[14] Among prosthetic complications, abutment or screw loosening are the most frequent.[14] Since the aforementioned prosthetic abutment problems are reversible and of reduced clinical complexity,[13] they are not well addressed in study descriptions, but they could be one of the first signs of future serious problems.

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In the literature, extra-short implant performance is still controversial. Some studies and reviews reported higher failure rates of extra-short implants in comparison to conventional-size implants associated with maxillary sinus augmentation,[4,15,16] while others hold opposite results.[17,18] When only nonsplinted single crowns are evaluated, a recently published systematic review[19] showed that extra-short implants must be indicated with caution in the posterior areas of alveolar bone since comparisons of long-term follow-ups indicated a poorer survival rate of extra-short implants in comparison to conventional-size implants (> 6 mm). The authors also reported the impossibility of performing a meta-analysis for complications, suggesting that further studies are essential to confirm the findings and to explore the failures in detail. To the best knowledge of the authors, no previous systematic review, with a wide approach, evaluated the types or proportions of extra-short implant failures. In addition, the inclusion of prospective clinical trials, besides randomized clinical trials, improves the performance assessment over the time of single crowns supported by extra-short implants. It is also allows the possibility of analyzing its performance according to each follow-up period.

Finally, the decision criteria for the indication of any treatment must be based on scientific evidence, surgical/prosthetic risk assessments, and factors related to the patient.[14] Thus, this systematic review aimed to answer the focused question: "What is the failure proportion of single crowns supported by extra-short implants (≤ 6 mm) in comparison to those supported by conventional implants, associated or not with previous maxillary sinus augmentation?" In addition, the objective was to describe the proportion of failures according to the type of complication and follow-up periods.

MATERIALS AND METHODS

Systematic Review Protocol and Registration

The protocol of this systematic review is in accordance with the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols).[20] The protocol registration number is CRD42019141507/PROSPERO (International Prospective Register of Systematic Review).[21] This systematic review was reported by following the PRISMA Checklist.[22]

Eligibility Criteria

Inclusion Criteria. The selected eligible studies were classified as randomized and prospective clinical trials, in which patients were rehabilitated with single crowns supported by extra-short implants (those ≤ 6 mm in length).[23] The studies should report clearly the follow-ups and outcomes (implant failure, biologic and prosthetic complications). Included studies were published in the Latin (Roman) alphabet.

Exclusion Criteria. The implemented exclusion criteria considered the following:

1. Studies in which the sample includes individuals rehabilitated only with implants longer than 6 mm or without comparison with extra-short implants (≤ 6 mm); or the number of ≤ 6 mm implants placed were below the minimum of 10
2. Studies with extra-short implants splinting to other implants or using overdentures or full fixed implant-supported prostheses
3. Book chapters, reviews of the literature, author letters, conference documents, abstracts in general, personal opinions, guidelines, case series (< 20 patients), case report, retrospective studies, protocol of clinical trials, and finite element analysis
4. Studies that did not present enough data, even after three attempts of contact with the authors
5. Types of research in which the sample includes individuals with uncontrolled systemic illnesses

Information Sources and Search Strategy

The search strategy was prepared with the direct assistance of a librarian with expertise in health sciences. The search was carried out on October 15, 2019. A search update was performed in August 2020. Keywords and MeSH terms were selected, and electronic search strategies were developed for each database: *(1)* Cochrane, *(2)* Embase, *(3)* LILACS, *(4)* PubMed, *(5)* Scopus, and *(6)* Web of Science. For searches related to grey literature, Google Scholar, OpenGrey, and ProQuest Dissertations and Thesis were used, and a manual search of the references of included studies was performed. The manuscripts were collected and brought together, followed by the exclusion of duplicates with the aid of a reference manager (EndNote X7, Thomson Reuters). More details on the proper truncation and all word combinations for each specific database are available in Appendix 1 (see Appendices in online version of this article at quintpub.com).

Study Selection

The study selection was done in two phases. In phase one, two investigators (M.M.B. and D.O.M.M.) independently screened the citations (titles and/or abstracts), using online software (Rayyan, Qatar Computing Research Institute). Subsequently, in phase two, the full texts of the selected studies were evaluated independently, according to the eligibility criteria. Any disagreements required re-analysis of the studies and resolution by consensus or consulting the third author (P.P.).

Data Collection Process

The same investigators (M.M.B. and D.O.M.M.) independently assessed and extracted the data through a preestablished data collection form (Table 1). A third author (P.P.) was involved if any disagreement arose.

Risk of Bias Within Studies

The risk of bias assessment of the selected studies was performed by the investigators M.M.B. and D.O.M.M, independently. The Joanna Briggs Institute Critical Appraisal Checklist for Randomized Controlled Trials and Quasi-Experimental Studies[24] was used. Disagreements were solved by a third reviewer (P.P.). The answers to each of the risk and bias questions were: "Yes (Y)," "No (N)," or "Unclear (UN)." The risk of bias was categorized as: *(1)* high—the studies achieve a "yes" score of up to 49%; *(2)* moderate—the "yes" score varied from 50% to 69%; and *(3)* low—the "yes" score exceeds 70%.

Summary Measures

The outcomes evaluated were the risk ratios and proportion of implant failures and the complications (biologic and prosthetic), considered as follows:

- Implant failure: The removal of the implant due to the absence of osseointegration, implant mobility without clinical signs of infection, progressive marginal bone loss, and implant body fracture with indicated removal[25]
- Biologic complications: Pain/swelling, neuropathy, loss of function, mucositis, peri-implantitis, fistula, suppuration, and/or exudation[25]
- Prosthetic complications: Failures of components and/or superstructure, fracture of veneering materials, fracturing or loosening of prosthetic components[25]

Articles from the same population were selected to collect accurate data on the exact moment when the failures occurred. In tables and figures, the articles from the same studies were kept together.

Synthesis of Results

Two statistical analyses were performed. First, a meta-analysis of comparison using implant failure risk ratio (RR) was performed comparing extra-short implants to conventional-size implants and extra-short implants to conventional-size implants associated with previous maxillary sinus augmentation. For this meta-analysis, only randomized clinical trials were included, and the RevMan software (Version 5.3, Copenhagen, The Nordic Cochrane Center, The Cochrane Collaboration, 2014) was used. Afterward, a proportion meta-analysis was performed including both types of studies, but considering only the extra-short implant group. This second analysis was performed using the MedCalc software (MedCalc Software; https://www.medcalc.org, 2016). The implant failure proportion meta-analysis was performed considering the overall failures, before loading, and at 1, 2, and 4 years of follow-up. A proportion meta-analysis focusing on the complications of biologic and prosthetic factors was also performed. The data were meta-analyzed in conformity with the fixed or random-effects models. If heterogeneity was considered above 50%, random effects were evaluated; if heterogeneity was less than 50%, fixed effects were adopted. The I^2 test was used to calculate statistical heterogeneity, and the level of significance was 5%. Heterogeneity was assessed according to Cochrane Handbook recommendations[26] and was categorized as follows: *(1)* might not be important—values varied from 0% to 40%; *(2)* moderate heterogeneity—30% to 60%; *(3)* substantial heterogeneity—50% to 90%; and *(4)* considerable heterogeneity—75% to 100%. The meta-analysis results were graphically represented in forest plots.

Certainty of Evidence Assessment

The overall certainty of evidence was presented, divided by the analyzed groups, using "Grading of Recommendations Assessment, Development and Evaluation" (GRADE).[27] The Summary of Findings (SoF) tables were produced on GRADE online software (GRADEpro GTD). The following domains were considered: risk of bias, inconsistency, imprecision, indirectness, and publication bias.

RESULTS

Study Selection

In phase one, 3,514 citations were found from the main electronic databases. After removing the duplicate citations, the titles and abstracts of 1,374 articles were evaluated. From the gray literature, 120 studies were identified (ProQuest returned 20 references, OpenGrey none, and in Google Scholar, the first 100 references were considered). Selected records of experts gathered 6 articles during the search update. Therefore, 57 articles comprised phase two, and after the update, the total was increased to 63 articles. From these remaining studies, 39 were excluded (see reasons in Appendix 2), resulting in 24 studies for qualitative and quantitative analysis. A flowchart summarizes this systematic selection process (Fig 1).

Study Characteristics

The data of interest were extracted from the 24 selected final articles (Table 1), of which 15 were classified as randomized clinical trials[1,3,4,15–17,28–34,41,44] and 9 were classified as prospective clinical trials.[13,35–40,42,43] A total

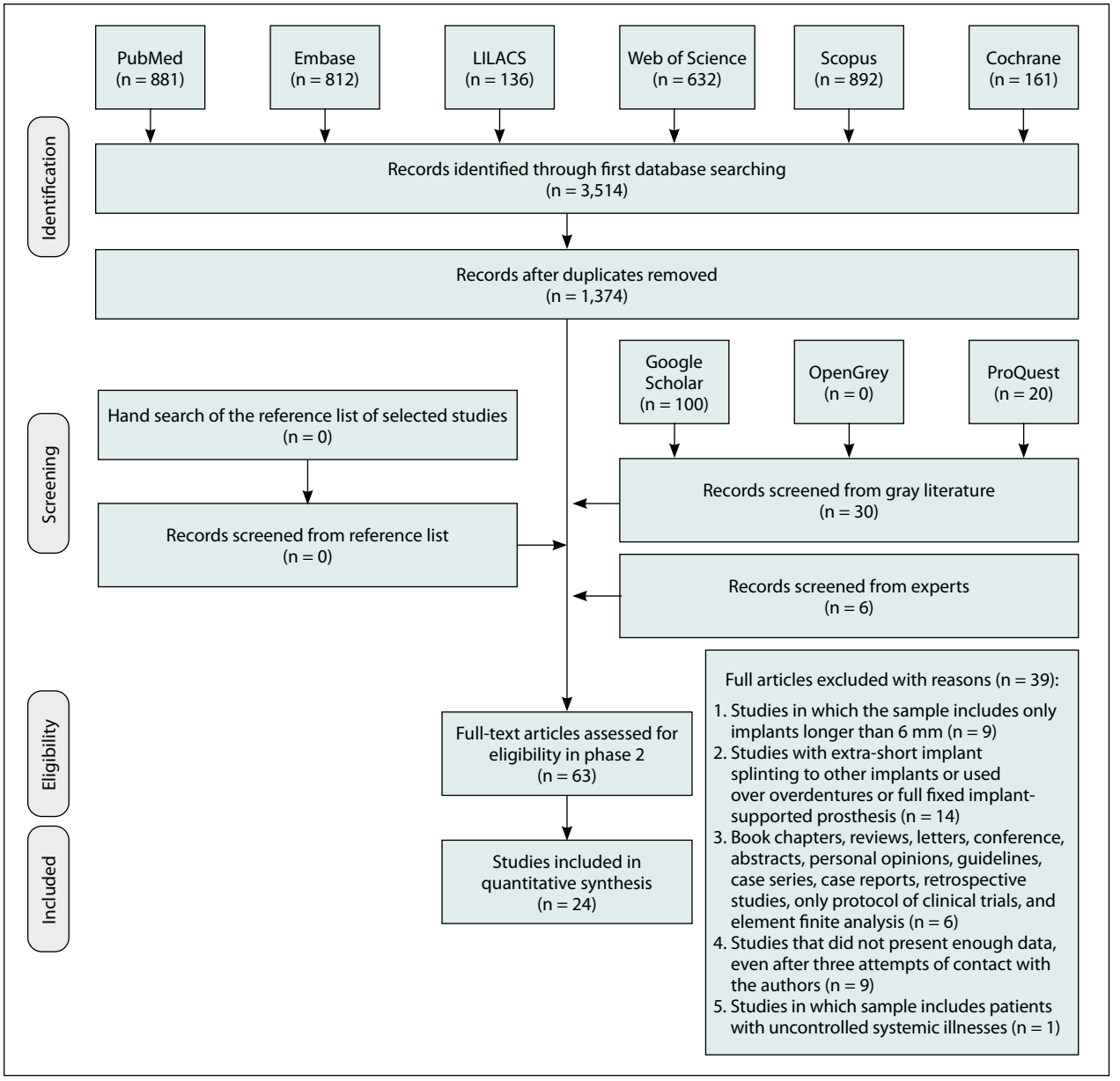


Fig 1 Flowchart of literature search and selection criteria.

of 657 extra-short implants were placed in the participants, with a mean age of 51.82 years (only the initial data were considered when the same study presented several publications with different follow-ups).

