Short Dental Implants: A Systematic Review

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CLINICAL REVIEW

Short Dental Implants: A Systematic Review

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ABSTRACT

Growing evidence has suggested the utility of short dental implants for oral reconstructive procedures in clinical situations of limited vertical bone height. The aim of this review was to systematically evaluate clinical studies of implants < 10 mm in length, to determine short implant-supported prosthesis success in the atrophic jaw. Implant survival, incidence of biological and biomechanical complications, and radiographic peri-implant marginal bone loss were evaluated. Screening of eligible studies, quality assessment, and data extraction were conducted by two reviewers independently. Meta-analyses were performed by the pooling of survival data by implant surface, surgical technique, implant location, type of edentulism, and prosthetic restoration. Two randomized controlled trials and 14 observational studies were selected and analyzed for data extraction. In total, 6193 short-implants were investigated from 3848 participants. The observational period was 3.2 ± 1.7 yrs (mean ± SD). The cumulative survival rate (CSR) was 99.1% (95%CI: 98.8-99.4). The biological success rate was 98.8% (95%CI: 97.8-99.8), and the biomechanical success rate was 99.9% (95%CI: 99.4-100.0). A higher CSR was reported for rough-surfaced implants. The provision of short implant–supported prostheses in patients with atrophic alveolar ridges appears to be a successful treatment option in the short term; however, more scientific evidence is needed for the long term.

KEY WORDS: dental implant, short implant, success rate, survival rate, literature review, dental prosthesis, implant-supported.

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INTRODUCTION

Over the years, various strategies have been proposed to overcome the dimensional limitations of the bone available for implant placement. Several surgical interventions for bone augmentation have been proposed, including bone grafts, guided bone regeneration, distraction osteogenesis, sinus floor elevation, mandibular nerve transposition, and the use of tilted or zygomatic implants. Although these techniques have gained a degree of success through the years, with the exception of sinus floor elevation, there are insufficient data on their predictability. Short implants (SHIs) have been proposed as an alternative choice for the prosthetic treatment of atrophic alveolar ridges, which may provide surgical advantages including reducing morbidity, treatment time, and costs.

However, longer implants have always been considered more reliable due to both an improved crown-to-implant ratio and a greater surface area available for osseointegration, which dissipates the imposed occlusal forces.

The introduction in the last decade of modified implant designs and microstructured implant surfaces that augment the integratable surface area could help to compensate for the adverse effects of decreasing the implant length, so as to maintain the extent of the bone-implant interface (Goené *et al*., 2005). The biomechanical rationale behind the use of SHIs is that the crestal portion of the implant body is the most involved in load-bearing, whereas very little stress is transferred to the apical portion (Lum, 1991) and the increase of implant length from 7 to 10 mm did not significantly improve its anchorage (Bernard *et al*., 2003). Therefore, implant length may not be a primary factor in distributing prosthetic loads to the bone-implant interface. However, the poor bone density of the atrophic jawbone, the posterior location in the mouth, and the augmented crown height of the restorations represent important risk factors in the use of SHIs that might jeopardize their survival.

The present study was undertaken to gather and evaluate data from published articles to assess if the provision of short implants in patients with atrophic alveolar ridges may satisfy the desired outcomes of a successful implant therapy, as described by the Academy of Osseointegration Guidelines (2010) (for a detailed description, see Appendix Table 1).

In this review, implants with lengths of less than 10 mm were considered "short".

MATERIALS & METHODS

Study Selection Criteria

Study selection criteria were as follows:

- Studies specifically designed to investigate SHIs.
- All types of clinical study designs except for case reports.
- Detailed data on implant length.
- Implant survival rates clearly indicated or calculable from the reported data.
- Criteria for implant failure clearly defined.
- Mean follow-up of at least 1 yr after prosthetic loading.
- Only the most inclusive publication from series for which the same data have been published on multiple occasions.
- English language.

Broad inclusion criteria were adopted to render the findings of this review more general, without distinguishing patient characteristics, implant type, surgical technique, or prosthetic rehabilitations (for a detailed description, see Appendix Table 1).

