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Predictability of short implants (< 10 mm) as a treatment option for the rehabilitation of atrophic maxillae. A systematic review

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Abstract

Background: Short implants (< 10 mm) are one of the treatment options available in cases of limited vertical bone. Although such implants are now widely used, there is controversy regarding their clinical reliability. The purpose of this paper is to evaluate the predictability of short implants as an alternative to technically more complex treatments in patients with atrophic maxillae, based on a systematic review of the literature and the analysis of the implant survival rates, changes in peri-implant bone level, and associated complications. It is postulated that short implants offer clinical results similar to those of longer implants.

Material and Methods: A Medline-PubMed search was made covering the period between January 2004 and December 2014 (both included). Studies in English published in indexed journals, involving at least 20 implants and with a follow-up period of at least 12 months were considered. A manual search in four high impact journals was also conducted.

Results: A total of 37 studies meeting the inclusion criteria were included in this review. 9792 implants placed in over 5000 patients were analyzed.

Conclusions: Based on the results of this review, short implants are seen to offer clinical results in terms of survival, bone loss and complications similar to those of longer implants.

Key words: *Survival rate, clinical results, dental implants, oral implants, short implants, short length.*

Introduction

Bone resorption occurring after tooth loss in either the upper maxilla or the mandible can give rise to an atrophic alveolar crest. In most such cases, a functional and esthetically satisfactory dental implant supported rehabilitation is not possible. According to Araujo & Lindhe (1), tooth loss gives rise to physiological resorption of the alveolar process. This resorption is characterized by a decrease in both the number of trabeculae and in bone density, as well as loss of bone width and height.

Depending on the time elapsed and the location within the maxillae, resorption will affect alveolar bone to one extent or other. It has been well established that bone loss in the first year after tooth loss is much greater than the loss observed over the subsequent years.

In the upper maxilla, bone resorption characteristically occurs towards the midline. This circumstance, added to the pneumatization of the maxillary sinus, can make implant placement in the posterior region more complicated. In the anterior region of the mandible, bone resorption occurs from the buccal plate towards the lingual aspect, while in the posterior areas it usually occurs from the lingual towards the buccal aspect. This fact gives rise to a centrifugal resorption pattern, which is characteristic of the mandible.

The posterior regions of both maxillae usually present less available bone height, as a consequence of bone resorption. In the upper maxilla the main anatomical limitation is caused by the pneumatization of the maxillary sinus, while in the mandible the mandibular canal is the structure that conditions the available bone height. For this reason, posterior regions of both maxillae are good candidates for rehabilitation using short dental implants.

Several surgical techniques have been described for the rehabilitation of patients with maxillary and mandibular atrophy using dental implants. These techniques originally attempted to increase the amount and quality of available bone, based on guided bone regeneration procedures, sinus lift techniques, block grafts and alveolar bone distraction.

Although all these techniques offer good results, they can be considered technically demanding procedures that in many cases give rise to complications such as graft failure, wound infection, a worse postoperative course, increased morbidity, longer treatment times, and higher economic costs for the patient. As an alternative to these techniques, the placement of short dental implants has been proposed for the rehabilitation of atrophic alveolar crests. According to Das Neves *et al.* (2), short implants are defined as implants measuring less than 10 mm in length. Other authors consider short implants to be implants measuring 8 mm or less in length - implants measuring 10 mm being regarded as conventional implants, due to their widespread use in recent years.

Some previous publications have found these short implants to offer clinical results comparable to those obtained with longer implants – the implant survival rates ranging between 92.3% according to Slotte *et al.* (3) and 100% as published by Anitua *et al.* (4) in the posterior region of the mandible, and between 94.6% according to Renouard & Nisand (5) and 100% as published by Taschieri *et al.* (6) in the posterior region of the upper maxilla.

Other factors to bear in mind when considering the use of short implants are their design and surface characteristics. In this regard, a rough surface means that despite the reduced implant length, the effective bone-implant contact surface area would be increased when being compared to a smooth surface.

Some three-dimensional finite element studies previously published have suggested that stress distribution is greater at a crestal level. According to these studies, the first three or four implant threads support most of the load. Therefore, maximum bone tension is independent of implant length - implant diameter being regarded as a more determinant factor than implant length.

When rehabilitating patients with missing teeth, one of the parameters to be taken into account is the influence of the crown-implant ratio upon the viability of the rehabilitation (in relation with biomechanics and stress distribution). When using short implants, the prognosis might be regarded as poorer as a result of the development of peri-implant bone loss. However, in 2009 Blanes (7) reported no relationship between crown-implant ratio and peri-implant bone loss.