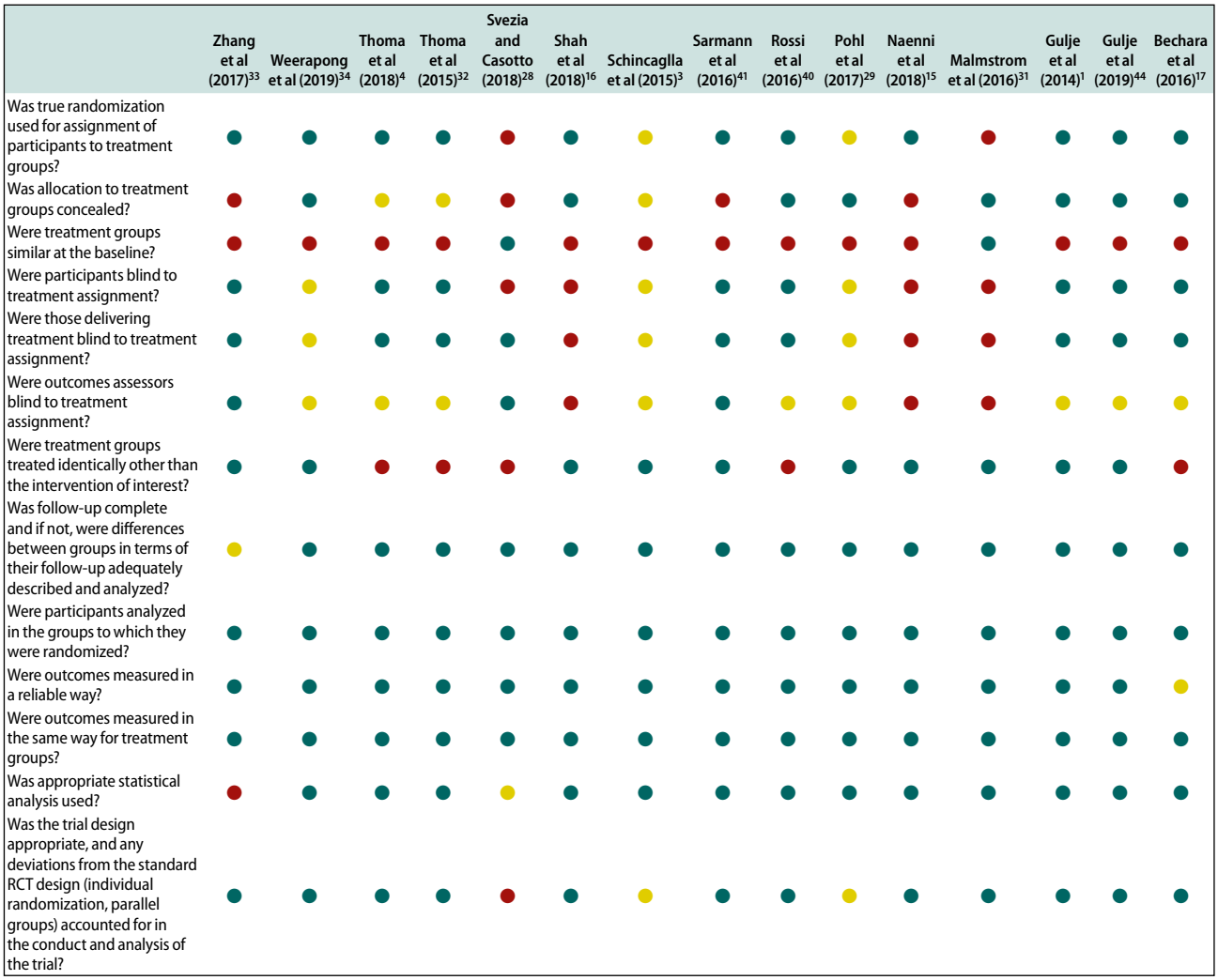
Risk of Bias

Two randomized clinical trials[3,29] were judged as high, three low,[1,30,44] and 10 moderate risk of bias[4,15–17,28,31–34,41] (Fig 2a). The most biased topic in these studies was related to similar treatment of groups at the baseline. Six prospective clinical trials[13,35-37,42,43] were judged as low and three[38–40] as moderate risk of bias (Fig 2b). The most biased topic in these studies was related to the absence of a control group. Further information about the risk of bias assessment can be found in Appendices 3 and 4.

Synthesis of Results

Qualitative Analysis. The main results of individual studies are detailed in Table 1. The highest survival rate was 100%,[1,3,17,29,32,33,36,42,43] with different follow-ups, ranging from 3,[33,36] 12,[1,3,32,42] 36,[17,29] and 60 months.[43] The lowest survival rate was 82.35%[35] after a 3-month follow-up. A longitudinal evaluation involving the same experiment distributed in three different articles[38–40] showed the survival rate of 95% (two lost implants be-

a



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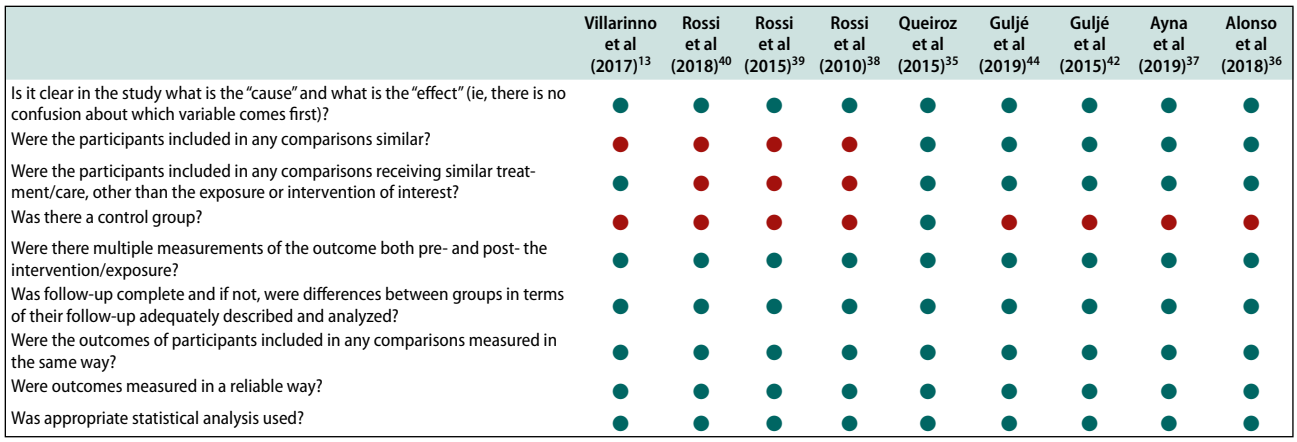


Fig 2 Risk of bias summary author's judgments for each included study, assessed by the *(a)* Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Randomized Controlled Trials and *(b)* Quasi-Experimental Studies, graphically represented by "traffic-light" plot (generated using the software RevMan).

Table 1 Characteristics of the Population, Interventions, Outcomes, and Main Conclusions of the Studies (n = 24)

		Intervention			
Study First author Year Design Country	**Population** 1. n of patients total (male; female) 2. n of patients for this review 3. Age (mean in years)	**Implant** 1. Manufacturer 2. Surface 3. Implant-abutment connection (internal vs external)	**Implant length (n)** 1. = 6 mm (n) 2. < 6 mm (n)	**Implant diameter (n)** 1. Regular (Ø4.0–Ø4.7mm) 2. Wide (Ø4.8–Ø6.0 mm)	**Surgical parameters (n)** 1. Timing of implant placement (immediate/early/late)* 2. Region of implant placement (maxilla — anterior/posterior; mandible — anterior/posterior)
Alonso et al (2018)[36] Prospective clinical trial Brazil	1. n = 18 (6;12) 2. n = 18 3. NR	1. Straumann 2. SLActive — Sand-blasted and acid-etched surfaces 3. Internal	1. n = 39 2. n = 0	1. n = 39 2. n = 0	1. NR 2. Maxilla (n = 16) and posterior mandible (n = 23)
Ayna et al (2019)[37] Prospective clinical trial Germany	1. n = 63 (30;33) 2. n = 63 3. 54.68 y	1. LGI plus, Hi-Tec 2. Sand-blasted and acid-etched surfaces 3. Internal	1. n = 63 2. n = 0	1. n = 0 2. n = 63	1. Late 2. Posterior maxilla
Bechara et al (2016)[17] RCT Lithuanian/Italy/Brazil	1. n = 53 (19;34) 2. n = 33 3. 48.1 y	1. Any-ridge Implants 2. Sand-blasted and acid-etched surfaces with nano layer of Ca_2 3. Internal	1. n = 45 2. n = 0	1. n = 11 2. n = 34	1. Immediate n = 9/Late n = 36 2. Posterior maxilla
Guljé et al (2014)[1] RCT Netherlands	1. n = 41 (20;21) 2. n = 21 3. 49 y	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed — fluoride-modified nanostructure 3. Internal	1. n = 21 2. n = 0	1. n = 21 2. n = 0	1. Late 2. Posterior maxilla
Guljé et al (2019)[44] RCT Netherlands	1. n = 38 (18;20) 2. n = 20 3. 50 y	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed — fluoride-modified nanostructure 3. Internal	1. n = 21 2. n = 0	1. n = 21 2. n = 0	1. Late 2. Posterior maxilla
Guljé et al (2015)[42] Prospective clinical trial Netherlands	1. n = 21 (7;14) 2. n = 21 3. 57.3 y	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed — fluoride-modified nanostructure 3. Internal	1. n = 31 2. n = 0	1. n =31 2. n = 0	1. Late 2. Posterior mandible
Guljé et al (2019)[43] Prospective clinical trial Netherlands	1. n = 21 (7;14) 2. n = 21 3. 57.3 y	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed — fluoride-modified nanostructure 3. Internal	1. n = 31 2. n = 0	1. n =31 2. n = 0	1. Late 2. Posterior mandible
Malmstrom et al (2016)[31] RCT USA	1. n = 30 (11;19) 2. n = NR 3. 53.6 y	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed — fluoride-modified nanostructure 3. Internal	1. n = 25 2. n = 0	1. n = 25 2. n = 0	1. Late 2. Posterior maxillae and mandible
Queiroz et al (2015)[35] Prospective clinical trial Brazil	1. n = 23 (5;18) 2. NR (n = 15 in implant group with 5.5- and 7-mm lengths reunited) 3. 53 y	1. Conexão Implants System 2. Master Porous (double acid-etched) 3. NR	1. n = 0 2. n = 17	1. n = 0 2. n = 17	1. Late 2. Posterior mandible

RCT = randomized clinical trial; NR = not reported.

