Meta-analysis of single crowns supported by short (<10 mm) implants in the posterior region


Abstract

Aim: To assess the failures and complications of short (<10 mm) implants supporting single crowns in the posterior region and its potential risk factors (RkF).

Materials and Methods: Prospective studies were screened according to eligibility criteria, followed by contact with authors. Quality assessment was performed using a standardized protocol. Mean implant failure proportion (FP), biological and prosthetic failure proportions (BFP/PFP) and marginal bone loss (MBL) including 95% confidence intervals were estimated using random-effects models for meta-analysis.

Results: Sixteen studies with a medium methodological quality (mean score: 8 ± 3; 2–14) had data collected. In summary, 762 short implants were followed up for up to 120 months in 360 patients (mean follow-up: 44 ± 33.72 months; mean dropout rate: 5.1%). The means FP, BFP, PFP and MBL were 5.9% (95% CI: 3.7–9.2%), 3.8% (95%CI: 1.9–7.4%), 2.8% (95%CI: 1.4–5.7%) and 0.83 mm (95%CI: 0.54–1.12 mm) respectively. Quantitative analysis showed that placement in the mandible (p = 0.0002) and implants with length ≤8 mm (p = 0.01) increased FP, BFP and MBL, whereas qualitative assessment revealed that crown-to-implant ratio did not influence MBL.

Conclusions: Single crowns supported by short implants in the posterior region are a predictable treatment option with reduced failure rates, biological/prosthetic complications and minimal bone loss.

Conflict of interest and source of funding statement

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The oral rehabilitation of short-span edentulous areas or single missing teeth with endosseous implants can provide optimal aesthetic and functional results, with good predictability (Jemt et al. 1991). However, limitations for implant placement in the posterior region of the jaws often occur when the alveolar ridge is resorbed due to periodontal disease and/or long-term edentulism. Moreover, anatomical structures such as the inferior alveolar nerve and the maxillary sinus may be damaged when implants with conventional lengths are used (Renouard & Nisand 2005).

Several surgical techniques have been proposed to overcome these situations and allow the placement of implant with conventional length, with varied success rates: sinus floor elevation (Summers 1994), vertical ridge augmentation (Felice et al. 2009), distraction osteogenesis (Chiapasco et al. 2004), inferior alveolar
nerve lateralization (Garg & Morales 1998) and placement of tilted (Krekeinanov et al. 2000) or zygo-
matic (Bedrossian et al. 2006) implants. Systematic reviews (Kot-
sovilis et al. 2009, Annibali et al. 2012) and randomized clinical trials (Felice et al. 2009, Esposito et al. 2011a) stated that these complex sur-
grafting even for single-tooth replace-
tive studies (Renouard & Nisand 2006, Neldam & Pin-
and case series where the test group
implants in augmented area (either
10 mm) implants supporting single
crowns in non-augmented, healed
jaw-bone, and the control group
considered as an alternative treatment
failure rates than implants of conven-
tional length. For this reason, short
implants were initially suggested to
be used splinted to longer ones (ten
Bruggenkaet al. 1998). In the last
decade, modified implant designs and
microstructured implant surfaces that
increase treatment duration, morbid-
ity, risk of complications and costs.
Therefore, implants of reduced
length (<10 mm) were suggested as a
more accessible treatment option to
both patients and clinicians, with
successful results and low incidence
of biological and biomechanical com-
plifications (Morand & Irinakis 2007).

Early clinical evidences from re-
rospective (Friberg et al. 1991) and
prospective (van Steenbergh et al.
1990) studies stated that machined
surface short implants had higher
failure rates than implants of conven-
tional length. For this reason, short
implants were initially suggested to
be used splinted to longer ones (ten
Bruggenkaet al. 1998). In the last
decade, modified implant designs and
microstructured implant surfaces that
increase the surface area have been
introduced. The surface treatment is
responsible for a faster new bone for-
mation and for the increase of the
contact area between bone and
implant, similar to the anchorage of
longer implants with smooth
machined surfaces (Hagi et al. 2004,
Renouard & Nisand 2006). Hence,
short implants with modified surfaces
have been recommended for regions
of poor bone quality and stronger
forces, such as the posterior region
of the maxilla and/or mandible,
reducing morbidity and costs of bone
grafting even for single-tooth replace-
ments (Fugazzotto 2008c; Monje
et al. 2013).

There has been an increasing num-
ner of systematic (Hagi et al. 2004,
das Neves et al. 2006, Renouard &
Nisand 2006, Kotsosviles et al. 2009,
Esposito et al. 2010, Neldam & Pin-
holt 2012, Menchero-Cantalejo et
al. 2011, Pommer et al. 2011, Sun et
al. 2011, Tellemann et al. 2011, Annibali
et al. 2012, Monje et al. 2013) and
narrative (Lum 1991, Lee et al. 2005,
Misch 2005, Morand & Irinakis 2007,
Romeo et al. 2010) reviews on short
implants being published in Medline-
indexed journals. These studies
claimed that short implants should be
considered as an alternative treatment
to advanced bone augmentation sur-
geries, showing similar survival rates
to longer implants (das Neves et al.
2006, Esposito et al. 2010, Pommer
Rev-
nevertheless, most of these reviews clus-
tered the outcomes of short implants
supporting different types of recon-
structions, from single crowns to fixed
partial dentures and overdentures.
Also, they usually focused at assess-
ing survival rates of the short implants
(Kotsosviles et al. 2009), based pre-
dominantly on heterogeneous data
from both retrospective and prospec-
tive studies (Renouard & Nisand
2006, Neldam & Pinhall 2012, Ann-
bali et al. 2012).

In despite of the evolution of the
macro- and microtopography (sur-
face) of the implants and the increas-
ing success rates of short implants,
there is still a lack of comprehensive
systematic reviews evaluating the
risk factors (RkF) on the prognosis
of the rehabilitation of the posterior
region with single crowns supported
by short implants. Thus, the aim of
this study was to answer the focused
question “In partially edentulous
patients presenting severe resorption
of the posterior region of the jaws,
what is the effect of restoring short
(<10 mm) implants with single
crowns compared with single crowns
supported by implants of conventional
length associated with bone grafts on
the failure rates of these implants and
prostheses and what are the RkF for
failure and/or complications?”, by
conducting a systematic review and a
meta-analysis of prospective studies
published in the dental literature up
to October 2012.

Materials and Methods

Design

The methodological procedures of
this review were based on the guide-
lines proposed by the Cochrane Col-
laboration (Higgins & Green 2001)
and Needleman (2002).

Eligibility criteria and study selection

Inclusion criteria

Randomized controlled clinical trials
(RCTs), controlled clinical trials
(CCTs), prospective cohort studies
and case reports; (2) retrospective and
prospective studies; (3) pre-clinical and
in vitro studies; (4) case reports and
series with less than 10 single
crowns supported by short implants
per group; (6) length of the implants
<10 mm or unclear; (7) location
where short implants were placed
were not the posterior region or
remained unclear; (8) studies with an
insufficient follow-up period; (9) stud-
ies evaluating splinted fixed partial or
complete dentures supported by short
implants; (10) studies placing short
implants in augmented area (either
simultaneously or previously); (11)
same population of a previous study
when multiple publications on the
same population and implants were
identified, only data from the most
recent report was used; (12) declina-
tion of the main author to provide
further information; and (13) contact
with author failed.

Search strategy and data collection

Key words were selected from MeSH
terms and descriptors from previous
studies to perform the specific
search strategies for each database
(Table 1). Electronic search was
performed by two independent and
calibrated reviewers in a duplicated

manner, at the following electronic databases: PubMed-Medline, Web of Science, Cochrane Library, Proquest-Dissertations and Thesis, Lilacs, Ebsco-Dentistry and Oral Sciences Source, Scirus, Embase, Scopus and Journal Ovid. No restriction to the year of publication was applied. Search was concluded in June 2012. The results were exported to the software EndNote Web® (Thomson Reuters, New York, NY, USA), where both title and abstract screenings, restricted to the English language, were performed.


Full-text screening was performed by two reviewers with no language restrictions. Professional translation was provided when necessary. In case of disagreement, the reviewers discussed the issue to reach a consensus; if the divergence persisted, a third reviewer was consulted. Finally, the reviewers independently used a standardized data-extraction form to clarify eligibility and collect the data about the overall characteristics of each included study and, finally, to assess the statistical analysis applied.