Regarding the prosthetic rehabilitation of these implants, there is some controversy as to whether splinting should be used in all cases or not. According to Bahat (8), 60% of the failed short implants (< 7 mm) were single implants. This study points to prosthetic splinting as one of the main factors conditioning implant survival in the case of posterior regions rehabilitation procedures.

- Purpose

The aim of the present study is to evaluate the predictability of short implants as an alternative to technically more demanding treatments, based on a systematic review of the literature and the analysis of the implant survival rates, changes in peri-implant bone level, and complications associated to the use of dental implants under 10 mm in length.

Material and Methods

- Search strategy

A Medline-PubMed search was made of studies published in English and covering the period between January 2004 and December 2014 (both included). The key words used in the search included a combination of the following terms: “survival rate”, “clinical results”, “dental implants”, “oral implants”, “short implants”, “short length”. The Boolean operators “AND” and “OR” were used. In order to minimize electronic search bias, a manual search was made for relevant articles in the following high impact journals: “The International Journal of Oral and Maxillofacial Implants”, “Clinical - Oral Implants

Research”, “Journal of Periodontology”, “Clinical Implant Dentistry and Related Research” and “European Journal of Oral Implantology”(Fig. 1).

- Study screening and inclusion criteria.

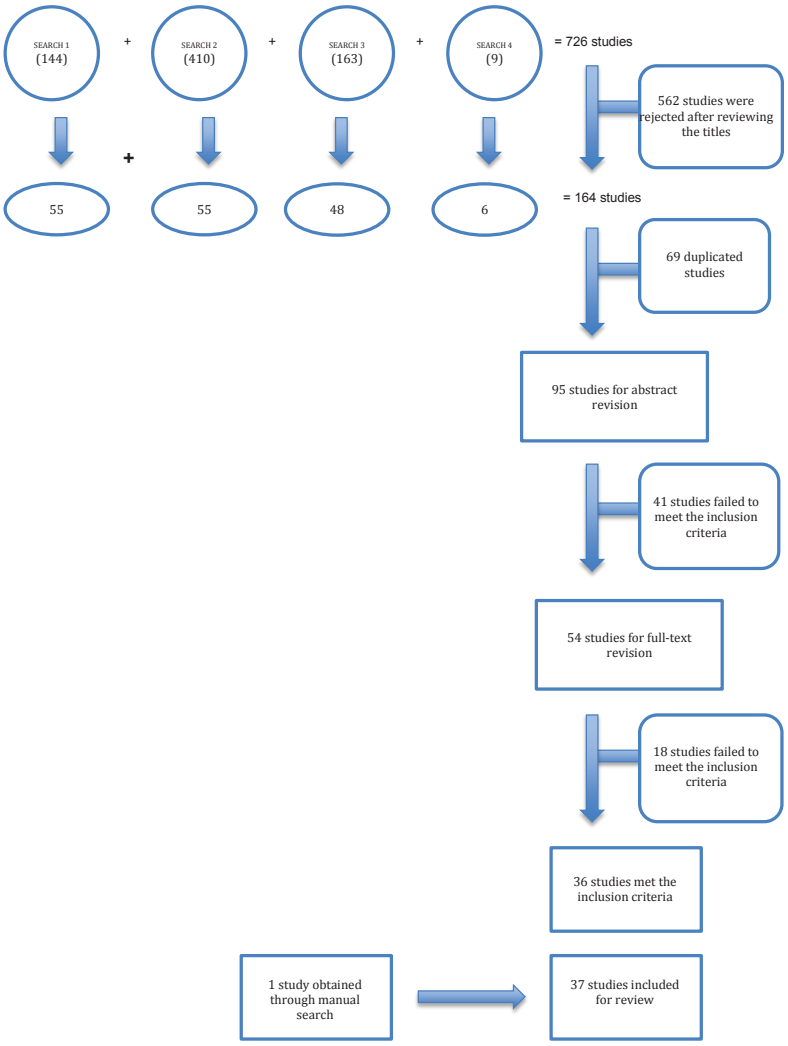

Fig. 1. Study screening and inclusion criteria.

Two reviewers carried out the search. The variables of interest were implant survival, changes in peri-implant bone level, and associated complications. Implant survival was defined as implant persistence in the mouth at the time of evaluation.

The studies included in the review were required to meet the following criteria:

- Full-text articles in English, published in indexed journals between January 2004 and December 2014 (both included).
- Presentation of clinical results with implants measuring < 10 mm in length (no additional bone regeneration techniques to gain bone height allowed).
- Randomized clinical trials and clinical cohort studies of a prospective or retrospective nature conducted in humans, and involving a minimum of 20 implants.
- A follow-up period of at least 12 months.

In a first phase, two reviewers independently assessed titles and abstracts for relevance, and then debated upon them. A third reviewer was consulted in order to clear up any possible discrepancies. In a second phase, the full text of the selected articles meeting the inclusion criteria was subjected to additional analysis by two reviewers.