Search Strategy

We searched the MEDLINE database of the National Library of Medicine to identify all articles published between January 1966 and December 2010 that contain the following key words:

- "Short dental implants"
- "Short implants"
- "Dental implants" [MeSH term] AND "short implants"
- "Dental Implants" [MeSH term] AND "short length"
- "Dental Implants" [MeSH term] AND "length".

A supplementary hand search was performed through 6 relevant peer-reviewed dental journals published between January 1990 and June 2009: *Clinical Oral Implant Research, International Journal of Oral and Maxillofacial Implants, Clinical Implant Dentistry and Related Research* (from 1999), *Journal of Periodontology, Journal of Clinical Periodontology,* and *International Journal of Periodontics and Restorative Dentistry*, and through the reference lists of all pertinent papers and review articles.

Titles and abstracts of all identified reports were analyzed by two examiners.

OUTCOME MEASURES

Outcome measures were as follows:

- *Implant survival*. This refers to the presence of an implant with or without complications. Failure was defined as removal of the implant. Implant survival was quantified here as the cumulative survival rate (CSR) and was calculated on the absolute number of implants placed and lost.
- *Implant biological success*. This refers to the presence of an implant in the absence of complications of a biological nature (*i.e.*, persistent pain, neuropathy and/or loss of function, persistent uncontrolled peri-implant inflammation and/or infection, persistent peri-implant radiolucency, implant mobility) (AO Guidelines, 2010). The biological success rate (BScR) was extracted from the publications as the absolute number of prosthetically restored implants relative (or not) to the above-defined success criteria. It includes late failures.
- *Radiographic peri-implant marginal bone loss (MBL).* This was studied as a measure to evaluate progressive bone loss or increased probing depths.
- *Implant biomechanical success*. This refers to the presence of an implant in the absence of complications of a biomechanical nature (*i.e.,* prosthesis instability, fractured occlusal materials, fractured or loosened prosthetic components, implant fracture) (AO Guidelines, 2010). The biomechanical success rate (MScR) was extracted as the absolute number of prosthetically restored implants presenting (or not) biomechanical complications.

Data Extraction

Two reviewers independently extracted the data using data-extraction tables. The data extracted included the following: year of publication, type of study, aim of the study, number of patients enrolled, numbers and types of implants used, oral location, type of prosthetic restoration, surgical technique used, follow-up period, survival rate, success rate, biomechanical complications, and authors' comments.

Quality Appraisal

The selected studies were screened for quality assessment. In the randomized controlled trials, the risk-of-bias was assessed by the Cochrane Collaboration tool (Higgins and Green, 2011). To assess the scientific evidence provided by the observational studies, we constructed a quality assessment system on the basis of previously accepted checklists (Wells *et al*., 2001; West *et al*., 2002; NICE, 2010). A 14-question checklist was completed for each study. Any disagreement was solved by discussion.

Data Analysis

Agreement between the reviewers was calculated by Cohen's *k* statistical analysis. The mean follow-up of the selected reports was calculated as the weighted mean on the number of implants investigated at each stage of the study. Data were presented at the implant level. Losses to follow-up were not considered.

CSR were meta-analyzed according to fixed and random-effects models. Statistical heterogeneity was assessed by means of the I^2 statistic: We reported fixed or random-effects model results according to the test of heterogeneity (but both can be evaluated as means of sensitivity analysis). All the analyses were performed with STATA11 (Statacorp, College Station, TX, USA).

RESULTS

Study Selection and Data Extraction

The MEDLINE search yielded 850 references, 10 were collected from the manual search of the 6 selected journals, and 24 from the reference list of pertinent articles and reviews. Of these 884 papers, 83 were screened as full-text articles. Sixteen studies fulfilled the inclusion criteria (Fig.1; Appendix Table 2)

Agreement in eligible studies selection and data extraction was unanimous between the two reviewers. The agreement in

quality assessment was excellent (k = 0.862) (Orwin, 1994).