Outcome measures

- **Implant failure proportion (FP):** The primary outcome variable was the percentage of implants failing out of the total number placed, after the first year of prosthetic loading, and was quantified as the FP. Failure was defined as removal of the implant due to loss of osseointegration or progressive marginal bone loss (Albrektsson et al. 1986).
- **Biological failure proportion (BFP):** This refers to the presence of an implant with complications of a biological nature (i.e. persistent pain, neuropathy and/or loss of function, persistent uncontrolled peri-implant inflammation and/or infection, implant mobility) (Albrektsson et al. 1986, Academy of Osseointegration 2010). BFP was defined as the absolute number of implants presenting one (or more) of the above-mentioned complications divided by the number of surviving/prosthetically restored implants. It includes late failures (Annibali et al. 2012).
- **Radiographic marginal bone loss (MBL):** This was studied as a measure to evaluate the mean bone loss (Annibali et al. 2012) among the surviving/prosthetically restored implants.
- **Prosthetic failure proportion (PFP):** Defined as the presence of an implant with complications of a prosthetic nature (i.e. fractured veneering materials, fractured or loosened prosthetic components) (Academy of Osseointegration 2010). PFP was defined as the absolute number of implants presenting one (or more) of the above-mentioned complica-

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**Table 1. Key words and MeSH terms used for electronic search**

<table>
<thead>
<tr>
<th>Population</th>
<th>Intervention/comparison</th>
<th>Outcome</th>
<th>Type of non-included studies</th>
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<tr>
<td>Tooth extraction, partially edentulous jaw, alveolar bone atrophy, bone resorption, bruxism, bite force</td>
<td>Dental implants, implant-supported dental prosthesis, single-tooth dental implant, bone substitutes, bone grafting</td>
<td>Dental prosthesis failure, survival rate, complications, patient satisfaction, quality of life</td>
<td>In vitro, animals, review, case reports, retrospective</td>
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<td>Key words</td>
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<tr>
<td>Posterior atrophic mandible</td>
<td>Short implant¹, bone augment¹</td>
<td>Success rate, dental implant fail¹, radiographic bone loss, radiographic bone density loss, primary stability, crown-to-implant ratio</td>
<td>Pre-clinical</td>
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</table>

*According to the PICO scheme (P, population or problem of interest; I, intervention under investigation; C, comparison of interest; O, outcomes considered most important in assessing results) (Needleman 2002).

¹means truncation, that is to say, whatever is the suffix after it, the word keeps the main radical.
Quality assessment

The levels of evidence of the included studies were assessed according to the methodology applied, confounding factors, ethical aspects, funding, conflict of interest, unit of analysis for statistics (patient or implant) and external validity. At the end, an estimated risk of bias (low, medium or high) was assigned to each of the included studies by the reviewers using the forms “Quality Assessment of a RCT” and “Quality Assessment of a Cohort Study”, with some adaptations (Table 2). These validity tools consist originally of nine and eight items, respectively, which have to be scored with a plus “+”, a minus “−”, or a question mark “?” (Tellemann et al. 2011). For the present review, nine additional items have been added to the forms. Thus, studies scoring 0–7, 8–13 and 14–18 plusses (in proportion to the original) were considered of high, medium and low risk of bias respectively. One reviewer performed the quality assessment and generated the scores for the included articles. No blinding for author, institute or journal was applied.

Quantitative data analysis

Percentage of agreement among reviewers was expressed as Cohen’s unweighted $\kappa$. Data were presented at the implant level. Dropouts/losses to follow-up were excluded from the analysis and thus the total number of implants was represented by those that completed at least one year of follow-up.

All statistical analyses and assessment of heterogeneity among studies were carried out using a commercially available software (Comprehensive Meta-Analysis®; CMA, Biostat, Englewood, NJ, USA). The outcomes FP, BFP, PFP and MBL were meta-analysed according to the random-effects models (a considerable heterogeneity among studies was anticipated). Considering that the outcomes evaluated as proportions (FP, BFP, PFP) had values very close to zero, a transformation of the data had to be carried out for appropriate calculations. The CMA software automatically converts proportions into the logit scale for the meta-analyses calculations, and eventually transforms the values back to the original proportion scale in the final results presentation.

Risk factors were considered co-variates and their influence on the main outcomes were evaluated. Continuous co-variates, such as patient’s age and gender, implant location, length and diameter, surgical approach, type of prosthetic retention and follow-up period had their proportions converted into percentages [from 0.0% (0.000) up to 100% (1.000)] and thus meta-regression analysis were run as fixed-effect models. The further co-variates, such as timing of prosthetic loading, type of implant-abutment connection, surface topography, presence of bruxism as well as periodontal disease, smoking and systemic diseases status, were dichotomized into “presence/absence,” or “1/0,” respectively, and thus subgroup analyses were run as mixed effect models. The level of significance was set at 5% ($p < 0.05$).

Results

Search yielding and screening process

Electronic search yielded 4514, 535 and 56 references for title, abstract and full-text screening respectively. Hand-search yielded additional 44 studies – 15 from the journals, 5 from the author themselves and the other 24 from the reference lists of articles and reviews. In summary, 100 articles were eligible for full-text screening. Disagreements were usually caused by slight differences in interpretation and were easily resolved in a consensus discussion. Percentage of agreement expressed as Cohen’s unweighted $\kappa$ achieved scores of $\kappa = 0.76$ and 0.97 for abstract and full-text screening, respectively, among the reviewers (Fig. 1) (Jekel et al. 2005).

Results of contact with authors

Due to limited information provided in some original articles (for instance, some studies did not detail individual failure scores for the different implant lengths), 31 authors were contacted and additional information was sought through electronic mail for 39 articles. Reminders were sent to the authors on a weekly basis up to a point that either the requested data could be obtained or the contact was considered as failed. At the end, the authors of 12 articles (30.7%) kindly provided the requested answers.

Quality assessment of the studies

Table 2 summarizes the quality assessment results. The scores of the included studies (mean: 8 ± 3; range: 2–14) indicated a medium methodological quality and a high methodological unconformity. Factors that most increased the risk-of-bias were the lack of a standardization of the treatment that patients underwent and a lack of a report of the sample size calculation. Ethical aspects were not entirely reminded as long as Helsinki Declaration was reported at only two studies. On the other hand, informed consent form was obtained for the majority of the studies, whereas ethical committee approval was sought for six studies. Furthermore, reasons for dropouts were disclosed at only nine studies. Once any RCT addressing the strict eligibility criteria of the present review was found, the form “Quality Assessment of a RCT” was not used.

Study characteristics

The overall characteristics of the included studies are described in Table 3. Twenty-one articles were included, accounting for 16 prospective parallel-designed studies – 10 cohorts and six case series. Due to the strict inclusion criteria, this systematic review failed to identify
Table 2. Quality assessment of the included studies (n = 16)

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<th>Score (total +)</th>
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<td>1. Has a sample size calculation and power been reported?§</td>
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<td>2. Has baseline homogeneity been achieved?§</td>
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<td>3. Has eligibility criteria been clearly described?‡</td>
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<td>4. Has a high risk of bias on patient’s selection been excluded?‡</td>
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<td>9. Is blinding used to assess the outcome? If not, does this have no effect on the evaluation of the results?‡</td>
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<td>10. Is calibration used to assess the outcome? If not, does this have no effect on the evaluation of the results?‡</td>
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<td>13. Can dropouts be excluded sufficiently?§</td>
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<td>14. Has the original protocol not been violated?§</td>
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<td>15. Has the STROBE statement been mentioned and followed?§</td>
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<td>16. Have the ethical considerations (Helsinki Declaration, Informed Consent and Ethics Committee approval) been considered?§</td>
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<td>17. Are the most important confounders or prognostic factors identified?§</td>
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<td>18. The authors have declared no conflict of interests?§</td>
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<th>Risk of bias*</th>
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<th>Medium</th>
<th>High</th>
<th>High</th>
<th>High</th>
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</tr>
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<tbody>
<tr>
<td>4 10 4 9 7 9 11 2 8 11 8 11 6 6 6 14</td>
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</tr>
</tbody>
</table>

*Studies scoring 0–7, 8–13 and 14–18 pluses were considered as of high, medium and low risk of bias respectively.
†Adapted from Telleman et al. (2011).
‡Original items.
§Items added by the authors of the present review.
any controlled clinical trial, either randomized or not, that is, using implants of conventional length in sites with or without bone augmentation as a control. Therefore, within-study comparison of short and long implants was not possible. Likewise, odds ratio and relative risk could not be calculated through meta-analysis. Seventy-nine studies did not meet the inclusion criteria, either before or after contact with authors, and were excluded from this analysis (supplementary material).

The studies #2 (Cannizzaro et al. 2012) and #9 (Nicolau et al. 2013), as well as the study #16 (Telleman et al. 2012), which were originally designed as randomized controlled trials evaluating different loading protocols and different implant-abutment platforms of short implants, respectively, had the results of groups test and control clustered into only one group and so were reclassified as cohort studies according to the criteria of the present review. Likewise, studies #1 (Brocard et al. 2000), #4 (Deporter et al. 2001a), #11 (Romeo et al. 2002), #13 (Stanford et al. 2010) and #14 (Strietzel & Reichert 2007), which were originally classified as prospective cohort studies and where short implants supporting single crowns in the posterior region represented a portion of the whole sample size, were reclassified as case series (Table 3).

The article from Deporter et al. (2001a) concerned the same population and implants of the papers from Deporter et al. (1999, 2000, 2002) and Rokni et al. (2005), whereas the article from Tawil et al. (2006) concerned the same patients and implants as the paper from Tawil & Younan (2003). Thus, data from these reports were used to supplement each other but accounted for as studies #4 (Deporter) and #15 (Tawil), respectively, in the meta-analysis. The paper of Rokni et al. (2005) comprised the population and implants from two studies – Deporter et al. 2001a, 2012, in the maxilla and the mandible respectively. Thus, their results were separated for both studies.