Prosthetic parameters (n) 1. Loading protocol (immediate/early/ conventional) 2. Type of restoration (cemented vs screwed) 3. Follow-up in months (mean; range)	Risk factors included/ assessed (yes/no) 1. Systemic disease 2. Smoking 3. Bruxism 4. Periodontal disease	Outcome Outcomes (n) Number types 1. Dropouts/losses to follow-up 2. Biologic failure (type/n/time) 3. Prosthetic failure (type/n/time) 4. Failures (early; late)** 5. Marginal bone loss (mean; SD)	Proportions (%) 1. Survival rate (%)/Implant failure (n/ failure time)	Main conclusions
1. Conventional 2. Screw-retained 3. 3 mo after implant placement	1. Yes 2. Yes 3. NR 4. Yes	1. 0 2. NR 3. NR 4. 0 5. NR	1. 100%/n = 0	Short dental implants had primary and secondary stability affected by the bone type. When placed in places with deficient bone, both stabilities were reduced, but with the placement of the abutment, there was an increase in secondary stability.
1. Immediate (n = 48); conventional (n = 15) 2. Screw-retained 3. 60 mo	1. No 2. No 3. No 4. No	1. n = 0 2. The implant failures with regard to the parameters assessed (insertion torque, plaque accumulation, implant width, bone resorption). n = 54 were positive to bleeding on probing (n = 8 delayed group; n = 46 immediate group); n = NR; periodontal probing depth increased consistently. 3. n = 0 4. Late n = 3 (n = 1, in the end of the first year; n = 2, in the end of the second year) 5. < 2 mm	1. 93.7%/ n = 3 (n = 1 at the end of 1 year and n = 2 at the end of 2 years)	The placement of short unitary implants in the posterior region of the maxilla obtained satisfactory clinical findings regarding immediate and delayed loading. For implants with immediate loading, there was increased bone loss throughout the analyzed period and greater bleeding on probing, especially between 2 and 3 years.
1. Conventional 2. Cemented or screw-retained 3. 36 mo after implant placement	1. Yes 2. Yes 3. No 4. Yes	1. n = 1; (dead) 2. n = 0 3. n = 0 4. n = 0 5. 0.201 (CI: 0.166–0.236)	1. 100%/n = 0	Both 6-mm and ≥ 10-mm implants in combination with maxillary sinus elevation procedures achieved good results within 3 years after loading; the treatment with short implants (6 mm) had a reduced time and was less expensive.
1. Conventional 2. Cemented 3. 12 mo	1. Yes 2. Yes 3. NR 4. No	1. n = 0 2. n = 0 3. n = 0 4. n = 0 5. 0.944 (–0.20 to 0.21; 1 y)	1. 100%/n = 0	After 1 year of follow-up, single crowns supported by 6-mm and 11-mm implants in association with elevation of the maxillary sinus were equally successful.
1. Conventional. 2. Cemented 3. 60 mo	1. Yes 2. Yes 3. NR 4. No	1. n = 1 (moved away) 2. n = 5 (loss of osseointegration n = 1; peri-implant mucositis; n = 4) 3. n = 4 (chipping n = 2; lost due to implant failure n = 1; loosening the screw n=1) 4. n = 1 (late) 5. 0.12 ± 0.36 mm	1. 94.7%/n = 2 (before loading)	Considering morbidity and economic aspects, 6-mm-long implants become the first option in the rehabilitation of the posterior region of the reabsorbed maxilla. It is concluded that after 5 years, there was equality between the 6-mm implants and 11-mm implants associated with elevating the maxillary sinus in support of single crowns.
1. Conventional 2. Cemented 3. 12 mo	1. No 2. Yes 3. NR 4. No	1. n = 0 2. n = 0 3. n = 0 4. n = 0	1. 100%/n = 0	After 1 year of follow-up, single crowns supported by 6-mm implants (OsseoSpeed 4.0 S) installed in the posterior region of the resorbed mandible are a stable solution, with healthy peri-implant soft tissue conditions and high satisfaction.
1. Conventional 2. Cemented 3. 60 mo	1. No 2. Yes 3. NR 4. No	1. n = 0 2. n = 0 3. n = 0 4. n = 0	1. 100%/n = 0	After 5 years, single crowns supported by 6-mm implants (OsseoSpeed 4.0 S) placed in the posterior region of resorbed mandible are a stable solution, with healthy conditions of the peri-implant soft tissues, and have high satisfaction.
1. Conventional 2. Cemented 3. 24 mo	1. Yes 2. No 3. NR 4. No	1. NR 2. n = 1 (NR) 3. n = 1 the abutment screw fractured 4. Early 5. 0.45 mm (IQR 0.99)	1. 97%/n = 1 (healing phase)	Considering 2 years of follow-up, the success rate was similar between implants with a rough surface and lengths of 6 and 8 mm, placed in the posterior region of the mandible and maxilla, and 11-mm implants.
1. Immediate 2. NR 3. 3 mo	1. Yes 2. No 3. No 4. NR	1. n = 0 2. n = 3 Bacterial colonization by exposure of the threads 3. NR 4. Early 5. NR	1. 82.35%/n = 3 (3 mo)	After 3 mo, short implants had a lower survival rate than regular implants. However, short implants can be a reasonable alternative to severely resorbed jaws to prevent bone reconstruction prior to implant placement.

Table 1 Characteristics of the Population, Interventions, Outcomes, and Main Conclusions of the Studies (n = 24)

		Intervention			
Study First author Year Design Country	**Population** 1. n of patients total (male; female) 2. n of patients for this review 3. Age (mean in years)	**Implant** 1. Manufacturer 2. Surface 3. Implant-abutment connection (internal vs external)	**Implant length (n)** 1. = 6 mm (n) 2. < 6 mm (n)	**Implant diameter (n)** 1. Regular (Ø4.0–Ø4.7mm) 2. Wide (Ø4.8–Ø6.0 mm)	**Surgical parameters (n)** 1. Timing of implant placement (immediate/early/late)* 2. Region of implant placement (maxilla — anterior/posterior; mandible — anterior/posterior)
Rossi et al (2016)[30] RCT Italy, Cuba, and Switzerland	1. n = 60 (32;28) 2. n = 30 3. 48 y	1. Straumann 2. SLA modified surface 3. Internal	1. n = 30 2. n = 0	1. n = 30 2. n = 0	1. Late 2. Posterior maxilla and mandible
Rossi et al (2010)[38] Prospective clinical trial Italy	1. n = 35 (13;22) 2. n = 35 3. 51 y	1. Straumann 2. SLActive modified surface — sand-blasted and acid-etched surfaces 3. Internal	1. n = 40 2. n = 0	1. n = 19 2. n = 21	1. Early 2. Posterior maxilla and mandible
Rossi et al (2015)[39] Prospective clinical trial Italy	1. n = 35 (13;22) 2. n = 35 3. 51 y	1. Straumann 2. SLActive — sand-blasted and acid-etched surfaces 3. SynOcta abutment — Internal	1. n = 40 2. n = 0	1. n = 19 2. n = 21	1. Early 2. Posterior maxilla and mandible
Rossi et al (2018)[40] Prospective clinical trial Italy/Switzerland	1. n = 35 (13;22) 2. n = 35 3. 51 y	1. Straumann 2.SLActive — sand-blasted and acid-etched surfaces moderately rough surface 3. Internal	1. n = 40 2. n = 0	1. n = 19 2. n = 21	1. Early 2. Maxilla and mandible molar and premolar sites
Sahrmann et al (2016)[41] RCT Switzerland	1. 96 (NR) 2. n = 41 3. 52 y	1. Straumann — Standard Plus Tissue Level Implant 2. SLActive — sand-blasted and acid-etched surfaces 3.Internal	1. n = 41 2. n = 0	1. n = 41 2. n = 0	1. Late 2. Posterior maxilla and mandible
Naenni et al (2018)[15] RCT Switzerland	1. 86 (39;47) 2. n = 40 3. 56 y	1. Straumann — Standard Plus Tissue Level Implant 2. SLActive — sand-blasted and acid-etched surfaces 3. Internal	1. n = 40 2. n = 0	1. n = 40 2. n = 0	1. Late 2. Posterior maxilla and mandible
Schincaglia et al (2015)[3] RCT Italy/Switzerland/ Austria/Poland/Spain/ USA	1. 101 (49;52) 2. n = 50 3. 55.5 y	1. Dentsply Implants 2. Astra Tech Implant System OsseoSpeed 4.0 S 3. Internal	1. n = 67 2. n = 0	1. n = 67 2. n = 0	1. NR 2. Maxilla posterior
Pohl et al (2017)[29] RCT Austria/Switzerland/ Poland/Spain/USA	1. n = 101 (NR) 2. n = 50 3. NR	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed 4.0 S 3. Internal	1. n = 67 2. n = 0	1. n= 67 2. n = 0	1. Late 2. Maxilla posterior

RCT = randomized clinical trial; NR = not reported.

		Outcome		
Prosthetic parameters (n) 1. Loading protocol (immediate/early/ conventional) 2. Type of restoration (cemented vs screwed) 3. Follow-up in months (mean; range)	**Risk factors included/ assessed (yes/no)** 1. Systemic disease 2. Smoking 3. Bruxism 4. Periodontal disease	**Outcomes (n)** Number types 1. Dropouts/losses to follow-up 2. Biologic failure (type/n/time) 3. Prosthetic failure (type/n/time) 4. Failures (early; late)** 5. Marginal bone loss (mean; SD)	**Proportions (%)** 1. Survival rate (%)/Implant failure (n/ failure time)	**Main conclusions**
1. Early 2. NR 3. 60 mo	1. No 2. Yes 3. Yes 4. No	1. n = 0 2. n = 4 (Lost osseointegration) 3. n = 0 4. Early/late (n =1, before loading; n = 2, between the second and third-year follow-ups; n = 1, during the 4-year follow-up period) 5. 2.30 ± 0.52 (0.14 mm)	1. 86.7%/n = 4 (n = 1 – before loading; n = 2 – between the 24 and 36 mo; n = 1–48 mo)	Over 5 years of follow-up, marginal bone loss was similar for 6- and 10-mm-length implants. However, there was a greater loss of short implants, probably due to the surrounding bone fracture.
1. Conventional 2. NR 3. 24 mo	1. Yes 2. Yes 3. Yes 4. No	1. n = 0 2. n = 2 lost implant before loading (in a molar and premolar region) 3. n = 0 4. Early (before loading) 5. 0.21 ± 0.39 mm	1. 95%/n = 2 (before loading); 100%/n = 0 (after loading)	After 45 days, during healing, implants with 6 mm in length and moderate surface roughness, placed with early loading, obtained high survival rates and moderate bone loss after 2 years of loading.
1. Conventional 2. Cemented 3. 60 mo	1. Yes 2. Yes 3. Yes 4. No	1. n = 0 2. n = 2 Minimal signs of inflammation 3. n = 0 4. Early (n = 2, before loading) 5. 0.7 ± 0.6 mm	1. 95%/n = 2 (before loading) and 100%/n = 0 (after loading)	Single crowns supported by 6-mm-long implants (SLActive — sand-blasted and acid-etched surfaces) with moderate surface roughness in the posterior region and loaded after 45 days, may have a reduced rate of marginal bone loss and maintains complete function for at least 5 years. There was no mechanical complication.
1. Conventional 2. Cemented 3. 120 mo following prosthesis delivery	1. No 2. Yes 3. No 4. No	1. n = 3 (n = 1 death — 2 implants and 2 not available to come for reevaluation — 1 implant each) 2. n = 2 (before loading); n = 1 (after 7 y): peri-implantitis 3. n = 0 4. Early/late 5. Maxilla: 0.9 ± 0.4 mm; mandible: 0.7 ± 0.8 mm	1. 91.7%/n = 3 (n = 2 - before loading; n = 1–84 mo)	Single crowns supported by 6-mm-long implants and moderate surface roughness (SLActive — sandblasted and acid-etched surfaces) in the posterior region and loaded after 45 days, maintains reduced marginal bone resorption and complete function for 10 years.
1. Immediate 2. Screw-retained 3. 36 mo	1. No 2. Yes 3. Yes 4. Yes	1. n = 1 2. n = 1 (loss of osseointegration — second year of loading) 3. n = 3; (loosening of the abutment screw) 4. Late 5. −0.19 ± 0.62 mm	1. 98%/n = 1 (48 mo)	With a 3-year follow-up, there was no difference between the experimental and control implants associated with single crowns in the posterior region of the mandible, in terms of survival and marginal bone tissue level. There was a reduced rate of technical complications (3.8%) and absence of biologic complications.
1. Immediate 2. Screw-retained 3. 60 mo	1. No 2. Yes 3. Yes 4. Yes	1. n = 3 2. n = 4 (lost osseointegration; n = 1 after 2 years; n = 3 after 4 years) n = 12; probing depth ≥ 5 mm n = 2; bleeding on probing was measured at > 3 sites 3. n = NR; (minor chipping, screw loosening). 4. Late 5. 0.29 mm	1. 91%/n = 4 (n = 1 – 24 mo; n = 3 – 48 mo)	With 5 years of follow-up, although there was a small difference in the survival rate between 6-mm (91%) and 10-mm (100%) implants, the placement of 6-mm single implants is a reasonable alternative for standard-length implants.
1. Conventional 2. Screw-retained or cemented 3. 12 mo after loading	1. Yes 2. Yes 3. Yes 4. Yes	1. n = 3 (1 died — 2 implants and 2 lost during follow-up — 1 implant each) 2. n = 36 peri-implant mucositis observed after 12 mo of loading 3.NR 4. 0 5. −0.22 ± 0.3 mm	1. 100%/n = 0	There was similarity regarding the clinical and radiographic performance of 6-mm-long implants and larger 11- to 15-mm implants associated with maxillary sinus elevation.
1. Conventional 2. Screw-retained or cemented 3. 36 mo after placement of crown	1. NR 2. Yes 3. Yes 4. Yes	1. n = 5 (1 died; 4 lost during the follow-up) 2. n = 0 3. n = 9 (loosening/fracture of abutment screw — n = 7/2 years and n = 1/3 years; decementation of crown – n = 1/2 years) 4. n = 0 5. Premolar region was 0.6 ± 0.7 mm; molar region was 0.4 ± 0.5 mm	1. 100%/n = 0	Single crowns supported by 6-mm-long implants in the posterior region of the maxilla is a viable solution, in comparison to longer-length implants associated with maxillary sinus elevation.