Study Quality

Two studies were randomized controlled trials (RCT), and 14 were observational studies. Overall, the 2 RCTs were well-conducted with respect to randomization, allocation, blinding, and data collection. Factors that mostly increased the risk-of-bias were the sample size and the follow-up duration. One study (Cannizzaro *et al*., 2009) had a high risk-of-bias from group imbalance, since the control group systematically received implants with a smaller diameter than those received by the test group. This might have confounded the results of the trial, whose objective was to study the role of implant length on the implant success rate (Table 1).

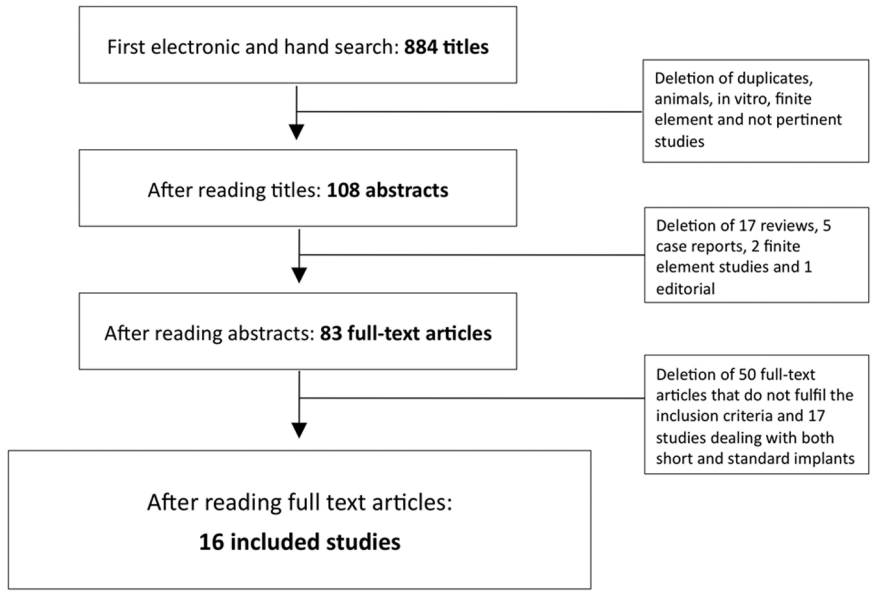

Figure 1. Flowchart of the selection of the studies for the review.

Two observational studies were prospective clinical studies, and 12 were retrospective clinical studies. Five of these were multicenter studies, while two were reported by single practitioners (Fugazzotto, 2008; Anitua and Orive, 2010). Selection criteria and outcomes definition were clearly described in less than half of the studies. Only one study assessed outcomes blindly. Most papers reported the number of implants monitored at each stage of study, but only 5 explained reasons for drop-outs. Six studies did not report a length of follow-up adequate for outcomes to occur. Three reports presented conflicts of interest. In one multicenter study (Misch *et al*., 2006), the first author was a member of the board of directors and a paid consultant for the implant manufacturer, but it was declared that no products, royalties, or reimbursements for any sale were received (Appendix Table 3).

Study Characteristics

The data extracted from the studies included in the review are summarized below (for a detailed description, see Appendix Table 4).

Patient Selection

In total, 3848 patients were treated: 1474 were male and 2374 female, with ages ranging from 18 to 94 yrs (mean age, 56 yrs). The selected patients were usually healthy, and smokers were included.

Implant Characteristics

We studied 6193 implants. The implant lengths ranged from 5 to 9 mm, the majority being 8 mm long. The implant diameters ranged from 2.5 to 6 mm. Approximately 298 of all implants (4.8%) had a diameter larger than 5 mm.

Implant design (*e.g*., threaded implant, hollow screw, or hollow cylinder) and surface characteristics varied between studies. Four studies with 605 implants dealt with machine-surfaced implants (9.8%); the remaining 5253 implants (84.8%) had different types of rough surface (acid-etched, hydroxyapatite-coated or -blasted, sandblasted acid-etched, titanium-plasma-sprayed, sintered porous, oxidized, humidified with plasma-rich growth factor). Grant *et al*. (2009) studied 335 8-mm-long implants, but did not specify surface characteristics.

