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

José-Luis Sierra-Sánchez, Fernando García-Sala-Bonmati, Amparo Martínez-González, Carlos García-Dalmau, José-Félix Mañes-Ferrer, Alejandro Brotons-Oliver

Associate Professor of the Master in Advanced Oral Implantology, European University of Valencia, Valencia, Spain

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 Slotté 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 splitting 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**
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.

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.

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                                                                       |
| Bindi 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 Type     | 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 x 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 PRGF  |
| Mangano 2014  | Rough And Machined       | 4.1 and 5.0 mm x 7.0 and 8.5 mm long | Internal and external | 2 phases   | Maxilla and mandible | Fixed bridges 2 and 3 units               | Not specified | 2 phases PRGF  |
| Peñarrocha 2014 | Rough                  | 4.2 and 5.5 mm x / 7 mm long | Internal            | 2 phases   | Posterior mandible | Fixed prosthesis and bridges              | Not specified | 2 phases PRGF  |
| 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 PRGF   |
| Tascheri 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                    | 4.1 mm and 4.8 mm x / 6 mm long | Internal            | 1 phase    | Maxilla and posterior mandible | Fixed screwed bridges                      | Not specified | 1 phase PRGF   |
| Kennedy 2013  | Rough And Machined       | 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 phase |
| 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 PRGF   |
| 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       | 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 PRGF   |
| 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 PRGF |
| Pieri 2012    | Rough                    | 4.0 mm x / 6 mm long     | Internal            | 2 phases   | Maxilla            | Fixed bridges 2 and 3 units               | III          | 2 phases PRGF   |
| Sanchez-Garcia 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 | 2 phases PRGF |
Table 2 continue. Variables associated to treatment characteristics.

| Year   | Technique | Diameter | Length | Site | Loading | Type of Restoration | Levels | Additional Procedures |
|--------|-----------|----------|--------|------|---------|---------------------|--------|-----------------------|
| Skotte 2012 | Rough | 4.1 mm x / 4.0 mm long | Internal | 1 and 2 phases | Posterior mandible | Fixed bridges | Not specified | Not specified |
| Van Asche 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/III/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 | III/III | Not specified |
| Fugazzotto 2008 | Rough | 4.1 mm x / 60, 70, 80 and 90 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 phase |
| 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 8.5 mm long | External | 1 phase | Posterior maxilla | Cemented single crowns and screws multiple prostheses | III/III/IV | Specific soft bone drilling |
| Rokni 2005 | Rough | 3.5, 4.1 and 5.0 mm x / 5.0, 70 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 |
| Manganu 2014     | 98.3 % Maxilla 98.9 % Mandible | 0.31±0.24 Mm, 0.4±0.129 Mm And 0.62±0.31 1.5, 10 Years | Porcelain Fracture / Additament Loosening And 3 Implant Failures |
| Mendoça 2014     | 97.1 %        | 1.0 Mm Mesial 0.9 Mm Distal | 1 Peri-Implantitis               |
| Peñarrocha 2014  | 91.6 %        | 1.01 ± 0.68 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 Mn Con Platform Switching | Not Specified |
| Gulje 2013       | 97%           | 0.24 Mm ± 0.21 6 Months 0.2 Mn ± 0.22 12 Months | Prosthesis Screw Loosening / Fracture Of Prosthetic 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   | 97.2 %        | 1.37 ± 0.5 Mn | 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 Mn (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 %        | 0.1 ± 0.9 Mm 1 Year | 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 Porcelain Fracture |
| Sanchez-Garces 2012 | 92.5 %     | Not Published | 4 Cases Of Implant Mobility And 2 Implant Failures                        |
| Slotte 2012      | 92.3 %        | 0.49 Mm | 7 Implant Failures                                                        |
| Van Assche 2012  | 97.6 %        | 0.7 Mm | 1 Implant Failure / 2 Loosening                                           |
| Pieri 2011       | 96.5 %        | 0.51 ± 0.38 Mn | 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    | 94.6%         | 0.44 ± 0.52 Mm 2 Years | 5 Implant Failures (4 Were Machined)                                       |
| Rokai 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), muco-
itis and peri-implantitis (51 implants in 8 studies), mo-
bility of the implant (4 implants in 1 study), perfora-
tion 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, in-
cluding cement loss, loosening, or fracture of the pro-
thesis 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 dura-
tion 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 maxi-
lae. Due to the great variety of the implants analyzed,
it is difficult to establish a relationship between the di-
different implant surface characteristics, diameters and
lengths and the implant survival.
We found most of the reviewed studies to publish survi-
val rates over 95%. These are high percentages, as seen
for example in the studies published by Anitu et al.
(22), Lops et al. (23) and Romeo et al. (9). All three stud-
ies 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 mandi-
bles, Al-Nawas et al. (25), in their systematic review, pu-
blished 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 morbi-
dity 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 im-
plants and narrow-diameter implants, where the bone-
implant contact surface area is reduced, it is essential
for the surface treatment to provide a correct osseo-
integration. 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, toge-
ther with implant loss, was the most common biological
complication.
In the three-dimensional study of finite elements pu-
lished 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 Anitu 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 systemat-
ic 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 mentio-
ned study, 297 implants were placed in the upper maxi-
lla. 13 of this 297 implants were seen to fail. In the man-
dible 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 maxi-
lla 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 obta-
ined, such loss does not seem to be influenced by implant
length. This is consistent with the findings of the syste-
matic review published by Monje et al. (30).
These authors found no statistically significant diffe-
rences 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, men-
tion can be made of the study published by Mendonca
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