Table 1 Characteristics of the Population, Interventions, Outcomes, and Main Conclusions of the Studies (n = 24)

		Intervention			
Study First author Year Design Country	**Population** 1. n of patients total (male; female) 2. n of patients for this review 3. Age (mean in years)	**Implant** 1. Manufacturer 2. Surface 3. Implant-abutment connection (internal vs external)	**Implant length (n)** 1. = 6 mm (n) 2. < 6 mm (n)	**Implant diameter (n)** 1. Regular (Ø4.0–Ø4.7mm) 2. Wide (Ø4.8–Ø6.0 mm)	**Surgical parameters (n)** 1. Timing of implant placement (immediate/early/late)* 2. Region of implant placement (maxilla — anterior/posterior; mandible — anterior/posterior)
Shah et al (2018)[16] RCT USA	1. n = 50 (19;31) 2. n = 25 3. 58.4 y	1. Mis Seven 2. Sand-blasted and acid-etched surfaces 3. Internal	1. n = 25 2. n = 0	1. NR 2. NR	1. Late 2. Posterior maxilla and mandible
Svezia and Casotto (2018)[28] RCT Italy	1. 110 (49;61) 2. NR 3. 58.4 y	1. JDEvolution 6 mm (n = 37) JDIcon 6 mm (n = 22) 2. Sand-blasted acid-etched surface up to the neck 3. Internal	1. n = 59 2. n = 0	1. NR 2. NR	1. NR 2. Maxilla (n = 40) and mandible (n = 18) posterior
Thoma et al (2015)[32] RCT Switzerland/Austria/ Poland/Spain/USA	1. 101 (49;52) 2. n = 50 3. 50.5 y	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed — fluoride-modified nanostructure 3. Internal	1. n = 67 2. n = 0	1. n = 67 2. n = 0	1. NR 2. Posterior maxilla
Thoma et al (2018)[4] RCT Switzerland/ Austria/ Poland/ Spain/ USA	1. 101 (49;52) 2. n = 44 3. 50.5 y	1. Dentsply Sirona Implants 2. Astra Tech Implant System OsseoSpeed — fluoride-modified nanostructure. 3. Internal	1. n = 60 2. n = 0	1. n = 60 2. n = 0	1. NR 2. Posterior maxilla
Villarinho et al (2016)[13] Prospective clinical trial Brazil	1. 20 (12;8) 2. n = 20 3. 52 y	1. Straumann Dental Implant System 2. SLActive — Sand-blasted and acid-etched surfaces 3. Internal	1. n = 46 2. n = 0	1. n = 46 2. n = 0	1. Late 2. Posterior maxilla and mandible
Weerapong et al (2018)[34] RCT Thailand	1. n = 46 (16;30) 2. n = 23 3. 50.5 y	1. PW+ Dental Implant System 2. Sand-blasting and etching process 3. Internal	1. n = 23 2. n = 0	1. NR 2. NR	1. Late 2. Posterior mandible
Zhang et al (2017)[33] RCT China	1. n = 56 (26;30) 2. n = 18 3. 37.5 y	1. Straumann Standard Plus 2. Sand-blasted and acid-etched surfaces 3. Internal	1. n = 18 2. n = 0	1. n = 7 2. n = 11	1. Late 2. Posterior maxilla

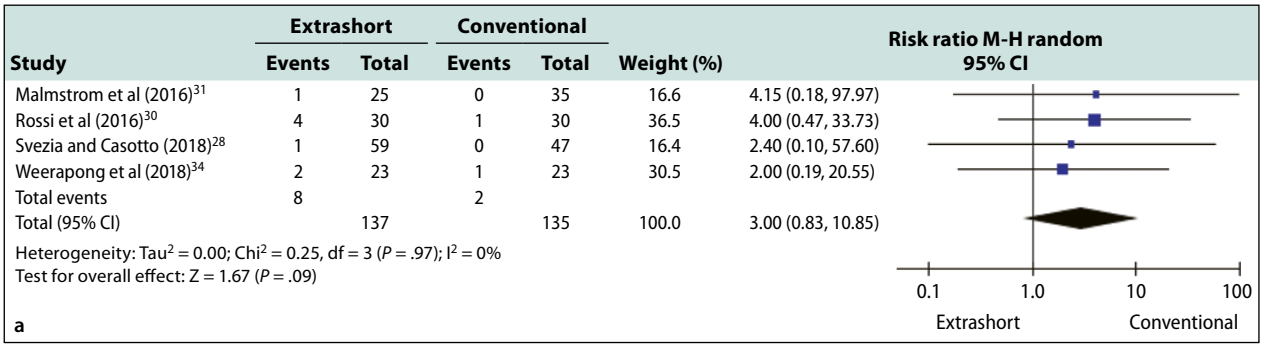
RCT = randomized clinical trial; NR = not reported.

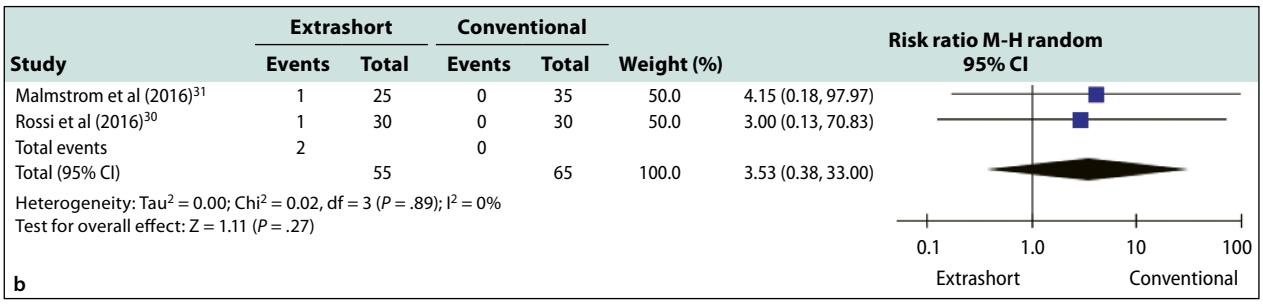
		Outcome		
Prosthetic parameters (n) 1. Loading protocol (immediate/early/ conventional) 2. Type of restoration (cemented vs screwed) 3. Follow-up in months (mean; range)	**Risk factors included/ assessed (yes/no)** 1. Systemic disease 2. Smoking 3. Bruxism 4. Periodontal disease	**Outcomes (n)** Number types 1. Dropouts/losses to follow-up 2. Biologic failure (type/n/time) 3. Prosthetic failure (type/n/time) 4. Failures (early; late)** 5. Marginal bone loss (mean; SD)	**Proportions (%)** 1. Survival rate (%)/Implant failure (n/ failure time)	**Main conclusions**
1. Conventional 2. NR 3. 12 mo	1. Yes 2. Yes 3. NR 4. Yes	1. n = 5 (relocation or unrelated medical conditions) 2. n = 4 lost implant prior restoration (prior restorations) 3. n = 0 4. Early 5. 0.6 ± 0.16 mm	1. 84%/n = 4 (all prior to restoration)	The survival rate of small-size implants was lower compared with conventional implants. Although they are a simple treatment alternative and convenient for placement in an atrophic mandible, the use of small-size implants requires caution in the face of the potential situation and available alternatives.
1. Conventional 2. Screw-retained or cemented 3. 24 mo after loading	1. Yes 2. Yes 3. NR 4.Yes	1. n = 4 were lost to follow-up of 24 mo, 2 withdrew consent to study protocol, 1 changed residence during the follow-up while 1 died due to a traffic accident 2. n = 1 (after 10 mo it became mobile and painful during function) 3. NR 4. Late 5. 0.38 ± 0.29 mm	1. 98.3%/n = 1 (after 10 mo)	The marginal bone loss was small and similar between 6-mm and 10-mm-long implants that support single crowns in the posterior region of the mandible and maxilla during 2 years of functional load. There was similarity regarding the failure of the implants.
1. Conventional 2. Screw-retained or cemented 3. 12 mo of loading	1. No 2. Yes 3. Yes 4. NR	1. n = 3 (1 died, 1 lost during follow-up, and 1 did not attend the 1-year examination; 4 implants were lost) 2. Surgically related (n = 2) 3. n = 1 (abutment loose); n = 1 (other abutment failure); n = 1 (fracture screw abutment) 4. NR 5. NR	1. 100%/n = 0	Small-size implants may be suitable for rehabilitation of the posterior region of the atrophied maxilla, and may be more favorable in terms of short-term morbidity, costs, and treatment time.
1. Conventional 2. Screw-retained or cemented 3. 60 mo after implant loading	1. No 2. Yes 3. Yes 4. NR	1. n = 6 (noncompliance, moved away, patient deceased, and could not be contacted) 2. n = 1 (lost — reason unknown); n = 5 (fistula, swelling, infection, and implant failure); n = 18, peri-implant mucositis (bleeding on probing): 40.9%; n = 6, plaque control record 3. n = 21 (fracture of abutment screw, screw loosening, chipping of veneering ceramic, lost crown, and loss of retention— decementation of crown) 4. Late 5. −0.12 ± 0.54 mm	1. 98.5%/n = 1 (48 mo)	The treatment modalities were suitable for rehabilitation with single implants in the posterior region of the atrophied maxilla, with no difference in survival rates, patient reports, marginal bone levels, and biologic and technical complications for up to 5 years.
1. Early 2. Screw-retained 3. 48 mo after baseline	1. Yes 2. NR 3. Yes 4. No	1. n = 1 (lost soon after the placement of the prosthesis) 2. n = 1 (clinical signs of infection with the presence of bleeding on probing and suppuration) n = 4 (after prosthetic loading) 3. n = 13 (loosening of the prosthetic screw; 28.3%) 4. Late 5. 0.3 ± 0.5 mm (−0.4; 1.5)	1. 91.3% / n = 4 (n = 2 – 12 mo; n = 1 – 36 mo; n = 1 – 48 mo)	Small-size implants placed in the posterior mandible and maxilla are an alternative treatment with high survival rates. There is a greater risk of implant loss in the mandible (95%) than in the maxilla. As for prosthetic complications, all of them could be reversible and of low complexity to correct, but they were greater than the reports in the literature. There was a loss of 0.1 mm of bone each year, with time being a predictor for bone loss. The clinical C/I ratio was considered a risk factor for bone loss, considering the loss of 0.1 mm for each increase of 0.1 in this proportion. There was no significance of other biologic and prosthetic factors tested with bone loss and prosthetic failure.
1. Immediate 2. Cemented 3. 12 mo	1. Yes 2. Yes 3. NR 4. No	1. n = 0 2. n = 2 (mobility at 2 and 4 mo after placement) 3. n = 3 (provisional crown fracture) 4. Early 5. 0.33 ± 0.47 mm	1. 91.3%/n = 2 (n = 1–2 mo; n = 1–4 mo)	Implant survival, stability quotient, and marginal bone level of small-size implants with immediate loading is comparable to conventional-size implants.
1. Conventional 2. Cemented 3. 3 mo	1. Yes 2. Yes 3. NR 4. Yes	1. n = 0 2. n = 0 3. NR 4. n = 0 5. NR	1. 100%/n = 0	Initial rates equal to zero for reduced implant size failure were considered safe in the posterior region of the atrophic maxilla. There was good patient satisfaction.