- Data extraction

All of the included studies were reviewed and analyzed independently. The variables related to the study design were extracted (year of publication, type of study and follow-up, number of patients, number of implants, mean age of the patients, inclusion or exclusion of smokers, and type of opposing dentition), along with the characteristics of treatment (implant surface, implant length and diameter, treated maxilla and localization of the implants, type of connection, characteristics of the surgical technique, type of prosthetic restoration, insertion torque and bone quality). The variables associated to treatment outcome (survival rate, peri-implant bone loss and associated complications) were also analyzed.

Results

Figure 1 shows the results of the electronic and manual searches. Out of a total of 54 reviewed full-text articles, 36 met the inclusion criteria and were selected. One further article was added from the manual search.

The following variables were studied in the 37 finally included articles:

1. Variables associated to study design (Table 1).

The review included a total of 37 studies published between 2004 and 2014. Of these, only 6 were randomized clinical trials. We also included 12 prospective and 19 retrospective cohort studies. The follow-up period of the studies ranged from 12 months to 14 years in the article published by Romeo *et al*. (9).

The 37 studies included over 5000 patients. Twelve studies involved more than 100 patients. The mean patient age ranged from 45.9 years to 62.1 years. In this review a total of 9792 implants were included.

Twenty-three of the 37 studies included smokers. Most of these articles established a limitation of between 5-10 cigarettes per day. Only one study published excluded smokers entirely, while 13 studies failed to indicate whether smokers were included or not. Twenty-nine of the reviewed studies provided no information on the type of opposing dentition. Seven studies specified the presence of natural teeth or fixed dentures (both teeth or implant supported) in the opposing arch, while only three publications published removable dentures (partial or complete) in the opposing arch.

2. Variables associated to treatment characteristics (Table 2 and 2 continue).

The studies included in this review used implants with a wide variety of designs and surface treatments. The length of the implants ranged between 4.0-9.0 mm, while the implant diameter ranged between 2.5-6.0 mm. All the studies presented results corresponding to implants with rough surfaces subjected to different treatments. Five of the 37 studies presented results comparing short implants with a rough surface versus short implants with a machined surface.

Twenty-eight of the 37 studies presented results on implants with internal connection, while only 7 studies published results on implants with external connection. One study, published by Mendoça *et al*. (10), compared short implants with both internal and external connection. Another two studies, published by Sánchez-Garcés (11) and Degidi (12), employed multiple implant systems, without offering further information on the type of connection involved.

In relation to the treated maxilla, 24 studies presented results on implants placed both in the maxilla and in the mandible. 9 studies presented results only in the mandible, while only 5 studies presented results on implants placed only in the maxilla.

Regarding implant location, 23 of the studies published results on implants placed in the posterior regions of both maxillae. Another 10 studies published results on implants placed both in the anterior and the posterior areas while four articles failed to specify implant location.

Regarding the characteristics of the surgical technique, all of the reviewed studies raised full-thickness flaps for implant placement. Seventeen articles provided results on short implants placed using two-step surgery, while 14 studies performed single-step surgery. Only Anitua *et al*. (13) and Degidi *et al*. (12) presented results with an immediate loading approach. Six studies included implants placed in both single and two-step surgical procedures.

Two studies modified the drilling protocol. These two studies adapted the surgical technique to increase implant stability in cases of soft bone. Another two studies, used surgical templates to guide the drilling of the implants.

The implants included in this review were used to support different types of prosthetic restorations such as fixed prostheses (single or multiple) and over dentures (with splinted implants). Twenty-four studies presented clinical results with short implants supporting single restorations, though only 5 of them published data on short implants supporting single-unit crowns on an exclusive basis. On the other hand, 22 studies included clinical results on short implants splinted with fixed prostheses to other implants of the same or greater length.

Ten of the reviewed studies presented information on the insertion torque applied at the time of implant placement. The values ranged from a minimum of $\leq$ 15 N in the study of Rossi *et al*. (14), to a maximum of 60 N in the studies published by Anitua *et al*. (15) and Pieri *et al*. (16).

Sixteen studies recorded information on the bone quality of the areas in which the short implants were placed. Fourteen of these articles recorded short implant placement in type III and type IV bone.

3. Variables associated to treatment outcome (Table 3).

The implant survival rates ranged from 83.3% referred to 6 implants measuring 8.5 mm in length and placed in the upper maxilla in the study of Mendoça *et al*. (10) to 100% reported in the studies of Anitua *et al*. (4), Taschieri *et al*. (6), Mertens *et al*. (17), Birdi *et al*. (18) and Rokni & Todescan (19).