v
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.

References

1. Araújo MG, Lindhe J. Ridge alterations following tooth extraction with and without flap elevation: an experimental study in the dog. Clin Oral Implants Res. 2009;20:545-9.
2. das Neves FD, Fones D, Bernardes SB, do Prado CJ, Neto AJ. Short implants-an analysis of longitudinal studies. Int J Oral Maxillofac Implants. 2006;21:86-93.
3. Slotte C, Grønningsaeter A. Four-Millimeter Implants Supporting Fixed Partial Dental Prosthesis in the Severely Resorbed Posterior Mandible: Two-Year Results. Implant Dent. 2012;14 Suppl 1:46-58.
4. Anitua E, Alkhrash MIH, Piñas L, Begolha L, Orive G. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. Int J Oral Maxillofac Implants. 2014;29:682-9.
5. Renouard F, Nisand D. Short implants in the severely resorbed maxilla: a 2-year retrospective clinical study. Clin Implant Dent Related Res. 2005;7 Suppl 1:S104-10.
6. Taschieri S, Corbella S, Del Fabbro M. Mini-invasive osteotomie sinus floor elevation in partially edentulous atrophic maxilla using reduced length dental implants: interim results of a prospective study. Clin Implant Dent Relat Res. 2014;16:185-93.
7. Blanes RJ. To what extent does the crown-implant ratio affect the survival and complications of implant-supported reconstructions? A systematic review. Clin Oral Implants Res. 2009;20 Suppl 4:67-72.
8. Bahat O. Bränemark System Implants in the Posterior Maxilla: Clinical Study of 660 Implants Followed for 5 to 12 Years. Int J Oral Maxillofac Implants. 2000;15:646-53.
9. Romeo E, Ghisolfi M, Rozza R, Chiapasco M, Lops D. Short (8-mm) dental implants in the rehabilitation of partial and complete edentulous: a 3- to 14-year longitudinal study. Int J Prosthodont. 2006;19:586-92.
10. Mendonça JA, Francischone CE, Senna PM, Matos de Oliveira AE, Sotto-Maior BS. A retrospective evaluation of the survival rates of splinted and non-splinted short dental implants in posterior partially edentulous jaws. J Periodontol. 2014;85:787-94.
11. Sánchez-Garcés M. Short implants: a descriptive study of 273 implants. J Periodontol. 2012;83:508-16.
12. Degidi M, Piattelli A, Zeggi G, Carinci F. Immediately loaded short implants: analysis of a case series of 133 implants. Quintessence Int. 2007;38:193-201.
13. Anitua E, Piñas L, Begolha L, Orive G. Long-term retrospective evaluation of short implants in the posterior areas: clinical results after 10-12 years. J Clin Periodontol. 2014;41:404-11.
14. Rossi F, Lang NP, Ricci E, Ferriarioli L, Marchetti C, Botticelli D. Early loading of 6-mm-short implants with a moderately rough surface supporting single crowns—a prospective 5-year cohort study. Clin Oral Implants Res. 2015;26:471-7.
15. Anitua E, Orive G, Aguirre JJ, Andia I. Five-year clinical evaluation of short dental implants placed in posterior areas: a retrospective study. J Periodontol. 2008;79:42-8.
16. Pieri F, Aldini NN, Fini M, Marchetti C, Corinaldesi G. Preliminary 2-year report on treatment outcomes for 6-mm-long implants in posterior atrophic mandibles. Int J Prosthodont. 2012;25:279-89.