Implant Location

Most of the implants (n = 5834, 94.2%) were placed in the posterior regions: 1871 (30.2%) in the posterior maxilla and 3458 (53.8%) in the posterior mandible. Ninety-nine (1.5%) implants replaced anterior teeth, and 260 (4.1%) were placed into the interforaminal region of extremely resorbed mandibles (Friberg *et al*., 2000).

Surgical Procedures

A two-stage operation was used to place 1983 implants (32.3%), while 3510 (56.7%) were placed by means of a single-stage surgical technique. A further 685 implants (11%) were placed by special surgical techniques (*i.e.,* immediate loading, sinus elevation, crest expansion, or reconstructive procedures).

Restoration Type

Only 7 studies used prosthetic restorations supported exclusively by SHIs. All of the other studies collected data from SHIs standing alone as well as from SHIs splinted to standard implants. In one study (Goené *et al*., 2005), it was not clear if SHIs were splinted to standard implants. In general, single-crown rehabilitations numbered 2351 implants (37.9%), while 1444 (23.4%) were SHIs splinted together in multiple implant restorations. The remaining 2398 (38.7%) were probably SHIs splinted to standard implants.

Table 1. Risk-of-Bias Assessment of the Randomized Controlled Trials Included in the Systematic Review

Reference	Cannizzaro *et al.*, 2009		Felice *et al.*, 2010	
Entry	Judgment	Support for Judgment	Judgment	Support for Judgment
Random sequence generation	Low risk	Patients were randomly allocated, by a computer-generated randomization list.	Low risk	Patients were randomly allocated, by a computer-generated randomization list.
Allocation concealment	Low risk	Only one of the investigators, who was not involved in the selection and treatment of the patients, was aware of the randomization sequence and had access to the randomization list stored in his password-protected portable computer.	Low risk	Only one of the investigators, who was not involved in the selection and treatment of the patients, was aware of the randomization sequence and had access to the randomization list stored in his password-protected portable computer.
Blinding of participants and personnel	Low risk	Treatment allocation was concealed: The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes. Envelopes were opened sequentially after eligible patients were anesthetized.	Low risk	Treatment allocation was concealed: The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes. Envelopes were opened sequentially after eligible patients signed the informed consent to treatment.
Blinding of outcome assessment	High risk	Follow-ups were conducted by an independent blind outcome assessor together with the operator, but the different interventions, and hence group allocations, were easily detectable.	High risk	Follow-ups were conducted by an independent blind outcome assessor together with the operator, but the different interventions, and hence group allocations, were easily detectable.
Incomplete outcome data	Low risk	No missing outcome data.	Low risk	1/30 drop-out from intervention group.
Selective reporting	Low risk	The study protocol is available, and all of the study's pre-specified outcomes have been reported in the pre-specified way.	Low risk	The study protocol is available, and all of the study's pre-specified outcomes have been reported in the pre-specified way.
Other sources of bias: group imbalance	High risk	Implants in one group had systematically smaller diameters than implants in the other group.	Low risk	The two groups were similar.
Other sources of bias: sample size inadequacy	High risk	The sample of patients recruited was smaller than the sample size statistically calculated for the primary outcome measures.	High risk	The sample of patients recruited was smaller than the sample size statistically calculated for the primary outcome measures.
Other sources of bias: time lag bias	High risk	The short duration of the follow-up might influence the outcomes.	High risk	The short duration of the follow-up might influence the outcomes.

Follow-up

The duration of follow-up from prosthetic restoration varied from 1 mo to 14 yrs (mean, 3.2 ± 1.7 yrs). In 8 studies, some patients were followed for at least 5 yrs. One study (Friberg *et al*., 2000) observed 116 implants for more than 10 yrs.