Twenty-nine studies measured the changes in peri-implant bone level after implant loading. The bone loss around the implants ranged from 0.1 mm after one year in the study published by Gulje *et al*. (20) to 2.5 ± 0.9 mm / 2.8 ± 1.0 mm measured after 5 years in the study of Rossi *et al*. (14).

A total of 31 studies provided information on the complications associated with short implants. A number of problems related to implant placement were recorded,

Table 1. Variables associated to study design.

Author/Year	Type Of Study/Follow-Up	Number Implants/Patient	Inclusion Smokers	Type Of Opposing Arch
Anitua 2014	RCT / 2 years	45 / 34	Yes	Complete fixed bridges and natural dentition
Anitua 2014	RCT / 12 years	111 / 75	Yes	Bridge on implants, natural dentition and complete rehabilitations
Esposito 2014	RCT / 3 years	60 / 30	Yes	Not specified
Mangano 2014	PCT / 10 years	215 / 194	Yes	Not specified
Mendoça 2014	RCT / 9 years	211 implants	Yes	Natural dentition and fixed prostheses
Peñarrocha 2014	PCT / 1 year	35 / 17	Yes	Not specified
Rossi 2014	PCT / 5 years	45 / 35	Yes	Not specified
Taschieri 2014	PCT / 1 year	25 implants	Not specified	Not specified
Tellemann 2014	RCT Split-mouth / 1 year	149 / 92	Not specified	Not specified
Gulje 2013	RCT / 1 year	208 / 49	Yes < 10 cig/day	Natural dentition, removable partial prostheses and implant supported prostheses
Kennedy 2013	PCT / 5 years	70 / 18	No	Not specified
Lai 2013	RCT / 10 years	231 / 168	Yes	Not specified
Sivolella 2013	RCT / 9 years	280 / 109	Yes < 10 cig/day	Not specified
Tellemann 2013	RCT Split-mouth / 1 year	62 / 17	Not specified	Not specified
Draenert 2012	RCT / 3 years	247 / 216	Not specified	Not specified
Gulje 2012	PCT / 1 year	48 / 12	Not specified	Not specified
Lops 2012	RCT / 10 years	108 implants	Yes	Natural dentition and fixed prostheses
Mertens 2012	RCT / 10 years	52 implants	Yes	Not specified
Pieri 2012	RCT 3 years	71 / 33	Yes	Natural dentition, implants and fixed prostheses
Sanchez-Garces 2012	RCT / 12 years	106 implants	Yes < 5 cig/day	Not specified
Slotte 2012	PCT / 5 years	100 / 32	Yes < 10 cig/day	Not specified
Van Assche 2012	PCT / 2 years	24 / 12.	Not specified	Not specified
Pieri 2011	PCT / 2 years	61 / 25	Yes < 10 cig/day	Not specified
Anitua 2010	RCT / 8 years	1287 / 661	Yes	Not specified
Birdi 2010	RCT / 2 years	309 / 194	Not specified	Not specified
Felice 2010	RCT / 1 year	60 / 79	Yes	Not specified
Grant 2009	RCT / 2 years	334 / 125	Yes	Not specified
Anitua 2008	PCT / 3 years	532 / 293	Yes	Not specified
Fugazzotto 2008	RCT / 3 years	2073 / 1774	Yes < 10 cig/day	Not specified
Degidi 2007	RCT / 4 years	57 implants	Yes < 20 cig/day	Not specified
Malo 2007	RCT / 9 years	408 / 237	Not specified	Not specified
Misch 2006	RCT / 5 years	745 / 273	Not specified	Not specified
Arlin 2005	PCT / 2 years	176 implants	Yes	Not specified
Renouard 2005	RCT / 2 years	85 / 96	Not specified	Not specified
Rokni 2005	RCT / 5 years	72 implants	Not specified	Not specified
Romeo 2005	PCT / 14 years	111 implants	Not specified	Excluded if opposing arch is complete or removable partial
Fugazzotto 2004	RCT / 7 years	979 implants	Not specified	Natural dentition, partial or complete prostheses, fixed and removable implant supported prostheses

Table 2. Variables associated to treatment characteristics.