17. Mertens C, Meyer-Bäumer A, Kappel H, Hoffmann J, Steveling HG. Use of 8-mm and 9-mm implants in atrophic alveolar ridges: 10-year results. Int J Oral Maxillofac Implants. 2012;27:1501-8.
18. Birdi H, Schulte J, Kovacs A, Weed M, Chuang SK. Crown-to-implant ratios of short-length implants. J Oral Implantol. 2010;36:425-33.
19. Rojni S, Todescan R. An assessment of crown-to-root ratios with short sintered porous-surface implants supporting prostheses in partially edentulous patients. Int J Oral Maxillofac Implants. 2005;20:69-76.
20. Ouljé F, Abrahamsson I. Implants of 6 mm vs. 11 mm lengths in the posterior maxilla and mandible: a 1-year multicenter randomized controlled trial. Clin Oral Implant Res. 2013;24:1325-31.
21. Monje A, Chan HL, Fu JH, Saarez F, Galindo-Moreno P, Wang HL. Are short dental implants (<10 mm) effective? A meta-analysis on prospective clinical trials. J Periodontol. 2013;84:895-904.
22. Anitua E, Alkhrash MIH, Piñas L, Begolha L, Orive G. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. Int J Oral Maxillofac Implants. 2014;29:682-9.
23. Lops D, Bressan E, Pisoni G, Cea N, Corazza B, Romeo E. Short implants in partially edentulous maxillae and mandibles: a 10 to 20 years retrospective evaluation. Int J Dent. 2012;2012:351793.
24. Del Fabbro M, Wallace SS, Testori T. Long-term implant survival in the grafted maxillary sinus: a systematic review. Int J Periodontics Restorative Dent. 2013;33:773-83.
25. Al-Nawas B, Schiegzeitig E. Augmentation procedures using bone substitute materials or autogenous bone - a systematic review and meta-analysis. Eur J Oral Implantol. 2014;7 Suppl 2:S219-34.
26. Heitz-Mayfield LJA, Mombelli A. The therapy of peri-implantitis: a systematic review. Int J Oral Maxillofac Implants. 2014;29 Suppl 2:325-45.
27. Petrie CS, Williams JL. Comparative evaluation of implant designs: influence of diameter, length, and taper on strains in the alveolar crest. A three-dimensional finite-element analysis. Clin Oral Implants Res. 2005;16:486-94.
28. Anitua E, Tapia R, Luzuriaga F, Orive G. Influence of implant length, diameter, and geometry on stress distribution: a finite element analysis. Int J Periodontics Restorative Dent. 2010;30:89-95.
29. Srinivasan M, Vazquez L. Survival rates of short (6 mm) micro-rough surface implants: a review of literature and meta-analysis. Clin Oral Implantol Res. 2014;25:539-45.
30. Monje A, Suarez F, Galindo-Moreno P, García-Nogales A, Fu HI, Wang HL. A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses. Clin Oral Implants Res. 2014;25:1119-24.
31. Misch C, Steigenga J. Short dental implants in posterior partial edentulism: a multicenter retrospective 6-year case series study. J Periodontol. 2006;77:1340-7.
32. [No authors listed]. Retraction. Rehabilitation of the atrophic posterior maxilla using short implants or sinus augmentation with simultaneous standard-length implant placement: a 3-year randomized clinical trial. Clin Implant Dent Relat Res. 2012;14:924.

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