Population characteristics
The sample size and age (mean; range) of the population of the included studies are listed in Table 3. In some reports, especially in large cohort studies where implants of different lengths were used, it was almost impossible to distinguish the sample of patients who have received implants with length <10 mm. Thus, the actual population of patients receiving short implants was surely larger than the 360 patients reported among the ten studies that dealt exclusively with short implants. Meta-regression analysis revealed significant effects for the variable age on both outcomes BFP and MBL (p = 0.0142 and 0.00000117 respectively), as well as for the variable gender (percentage of females) on the MBL (p = 0.000) (Table 4).

Implant characteristics
The characteristics of the implants (location, length, diameter and surface) of the included studies are summarized in Table 3.

Implant location
The means FP, BFP and MBL for implants placed in the mandible revealed by fixed effect meta-regression were significantly higher than that for implants in the maxilla (p = 0.0002, 0.00375 and 0.00000117 respectively) (Table 4). Due to the small number of studies reporting if short implants were placed either in the premolar or in the molar area (n = 6), statistical analysis over the site of placement could not be performed. Except for study #15 (Tawil), which did not find significant differences in terms of failures and complications between implants placed in molar as compared to premolar positions, the other original studies did not report relevant information.

Implant length
The distribution of the implants with regards to the length was as follows: 8 × 5 mm (8/803, 0.99%), 57 × 6 mm (57/803, 7.09%), 53 × 6.5 mm (53/803, 6.60%), 247 × 7 mm (247/803, 30.76%), 154 × 8 mm (83/803, 19.18%), 201 × 8.5 mm (201/803, 25.03%) and 83 × 9 mm implants (83/803, 10.33%). Dropouts and losses to follow-up (n = 41) were considered neither as failed nor as successful implants. Therefore, 762 implants were available for meta-analysis. All but one study (#11) stated that short implant length obtained similar if not superior survival rates with minimal bone loss than those reported for other implant lengths.
### Table 3. Characteristics of the population, interventions and outcomes of the studies (n = 16).

<table>
<thead>
<tr>
<th>Study Reference</th>
<th>First Author</th>
<th>Year of publication (Publication)</th>
<th>Type</th>
<th>Design</th>
<th>Study Population</th>
<th>Implant characteristics</th>
<th>Implant length (n)</th>
<th>Implant diameter (n)</th>
<th>Surgical parameters (n)</th>
<th>Prosthetic parameters (n)</th>
<th>Follow-up in months</th>
<th>Risk factors included/assessed (yes/no)</th>
<th>Outcomes (n)</th>
<th>Proportions Mean (CI: lower-upper limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Brocard (2000)</td>
<td>2000 (184; 256)</td>
<td>Parallel</td>
<td>16-90 years</td>
<td>Maxilla</td>
<td>1.0 mm ≤ x ≤ 3.5 mm</td>
<td>1. Narrow</td>
<td>1. Timing of implant placement (conventional)</td>
<td>1. Loading protocol (implantation)</td>
<td>1. Mean</td>
<td>1. Systemic disease</td>
<td>1. Failure</td>
<td>1.05 (0.001-0.201)</td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td>Cannizzaro 2012</td>
<td>2012 (15; 15)</td>
<td>Cohort</td>
<td>4. 18-57 years</td>
<td>Maxilla</td>
<td>1.0 mm ≤ x ≤ 3.5 mm</td>
<td>1. Narrow</td>
<td>1. Timing of implant placement (conventional)</td>
<td>1. Loading protocol (implantation)</td>
<td>1. Mean</td>
<td>1. Systemic disease</td>
<td>1. Failure</td>
<td>1.05 (0.001-0.201)</td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td>Corrino (2009)</td>
<td>2009 (22;26)</td>
<td>Parallel</td>
<td>4. N/R</td>
<td>Maxilla</td>
<td>1.0 mm ≤ x ≤ 3.5 mm</td>
<td>1. Narrow</td>
<td>1. Timing of implant placement (conventional)</td>
<td>1. Loading protocol (implantation)</td>
<td>1. Mean</td>
<td>1. Systemic disease</td>
<td>1. Failure</td>
<td>1.05 (0.001-0.201)</td>
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<tr>
<td>#4</td>
<td>Deporter 2001a</td>
<td>2001 (25; 25)</td>
<td>Case series</td>
<td>3. N/R</td>
<td>Maxilla</td>
<td>1.0 mm ≤ x ≤ 3.5 mm</td>
<td>1. Narrow</td>
<td>1. Timing of implant placement (conventional)</td>
<td>1. Loading protocol (implantation)</td>
<td>1. Mean</td>
<td>1. Systemic disease</td>
<td>1. Failure</td>
<td>1.05 (0.001-0.201)</td>
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</table>
Table 3. (continued)

<table>
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<tr>
<th>Study</th>
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<th>Prosthetic parameters (n)</th>
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<th>Proportions Mean (CI: lower-upper limits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5</td>
<td>1. n = 24 (8; 16)</td>
<td>1. n = 0</td>
<td>1. Endopore®x</td>
<td>1. n = 0</td>
<td>1. N/R</td>
<td>1. Late (35)</td>
<td>1. Conventional (53)</td>
<td>1. N/R</td>
<td>1. No</td>
<td>1. n = 7</td>
<td>1.0 (0.018 - 0.245)</td>
</tr>
<tr>
<td>Deporter 2012</td>
<td>2. N = 24</td>
<td>1. n = 35</td>
<td>2. Porous</td>
<td>2. n = 32</td>
<td>2. N/R</td>
<td>2. Yes (35)</td>
<td>2. Porcelain-fused to metal (53)</td>
<td>1. 12–120</td>
<td>1. No</td>
<td>2. n = 2; n = 0</td>
<td>2. N/R (0.001-0.236)</td>
</tr>
<tr>
<td>Parallel</td>
<td>3. n = 49.6 years</td>
<td>4. N/R</td>
<td>4. 1.21 mm</td>
<td>4. 0.040</td>
<td>4. N/R</td>
<td>4. 2-stages (29)</td>
<td>4. External (29)</td>
<td>4. 24–48</td>
<td>4. Yes</td>
<td>4. 0.6 mm</td>
<td>4. N/R (0.522-0.678)</td>
</tr>
<tr>
<td>#6</td>
<td>1. n = 46 (21; 25)</td>
<td>1. n = 6</td>
<td>2. Biocare®x</td>
<td>1. n = 0</td>
<td>2. N/R</td>
<td>1. Late (29)</td>
<td>1. Conventional (29)</td>
<td>2. 12-48</td>
<td>4. 0.60</td>
<td>4. 0.060</td>
<td>4. N/R (0.000-0.235)</td>
</tr>
<tr>
<td>De Santin 2011</td>
<td>2. n = 12</td>
<td>2. n = 23</td>
<td>2. TuUnit® (anodically oxidized surface)</td>
<td>2. n = 9</td>
<td>2. N/R</td>
<td>2. Yes (29)</td>
<td>2. Porcelain-fused to metal (29)</td>
<td>2. 12-48</td>
<td>2. Yes</td>
<td>2. 4; 4; n = 0</td>
<td>2. N/R (0.001-0.235)</td>
</tr>
<tr>
<td>Cohort</td>
<td>3. n = 11</td>
<td>3. n = 3</td>
<td>3. N/R</td>
<td>3. n = 12</td>
<td>3. N/R</td>
<td>3. Yes (74)</td>
<td>3. Porcelain-fused to metal (29)</td>
<td>2. 2-stages (29)</td>
<td>3. No</td>
<td>3. n = 1</td>
<td>3.0 (0.003-0.116)</td>
</tr>
<tr>
<td>Malo 2011</td>
<td>2. n = 74</td>
<td>2. n = 74</td>
<td>2. TuUnit® (anodically oxidized surface)</td>
<td>2. n = 0</td>
<td>2. N/R</td>
<td>2. Yes (74)</td>
<td>2. Porcelain-fused to metal (74)</td>
<td>2. N/R</td>
<td>2. N/R</td>
<td>2. n = 10; n = 0</td>
<td>2.0 (0.084-0.259)</td>
</tr>
<tr>
<td>Parallel</td>
<td>4. n = 23–78 years</td>
<td>4. 5.0 mm</td>
<td>4. 1.27 mm</td>
<td>4. 0.040</td>
<td>4. N/R</td>
<td>4. 2-stages (29)</td>
<td>4. External (74)</td>
<td>4. 24-48</td>
<td>5. N/R</td>
<td>5. n = 0</td>
<td>5.0 (0.017-0.125)</td>
</tr>
<tr>
<td>#8</td>
<td>1. n = 30 (10; 20)*</td>
<td>1. n = 0</td>
<td>1. ITI (Struamun®x)</td>
<td>1. n = 0</td>
<td>1. N/R</td>
<td>1. Late (36)</td>
<td>1. Conventional (36)</td>
<td>1. N/R</td>
<td>1. Yes</td>
<td>1. n = 1*</td>
<td>1.0 (0.000-0.125)</td>
</tr>
<tr>
<td>Nieder 2004</td>
<td>2. n = 30*</td>
<td>2. n = 19*</td>
<td>2. TP5® (titanium-plasma-spray) and SLA® (sand-blasted, large-grit, acid-etched)</td>
<td>2. n = 36</td>
<td>2. N/R</td>
<td>2. Porcelain-fused to metal (36)*</td>
<td>2. Porcelain-fused to metal (36)</td>
<td>2. N/R</td>
<td>2. Yes</td>
<td>2. n = 2; n = 0</td>
<td>2.0 (0.001-0.125)</td>
</tr>
<tr>
<td>Parallel</td>
<td>4. n = 32.8-73.3 years*</td>
<td>5. n = 36</td>
<td>4. Internal (36)</td>
<td>4. 1.21 mm</td>
<td>4. N/R</td>
<td>4. Internal (36)</td>
<td>4. Internal (36)</td>
<td>4. 0.040</td>
<td>4. N/R</td>
<td>4. N/R</td>
<td>4.0 (0.014-0.202)</td>
</tr>
<tr>
<td>#9</td>
<td>1. n = 17*</td>
<td>1. L = 27*</td>
<td>1. ITI (Struamun®x)</td>
<td>1. n = 0</td>
<td>1. N/R</td>
<td>1. Late (17)</td>
<td>1. Conventional (17)</td>
<td>1. N/R</td>
<td>1. Yes</td>
<td>1. n = 1</td>
<td>1.0 (0.000-0.125)</td>
</tr>
<tr>
<td>Popowicz 2008</td>
<td>2. n = 36*</td>
<td>2. n = 12*</td>
<td>2. TP5® (titanium-plasma-spray) and SLA® (sand-blasted, large-grit, acid-etched)</td>
<td>2. n = 36</td>
<td>2. N/R</td>
<td>2. Porcelain-fused to metal (36)*</td>
<td>2. Porcelain-fused to metal (36)</td>
<td>2. N/R</td>
<td>2. Yes</td>
<td>2. n = 2; n = 0</td>
<td>2.0 (0.001-0.125)</td>
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</table>
### Table 3. (continued)