Failure Analysis

One hundred three implants (1.7%) were lost. Thirty-four had a machined surface, 64 had a rough surface, and 5 were not specified. Failures were categorized as early (implants that failed before prosthetic loading, 75.5% = 71 implants) and late (implants that failed after prosthetic loading, 24.5% = 23 implants). The prevalence of late failures was higher for machined implants. One study (Anitua and Orive, 2010) did not specify whether failures (9 implants) occurred before or after prosthetic loading, but all occurred within 9 mos from implant placement.

Cumulative Survival Rate

The CSR reported in the studies varied from 92.2% at the 1-year follow-up (Gentile *et al*., 2005) to 100% after 5 yrs of observation (Griffin and Cheung, 2004). Only Friberg *et al*. (2000) produced results for CSRs over time, decreasing from 97.7% at 1-year follow-up to 95.5% at 5 yrs and 92.3% at 10 yrs.

Biological Success Rate

The BScR extracted from the studies varied from 89.5% (mean follow-up, 3.9 yrs) (ten Bruggenkate *et al*., 1998) to 100% (mean follow-up, 4.7 yrs) (Maló *et al*., 2007; Deporter *et al*.,

2008). When the observational period was augmented (mean follow-up, 8 yrs) (Friberg *et al*., 2000), the BScR remained high (95.3%). Five papers did not report information available for the analysis of biological success as described in this review.

Marginal Bone Loss

Only 6 studies calculated the mean MBL for the observed implants, while others (Griffin and Cheung, 2004; Goené *et al*., 2005; Fugazzotto, 2008; Grant *et al*., 2009) set bone loss limits to quantify implant success without specifying their own findings. Ten Bruggenkate *et al*. (1998) calculated the MBL at 6-year follow-up and found no bone loss in 72% of 126 patients, up to 1 mm of MBL in 16%, up to 2 mm of MBL in 9%, and more than 2 mm of MBL in 3%.

Biomechanical Complications

Four studies did not observe any biomechanical complication: Two of them did not go beyond the 1- (Felice *et al*., 2010) and 2-year follow-up (Rossi *et al*., 2010); the others followed 55 (ten Bruggenkate *et al*., 1998) and 230 implants (Maló *et al*., 2007) for more than 5 yrs. Misch *et al*. (2006) stated only that none of 338 restorations was refabricated. Friberg *et al*. (2000), through their 14 years of observation, described 2 abutment screw fractures in one patient and no major construction complication. Cannizzaro *et al*. (2009) reported the fracture of the prosthetic ceramic coating in one patient and Goené *et al*. (2005) mentioned "screw loosenings, that do not affect implant survival". One 8-mm-long implant fractured after 10 mos of functional loading as a single crown in the posterior mandible (Grant *et al*., 2010). Eight papers did not report any information about biomechanical complications. Overall, 4 biomechanical complications were reported on 1346 prosthetically restored implants that were investigated in 7 trials for a mean follow-up of 3.2 ± 2.6 yrs.

Data Analysis

The pooled CSR (according to the random-effects model) was 99.1% (95%CI: 98.8-99.4). The sub-group analysis (according to the fixed-effects model) *per* study design reported lower CSR for prospective studies (Fig. 2).

The meta-analyses (according to the fixed-effects model) of survival data pooled by different variables did not show important changes in CSR between groups (Table 2), except for surface characteristics [rough-surfaced, 99.2% (95%CI: 98.9-99.4) *vs*. machine-surfaced, 94.6% (95%CI: 92.6-96.6)] (for a detailed description, see Appendix 5). Very low CSR was reported for implant location in the anterior maxilla, but the number of investigated implants was too small to be representative.