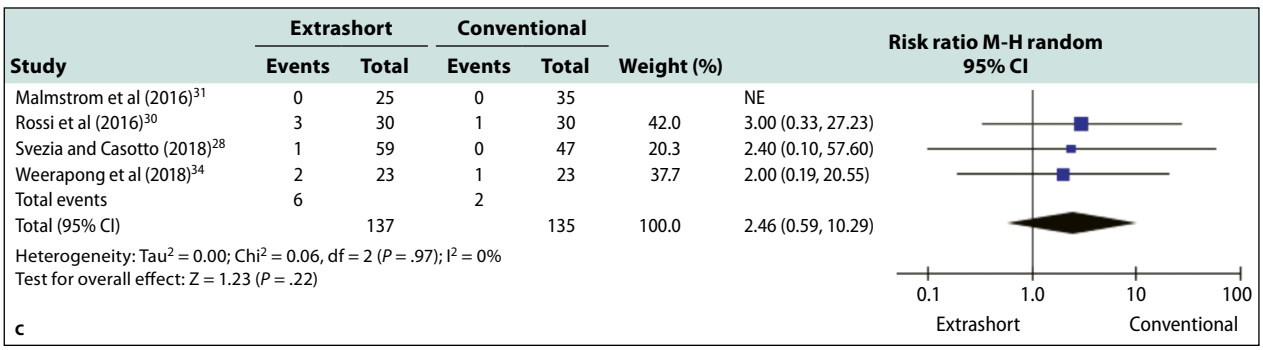
Table 2 Prosthetic Failure According to Number, Percentage, and Total of Implants Placed by Study

Prosthetic failures/study	Failure (n)	%	Total of implants (n)
Abutment failure			
Malmstrom et al (2016)[31]	1	4	25
Pohl et al (2017)[29]/Schincaglia et al (2015)[3]	8	12	67
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	3	7.5	40
Thoma et al (2018)[4]/Thoma et al (2015)[32]	21	28.6	60
Chipping			
Guljé et al (2019)[44]/Guljé et al (2014)[1]	2	9.5	21
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	NR	–	40
Decementation of crown			
Pohl et al (2017)[29]/Schincaglia et al (2015)[3]	1	1.5	67
Loosening of the prosthetic screw			
Guljé et al (2019)[44]/Guljé et al (2014)[1]	1	4.8	21
Villarinho et al (2016)[13]	13	28	46
Provisional crown fracture			
Weerapong et al (2018)[34]	3	13	23

NR= not reported.







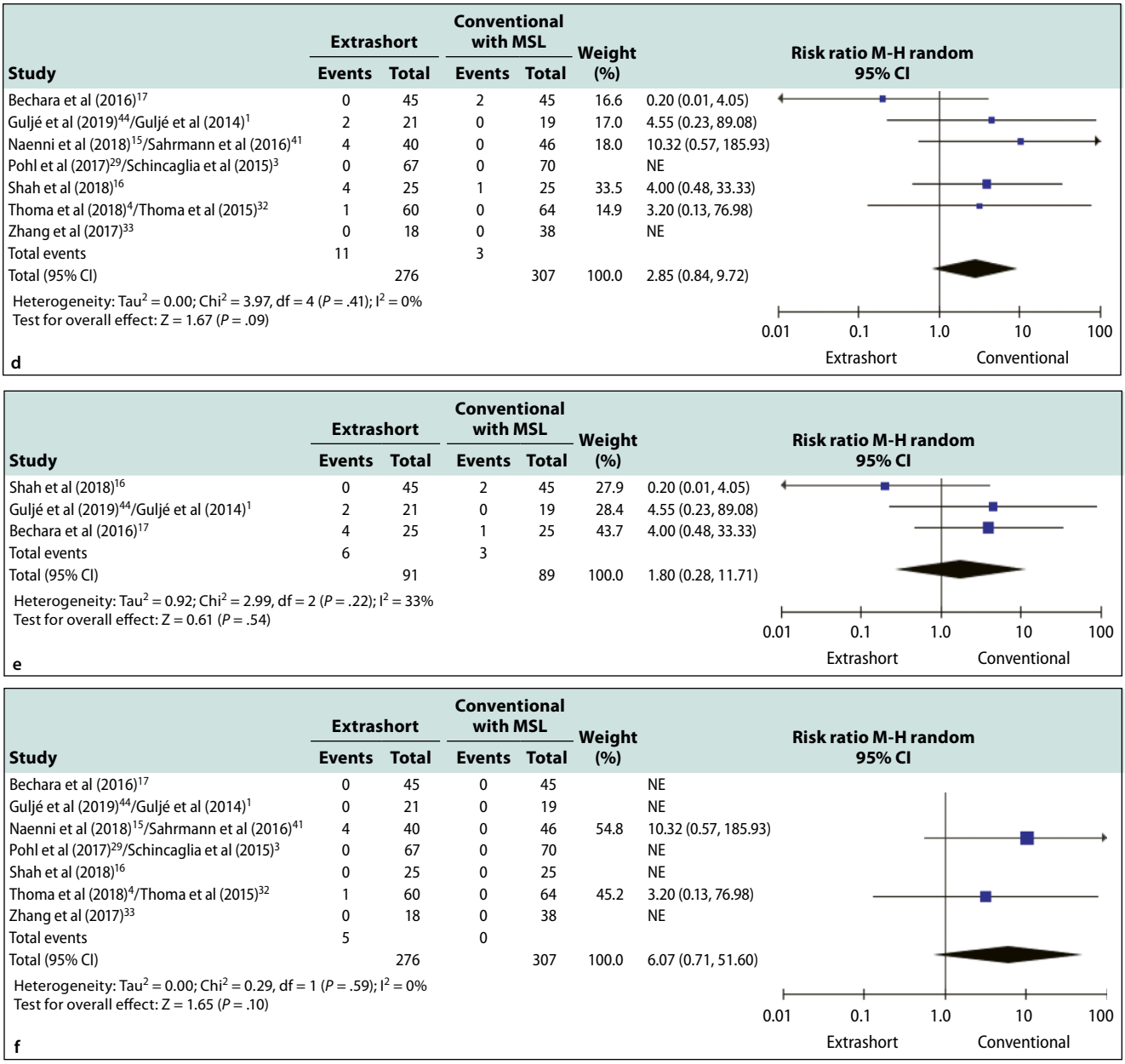


Fig 3 Meta-analysis graphs for risk ratio of failure between single crowns supported by extra-short and conventional implants, without previous maxillary sinus augmentation: *(a, facing page)* overall; *(b, facing page)* before loading; *(c, facing page)* after loading; and with previous maxillary sinus augmentation: *(d)* overall; *(e)* before loading; *(f)* after loading generated by RevMan software.

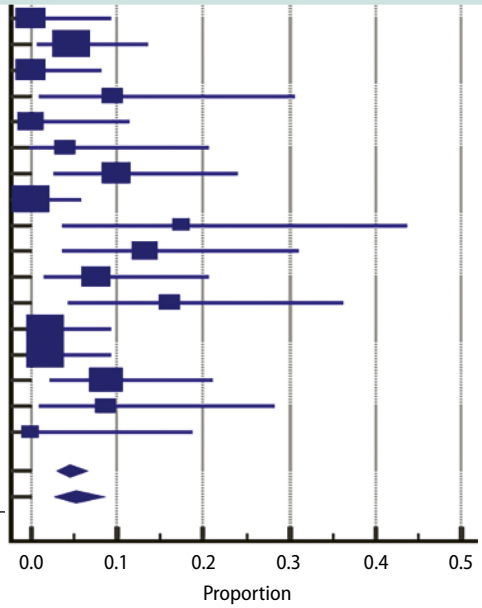
fore loading; the study follow-ups were 24[38] and 60[39] months) and 91.7% (one lost implant at 7 years; the study follow-up was 120[40] months). In other research, with two different follow-ups of the same experiment, the 12-month survival rate was 100% for all of them,[1,32,42] while after 60 months, it dropped to 98.5%[4] (one implant loss at 4 years) and 94.7%[44] (two implants lost before loading). Only one study had a survival rate of 98% (one implant loss at 2 years)[41] at 36 months and dropped to 91% (three implants lost at 4 years)[15] at 60 months of follow-up. Two studies maintained a survival rate of 100% after 36[29] and 60[43] months.

Considering implant complications, 10 RCT studies[3,4,15,16,28,30,32,34,41,44] reported the frequency of affected implants. However, three studies[1,17,33] reported the total absence of complications, and two did not report them.[29,31] For the prospective clinical trials, six[13,35,37–40] reported the occurrences of complications, with the exception of three studies.[36,42,43]

The most frequent biologic complications were bleeding on probing,[3,4,15,37,44] peri-implantitis,[4,39,40] infection,[13,40] and loss of osseointegration.[15,16,28,30,34,37,38,41,44] However, there were still reports of the following events: periodontal probing depth increased consistently[37];

Study	Sample size	Proportion (%)	95% CI
Alonso et al (2018)[36]	39	0.000	0.000–9.025
Ayna et al (2019)[37]	63	4.762	0.993–13.292
Bechara et al (2016)[17]	45	0.000	0.000–7.871
Guljé et al (2019)[44]/Guljé et al (2014)[1]	21	9.524	1.175–30.377
Guljé et al (2019)[42]/Guljé et al (2015)[43]	31	0.000	0.000–11.219
Malmstrom et al (2016)[31]	25	4.000	0.101–20.352
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	40	10.000	2.793–23.664
Pohl et al (2017)[29]/Schincaglia et al (2015)[3]	67	0.000	0.000–5.357
Queiroz et al (2015)[35]	17	17.647	3.799–43.432
Rossi et al (2016)[30]	30	13.333	3.755–30.722
Rossi et al (2018)[40]/ Rossi et al (2015)[39]/ Rossi et al (2010)[38]	40	7.500	1.574–20.386
Shah et al (2018)[16]	25	16.000	4.538–36.083
Svezia and Casotto (2018)[28]	59	1.695	0.0429–9.086
Thoma et al (2018)[4]/ Thoma et al (2015)[32]	60	1.667	0.0422–8.940
Villarinho et al (2016)[13]	46	8.696	2.420–20.792
Weerapong et al (2018)[34]	23	8.696	1.071–28.038
Zhang et al (2017)[33]	18	0.000	0.000–18.530
Total (fixed effects)	649	4.568	3.112–6.442
Total (random effects)	649	5.191	2.849–8.183

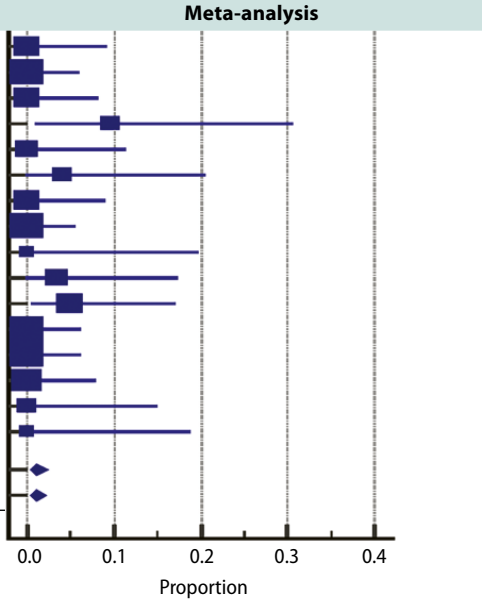
Q = 38.4391; df = 16; P = .0013; I^2 = 58.38%; 95% CI for I^2 = 28.80 to 75.67



a

Study	Sample size	Proportion (%)	95% CI
Alonso et al (2018)[36]	39	0.000	0.000–9.025
Ayna et al (2019)[37]	63	0.000	0.000–5.687
Bechara et al (2016)[17]	45	0.000	0.000–7.871
Guljé et al (2019)[44]/Guljé et al (2014)[1]	21	9.524	1.175–30.377
Guljé et al (2019)[43]/Guljé et al (2015)[42]	31	0.000	0.000–11.219
Malmstrom et al (2016)[31]	25	4.000	0.101–20.352
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	40	0.000	0.000–8.810
Pohl et al (2017)[29]/Schincaglia et al (2015)[3]	67	0.000	0.000–5.357
Queiroz et al (2015)[35]	17	0.000	0.000–19.506
Rossi et al (2016)[30]	30	3.333	0.0844–17.217
Rossi et al (2018)[40]/ Rossi et al (2015)[39]/ Rossi et al (2010)[38]	40	5.000	0.611–16.920
Svezia and Casotto (2018)[28]	59	0.000	0.000–6.061
Thoma et al (2018)[4]/Thoma et al (2015)[32]	60	0.000	0.000–5.963
Villarinho et al (2016)[13]	46	0.000	0.000–7.706
Weerapong et al (2018)[34]	23	0.000	0.000–14.819
Zhang et al (2017)[33]	18	0.000	0.000–18.530
Total (fixed effects)	624	1.176	0.493–2.350
Total (random effects)	624	1.176	0.488–2.157

Q = 14.1945; df = 15; P = .5108; I^2 = 0.00%; 95% CI for I^2 = 0.00 to 49.65



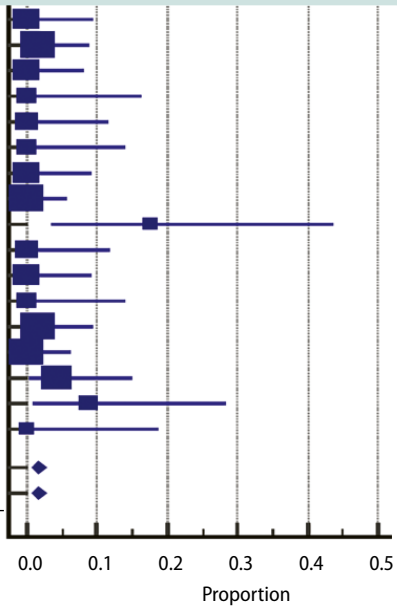
b

greater probing depth equal to 5 mm[15]; diseased-blood cancer[29]; bacterial colonization by exposure of the threads[35]; painful during function[28]; fistula, swelling, and implant failure[4]; and suppuration.[13]

Eight randomized clinical trials[4,15,29,31,32,34,41,44] reported the causes and frequency of prosthetic complications, and another seven stated total absence of complications (n = 3)[1,16,17,30] or did not report (n = 3).[3,28,33] Only one study[15] did not provide the number of affected implants. Six prospective clinical trials[37–40,42,43] reported no prosthetic complications, two others did not report,[35,36] and only one reported what happened (prosthetic screw loosening).[13] The most frequent were abutment screw fracture,[4,29,31,32] screw loosening,[13,15,38,44] loosening of abutment screw,[29] healing abutments,[35] and loose abutment.[32] The following complications still occurred less frequently: chipping of veneering ceramic, lost crown and loss of retention,[4] provisional crown fracture,[34] minor chipping,[15,44] and decementation of crown[29] (Table 2).