<table>
<thead>
<tr>
<th>Study</th>
<th>Population characteristics</th>
<th>Implant location (n)</th>
<th>Implant characteristics</th>
<th>Implant length (n)</th>
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<th>Risk factors included/assessed (yes/no)</th>
<th>Outcomes (n)</th>
<th>Proportions Mean (CI:lower-upper limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#9</td>
<td>1. n = 266 (118-148)</td>
<td>1. Both (?)</td>
<td>1. ITI</td>
<td>1. n = 0</td>
<td>1. N/R</td>
<td>1. Late (38)</td>
<td>1. Conventional (38)</td>
<td>1. N/R</td>
<td>1. Yes</td>
<td>1. n = 2*</td>
<td>1. 0.064 (0.014-0.197)</td>
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<tr>
<td>#11</td>
<td>1. n = 309 (40, 69)</td>
<td>2. n = 7</td>
<td>2. ITI</td>
<td>2. n = 0</td>
<td>2. N/R</td>
<td>1. Late (14)</td>
<td>1. Conventional (14)</td>
<td>1. N/R</td>
<td>1. Yes</td>
<td>1. n = 0</td>
<td>1. 0.02 (0.002-0.036)</td>
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<tr>
<td>#12</td>
<td>1. n = 35 (13, 22)</td>
<td>2. n = 15</td>
<td>1. ITI</td>
<td>1. n = 0</td>
<td>1. N/R</td>
<td>1. Early (40)</td>
<td>1. Conventional (40)</td>
<td>1. N/R</td>
<td>1. Yes</td>
<td>1. n = 2</td>
<td>1. 0.053 (0.013-0.187)</td>
</tr>
<tr>
<td>Rossi 2010</td>
<td>Cohort (13, 22)</td>
<td>3. n = 25</td>
<td>2. Early (40)</td>
<td>2. n = 0</td>
<td>2. N/R</td>
<td>2. Porcelain-fused to metal (40)</td>
<td>2. N/R</td>
<td>2. Yes</td>
<td>3. No</td>
<td>4. No</td>
<td>5. N/R</td>
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### Table 3. (continued)

<table>
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<tr>
<th>Study</th>
<th>Reference</th>
<th>Population characteristics</th>
<th>Implant location (n)</th>
<th>Implant characteristics</th>
<th>Implant length (n)</th>
<th>Implant diameter (n)</th>
<th>Surgical parameters (n)</th>
<th>Prosthetic parameters (n)</th>
<th>Follow-up in months</th>
<th>Risk factors included/ assessed (yes/no)</th>
<th>Outcomes (n)</th>
<th>Proportions Mean (CI: lower-upper limit)</th>
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<tbody>
<tr>
<td>Stanford 2010</td>
<td>1. n = 142, 157; 307</td>
<td>1. n = 3; 2. n = 7</td>
<td>1. Maxilla</td>
<td>1. Company</td>
<td>1. ≤ 6 mm</td>
<td>1. Narrow (3.5–3.7 mm)</td>
<td>1. Timing of implant placement (immediate/early/late)</td>
<td>1. Loading protocol (immediate/early/conventional)</td>
<td>1. Mean</td>
<td>1. No</td>
<td>1. Drop-outs/losses to follow-up (yes/no)</td>
<td>1. Failure proportion (FP)</td>
</tr>
<tr>
<td>Case series</td>
<td>1. n = 142, 157; 307</td>
<td>1. n = 3; 2. n = 7</td>
<td>1. Mandible</td>
<td>1. Company</td>
<td>1. ≤ 6 mm</td>
<td>1. Narrow (3.5–3.7 mm)</td>
<td>1. Timing of implant placement (immediate/early/late)</td>
<td>1. Loading protocol (immediate/early/conventional)</td>
<td>1. Mean</td>
<td>1. No</td>
<td>1. Drop-outs/losses to follow-up (yes/no)</td>
<td>1. Failure proportion (FP)</td>
</tr>
<tr>
<td>Parallel</td>
<td>1. n = 142, 157; 307</td>
<td>1. n = 3; 2. n = 7</td>
<td>1. Premolars</td>
<td>1. Company</td>
<td>1. ≤ 6 mm</td>
<td>1. Narrow (3.5–3.7 mm)</td>
<td>1. Timing of implant placement (immediate/early/late)</td>
<td>1. Loading protocol (immediate/early/conventional)</td>
<td>1. Mean</td>
<td>1. No</td>
<td>1. Drop-outs/losses to follow-up (yes/no)</td>
<td>1. Failure proportion (FP)</td>
</tr>
<tr>
<td>Tawil et al. 2006</td>
<td>1. n = 142, 157; 307</td>
<td>1. n = 3; 2. n = 7</td>
<td>1. Pterygoids</td>
<td>1. Company</td>
<td>1. ≤ 6 mm</td>
<td>1. Narrow (3.5–3.7 mm)</td>
<td>1. Timing of implant placement (immediate/early/late)</td>
<td>1. Loading protocol (immediate/early/conventional)</td>
<td>1. Mean</td>
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<td>1. Company</td>
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<td>1. Mean</td>
<td>1. No</td>
<td>1. Drop-outs/losses to follow-up (yes/no)</td>
<td>1. Failure proportion (FP)</td>
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<td>1. Company</td>
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<td>1. Narrow (3.5–3.7 mm)</td>
<td>1. Timing of implant placement (immediate/early/late)</td>
<td>1. Loading protocol (immediate/early/conventional)</td>
<td>1. Mean</td>
<td>1. No</td>
<td>1. Drop-outs/losses to follow-up (yes/no)</td>
<td>1. Failure proportion (FP)</td>
</tr>
<tr>
<td>Overall</td>
<td>1. n = 142, 157; 307</td>
<td>1. n = 3; 2. n = 7</td>
<td>1. Maxilla</td>
<td>1. Company</td>
<td>1. ≤ 6 mm</td>
<td>1. Narrow (3.5–3.7 mm)</td>
<td>1. Timing of implant placement (immediate/early/late)</td>
<td>1. Loading protocol (immediate/early/conventional)</td>
<td>1. Mean</td>
<td>1. No</td>
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<th>Outcomes (n)</th>
<th>Proportions (CI: lower-upper limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. n</td>
<td>Maxilla</td>
<td>Company</td>
<td>1.6 mm ≤ x &lt; 3 mm</td>
<td>3.8 mm ≤ x &lt; 10 mm</td>
<td>1. Timing of implant placement (immediate/early/late)</td>
<td>1. Loading protocol (immediate/early/conventional)</td>
<td>1. Mean (± Range)</td>
<td>1. Systemic failure</td>
<td>1. Drop-out/loss to follow-up</td>
<td>1. Failure proportion (FP)</td>
</tr>
<tr>
<td>2. n</td>
<td>Maxillary</td>
<td>Surface</td>
<td>4.14%</td>
<td>21.4%</td>
<td>2. Failures (early/late)</td>
<td>2. Type of prosthesis (cemented- versus screw retained)</td>
<td>2. Mean (± Range)</td>
<td>2. Biological failure proportion (BFP)</td>
<td>2. Radiographic marginal bone loss (mean)</td>
<td>2. Prosthetic failure proportion (PPP)</td>
</tr>
<tr>
<td>5. n</td>
<td>Total</td>
<td></td>
<td>1. Immediate (48)</td>
<td>1. Immediate (90); Conventional (480)</td>
<td>5. Cetemented</td>
<td>5. Prosthetic connection (cemented versus internal)</td>
<td>5. Mean (± Range)</td>
<td>5. Prosthetic complications</td>
<td>5. Prosthetic failure proportion (PPP)</td>
<td></td>
</tr>
</tbody>
</table>