Author/Year	Surface	Diameter/Length	Connection	1/2 Phases	Maxilla/Mandible	Type Of Prosthesis	Bone Quality	Type Of Surgery
Anitua 2014	Rough	3.75 and 5.0 mm x 5.5 and 6.5 mm long	Internal	2 phases	Posterior mandible	Fixed both cemented and screwed	III	2 phases PRGF
Anitua 2014	Rough	3.3, 3.75, 4.0, 4.5 and 5 mm 7.0, 7.5 and 8.5 mm long	Internal	1 and 2 phases	Maxilla and posterior mandible	Fixed bridges, overdentures and single crowns	Not specified	Immediate loading PRGF
Esposito 2014	Rough	6 mm x / 5 mm long	Internal	2 phases	Anterior and posterior maxilla and mandible	Single crowns and screwed bridges	Not specified	2 phases
Mangano 2014	Rough	3.3 mm, 4.1and 4.8 x / 8 mm long	Internal	2 phases	Maxilla and posterior mandible	Single crowns	II/III/IV	2 phases
Mendoça 2014	Rough And Machined	4.1 and 5 mm x / 7 and 8.5 mm long	Internal and external	2 phases	Maxilla and mandible	Fixed bridges 2 and 3 units	Not specified	2 phases
Peñarrocha 2014	Rough	4.2 mm and 5.5 mm x / 7 mm long	Internal	2 phases	Posterior mandible	Fixed prostheses and bridges	Not specified	2 phases
Rossi 2014	Rough	4.1 mm and 4.8 mm x / 6 mm long	Internal	1 phase	Maxilla and posterior mandible	Cemented	I/II/III/IV	1 phase
Taschieri 2014	Rough	3.75, 4.0, 4.5 and 5.0 mm x 6.5, 8.5 mm long	Internal	2 phases	Posterior maxilla	Cemented bridge splinted to implant ≥ 10 mm	Not specified	Sub-preparation
Tellemann 2014	Rough	4.1 and 5.0 mm x / 8.5 mm long	Internal	1 phase	Maxilla and posterior mandible	Single crowns and bridges	I/II/III/IV	Guided surgery 1 phase
Gulje 2013	Rough	4 mm x / 6 mm long	Internal	1 phase	Maxilla and posterior mandible	Fixed screwed bridges	Not specified	1 phase
Kennedy 2013	Rough	3.5, 4.0 and 5.0 mm x 6.0, 8.0 and 9.0 mm long	External	2 phases	Maxilla and posterior mandible	Single crowns and bridges	Not specified	Guided surgery 2 phases
Lai 2013	Rough	4.1 and 4.8 mm x / 6.0 and 8.0 mm long	Internal	1 phase	Maxilla and posterior mandible	Single crowns	I/II/III/IV	1 phase
Sivolella 2013	Rough And Machined	3.75 and 4.0 mm x 7.0 and 8.5 mm long	External	2 phases	Posterior mandible	Prostheses, fixed crowns and bridges	II/III	Not specified
Tellemann 2013	Rough	4.1 and 5.0 mm x / 8.5 mm long	Internal	2 phases	Maxilla and mandible	Crowns and bridges	Not specified	Not specified
Draenert 2012	Rough	3.5 and 6.0 mm x / 8 and 9 mm long	Internal	1 phase	Posterior mandible	Prostheses, fixed crowns and bridges	Not specified	Not specified
Gulje 2012	Rough	4.0 mm x / 6mm long	Internal	2 phases	Mandible	Overdentures (retained to bars)	II	Not specified
Lops 2012	Rough	3.75, 4.1 and 4.8 mm x / 8 mm long	Internal	1 phase	Anterior and posterior maxilla and mandible	Single crowns, bridges and complete rehabilitations	Not specified	1 phase
Mertens 2012	Rough	3.5, 4.0 and 4.5 mm x 8.0 and 9.0 mm long	Internal	2 phases	Anterior and posterior maxilla and mandible	Single crowns, bridges and full-arch fixed prostheses	Not specified	2 phases
Pieri 2012	Rough	4.0 mm x / 6 mm long	Internal	2 phases	Maxilla	Fixed bridges 2 and 3 units	III	2 phases
Sanchez-Garces 2012	Rough And Machined	5.0, 6.0, 7.0, 8.5 and 9.0 mm long	Multiple implants	2 phases	Anterior and posterior maxilla and mandible	Not specified	Not specified	2 phases

Table 2 continue. Variables associated to treatment characteristics.