Study	Sample size	Proportion (%)	95% CI
Alonso et al (2018)[36]	39	0.000	0.000–9.025
Ayna et al (2019)[37]	63	1.587	0.0402–8.530
Bechara et al (2016)[17]	45	0.000	0.000–7.871
Guljé et al (2019)[44]/Guljé et al (2014)[1]	21	0.000	0.000–16.110
Guljé et al (2019)[42]/Guljé et al (2015)[43]	31	0.000	0.000–11.219
Malmstrom et al (2016)[31]	25	0.000	0.000–13.719
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	40	0.000	0.000–8.810
Pohl et al (2017)[29]/Schincaglia et al (2015)[3]	67	0.000	0.000–5.357
Queiroz et al (2015)[35]	17	17.647	3.799–43.432
Rossi et al (2016)[30]	30	0.000	0.000–11.570
Rossi et al (2018)[40]/ Rossi et al (2015)[39]/ Rossi et al (2010)[38]	40	0.000	0.000–8.810
Shah et al (2018)[16]	25	0.000	0.000–13.719
Svezia and Casotto (2018)[28]	59	1.695	0.0429–9.086
Thoma et al (2018)[4]/ Thoma et al (2015)[32]	60	0.000	0.000–5.963
Villarinho et al (2016)[13]	46	4.348	0.531–14.839
Weerapong et al (2018)[34]	23	8.696	1.071–28.038
Zhang et al (2017)[33]	18	0.000	0.000–18.530
Total (fixed effects)	649	1.524	0.738–2.773
Total (random effects)	649	1.557	0.704–2.737

Q = 18.3881; df = 16; P = .3017; I^2 = 12.99%; 95% CI for I^2 = 0.00–49.75



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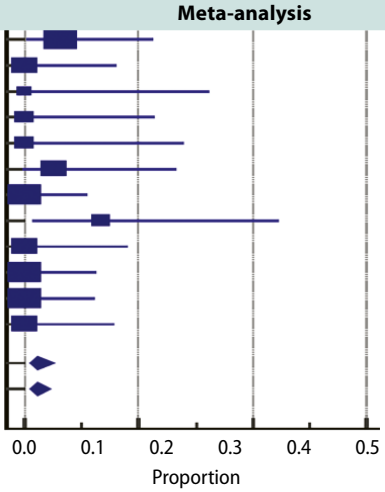
Study	Sample size	Proportion (%)	95% CI
Ayna et al (2019)[37]	63	3.175	0.387–11.002
Bechara et al (2016)[17]	45	0.000	0.000 – 7.871
Guljé et al (2019)[44]/Guljé et al (2014)[1]	21	0.000	0.000 – 16.110
Guljé et al (2019)[42]/Guljé et al (2015)[43]	31	0.000	0.000 – 11.219
Malmstrom et al (2016)[31]	25	0.000	0.000–13.719
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	40	2.500	0.0633–13.159
Pohl et al (2017)[29]/Schincaglia et al (2015)[3]	67	0.000	0.000 – 5.357
Rossi et al (2016)[30]	30	6.667	0.818–22.074
Rossi et al (2018)[40]/ Rossi et al (2015)[39]/ Rossi et al (2010)[38]	40	0.000	0.000–8.810
Svezia and Casotto (2018)[28]	59	0.000	0.000–6.061
Thoma et al (2018)[4]/ Thoma et al (2015)[32]	60	0.000	0.000–5.963
Villarinho et al (2016)[13]	46	0.000	0.000–7.706
Total (fixed effects)	527	1.197	0.461–2.521
Total (random effects)	527	1.197	0.454–2.288

Q = 7.6119; df = 7; P = .3681; I^2 = 8.04%; 95% CI for I^2 = 0.00–70.50



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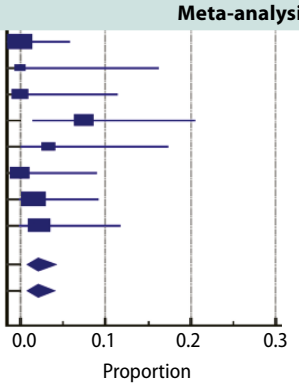
Study	Sample size	Proportion (%)	95% CI
Ayna et al (2019)[37]	63	0.000	0.000–5.687
Guljé et al (2019)[44]/Guljé et al (2014)[1]	21	0.000	0.000 – 16.110
Guljé et al (2019)[42]/Guljé et al (2015)[43]	31	0.000	0.000 – 11.219
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	40	7.500	1.574–20.386
Rossi et al (2016)[30]	30	3.333	0.0844–17.217
Rossi et al (2018)[40]/ Rossi et al (2015)[39]/ Rossi et al (2010)[38]	40	0.000	0.000–8.810
Thoma et al (2018)[4]/ Thoma et al (2015)[32]	60	1.667	0.0422–8.940
Villarinho et al (2016)[13]	46	2.174	0.0550–11.527
Total (fixed effects)	331	2.086	0.847–4.236
Total (random effects)	331	2.100	0.802–3.993

Q = 9.2810; df = 11; P = .5960; I^2 = 0.00%; 95% CI for I^2 = 0.00 – 50.74



e

Fig 4 Meta-analysis graphs for extra-short implant failure proportion: *(a, facing page)* overall and according to the follow-up: *(b, facing page)* before loading, *(c)* until 12 months, *(d)* 24 months, and *(e)* 48 months generated by MedCalc software.

Quantitative Analysis

Comparison of Survival Rates Between Extra-short Implants and Control Groups. The risk ratio meta-analysis (RR) compared the survival rates of single crowns supported by extra-short implants (≤ 6 mm) to those associated with conventional-size implants. Statistical heterogeneity across studies was considered low (I^2 = 0%); therefore, the fixed effects model was used. The overall RR was 3.00 (95% CI: 0.83 to 10.85, *P* = .09; Fig 3a), and it varied according to each follow-up. Before loading, the RR was 3.53 (95% CI: 0.38 to 33.00, *P* = .27; Fig 3b), and after loading, it decreased to 2.46 (95% CI: 0.59 to 10.29, *P* = .22; Fig 3c). However, all the results were not statistically significant (*P* > .05).

An additional analysis was performed comparing the single crowns supported by extra-short implants to those associated with conventional-size implants (> 6 mm) with previous maxillary sinus augmentation. The heterogeneity was also low (I^2 = 0%), so the fixed effects model was used. Similar to previous analysis, the RR of single crowns supported by extra-short implants was 2.85 (95% CI: 0.84 to 9.72, *P* = .09; Fig 3d) and varied according to the follow-up period. However, in this case, the RR before loading was lower, 1.80 (95% CI: 0.28 to 11.71, *P* = .54; Fig 3e), and it increased after loading up to 6.07 (95% CI: 0.71 to 51.60, *P* = .10; Fig 3f). In all cases, no statistically significant differences were found (*P* > .05).

Proportion of Failures

The overall proportion of failures of single crowns supported by extra-short implants was 5.19% (95% CI: 2.85% to 8.18%; I^2: 58.38%; *P* = .0013; Fig 4a). When the time of loading was considered, the proportion of failures was reduced to 1.18% (95% CI: 0.49% to 2.16%; *P* = .5108) before loading (Fig 4b) and varied according to the different follow-up periods after loading. Within 12 months, it was 1.56% (95% CI: 0.70% to 2.74%; *P* = .3017; Fig 4c); 24 months was 1.20% (95% CI: 0.45% to 2.29%; *P* = .5960; Fig 4d) and, finally, at 48 months, it was 2.10% (95% CI: 0.80% to 3.99%; *P* = .3681; Fig 4e).

Biologic Complications

Regarding biologic complications, the most frequent were: bleeding on probing, 37.90% (95% CI: 11.62% to 68.84%; *P* < .0001; Fig 5a); peri-implantitis, 22.45% (95% CI: 1.23% to 59.05%; *P* = .0001; Fig 5b); infection, 11.29% (95% CI: 6.38% to 17.38%; *P* = .5275; Fig 5c); and loss of osseointegration, 7.71% (95% CI: 4.66% to 11.45%; *P* = .26; Fig 5d).

Prosthetic Complications

Regarding prosthetic complications, the most frequent complications were: abutment failures, 14.88% (95% CI: 4.84% to 29.13%; *P* = .0005; Fig 6a); and prosthetic screw loosening, 14.73% (95% CI: 0.26% to 45.19%; *P* = .022; Fig 6b). These are the only parameters of prosthetic complications that allowed further analysis.

Certainty of Evidence Assessment

The certainty of evidence assessment (GRADE) was downgraded to very low, evaluating the following domains: risk of bias, inconsistency, imprecision, and indirectness. Both types of studies (randomized clinical trials and prospective clinical trials) showed wide confidence intervals; heterogenous methodology contributed to this decision (Table 3).

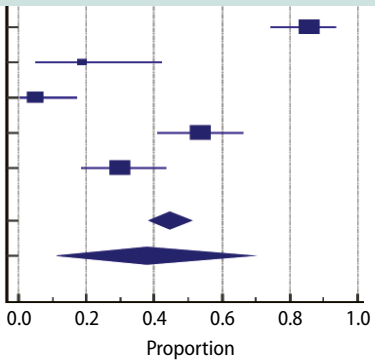
DISCUSSION

The close understanding of failures and complications of extra-short implants is extremely important to predict the clinical behavior of such treatment, improving the clinical practice. In this sense, this is the first systematic review that described, in detail, the failure time, prevalence of failures, and complications regarding the performance of single crowns supported by extra-short implants.

The risk of failure of single crowns supported by extra-short implants was similar to those associated with conventional implants, regardless of the association or not with previous maxillary sinus augmentation. According to the ITI Consensus Report,[45] the risk of extra-short implant failures is closely related to the time of the single crown in function. There is a shortage of longitudinal approaches comparing extra-short implants and conventional implants to define the exact moment when failures occur. Similar to the findings of the present study, Papaspyridakos et al (2018)[46] found no differences in RR of extra-short implants and conventional implants (1.29; 95% CI: 0.67, 2.50, *P* = .45). In addition, according to the same ITI consensus, extra-short implants seem to be a viable treatment option to reduce morbidity associated with bone grafting, reducing treatment times or damage to the adjacent structures.[45] Thus, since similar long-term behavior is observed between crowns supported by extra-short implants or conventional implants, the extra-short implant–based treatment seems to be preferred since it diminishes the necessity of invasive surgeries while reducing costs.