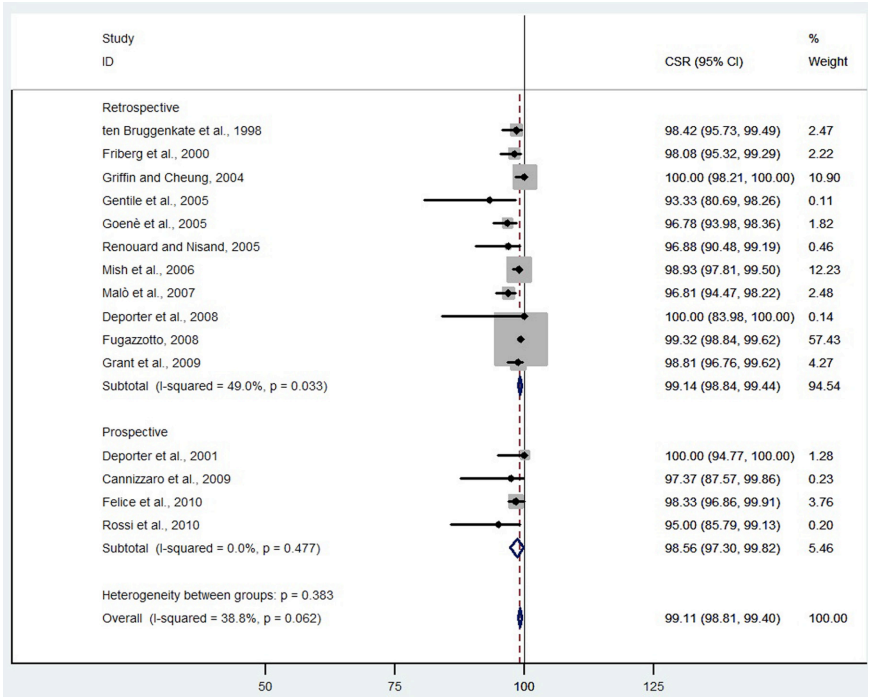

Figure 2. Forest plot of Cumulative Survival Rate and subgroup analysis *per* study design (mean follow-up, 3.2 ± 1.7 yrs).

Pooled BScR (according to the random-effects model) was 98.8% (95%CI: 97.8-99.8). Pooled biomechanical success rate (according to the random-effects model) was 99.9% (95%CI: 99.4-100.0).

DISCUSSION

Although SHIs have been historically considered less reliable than standard implants, in this review, recent publications specifically designed to study SHIs have reported successful results, with a pooled survival rate of 99.1% (95%CI: 98.8-99.4) and a low incidence of biological and biomechanical complications after a mean follow-up period of 3.2 ± 1.7 yrs. It may be speculated that improvements in implant design and surface characteristics, which guarantee higher primary stability and wider bone-to-implant contact, as well as the elaboration of focused surgical protocols and adapted prosthetic restorations, have increased the clinical performance rates of SHIs. Comments and conclusions from reviewed works seem to agree with this. Six studies (Deporter *et al*., 2001, 2008; Gentile *et al*., 2005; Goené *et al*., 2005; Misch *et al*., 2006; Maló *et al*., 2007) stressed the importance of the specific implant system used, and Griffin and Cheung (2004) recognized "the implant maximized surface area as the main contributing factor to the high success rate". Renouard and Nisand (2006) identified a surgical protocol optimized to achieve high primary implant stability as a prerequisite of their study on SHI survival; Fugazzotto (2008) and Anitua

Table 2. Meta-analyses of Data on Implant Survival Pooled by Different Variables*