Slotte 2012	Rough	4.1 mm x / 4.0 mm long	Internal	1 and 2 phases	Posterior mandible	Fixed bridges	Not specified	Not specified
Van Assche 2012	Rough	4.1 mm x / 6 mm long	Internal	1 phase	Posterior maxilla	Overdentures (retained to bars)	III/IV	Not specified
Pieri 2011	Rough	4.0 mm x / 6 mm long	Internal	2 phases	Posterior mandible	Prostheses and fixed bridges	II/III	Not specified
Anitua 2010	Rough	2.5, 3.0, 3.3, 3.75, 4.0, 4.5, 5.0, 5.5 and 6.0 mm x 6.5, 7.0, 7.5 and 8.0 mm long	Internal	1 and 2 phases	Posterior maxilla and mandible	Bridges, single crowns and cemented and screwed hybrid prostheses	I/II/III	1 and 2 phases / PRGF
Birdi 2010	Rough	5.0 and 6.0 mm x / 5.7 and 6.0 mm long	Internal	1 and 2 phases	Anterior and posterior maxilla and mandible	Single crowns	Not specified	1 and 2 phases
Felice 2010	Rough	4.0 mm x / 7 mm long	External	2 phases	Posterior mandible	Fixed prostheses, crowns and bridges	Not specified	Not specified
Grant 2009	Rough	3.5 and 6.0 mm x / 8 mm long	Internal	2 phases	Posterior mandible	Fixed prostheses, crowns and bridges	Not specified	Not specified
Anitua 2008	Rough	3.3, 3.75, 4.0, 4.5 and 5.0 mm x 7.0, 7.5 and 8.0 mm long	Internal	1 and 2 phases	Anterior and posterior maxilla and mandible	Bridges, single crowns and cemented and screwed hybrid prostheses	I/II/III	1 and 2 phases PRGF and biological drilling
Fugazzotto 2008	Rough	4.1 mm x / 6.0, 7.0, 8.0 and 9.0 mm long	Internal	1 phase	Posterior maxilla and mandible	Single crowns and bridges	Not specified	2 phases
Degidi 2007	Multiple systems	Multiple systems	Multiple implants	1 phase and immediate loading	Anterior and posterior maxilla and mandible	Cemented crowns	Not specified	1 phase and immediate loading / Post-extraction
Malo 2007	Rough and machined	3.75 and 4.0 mm x / 7 and 8 mm long	External	1 phase	Anterior and posterior maxilla and mandible	Single crowns and bridges	Not specified	1 phase
Misch 2006	Rough	3.5, 4.0, 5.0 and 6.0 mm x / 7.0 and 9.0 mm long	External	1/2 phases	Posterior maxilla and mandible	Single crowns and bridges	II/III/IV	1 and 2 phases
Arlin 2005	Rough	3.3, 4.1 and 4.8 mm x / 6.0 and 8.0 mm long	Internal	1 phase	Maxilla and mandible	Not specified	I/II/III/IV	1 phase
Renouard 2005	Rough and machined	3.75 and 5.0 mm x / 6.0, 7.0 and 8.5mm long	External	1 phase	Posterior maxilla	Cemented single crowns and screwed multiple prostheses	I/II/III/IV	Specific soft bone drilling
Rokni 2005	Rough	3.5, 4.1 and 5.0 mm x / 5.0, 7.0 and 9.0 mm long	External	2 phases	Anterior and posterior maxilla and posterior mandible	Single crowns and bridges	Not specified	Not specified
Romeo 2005	Rough	3.75, 4.1 and 4.8 mm x / 8 mm long	Internal	1 phase	Anterior and posterior maxilla and mandible	Single crowns, bridges and full-arch fixed prostheses	I/II/III/IV	1 phase
Fugazzotto 2004	Rough	4.1 mm and 4.8 mm x / 6.0 and 8.0 mm long	Internal	1 phase	Posterior maxilla	Single crowns	Not specified	1 phase

Table 3. Variables associated to treatment outcome.