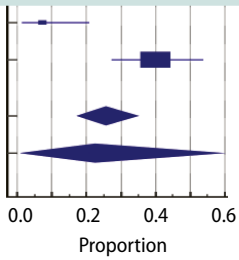
The follow-up periods are also important when considering the performance of single crowns supported by extra-short implants. The present systematic review considered the exact time that the failure occurred in each study. The overall follow-up varied from 3[33,35,36] to 120[40] months. The highest proportion of failures occurred at 48 months, and the lowest occurred before loading,

Study	Sample size	Proportion (%)	95% CI
Ayna et al (2019)[37]	63	85.714	74.606 – 93.254
Guljé et al (2019)[44]/Guljé et al (2014)[1]	21	19.048	5.446 – 41.907
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	40	5.000	0.611 – 16.920
Schincaglia et al (2015)[3]	67	53.731	41.120–66.002
Thoma et al (2018)[4]/Thoma et al (2015)[32]	60	30.000	18.845–43.208
Total (fixed effects)	251	44.597	38.406–50.913
Total (random effects)	251	37.901	11.619–68.839
Q = 102.4183; df = 4; $P < .0001$; $I^2 = 96.09\%$; 95% CI for $I^2 = 93.27–97.73$			



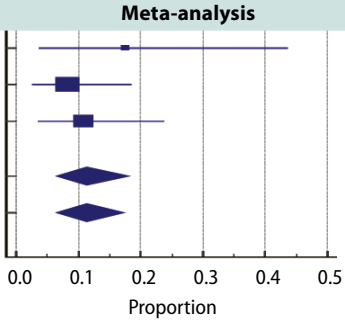
a

Study	Sample size	Proportion (%)	95% CI
Rossi et al (2018)[40]/ Rossi et al (2015)[39]/Rossi et al (2010)[38]	40	7.500	1.574–20.386
Thoma et al (2018)[4]/Thoma et al (2015)[32]	60	40.000	27.562–53.459
Total (fixed effects)	100	25.502	17.386–35.090
Total (random effects)	100	22.452	1.225–59.049
Q = 14.9629; df = 1; $P < .0001$; $I^2 = 93.32\%$; 95% CI for $I^2 = 78.11–97.96$			



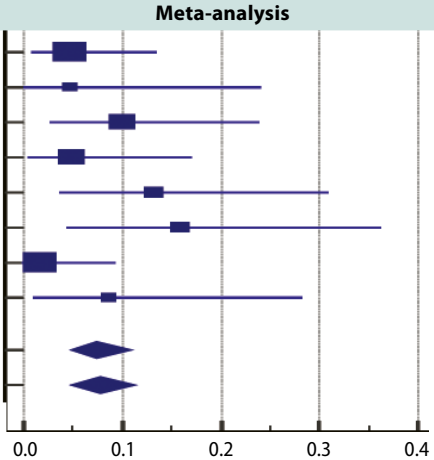
b

Study	Sample size	Proportion (%)	95% CI
Queiroz et al (2015)[35]	17	17.647	3.799–43.432
Thoma et al (2018)[4]/Thoma et al (2015)[32]	60	8.333	2.761–18.386
Villarinho et al (2016)[13]	46	10.870	3.625–23.570
Total (fixed effects)	123	11.293	6.348–18.154
Total (random effects)	123	11.293	6.383–17.380
Q = 1.2791; df = 2; $P = .5275$; $I^2 = 0.00\%$; 95% CI for $I^2 = 0.00–94.75$			



c

Study	Sample size	Proportion (%)	95% CI
Ayna et al (2019)[37]	63	4.762	0.993–13.292
Guljé et al (2019)[44]/Guljé et al (2014)[1]	21	4.762	0.120–23.816
Naenni et al (2018)[15]/Sahrmann et al (2016)[41]	40	10.000	2.793–23.664
Rossi et al (2018)[40]/ Rossi et al (2015)[39]/Rossi et al (2010)[38]	40	5.000	0.611–16.920
Rossi et al (2016)[30]	30	13.333	3.755–30.722
Shah et al (2018)[16]	25	16.000	4.538–36.083
Svezia and Casotto (2018)[28]	59	1.695	0.0429–9.086
Weerapong et al (2018)[34]	23	8.696	1.071–28.038
Total (fixed effects)	301	7.427	4.764–10.941
Total (random effects)	301	7.710	4.659–11.449
Q = 8.8982; df = 7; $P = .2600$; $I^2 = 21.33\%$; 95% CI for $I^2 = 0.00–63.47$			



d

Fig 5 Meta-analysis graphs for biologic complication proportion of extra-short implants: *(a)* bleeding on probing, *(b)* peri-implantitis, *(c)* infection, and *(d)* loss of osseointegration generated by MedCalc software.

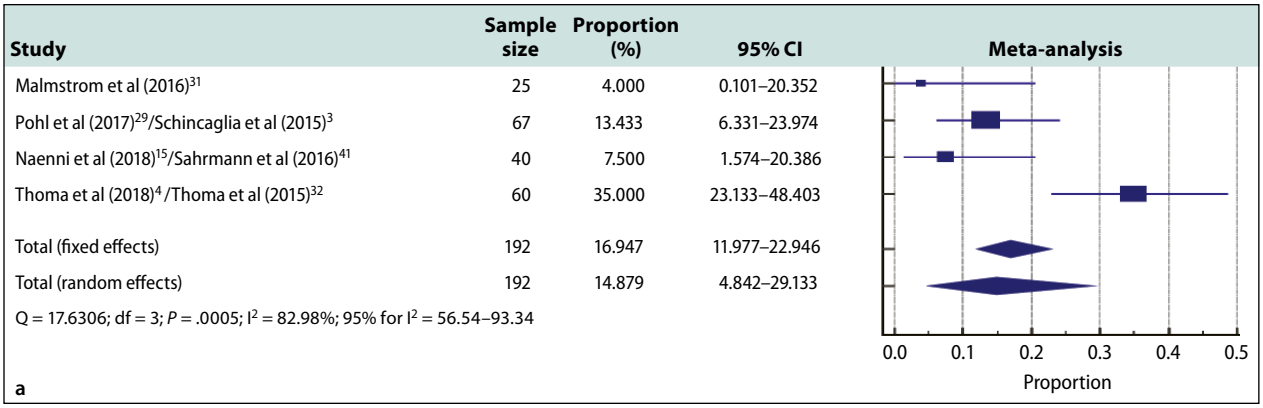


Fig 6 Meta-analysis graphs for prosthetic complications proportion of extra-short implants: *(a)* abutment failure and *(b)* loosening prosthetic screw proportions generated by MedCalc software.

Table 3 Certainty of the Evidence Assessment of Prospective Clinical Trials (n = 9) and Randomized Clinical Trials (n = 15): GRADE Summary of Findings

		Certainty assessment					
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Certainty
9	Prospective cinical trials	Not serious	Very serious[a]	Serious	Serious[b]	None	⊕◯◯◯ Very low
15	Randomized clinical trials	Serious	Very serious[a]	Serious	Very serious[b]	None	⊕◯◯◯ Very low

[a]It is possible to observe considerable clinical, methodologic, and statistical heterogeneity for both study designs.
[b]Wide confidence intervals, for the results of the meta-analysis, for both types of studies.

corroborating the systematic review by Ravidà et al[47] (2019), in which most of the failures occurred after loading. Moreover, according to Vazouras et al,[48] extra-short implant failure rates in function for more than 3 years are higher compared with shorter periods. In contrast, Srinivasan et al[49] reported that early failures (before loading) are more commonly observed in the first 4 months after the extra-short implant placement, which was different from this systematic review. Different reasons might contribute to explain failures, including insufficient osseointegration,[50] compromised local bone quality/quantity, smoking, implant characteristics, local infection,[51] and splinting or not of extra-short implants.[47]

It is evident that earlier failures are more related to biologic factors, while prosthetic factors are more related to failures observed in extra-short implant in function for longer periods. Knowledge about extra-short implant biologic and mechanical complications is crucial to anticipate problems and step in before complete failure. In regard to the biologic complications, different terms were used to report the clinical problems in the selected studies. In spite of that, some of the complications reported were similar, which allowed data analyses. The most common biologic complication was bleeding on probing (37.90%). Bleeding on probing is an important parameter to the diagnosis of inflammation in the peri-implant mucosa, distinguishing health and disease conditions in the peri-implant region.[52] It is also considered one of the first signs of peri-implant mucositis and peri-implantitis, requiring special attention to prevent future major problems.[53]

There was a higher incidence of plaque accumulation in the select studies.[4,32,37] This fact was expected since there is a close relation of cause-effect between poor hygiene and gingival inflammation.[54] Difficulties in cleaning the implant-supported fixed prostheses are common, and therefore, plaque accumulation occurs on the surfaces of these prostheses. This plaque accumulation affects the health condition of the related soft tissues, leading to peri-implant mucositis or even peri-implantitis.[55] Therefore, a high hygiene level is crucial to prevent peri-implant tissue infection, and in the case of single crowns, it is facilitated by the direct use of dental floss in the interdental space.

Peri-implantitis was the second most frequent complication in the selected studies, followed by infection. A slightly lower frequency of peri-implantitis is reported for conventional-size implants, varying from 5% to 8%.[56] Peri-implantitis is an inflammatory reaction, which causes loss of bone tissue support surrounding a functioning implant.[57] Studies suggest that anaerobic plaque and overloading are the two main factors that contribute to increase the incidence of infection[52] and inflammatory processes of the implant surrounding tissues.[58] Therefore, correct and early diagnosis is very important to maintain longevity of treatment and avoid failure of a dental implant by loss of osseointegration.

The less prevalent biologic complication reported was loss of osseointegration. This parameter is important because it is the only one considered at the survival rate analysis. In the present review, the overall proportion of extra-short implant failures was 5.19%, which was very similar to those reported in a previous study[47] (3.5%). It is important to understand that loss of osseointegration is closely related to implant loss. In this sense, the recognition of the first signs of biologic and mechanical complications is imperative to decrease the frequency of osseointegration failure and prevent implant loss.

Regarding prosthetic complications, abutment failures were the most prevalent, with an incidence of 14.88%, followed by loosening of the prosthesis screw (14.73%). According to Ravidà et al (2019),[10] extra-short implants were a total of 3.3 times more likely to develop complications of prosthetic origin compared with conventional-size implants. However, in the present study, most of the reported prosthetic complications were reversible, thus presenting low complexity for clinical resolution. Similar results were also observed in previous research.[13] The most frequent complication was screw loosening (abutment and prosthetic screw), which is in agreement with previous reports.[10,46] These prosthetic complications were more easily resolved by replacing the component, usually not compromising the extra-short implant itself. Factors related to occlusal loads, such as magnitude, distribution, and variation during function, can influence the loosening of the screw, fracture of the implant component, and/or bone resorption.[59] In this systematic review, only two studies showed minor chipping[15,44] and another the fracture of provisional prosthesis,[34] which also related to the study of Papaspyridakos et al (2018).[46] In this case, clinicians should be aware of the presence of occlusal interference in centric and eccentric movements, making an adequate occlusal adjustment.

A limitation of the present systematic review was the large discrepancy of available information, especially regarding the description of failures, follow-up periods, and characteristics of the sample. The lack of a common guideline to organize data collection and report jeopardizes the prevalence analysis, reducing the quality of the studies and the power of the evidence. Moreover, based on the analysis of risk of bias, future studies should be more detailed in regard to sample selection and guarantee the blinding condition during the experimental periods. Considering the sample selection, considerable heterogeneity was noticed. The eligibility criteria adopted might have contributed to influence the observed results. In the present review, important requirements, such as age; periodontitis history; oral hygiene; abrasion; smoking habits; implant characteristics in terms of length, location, and surface; surgical procedure performed; and type of prosthesis were no longer an integral part of the exclusion criteria. Since the marginal bone loss and implant loss are closely related to some of these factors,[60] the occurrence could influence the outcomes and thereby interfere in the interpretation with the results presented. Thus, future studies with standard criteria in the outcome assessment and clinical interpretation are still needed to consolidate the reasons for implant failure and complications.

CONCLUSIONS

Single crowns supported by extra-short implants presented a risk of failure similar to those supported by conventional implants, associated or not with previous maxillary sinus augmentation, before and after loading. The proportion of overall failures was 5.19% and varied over time: before loading (1.17%), 1 year (1.55%), 2 years (1.19%), and 4 years (2.1%). The most prevalent biologic complication was bleeding on probing, followed by peri-implantitis and infection. The most common prosthetic complications were related to abutment failure and prosthetic screw loosening.