CI, confidence interval; N/R, not reported; N/A, not available.
*Information retrieved after contact with the corresponding author of the study.
†Value calculated for this review from the raw data of the original articles.
‡ITI/Straumann AG (Walhenburg, Switzerland).
§First Author (Year of publication).
¶Endopore® (Innova Corporation, Toronto, Canada).
##Astra Tech (Mönadal, Sweden).
###Nobel Biocare® (Göteborg, Sweden).
####Camlog® (Wimsheim, Germany).
Surgical parameters

Table 4. P-values from the statistical analysis (covariates × outcomes)

<table>
<thead>
<tr>
<th>Covariates</th>
<th>Failure proportion (FP)</th>
<th>Biological failure proportion (BFP)</th>
<th>Radiographic marginal bone loss (MBL)</th>
<th>Prosthetic failure proportion (PFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (mean)</td>
<td>0.193</td>
<td>0.0142*</td>
<td>&lt;0.001*</td>
<td>0.060</td>
</tr>
<tr>
<td>Gender (males versus females)</td>
<td>0.155</td>
<td>0.428</td>
<td>&lt;0.001*</td>
<td>0.198</td>
</tr>
<tr>
<td>Implant characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location (mandible versus maxilla)</td>
<td>&lt;0.001*</td>
<td>&lt;0.01*</td>
<td>&lt;0.001*</td>
<td>–</td>
</tr>
<tr>
<td>Implant length (6 mm)</td>
<td>0.445</td>
<td>0.956</td>
<td>0.423</td>
<td>0.426</td>
</tr>
<tr>
<td>Implant length (8 mm)</td>
<td>0.019*</td>
<td>&lt;0.01*</td>
<td>&lt;0.001*</td>
<td>0.275</td>
</tr>
<tr>
<td>Implant diameter (narrow/regular versus wide)</td>
<td>0.067</td>
<td>0.0847</td>
<td>&lt;0.001*</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Implant surface (rough versus machined)</td>
<td>0.050</td>
<td>0.135</td>
<td>0.424</td>
<td>0.000*</td>
</tr>
<tr>
<td>Surgical parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical Approach (one-stage versus two-stage)</td>
<td>0.784</td>
<td>0.068</td>
<td>&lt;0.001*</td>
<td>–</td>
</tr>
<tr>
<td>Prosthetic parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of retention (screw- versus cemented retained)</td>
<td>0.986</td>
<td>–</td>
<td>–</td>
<td>0.622</td>
</tr>
<tr>
<td>Timing of Loading (immediate/early versus conventional)</td>
<td>0.568</td>
<td>0.172</td>
<td>&lt;0.01*</td>
<td>0.910</td>
</tr>
<tr>
<td>Follow-up (mean in months)</td>
<td>0.801</td>
<td>0.0323*</td>
<td>&lt;0.001*</td>
<td>0.0229*</td>
</tr>
<tr>
<td>Risk factors included (yes versus no)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systemic disease</td>
<td>0.235</td>
<td>0.285</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Smokers</td>
<td>0.537</td>
<td>0.656</td>
<td>0.362</td>
<td>–</td>
</tr>
<tr>
<td>Bruxism</td>
<td>0.016</td>
<td>0.586</td>
<td>0.081</td>
<td>0.930</td>
</tr>
<tr>
<td>Periodontal disease</td>
<td>0.011*</td>
<td>0.385</td>
<td>&lt;0.001*</td>
<td>–</td>
</tr>
</tbody>
</table>

*Statistically significant.
(1) Calculations not run due to the lack of a clinical correlation or insufficient data.

For statistical purposes, implants were divided into two subgroups. In the first scenario, Groups 1 and 2 were defined as implants ≤6 mm long and 6 mm < x < 10 mm long, respectively. Six studies were included in Group 1, accounting for 65 implants (80.9%). Meta-regression analysis with fixed-effect models failed to identify statistically significant difference between the two groups on the outcomes FP, BFP, mean MBL and PFP (p = 0.445, 0.956, 0.423 and 0.426 respectively) (Table 4).

In the second scenario, Groups 1 and 2 represented implants ≤8 mm long and 8 mm < x < 10 mm long, respectively. Ten studies were included in Group 1, accounting for 365 implants (45.45%). Meta-regression analysis with fixed-effect models revealed statistically significant inter-groups differences on FP, BFP and MBL (p = 0.019, 0.00351 and 0.000367, respectively) (Table 4), whereas PFP was not significantly influenced (p = 0.275).

Implant diameter

Due to the small sample size and for statistical purposes, the narrow-diameter (ø3.3–ø3.5 mm) were clustered with the regular-diameter (ø3.75–ø4.3 mm) implants, accounting for Implant Diameter Group 1 (n = 377; 74.36%), whereas the wide-diameter (ø4.8–ø6.0 mm) group accounted for Implant Diameter Group 2. Meta-regression analysis resulted in no statistically significant difference between the two groups on both FP and BFP (p = 0.067 and 0.0847 respectively) (Table 4). On the other hand, regular-diameter short implants presented significantly less radiographic MBL and incidence of prosthetic complications (PFP) (p = 0.000 and 0.000347 respectively) than the wide-diameter implants (Table 4).

Implant surface

One study (n=15) used machine-surfaced implants (116 implants, 14.44%); the other 687 implants (85.56%) had different types of rough surfaces of different manufacturers. The overall results of the subgroup analysis for all short implants showed FPs of 7.0% (95% CI: 4.6–10.7%) for rough surface implants and 1.0% (95% CI: 0.1–6.7%) for the machined surface implants respectively. FP, BFP and MBL were not significantly influenced by surface treatment (p = 0.05, 0.135 and 0.424 respectively). The incidence of prosthetic complications (PFP), on the other hand, was significantly influenced by the type of implant surface (p < 0.001) (Tables 3, 4).

Surgical parameters

Due to limited information (Table 3), a quantitative analysis of the surgical protocols used in the original articles could not be performed. A qualitative assessment failed to identify any relevant impact of the timing of implant placement, elevation of a mucoperiosteal full-thickness flap and primary wound closure on implant failure and/or biological complications.

In relation to the surgical approach (one-stage versus two-stage), fixed effect meta-regression analysis revealed no statistically significant difference on the FP and BFP of short implants (p = 0.784 and p = 0.068 respectively). However, the mean MBL was significantly affected by the variable one-stage versus two stage (p = 0.0000799) (Table 4).

Post-operative surgical complications were rare. Seven studies did
not report it, whereas other five reported no surgical complications with short implants, such as vestibular or lingual bone dehiscence or episodes of paraesthesia. Study #14 (Strietzel & Reichert 2007) reported premature mucosal dehiscences in two implants placed with a submerged approach (one in the left posterior maxilla and one in the left posterior mandible) (information provided by the author). There was a report of one single implant placed in the mandible that had a sensation alteration that abated after 8 weeks in study #8 (Nedir et al. 2004). In the study #11 (Romeo et al. 2002), perforation of the cortical of the mandibular canal with inferior alveolar nerve lesion occurred; however, this complication was related to a longer implant.

Criteria for implant success

In despite of the lack of standardization of the success criteria adopted among the studies (Table 3), they usually included the following aspects as determinants: (1) absence of pain or discomfort or any negative subjective sensation, (2) absence of clinically detectable implant mobility, (3) absence of any recurrent peri-implant mucositis and/or peri-implantitis accompanied by bleeding on probing of the peri-implant sulcus and (4) absence of continuous peri-implant radiolucency. Three studies (#2, #7 and #15) adopted their own success criteria. Maló et al. 2011 (#7) was the only study that has considered the aesthetic outcomes achieved with the prostheses.

Prosthetic parameters

In total, 731 single crowns were followed up for at least 1 year (Table 3). The majority of the implants followed a conventional loading protocol, except on studies #2 (Cannizzaro et al. 2012) and #12 (Rossi et al. 2010). Data were then categorized into two subgroups – immediate/early loading (Group 1) versus conventional loading (Group 2). Mixed-effect subgroup analysis revealed that FPVs for groups 1 and 2 were 4.8% (95% CI: 2.2–10.3%) and 6.3% (95% CI: 3.6–10.9%), respectively (Table 3), and this difference was not statistically significant (p = 0.568) (Table 4). BFVs were 7.3% (95% CI: 3.6–14.5%) and 3.3% (95% CI: 1.3–8.0%) for groups 1 and 2 respectively. This difference was not statistically significant (p = 0.172) (Table 4). The means radiographic MBL of the two types of loading protocol were 0.364 mm (95% CI: 0.281–0.446 mm) and 0.940 mm (95% CI: 0.581–1.300 mm) (groups 1 and 2 respectively). This difference reached statistical significance (p = 0.002) (Table 4).

Porcelain-fused to metal as a veneering material was a constant between the included studies and, thus, no statistics were applied. Provisional prostheses were used in eight out of the sixteen studies, for 297 implants. Data on the type of retention (screw- versus cemented retained) were available in eight studies (Table 3). Fixed effect meta-regression revealed no statistically significant differences between the two types of crown retention on the outcomes FP and PFP (p = 0.986 and 0.622 respectively) (Table 4).