Author/Year	Survival Rate	Bone Loss	Complications
Anitua 2014	100%	1.01 ± 0.68 Mm Mesial 0.89 ± 0.7 Mm Distal	No Complication
Anitua 2014	98.9 %	1.0 Mm Mesial 0.9 Mm Distal	1 Peri-Implantitis
Esposito 2014	91.6 %	1.22 ± 0.49 Mm (3 Years)	3 Peri-Implantitis / 1 Mucositis / 3 Post Loosenings / 3 Transient Paresthesias And 3 Sinus Perforations
Mangano 2014	98.3 % Maxilla 98.9 % Mandible	0.31±0.24 Mm, 0.43±0.29 Mm And 0.62±0.31 1, 5, 10 Years	Porcelain Fracture / Additament Loosening And 3 Implant Failures
Mendoça 2014	(7 Mm) 95 % 94.1 % (8.5 Mm) 100 %, 83.3 % , 98.7 %, 86.4 %	7 Mm 1.35 ± 0.98 / 1.03 ± 0.69 Mm 8.5 Mm 0.50 ± 0.41 / 1.40 ± 1.20 / 1.07 ± 0.80 / 1.37 ± 1.21 Mm	Marginal Bone Loss And 21 Failed Implants
Peñarrocha 2014	97.1 %	0.6 ± 0.3 Mm	1 Failure / Dehiscences
Rossi 2014	95%	2.5 ± 0.9 Mm Mesial 5 Years 2.8 ± 1.0 Mm Distal 5 Years	2 Implant Failures / Signs Of Mild Inflammation
Taschieri 2014	100%	0.34 ± 0.21 Mm Implants ≤ 8.5 Mm	Not Specified
Tellemann 2014	92.1 % No Platform Switching 95.9 % Platform Switching	0.74 ± 0.61 Mm No Platform Switching 0.50 ± 0.53 Mm Con Platform Switching	Not Specified
Gulje 2013	97%	0.24 Mm ± 0.21 6 Months 0.2 Mm ± 0.22 12 Months	Prosthesis Screw Loosening / Fracture Of Provisional Prosthesis
Kennedy 2013	90%	Not Published	7 Implant Failures (Over-Heating)
Lai 2013	98.3 %	0.63 ± 0.68 Mm 10 Years	Biological (15 Mucositis And Peri-Implantitis) And Prosthetic (Post Loosening, Post Fracture And Porcelain Fracture)
Sivolella 2013	Machined 95.7% Rouhg Surface 97.2 %	1.37 ± 0.5 Mm	7 Implant Failures And 8 Peri-Implantitis, 33 Prosthetic Complications Of Different Kinds
Tellemann 2013	93.6 %	0.85 ± 0.65 Mm / 0.53 ± 0.54 Mm (Platform Switching)	Gingival Swelling And Bleeding
Draenert 2012	98%	0.95 Mm	1 Failure / Dehiscences
Gulje 2012	96%	0.1 Mm 1 Year	2 Failures And 1 Mandibular Fracture
Lops 2012	96.4 %	1.8 ± 1.5 Mm	10 Peri-Implantitis / Severe Bone Loss
Mertens 2012	100%	0.3 ± 0.4 Mm	Not Specified
Pieri 2012	98.6 %	0.45 ± 0.34 3 Years	1 Failure / 1 Mucositis /1 Peri-Implantitis / 1 Perforation / Loosening-Decementing And Porclain Fracture
Sanchez-Garces 2012	92.5 %	Not Published	Not Specified
Slotte 2012	92.3 %	0.49 Mm	7 Implant Failures
Van Assche 2012	97.6 %	0.7 Mm	1 Implant Failure / 2 Loosenings
Pieri 2011	96.5 %	0.51 ± 0.38 Mm	2 Implant Failures / Decementing, Loosening And Chipping
Anitua 2010	99.3 %	Not Published	9 Implant Failures
Birdi 2010	100%	20.2 ± 0.7 Mm Mesial 20.2 ± 0.9 Mm Distal	Not Specified
Felice 2010	95%	1 Mm 1 Year	1 Implants Failure / 1 Prosthetic Complication
Grant 2009	99%	1 Mm First Year + 0.1 Per Year	1 Implant Failure / 1 Implant Fracture
Anitua 2008	99.2 %	Not Published	2 Implant Failures
Fugazzotto 2008	98.1% 99.7 %	Not Published	4 Cases Of Implant Mobility And 2 Implant Failures
Degidi 2007	98.2%	0.2 Mm	1 Implant Failure
Malo 2007	96.6 %	1.8 Mm 5 Years ± 0.8 Mm	13 Implant Failures / 4 Mucositis / Loosening Healing Post
Misch 2006	98.9%	Not Published	6 Implant Failures
Arlin 2005	(6 Mm) 94.3 % (8 Mm) 99.3 %	Not Published	3 Implant Failures 2 (6 Mm) And 1 (8 Mm)
Renouard 2005	94,60%	0.44 ± 0.52 Mm 2 Years	5 Implant Failures (4 Were Machined)
Rokni 2005	100%	0.2 ± 0.4 Implants < 9 Mm	Not Specified
Romeo 2005	Plasma Spray 92.3 % Sla 100 %	1.6 ± 1.5 Mm	Probing Depth > 3 Mm / 10 Peri-Implantitis And Thread Exposure
Fugazzotto 2004	95.1 %	Not Published	9 Implant Failures

such as implant loss (135 implants in 23 studies), mucositis and peri-implantitis (51 implants in 8 studies), mobility of the implant (4 implants in 1 study), perforation of the sinus membrane (4 perforations in 2 studies), and mandibular fracture (1 fracture). Other complications recorded in the studies were related to the prosthesis, including cement loss, loosening, or fracture of the prosthesis or of some of its components (screw or abutment), and fracture of the implant (1 case).

Discussion

Short implants (< 10 mm in length) produce results comparable to those obtained with implants of greater length after prolonged follow-up periods, as reported by Monje *et al*. in their meta-analysis published in 2013 (21). Our review included only 6 randomized clinical trials supporting this affirmation. The minimum duration of follow-up was 12 months in all the studies, thus allowing us to conduct an analysis of the middle-term results obtained. The patient sample was quite large and included individuals

who were partially or totally edentulous in both maxillae. Due to the great variety of the implants analyzed,

it is difficult to establish a relationship between the different implant surface characteristics, diameters and lengths and the implant survival.