Variables	Studies (n)	Implants (n)	Pooled CSR (95% CI)	Homogeneity Test P-value	I^2 (%)
Surface Characteristics					
Rough	14	5253	99.152 (98.865-99.440)	0.173	26.1
Machined	4	605	94.565 (92.561-96.568)	0.589	0.0
Implant Location					
Posterior Maxilla	10	1845	99.060 (98.526-99.595)	0.082	41.4
Posterior Mandible	11	3400	98.330 (89.860-99.910)	0.666	0.0
Anterior Maxilla	3	26	88.443 (73.763-100.00)	0.333	9.0
Anterior Mandible	3	332	96.426 (94.031-98.821)	0.029	71.8
Implant Length					
5.0-6.0 mm	7	646	97. 98.934)	0.880	0.0
6.5-7.5 mm	9	1047	99.128 (98.380-99.875)	0.009	61.0
8.0-9.0 mm	10	4500	99.179 (98.872-99.485)	0.139	33.6
Surgical Technique					
2-stage	8	1303	98.962 (98.385-99.538)	0.003	68.2
1-stage	6	3501	99.187 (98.845-99.529)	0.036	58.0
Special surgery	6	681	98.714 (97.639-99.789)	0.757	0.0
Restoration Type					
Single crown	10	2266	99.310 (98.894-99.725)	0.901	0.0
Fixed Partial Denture	8	2482	99.091 (98.649-99.534)	0.687	0.0
Full arch (fixed and removable)	3	456	98.430 (96.983-99.876)	0.000	87.9
Splinting					
Single standing	10	2266	99.310 (98.894-99.725)	0.901	0.0
All-short implants	7	1211	99.830 (99.436-100.00)	0.083	46.3
Short and Standard implants	6	1870	99.241 (98.770-99.711)	0.524	0.0

*Analyses were performed according to a fixed-effects model.

and Orive (2010) reported very positive results with SHIs, but recommended that they be used "under strict clinical protocols". With regard to the prosthetic aspect, although the success of many different kinds of prostheses has been demonstrated in the reviewed works (*e.g.,* single crowns, fixed partial prostheses, cantilevered fixed partial prostheses, full fixed prostheses, overdentures on bars or with retentive anchors), the authors have recommended precautions, *i.e*., joining SHIs with standard implants (ten Bruggenkate *et al*.,1998), eliminating lateral contacts on mandibular excursions, avoiding cantilevers, augmenting implant numbers, and splinting multiple implants (Misch *et al*., 2006).

In this review, implant surface topography seems to have an impact on short-implant survival, improving CSR when rough-surfaced implants are analyzed [CSR = 99.2% (95%CI: 98.9-99.4)] *vs*. machine-surfaced implants [94.6% (95%CI: 92.6-96.6)]. However, this difference should have been a consequence of the small number of studies investigating machine-surfaced implants.

Even though the surgical technique, the implant location, and the type of edentulism did not seem to affect short-implant survival, a notable finding is that most of the failures occurred before prosthesis placement.

It is likely that bone quality and suitable surgical protocols play a more major role in short-implant prognosis than prosthetic features. The capacity of SHIs to withstand biomechanical stresses is supported in this review by a large number of implants (37.9%) being restored as single crowns, reporting CSR as high as that of implants splinted to other short implants or to standard implants, and by the high biological [98.8% (95%CI: 97.8-99.8)] and biomechanical [99.9% (95%CI: 99.4-100.0)] success rates recorded. The biological success rate also takes into account late failures.

However, it is possible that the lack of sufficient follow-ups in the analyzed papers underestimated the effect of prosthetic loading on SHIs outcome, and additional implant failures and biological or biomechanical complications might be expected over the long term. The work of Friberg *et al*. (2000) on machined 6- and 7-mm-long implants, which had the longest observational period, found that most implant losses occurred prior to or around the first few yrs of loading, and no major complications occurred over time. In any case, insufficient findings have been produced on MBL. Only 6 papers calculated progressive MBL around implants, and only 3 (Friberg *et al*., 2000; Deporter *et al*., 2001; Renouard and Nisand, 2005) described the range of bone loss observed, which has a more significant clinical meaning than the statistical average. Moreover, it was not possible to compare the data gathered from the selected studies, since some referred to the baseline at implant insertion, while others cited the time of prosthetic connection. Within the limits of the little amount of data, MBL around SHIs does not exceed the criteria accepted for standard implants (Albrektsson *et al*., 1986). It should be noted that 2 mm of bone loss around a 6-mm-long implant corresponds to nearly half of the entire implant length, and therefore should be interpreted differently on clinical grounds. Actually, to aid clinical interpretation, the success rate