At least four different types of implant-abutment connection were reported. External hexagon, internal hexagon, internal morse taper and, finally, internal triple-cam tube were used in 433 (53.92%), 146 (18.18%), 212 (26.4%) and 12 (1.49%) implants respectively. They were then dichotomized into two subgroups – external versus internal connection. The mixed-effect subgroup analysis showed estimated FPVs of implants of 6.8% (95% CI: 3.4–13.4%) and 5.2% (95% CI: 3.2–8.5%) for external and internal implant-abutment connections respectively. These results were not statistically different for any of the outcomes FP, BFP, MBL and PFP (p = 0.542, 0.976, 0.184 and 0.590 respectively) (Table 4).

Studies where comparisons between splinted or non-splinted crowns were made are noteworthy. Study #7 (Maló et al. 2011) claimed that both types of prosthetic reconstructions supported by 7-mm short implants are successful in the short term. Studies #4 and #5 (Deporter et al. 2001a, 2012) found that splinted implants showed significantly greater (0.2 mm more) crestal bone loss than non-splinted implants, and these differences were statistically significant. On the other hand, study #6 (De Santis et al. 2011) found significantly higher implant success rates for fixed prostheses supported by short implants (98.3%), compared to the 93.1% for single crowns.

Follow-up

Table 3 summarizes the details of the follow-up periods of the included studies. Deporter et al. 2012 (#5) observed 38 implants in the posterior mandible for 120 months. The majority of the short implant losses (FP) occurred before loading (89.74%). However, the fixed effect meta-regression analysis failed to identify statistically significant correlation (p = 0.801) between greater follow-up periods and reduced implant FPVs (Table 4). On the other hand, the incidence of biological/prosthetic complications (BFP/PFP) as well as the MBL tend to statistically increase over the time (p = 0.0323, 0.0229 and 0.00000013 respectively) (Table 4).

Peri-implant health parameters

The health of the peri-implant tissues is crucial for the long-term implant survival/success (Anner et al. 2010). However, details on these parameters were scarce and usually assessed in a non-standardized manner among the primary studies. Four studies (#2, #3, #5 and #15) did not assess any peri-implant health parameter at all. Plaque score, bleeding on probing and pocket probing depth were assessed at only five, four and five studies respectively. Presence of peri-implantitis, which presents clear signs and symptoms, was mentioned in eight out of the sixteen studies (#1, #6, #10, #11, #13 and #16). Due to the limited information available and to the lack of standardization, neither quantitative nor qualitative analysis could be performed correlating these variables to the outcomes.

Risk factors

The information about the RkF on the prognosis of short dental implants is described in Table 3 and the corresponding p values (whenever applicable) are listed in Table 4. For the patient-related covariates
systemic disease, smoking status, bruxism and periodontal disease, the actual implant sample size could not be extracted from the original articles because of very limited information. Therefore, studies were dichotomously categorized into two subgroups for statistical purposes — those that included versus those that did not include the covariate according to their eligibility criteria. For the implant-related covariates bone quality, primary stability and crown-to-implant ratio, meta-regression could not be performed due to restricted data available. Therefore, conclusions about their influence on the outcomes were based exclusively from the interpretation of the raw data of the original articles.

Systemic disease

Pregnants, immunodeficients, patients under medication and those undergoing radiotherapy of the head and neck were excluded from all the studies. Subgroup analysis revealed that the mean FP among studies that included systemically compromised patients was slightly lower than the overall mean presented in the meta-analysis (3.5% (95% CI: 1.1–10.4%) versus 5.9% (95% CI: 3.7–9.2%) respectively. However, the FP was not statistically significant compared to those studies that did not include systemically compromised patients (7.3% (95% CI: 4.6–11.3%)) (p = 0.235) (Tables 3, 4). Furthermore, the mean BFP was not statistically different between studies that included versus studies that did not include systemically compromised patients (p = 0.285) (Table 4).

Smoking status

The FP revealed by mixed-effect subgroup analysis from studies in which smokers were included was higher [7.1% (95% CI: 4.2–11.7%)] compared with those in which smokers were excluded [5.9% (95% CI: 2.9–10.0%)]; however, the differences of means FP, BFP and MBL of studies where smokers were included were not statistically significant when compared to studies where smokers were not included (p = 0.537, 0.656 and 0.362 respectively) (Table 4).

In study #12 (Rossi et al. 2010), two implants failed in two heavy smokers, and the failure rate obtained in that study might have been determined by this confounding risk factor. Besides that, in the large cohort study of Strietzel & Reichert (2007) (#14), a significant association between heavy smoking (>10 cigarettes/day) and the frequency of implant loss was found.

Bruxism

The FP revealed by mixed-effect subgroup analysis from studies in which bruxers were included was lower [4.0% (95% CI: 1.6–9.8%)] compared to those in which bruxers were not included [14.0% (95% CI: 8.5–22.1%)]. This difference was statistically significant (p = 0.016) (Table 4). On the other hand, the means BFP, MBL and PFP of studies that included bruxers in their sample were not statistically different from those studies that did not include bruxers (p = 0.586, 0.801 and 0.930 respectively) (Table 4). Particular attention should be given to the study of Tawil et al. (2006) (#15). Authors found that although more serious prosthetic complications such as veneering fractures and screw-looseneds occurred in the bruxer-group, there was no statistical difference in the proportion of complications between the different groups examined (bruxer-, occasional bruxer- and the non-bruxer group).

Periodontal disease

Patients usually underwent periodontal treatment before the commencement of the studies and were included in a strict maintenance programme that included professional oral hygiene on a regular basis. The FP revealed by mixed-effect subgroup analysis from one study in which periodontal patients were included (#7) was higher [15.2% (95% CI: 8.4–25.9%)] compared with those in which periodontal patients were not included [5.5% (95% CI: 3.3–9.1%)]. These results were statistically significant (p = 0.011) (Table 4). Furthermore, the mean BFP of studies that included periodontal patients were not statistically different from those studies that did not include periodontal patients (p = 0.385), whereas the mean MBL was statistically significant between the two categories of studies (p = 0.001) (Table 4).

Bone quality

The bone quality of the recipient site was assessed intra-surgically for 185 implants only, whereas radiographic bone quality assessment was not performed at all. Types II and III bone (Lekholm & Zarb 1985) were the most common sites where short implants were placed in the posterior region (n = 66 and 70 respectively).

This study found contradictory results of the effects of low bone quality on the failure rates and crestal bone level changes of short implants. Nicolau et al. 2013 (#9) found a 100% survival rate for implants placed in bone of low quality (type IV). Likewise, study #14 (Strietzel & Reichert 2007) failed to identify any association between low bone quality and high failure rates of short implants. On the other hand, failures were more critical when machined-surface implants were used in bone of lower quality (Tawil, study #15).

Primary stability

Primary stability was assessed by means of three methods among the included studies: insertion torque, damping capacity/subclinical mobility (Periotest®) and resonance frequency analysis (RFA). Regarding insertion torque, there seemed to have a lack of standardization of the parameters in terms of N-cm, as a consequence of the different implant brands used. In some cases, an adapted surgical protocol (under-preparation) of the implant sites was used to facilitate implant placement with a higher insertion torque (#2), to obtain adequate primary stability in sites of poor bone density.

One single study assessed primary stability by means of damping capacity (Periotest®). Deporter et al. (2001a) found no relationship between Periotest® values (PTVs) and the different implant lengths (mean PTV = −2.39). Single crowns obtained better PTVs when compared to splinted crowns supported by short implants. The authors concluded that splinting is not a necessary prerequisite for the success of short rough-surfaced implants. Likewise, the ISQ (implant stability quotient), as assessed by means of RFA, was measured only by the study of Rossi et al. (2010). The mean value
after 6 weeks was higher compared with the initial registration [74.8 ± 6.1 (60–84) versus 70.2 ± 9 (42–84) respectively], and the difference was statistically significant. A positive correlation was found between insertion torques and RFA values, while negative correlations were found between bone morphology and RFA values.

**Crown-to-implant ratio**

Four studies adopted, for descriptive analysis, three categories of C/I ratio: C/I ratio ≤ 1, C/I ratio = 1.1–2.0, and C/I ratio > 2 (#4, #5, #8 and #15). No evidences of the effect of the C/I ratio on the outcome implant failure have been found; however, the findings suggest that there is not a significant effect of the C/I ratio on the crestal bone levels of either rough-surfaced (#4, #5) or machined-surface implants (#15). Rossi et al. (2010) found that the mean clinical C/I ratio increased from the time of delivery of the prosthesis to the 2-year follow-up from 1.5 ± 0.3 to 1.8 ± 0.6 mm—that is, the lever arm increased. However, according to Deporter et al. (#4, #5), a C/I ratio of ≥1.5 is not detrimental to the continued health of a rough-surface implant.

Tawil et al. (2006) (#15) assessed the effect of the C/I ratio on the prosthetic outcomes. They claimed that this variable did not prove to be a major biomechanical risk factor, as long as the occlusion is properly adjusted and occlusal contacts are placed as closely as possible to the emerging axis of the implant, that is, when force orientation and load distribution are favourable.