We found most of the reviewed studies to publish survival rates over 95%. These are high percentages, as seen for example in the studies published by Anitua *et al*. (22), Lops *et al*. (23) and Romeo *et al*. (9). All three studies involved a follow-up period of over 10 years, with survival rates greater than those recorded for implants placed in posterior regions of the upper maxilla using the sinus lift with lateral window technique, according to a recent systematic review published by Del Fabbro *et al*. (24). These authors recorded a survival rate of about 93.7% for implants placed in grafted bone.

Likewise, in relation to the treatment of atrophic mandibles, Al-Nawas *et al*. (25), in their systematic review, published survival results in the order of 96% for implants placed in grafted bone using different techniques. It therefore can be affirmed that short implants offer good clinical results with shorter treatment times, low morbidity rates, and few intraoperative complications.

As seen from our review, another factor to be taken into account is the type of implant surface involved. The survival results obtained are much better for implants with a rough surface than for implants with a machined smooth surface. Furthermore, in the case of shorter implants and narrow-diameter implants, where the bone-implant contact surface area is reduced, it is essential for the surface treatment to provide a correct osseointegration. On the other hand, as indicated by Heitz-Mayfield & Mombelli in their systematic review (26), it is also true that surface roughness is associated to an increased risk of peri-implantitis if good maintenance is not ensured. In our review, this circumstance, together with implant loss, was the most common biological complication.

In the three-dimensional study of finite elements published by Petrie & Williams (27), low biomechanical stress levels were associated to large-diameter implants. Increasing the diameter was found to result in a 3.5-fold decrease in crestal strain. In contrast, an increase in implant length only resulted in a 1.65-fold decrease in crestal strain. This author considered implant diameter to have a stronger influence than implant length - in agreement with other authors such as Anitua *et al*. (28).

Most of the studies reported results on implants placed in both maxillae. The few studies presenting data on short implants exclusively placed in the upper maxilla also described good results. According to the systematic review published by Srinivasan & Vazquez (29) also published survival rates between 92.2% and 100% for short implants measuring 4-7.5 mm in length - with a higher failure rate in the upper maxilla. In the mentioned study, 297 implants were placed in the upper maxilla. 13 of this 297 implants were seen to fail. In the mandible 826 implants were placed and only 19 out of this 826 implants failed. These differences can be explained by the fact that the posterior region of the upper maxilla is characterized by type IV bone. In this regard, the presence of poorer quality bone is a decisive factor in quantifying implant survival.

Another of the objectives of our review was to analyze peri-implant bone loss. According to the results obtained, such loss does not seem to be influenced by implant length. This is consistent with the findings of the systematic review published by Monje *et al*. (30).

These authors found no statistically significant differences in bone loss between standard-length implants versus shorter implants. In this respect, the new implant designs and types of connections appear to play a very important role. More rigid internal connections with fewer micromovements cause the peri-implant tissues to remain more stable over time. In this regard, mention can be made of the study published by Mendonça *et al*. (10), in which the poorest results were obtained with non-splinted externally connected implants presenting a smooth machined surface. Most of the studies in our review used internal connections.

Another important parameter analyzed in our review is whether or not prosthetic splinting of short implants is necessary. In this regard, a number of authors such as Misch & Steigenga (31) recommend the splinting of short implants.

As an example, the retrospective study published by Misch & Steigenga combined the splinting of short implants with implants of standard size (62 implants). At the same time, splinting of multiple short implants

was also carried out (174 implants). On the other hand, in the same study 64 short implants were placed in the mandible and 38 in the upper maxilla supporting unit restorations. The success rate was higher for splinted short implants. On examining the different studies included in our review, most of them were seen to use splinted prostheses. However, many of the publications also used short implants to support single crowns, with similar results.

Likewise in relation to the prosthetic rehabilitation of short implants, a disproportionate crown-implant ratio has not been identified as a decisive factor in treatment outcome. This is consistent with the observations of Birdi *et al*. (18), though other investigators argue that disproportion between the size of the crown and of the implant is indeed associated to a greater risk of fracture and loosening of the prosthesis. No authors *et al*. (32) found that despite the greater risk of loosening, the peri-implant bone levels are not significantly affected as a result. This implies that when using short implants to support single-unit restorations, loosening of the prosthesis is the main prosthetic complication.

Conclusions

Despite the limitations inherent to this systematic review, the results obtained appear to confirm that short dental implants offer clinical results in terms of survival, bone loss and complications similar to those of longer implants. Further studies are needed, involving longer periods of follow-up, in order to confirm these conclusions.

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Conflict of Interest

The authors of this paper have no conflict of interest to report regarding this publication.