of SHIs should not be compared with the success of longer implants placed in the native jawbone, but should be compared with the success rate of the advanced surgical techniques necessary to place standard implants in resorbed posterior jaws. In recent systematic reviews of the literature, Chiapasco *et al*. (2009) found that the survival rates of implants placed in the maxilla and mandible reconstructed with onlay bone grafts were 79.5% (follow-up, 6-240 mos) and 94.8% (follow-up, 6-90 mos), respectively; the CSR of implants placed in the augmented maxillary sinus was 95% (follow-up, 6-144 months); that in vertical distraction osteogenesis procedures was 95.9% (follow-up, 6-72 mos), and that in the guided bone regeneration technique protocols ranged from 92% to 100% (follow-up, 6-133 mos) (Chiapasco *et al*., 2006). They concluded that priority should be given to simpler approaches.

The two randomized controlled trials included in our review addressed these issues. Cannizzaro *et al*. (2009) studied the efficacy of ≥ 10-mm-long implants inserted into maxillary sinuses augmented according to a lateral approach technique, *vs.* 8-mm-long implants placed in crestally augmented sinuses according to the Cosci technique. Thirty-eight SHIs and 44 standard implants were placed and followed up for 1 yr after loading. There were no statistically significant differences between the procedures, but more failures and complications occurred when the most invasive procedure was used. Moreover, 12 out of 17 non-participating patients refused to undergo the lateral approach sinus lift and preferred SHIs.

Felice et al. (2010) investigated whether SHIs could be an alternative to standard implants placed in vertically augmented posterior mandibles. Sixty SHIs and 61 standard implants were placed and followed up to 1 yr after loading. They concluded that there were no significant differences in bone loss between groups, but the augmentation procedure required a longer healing time, further technical skills, and augmented costs, and caused post-operative paresthesia of the alveolar inferior nerve in a highly statistically significant manner.

A limitation of this review was that most (72.6%) of the SHIs investigated were 8, 8.5, or 9 mm long. The number of 5- and 6-mm-long implants (n = 646, 10.4%) was very small, so that any conclusions about their clinical outcomes should be drawn with caution.

Moreover, the evidence obtained should be considered as moderate. Fourteen of the selected studies were observational studies, and 12 of these were retrospective trials. The subgroup meta-analysis of survival by study design reported a slightly higher CSR for retrospective studies. The high susceptibility to bias of this kind of study might suggest our results to be optimistic. Other questionable issues of the reviewed papers are sample size and follow-up duration. It has been speculated that for detection of a difference in implant survival between 85% and 95% in a statistically meaningful manner, a controlled study needs to include 135 implants in each arm, for a total sample size of 270 implants (Eckert *et al*., 2003). Excluding the existence of the control group, 9 studies provided an adequate sample size. In addition, 1 of 2 very-large-sized studies was conducted by one single practitioner who presented a clear conflict of interests, being the owner of the company of the implants used (Anitua and Orive, 2010).

Concerning the follow-up duration, the mean observational period was less than 5 yrs, and only 1 study produced data after 10 yrs. The decision to include articles that reported a mean follow-up period of at least 1 yr after prosthetic loading was supported by: (1) results from published studies (Åstrand *et al*., 2004; Berglundh *et al*., 2005; Cochrane *et al*., 2009) showing that most marginal bone remodeling occurs between implant placement and prosthesis delivery, while little changes continue up to 5 yrs post-loading; and (2) the idea of increasing the number of eligible studies and therefore the number of implants susceptible to the analysis of our primary outcome (CSR).

Moreover, no specific measures were taken in this review to analyze for a cluster effect, and losses to follow-up were also not considered. The results presented should thus be interpreted descriptively.

In conclusion, short implant-supported prostheses appear to be a valid option in the treatment of the atrophic jaw. High survival rates [99.1% (95%CI: 98.8-99.4)] and low incidence of biological and biomechanical complications are reported after a mean follow-up period of 3.2 ± 1.7 yrs. Surgical technique, implant location, and type of edentulism and prosthetic restoration did not affect short-implant survival. Improvements are possible, with rough-surfaced implants preferred. Randomized controlled trials and prospective studies with longer follow-up times and larger samples are necessary to validate the current findings.

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