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Appendix

Appendix 1 Search Strategy Applied on Each Database

Database	Search strategy
Cochrane	("Dental Implantation" OR "dental implants" OR "Dental Implant") AND ("short" OR "extrashort" OR "extra short" OR "extra-short" OR "ultrashort" OR "ultra short" OR "ultra-short" OR "supershort" OR "super short" OR "super-short" OR "4mm long" OR "5mm long" OR "6mm" OR "4 mm long" OR "5 mm long" OR "6 mm long" OR "four-millimeter" OR "five-millimeter" OR "six-millimeter" OR "four millimeter" OR "five millimeter" OR "six millimeter") AND ("failure" OR "failures" OR "survival" OR "failed" OR "treatment outcome")
Embase	("Dental Implantation" OR "dental implants" OR "Dental Implant") AND ("short" OR "extrashort" OR "extra short" OR "extra-short" OR "ultrashort" OR "ultra short" OR "ultra-short" OR "supershort" OR "super short" OR "super-short" OR "4mm long" OR "5mm long" OR "6mm" OR "4 mm long" OR "5 mm long" OR "6 mm long" OR "four-millimeter" OR "five-millimeter" OR "six-millimeter" OR "four millimeter" OR "five millimeter" OR "six millimeter") AND ("failure" OR "failures" OR "survival" OR "failed" OR "treatment outcome")
LILACS	(tw:("Dental Implantation" OR "dental implants" OR "Dental Implant" OR "implantação dentaria" OR "implante dentario" OR "implantes dentarios" OR "implante de dente" OR "implante de dentes" OR "implantacion dental" OR "implantes dentales" OR "implante dental")) AND (tw:("short" OR "extrashort" OR "extra short" OR "extra-short" OR "ultrashort" OR "ultra short" OR "ultra-short" OR "supershort" OR "super short" OR "super-short" OR "curto" OR "extra curto" ou "extracurto" OR "ultracurtado" OR "ultra curto" OR "super curto" OR "corto")) AND (tw:("failure" OR "failures" OR "survival" OR "failed" OR "treatment outcome" OR "falha" OR "falhas" OR "sobrevivencia" OR "sobrevida" OR "resultado do tratamento" OR "fracaso" OR "fallas" OR "falla" OR "fallido" OR "resultado del tratamiento")) AND (instance:"regional") AND (db:("LILACS") AND type:("article"))
PubMed	(("Dental Implantation"[MeSH Terms] OR "Dental Implantation"[All Fields] OR "dental implants"[MeSH Terms] OR "dental implants"[All Fields] OR "Dental Implant"[All Fields]) AND ("short"[All Fields] OR "extrashort"[All Fields] OR "extra short"[All Fields] OR "extra-short"[All Fields] OR "ultrashort"[All Fields] OR "ultra short"[All Fields] OR "ultra-short"[All Fields] OR "supershort"[All Fields] OR "super short"[All Fields] OR "super-short"[All Fields] OR "4mm long"[All Fields] OR "5mm long"[All Fields] OR "6mm"[All Fields] OR "4 mm long"[All Fields] OR "5 mm long"[All Fields] OR "6 mm long"[All Fields] OR "four-millimeter"[All Fields] OR "five-millimeter"[All Fields] OR "six-millimeter"[All Fields] OR "four millimeter"[All Fields] OR "five millimeter"[All Fields] OR "six millimeter"[All Fields])) AND ("failure"[All Fields] OR "failures"[All Fields] OR "survival"[All Fields] OR "failed"[All Fields] OR "treatment outcome"[All Fields])
Scopus	TITLE-ABS-KEY("Dental Implantation" OR "dental implants" OR "Dental Implant") AND TITLE-ABS-KEY("short" OR "extrashort" OR "extra short" OR "extra-short" OR "ultrashort" OR "ultra short" OR "ultra-short" OR "supershort" OR "super short" OR "super-short" OR "4mm long" OR "5mm long" OR "6mm" OR "4 mm long" OR "5 mm long" OR "6 mm long" OR "four-millimeter" OR "five-millimeter" OR "six-millimeter" OR "four millimeter" OR "five millimeter" OR "six millimeter") AND TITLE-ABS-KEY("failure" OR "failures" OR "survival" OR "failed" OR "treatment outcome") AND (LIMIT-TO (DOCTYPE,"ar"))
Web of Science	("Dental Implantation" OR "dental implants" OR "Dental Implant") AND ("short" OR "extrashort" OR "extra short" OR "extra-short" OR "ultrashort" OR "ultra short" OR "ultra-short" OR "supershort" OR "super short" OR "super-short" OR "4mm long" OR "5mm long" OR "6mm" OR "4 mm long" OR "5 mm long" OR "6 mm long" OR "four-millimeter" OR "five-millimeter" OR "six-millimeter" OR "four millimeter" OR "five millimeter" OR "six millimeter") AND ("failure" OR "failures" OR "survival" OR "failed" OR "treatment outcome")
Google Scholar	("Dental Implantation" OR "dental implants" OR "Dental Implant") AND ("short" OR "extrashort" OR "extra short" OR "ultrashort" OR "ultra short" OR "supershort" OR "super short") AND ("failure" OR "failures" OR "survival" OR "failed")
OpenGrey	("Dental Implantation" OR "dental implants" OR "Dental Implant") AND ("short" OR "extrashort" OR "extra short" OR "extra-short" OR "ultrashort" OR "ultra short" OR "ultra-short" OR "supershort" OR "super short" OR "super-short" OR "4mm long" OR "5mm long" OR "6mm" OR "4 mm long" OR "5 mm long" OR "6 mm long" OR "four-millimeter" OR "five-millimeter" OR "six-millimeter" OR "four millimeter" OR "five millimeter" OR "six millimeter") AND ("failure" OR "failures" OR "survival" OR "failed" OR "treatment outcome")
Proquest—Dissertation and Theses	noft(("Dental Implantation" OR "dental implants" OR "Dental Implant") AND ("short" OR "extrashort" OR "extra short" OR "extra-short" OR "ultrashort" OR "ultra short" OR "ultra-short" OR "supershort" OR "super short" OR "super-short" OR "4mm long" OR "5mm long" OR "6mm" OR "4 mm long" OR "5 mm long" OR "6 mm long" OR "four-millimeter" OR "five-millimeter" OR "six-millimeter" OR "four millimeter" OR "five millimeter" OR "six millimeter") AND ("failure" OR "failures" OR "survival" OR "failed" OR "treatment outcome"))

Appendix 2 Excluded Articles and Reasons for Exclusion (n = 39)

Author, Year	Reason for exclusion
Adanéz et al (2018)	1
Akram et al (2019)	2
Amri et al (2017)	4
Anitua et al (2019)	3
Arlin (2006)	2
Aschee et al (2012)	2
Bechara et al (2017)	3
Bruggenkate et al (1998)	4
Calvo-Guirado et al (2016)	2
De Santis et al (2011)	1
Esposito et al (2011)	1
Feldman et al (2004)	1
Felice et al (2009)	2
Felice et al (2015)	5
Felice et al (2019)	2
Geckki et al (2014)	3
Le et al (2013)	3
Malchiodi et al (2017)	4
Malchiodi et al (2019)	2
Mangano et al (2016)	1
Mendoza-Azpur et al (2016)	4
Mokeem et al (2019)	4
Molon et al (2017)	2
Nedir et al (2004)	4
Perelli et al (2011)	4
Perelli et al (2012)	1
Rosen et al (2018)	3
Rossi et al (2017)	2
Santagata et al (2012)	1
Sharma et al (2015)	4
Shi et al (2015)	3
Slotte et al (2012)	2
Stellingsma et al (2014)	2
Storelli et al (2018)	2
Tabrizi et al (2016)	2
Tawil et al (2003)	4
Teixeira et al (1997)	1
Yadav et al (2019)	2
Yilmaz et al (2011)	3

Reasons for exclusion: *(1)* Studies in which the sample includes individuals rehabilitated only with implants longer than 6 mm or without comparison with extra-short (≤ 6 mm) or the number of ≤ 6 mm implants placed were below the minimum of 10; *(2)* studies with extra-short splinting to other implants or overdenture or full fixed implant-supported prosthesis; *(3)* book chapters, reviews, letters, conference, abstracts, personal opinions, guidelines, case series (less than 20 implants placed), case reports, retrospective studies, only protocol of clinical trials, and finite element analysis; *(4)* studies that did not present enough data, even after three attempts of contact with the authors; *(5)* studies in which the sample included patients with uncontrolled systemic illnesses.

Appendix 3 Joanna Briggs Institute Critical Appraisal Checklist for Prospective Clinical Trial (n = 9)

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Risk of bias
Alonso et al (2018)[36]	Y	Y	Y	N	Y	Y	Y	Y	Y	Low
Ayna et al (2019)[37]	Y	Y	Y	N	Y	Y	Y	Y	Y	Low
Guljé et al (2015)[42]	Y	Y	Y	N	Y	Y	Y	Y	Y	Low
Guljé et al (2019)[43]	Y	Y	Y	N	Y	Y	Y	Y	Y	Low
Queiroz et al (2015)[35]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Low
Rossi et al (2010)[38]	Y	N	N	N	Y	Y	Y	Y	Y	Moderate
Rossi et al (2015)[39]	Y	N	N	N	Y	Y	Y	Y	Y	Moderate
Rossi et al (2018)[40]	Y	N	N	N	Y	Y	Y	Y	Y	Moderate
Villarinho et al (2017)[13]	Y	N	Y	N	Y	Y	Y	Y	Y	Low

Q1: Is it clear in the study what is the "cause" and what is the "effect" (ie, there is no confusion about which variable comes first)?
Q2: Were the participants included in any similar comparisons?
Q3: Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?
Q4: Was there a control group?
Q5: Were there multiple measurements of the outcome both before and after the intervention/exposure?
Q6: Was the follow-up complete, and if not, were differences between groups in terms of their follow-up adequately described and analyzed?
Q7: Were the outcomes of participants included in any comparisons measured in the same way?
Q8: Were outcomes measured in a reliable way?
Q9: Was appropriate statistical analysis used?

Appendix 4 Joanna Briggs Institute Critical Appraisal Checklist for Randomized Controlled Trials (n = 15)

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Risk of bias
Bechara et al (2016)[17]	Y	Y	N	Y	Y	U	N	Y	Y	Y	U	Y	Y	Moderate
Guljé et al (2014)[1]	Y	Y	N	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Low
Guljé et al (2019)[44]	Y	Y	N	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Low
Malmstrom et al (2016)[31]	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Moderate
Naenni et al (2018)[15]	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Moderate
Pohl et al (2017)[29]	U	Y	N	U	U	U	Y	Y	Y	Y	Y	Y	U	High
Rossi et al (2016)[30]	Y	Y	N	Y	Y	U	N	Y	Y	Y	Y	Y	Y	Low
Sahrmann et al (2016)[41]	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Moderate
Schincaglia et al (2015)[3]	U	U	N	U	U	U	Y	Y	Y	Y	Y	Y	U	High
Shah et al (2018)[16]	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Moderate
Svezia and Casotto (2018)[28]	N	N	Y	N	Y	Y	N	Y	Y	Y	Y	U	N	Moderate
Thoma et al (2015)[32]	Y	U	N	Y	Y	U	N	Y	Y	Y	Y	Y	Y	Moderate
Thoma et al (2018)[4]	Y	U	N	Y	Y	U	N	Y	Y	Y	Y	Y	Y	Moderate
Weerapong et al (2019)[34]	Y	Y	N	U	U	U	Y	Y	Y	Y	Y	Y	Y	Moderate
Zhang et al (2017)[33]	Y	N	N	Y	Y	Y	Y	U	Y	Y	Y	N	Y	Moderate

Y = Yes; N = No; U = Unclear.
Total = ΣY/Applicable Items (the not applicable [NA] items were excluded from the sum).
Risk of bias was categorized as high when the study reaches up to 49% score "yes", moderate when the study reached 50% to 69% score "yes", and low when the study reached more than 70% score "yes".
Q1: Was true randomization used for assignment of participants to treatment groups?
Q2: Was allocation to treatment groups concealed?
Q3: Were treatment groups similar at the baseline?
Q4: Were participants blind to treatment assignment?
Q5: Were those delivering treatment blind to treatment assignment?
Q6: Were outcomes assessors blind to treatment assignment?
Q7: Were treatment groups treated identically other than the intervention of interest?
Q8: Was follow-up complete, and if not, were differences between groups in terms of their follow-up adequately described and analyzed?
Q9: Were participants analyzed in the groups to which they were randomized?
Q10: Were outcomes measured in the same way for treatment groups?
Q11: Were outcomes measured in a reliable way?
Q12: Was appropriate statistical analysis used?
Q13: Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?