**Outcomes**

The overall means for the implant FP, BFP, radiographic MBL and PFP are listed in Table 3 and the graphic representation of the meta-analysis are illustrated in Fig. 2.

**Implant failure proportion**

The pooled FP (according to the random-effects model) was 5.9% (95% CI: 3.7–9.2%) (Table 3; Fig. 2). The heterogeneity between studies was found as moderate (<50%). The majority of the implant losses occurred before prosthesis placement (89.74%), varying from 2.1% at the 1-year follow-up (Stanford et al. 2010) to 7.1% after 10 years of observation (Deporter et al. 2012). Teleman et al. (2012) found 66% (n = 6) of the failures before loading.

Peri-implantitis, premature loading and implant fracture have been sought as the reason for failure in four (#6, #7, #10 and #15), two (#13 and #15) and two (#15 and #16) studies respectively. Other reasons reported in the original articles included insufficient residual crest height (study #3), surgical error, a combination of a narrow alveolar ridge and lack of buccal keratinized gingiva (study #5), osteoporosis, (a)

**Fig. 2.** Forest plot of the outcomes (mean follow-up 44 ± 33.72 months). (a) failure proportion (FP); (b) biological failure proportion (BFP); (c) radiographic marginal bone loss (MBL); and (d) prosthetic failure proportion (PFP).

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severe bruxism, overheating of the site at the time of preparation and unknown reason (study #15) and, finally, implant placed in type 2 bone that was lost after 7 years of loading (study #16).

**Biological failure proportion**

The reported BFP varied from 0.5% (Tawil & Younan 2003, mean follow-up: 53 months) to 35.3% (Perelli et al. 2011, mean follow-up: 60 months). When the observational period was increased (mean follow-up, 120 months) (Deporter et al. 2012), the BFP decreased dramatically (0.7%). Pooled BFP (according to the random-effects model) was 3.8% (95% CI: 1.9–7.4%) (Table 3; Fig. 2). The heterogeneity between studies for the outcome BFP was high (55%).

The most common biological complications were: increased pocket probing depth ($>4$ mm) in 19 implants (study #12), followed by peri-implantitis ($n = 6$, studies #2, #11, #12 and #15), increased plaque scores ($n = 4$, study #16), loss of osseointegration after loading ($n = 4$, study #10), increased bleeding scores and perimucositis ($n = 3$, studies #16 and #2 respectively), and neuropathy/loss of function ($n = 1$, study #8).

**Radiographic marginal bone loss**

Pooled MBL (random-effects model) was 0.835 mm (95% CI: 0.545–1.125 mm) (Table 3; Fig. 2). Figure 3 represents the scatter plots of the relevant clinical covariates that significantly influenced the outcome MBL. The heterogeneity between studies for MBL was very high (98%).

The studies of Deporter et al. (2001a, 2012) (#4 and #5) found that longer and splinted implants appeared to favour greater crestal bone loss. On the other hand, study #14 (Strietzel & Reichert 2007) found that the difference of mean bone loss between long and short implants was not significant. Deporter et al. (2012) found no statistically significant changes in the mean crestal bone level from baseline to the end of the observation time. In the study by Tawil & Younan (2003) 8.9% of the sites lost more than 1.5 mm (ranging from 1.6 to 3.18 mm). A greater bone loss also presented a strong correlation with the deeper placement of the machined collar of some short implants (Nicolau et al. 2013, study #9) and when two or more adjacent implants were placed (study #16).

When a within-comparison of short implants was made (Tawil, study #15), no statistically significant effect of the prosthetic variables occlusal table, C/I ratio, mesial and distal cantilever, and type of occlusal pattern on the mean mesiodistal bone loss could be found ($p = 0.242$). Regarding the design of the implant-abutment platform, Tell-

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Fig. 3. Scatter plots of the meta-regression analysis for the most clinically relevant covariates that resulted in statistically significant differences on the outcome marginal bone loss (as reported in ten studies). The “x”-axis of each panel expresses the percentages for each covariate (from 0.02 up to 0.98). (a) Implant location (mandible): the straight line across the studies (circles) represents an almost perfect positive cause-effect relationship (slope = 0.8126), for example, the larger the sample of implants placed in the mandible, the greater the mean bone loss; (b) implant length ($\leq 8$ mm or $>8$ mm): although positively correlated, the variable “length 8 mm” was not a major risk factor (slope = 0.20002); (c) implant diameter: negatively correlated, for example, the larger the number of regular-diameter short implants, the lower the mean bone loss (slope = −0.4546); and (d) surgical approach (one versus two-stage): as well as the variable “length 8 mm”, this variable was positively correlated although it was not a major risk factor (slope = 0.1428).

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eman et al. (2012) found significantly less peri-implant bone loss after 1 year in function for platform-switched implants 8.5 mm in length. Study #12 (Rossi et al. 2010) found that short (6 mm) implants loaded in an early phase of the healing (after 6 weeks) supported single crowns with a minimal loss of marginal alveolar bone after 2 years. Moreover, surgical variables such as implant location, implant diameter, microbiological status, mucosal thickness, and type of bone apparently played no significant role on the peri-implant bone loss (Telleman et al. 2012).

**Prosthetic failure proportion**

Incidence of reported prosthetic complications was very low. Pooled PFP (random-effects model) was 2.8% (95% CI: 1.4–5.7%) (Table 3; Fig. 2), and the heterogeneity between studies was moderate (<50%). Eleven studies did not report any biomechanical complications, whereas the study of Brocard et al. (2000) did not find prosthetic complications. Cannizzaro et al. (2012) reported one decementation, one veneer fracture and one case of food impaction. De Santis et al. (2011) mentioned one case of occlusal overloading, whereas Nedir et al. (2004) reported one case of decementation and one single case of abutment fracture. On the study of Tawil & Younan, where external-hexagon implant-abutment connection was used, six cases of fracture of the veneering material and nine cases of screw loosening occurred.

**Discussion**

In this study, a systematic review of prospective studies was conducted to answer the clinical question whether single crowns supported by short implants could be successfully used to restore the posterior region of partially edentulous patients. Meta-analyses revealed means FP, biological/prosthetic failure proportions and marginal bone loss of 5.9%, 3.8%, 2.8% and 0.083 mm, respectively, for implants <10 mm long supporting single crowns in the posterior region of partially edentulous patients. These results are comparable with those from clinical studies reported for longer implants placed in the same region supporting FPDs (Romeo et al. 2006) or previous reviews assessing survival of longer implants placed in augmented bone (Aghaloo & Moy 2007). Hence, prostheses supported by short implants seem to be an acceptable alternative for single-tooth replacement in partially edentulous patients with minimal bone height, compared to conventional rehabilitation procedures and advanced surgery since at least 94% of the short implants analysed were successfully restored and presented minimal biological/prosthetic complications.

**Primary outcomes**

The majority of the studies consulted were limited at mentioning the cumulative survival rates of implants, which provide information on how the risk of failure at the implant level varies over time. However, it does not inform about the absolute failure rate and the characteristics of the implants lost (Nellemann et al. 2012). For instance, the handling of the recipient site may play an important role for determining early failures of short implants, as long as any small deviation of the handpiece during drilling may enlarge the crestal portion of the prepared socket. This, in turn, may compromise the anchorage of the implant (primary stability), resulting in a higher likelihood for failure.

In this review, a mean MBL of 0.83 mm was found for the entire follow-up period. Within the limits of the little amount of data, marginal bone loss around short implants did not exceed the criteria accepted for standard implants. Nevertheless, it should be noted that 2- to 3 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 (Annibali et al. 2012). Limitations found on the different methods of assessment were that the reading of the radiographs might have been impaired by anatomical limitations of the jaws (Maló et al. 2011). Moreover, radiographs only reflected a two-dimensional situation of the real situation in the patient and any information of the buccal and lingual aspects of an implant can be elucidated (Nicolaou et al. 2013).

Since the majority of the studies aims at assessing survival rates of short dental implants only, the low incidence of complications of biological and/or prosthetic nature, as expressed by means of BFP and PFP (3.8% and 2.8% respectively), should be interpreted with caution. Reports on the incidence of complications after the osseointegration/prosthetic loading stages are scarce or even absent. Hence, it is likely that reporting biases including, but not limited to publication bias, could have a substantial impact on the findings of this review. It should be emphasized that, to precisely estimate the influence of such determinants, the original data sets should be accessed in order to perform the analyses on an individual level. In the present review, an attempt to retrieve such information has been made, but was impaired by the lack of consistent data on the original studies. Therefore, the potential for reporting bias and the possible impact on our findings will need to be considered carefully.

**Implant characteristics**

In this study, a combination of strict eligibility criteria was set and this may have led to findings others than those reported in the previous reviews assessing short implants. One relevant finding of this meta-analysis was that the incidence of failures/complications and marginal bone loss of maxillary short implants were lower than those of mandibular short implants. This is contrary to previous clinical (Adell et al. 1990, Buser et al. 1997) and review (Telleman et al. 2011, Monje et al. 2013) studies, which have shown that the failure rates for the upper jaw were significantly higher. The above-mentioned results could be attributed to the comparisons established, in many instances, between anterior versus posterior regions of the jaws, with different types of prosthetic reconstructions. The opposing findings of the present review, in turn, could be attributed to the fact that the incidence of failures and complications of short implants supporting single crowns in the posterior region of both jaws may not be influenced.
by the bone quality or implant length only. These variables have somehow been compensated by the enhancements of the surface topography (rough-surfaces) of the implants. Since in the present review the majority of the implants had a rough surface (85.56%), our findings corroborate those reported by another meta-analysis that reported that, in partially edentulous patients, implants with a rough surface had significantly higher success rates in the maxilla than in the mandible (Cochran 1999). Furthermore, prosthetic-related factors, such as occlusal table, cantilever extension, distance to the temporo-mandibular joint and the inclination of the cusps may also explain the higher failure and complication proportions found in the mandible.

The definition of a short implant is still controversial and appears to change over time. Both lengths <10 mm (Morand & Irinakis 2007) and <8 mm (Renouard & Nisand 2006) have been considered short. This last one is closer to the most recent discussions in the dental community – that an 8-mm implant is no longer considered a short implant. Hence, in this study, two subgroups have been created and meta-regression failed to identify significant differences between implants ≤ and >6 mm long in all the outcomes assessed. It is likely that the larger the sample would be (only 8.09% of the implants were ≤6 mm long), the greater would be the incidence of failures and complications, probably leading to different results. On the other hand, with a larger sample size, meta-regression found statistically significant differences between implants ≤8 mm and >8 mm long in all the outcomes but PFP.

Longer implants used to be suggested to ensure sufficient surface area for bone contact, leading to more favourable results within the same implant system (van Steenberghhe et al. 1990). However, the success of short implants should not be compared with the success of longer implants placed in the native jawbone of good quality, but should be compared with the success rate of the advanced surgical techniques necessary to place standard implants in resorbed implants in posterior jaws (Del Fabbro et al. 2012). Although distinct, the FP for both situations in the present review are consistent with clinical evidences of 6 mm implants used in different areas of the jaw with different types of prostheses (ten Bruggenkate et al. 1998) as well as with those for longer implants placed in augmented bone (Del Fabbro et al. 2012), regardless of the length (≤6 mm or ≤8 mm). However, isolated variables such as implant length should not be over-emphasized and multifactorial requirements such as overall implant characteristics, surgical and prosthetic variables and systemic conditions should be respected.

Another issue is to what extent an increase of the implant diameter compensates (das Neves et al. 2006) or not (Pommer et al. 2011) the length reduction. Malò et al. (2007), Pommer et al. (2011) and Neldam and Pinholt (2012) found that wider implants showed less favourable results than the implants of regular diameter for all lengths. This statement found agreement with our findings, once the regular diameter short implants presented significantly less radiographic MBL and incidence of prosthetic complications (PFP). It can be speculated that a regular platform can better withstand the masticatory forces due to the increased width of the buccal and lingual bone walls, resulting in lower incidence of complications of the prosthetic components and lower transmission of stresses to the crestal bone. Thus, although the compensation for a reduced length with an implant of wider diameter may seem obvious, the results may not be that encouraging.

Systematic reviews (das Neves et al. 2006, Renouard & Nisand 2006, Neldam & Pinholt 2012; Pommer et al. 2011, Annibali et al. 2012, Monje et al. 2013) found that a rough surface increases survival rates of short implants when compared to machined-surface implants. This statement is not in agreement with our findings, where rough-surface short implants presented higher FP (0.07 versus 0.01). However, this difference was not statistically significant, as well as the means BFP and MBL for both surfaces. It is likely that the larger the sample of machined-surfaced implants (approximately 15% of the whole sample) would be, the greater would be the FP. The findings of this review are consistent with a recent published systematic review (Telleman et al. 2011), where no statistically significant difference between the survival rates of implants with either a rough- or a machined-surface was noted.

Compared with longer implants with identical design and surface topography, short implants have less bone-to-implant contact due to the decreased implant surface. However, the new developments of the surface micro-topography and chemistry, such as roughness and hydrophilicity, induced a greater amount of bone in contact with the implant surface and a faster bone formation during healing of rough-surfaced short implants when compared to machined-surface ones. This, in turn, results in better maintenance of implant stability, despite the reduced implant length (Hagi et al. 2004, Blanes 2009, Kotsovilis et al. 2009, Rossi et al. 2010, Monje et al. 2013). Thus, the surface configuration of the implants may be a more significant factor than implant length in determining survival.

Surgical parameters

Although a qualitative analysis did not identify an impact of the surgical techniques on failures and/or biological complications and the report of morbidity and incidence of post-operative complications was low, the MBL seemed to be significantly higher with non-submerged implants than with submerged ones. This is not consistent with previous clinical findings (Cecchinato et al. 2004) that claimed that the bone level change in partially edentulous patients seemed to be unrelated to whether initial soft-tissue healing had occurred under submerged or non-submerged conditions.

Prosthetic parameters

A relevant finding of this structured review was that, contrary to what was considered to be a rule, short implants can be predictably and successfully restored with single crowns and may not require splitting of multiple implant units. The low incidence of implant failure (5.9%) and
biological/prosthetic complications (3.8% and 2.8% respectively) is encouraging and may shift the paradigm towards simpler restorations with minimally invasive procedures for partially edentate in the posterior regions of the jaws. Prosthetic variables may have influenced the outcomes – for instance, implants conventionally (3 months) loaded presented increased MBL compared to implants loaded either immediately or early. Furthermore, the variables type of retention (screw- versus cemented retained) and type of implant-abutment connection (internal versus external) failed to reach statistical significance for any of the outcomes assessed. However, larger samples of the above-mentioned variables should be evaluated in order to draw conclusions more prudently.

A minimum of 1 year after loading was determined as the threshold for this review. From studies on totally edentulous jaws, most failures were detected during the first year of service, which is crucial for the survival of short implants (Lindh et al. 1998, Maló et al. 2007). This pattern was also observed with longer implants that are lost during the healing phase, abutment connection or during the first year of loading. One notable finding of this study is that most of the implant failures occurred before single crown installation (89.74%), and no major complications occurred over time. This finding is in agreement with previous systematic reviews (das Neves et al. 2006, Neldam & Pinholt 2012; Annibali et al. 2012). Moreover, our findings showed that the incidence of biological and prosthetic complications, as well as peri-implant marginal bone loss seemed to be higher with greater follow-up periods.

Risk factors

Peri-implantitis was found to be a risk factor for short implant loss. One millimetre of bone loss around the neck of an implant shorter than 8 mm means a loss of 12.5% of bone support (Neldam & Pinholt 2012). However, only half of the included studies reported peri-implantitis as the cause of failure, and these data were not usually related to the length or to the location of the implant. Furthermore, means FP and MBL of patients with periodontal disease were found to be higher than those of healthy patients. However, no differences were found with regards to biological complications.

Smoking did not seem to be a strict exclusion criterion among the selected studies (approximately 3/4 of the studies included smokers in their sample). The higher incidence of implant loss among smokers found on the qualitative analysis of the current review could also be seen in previous clinical (Strietzel & Reichert 2007, Rossi et al. 2010, Pieri et al. 2012) and review (Monje et al. 2013) studies. However, the results of the meta-analysis failed to reach statistical association for none of the outcomes assessed (FP, BFP and MBL) and the variable smoking.

Our results showed that systemic disease did not characterize as a risk factor for implant failure and/or complication. However, it should be kept in mind that the patients with systemic diseases were either excluded from the analysis or had their pathologies (diabetes, hypertension) treated and stabilized within normal biological parameters before the commencement of the studies. Thus, these findings are not conclusive.

The findings of the present review showed that the incidence of implant failures was even higher in the studies that did not include bruxers in their sample. However, it failed to identify significant differences on biological/prosthetic complications (BFP/PFP) and MBL between the two groups. Limited information about parafunction (bruxism) and overloading as potential RkF was mentioned, whereas individual biting force was not mentioned at all. These factors are particularly important in the posterior region of the jaws, where the most distal position usually involves greater masticatory load than the anterior one. This load, in turn, could be intensified in an individual with stronger muscular strength (biotype). It is possible that a larger sample of bruxers included would have resulted in different findings. Even necessary, we believe that a larger sample of patients with parafunction to run a clinical study is almost unfeasible. Thus, statements about bruxism as a risk factor are mostly based on the report of few cases. This is the case of the study of Tawil & Younan (2003), who claimed that attention should be given to the nature of the complications themselves – bruxers usually presented more serious prosthetic complications than non-bruxers.

Among the RkF, poor bone quality in association with short implant has been suggested to play a major role on the prognosis than prosthetic features (das Neves et al. 2006). Short implants are mostly placed in the posterior zone (types III and IV) and does not appear to withstand the same forces as dense bone usually found in the interforaminal region of the mandible (types I or II). Hence, short implants were not recommended in poor quality bone (Romeo et al. 2006). Although the quality of the bone has been mentioned in some of the included studies, the total number of sites with various bone quality classifications was not available. In addition, bone classification criteria were not uniform, making direct comparisons difficult. Therefore, the actual effect of bone quality on the prognosis of short implants supporting single crowns in the posterior region of the jaws remains unknown.

Primary implant stability is a prerequisite for the success of any loading protocol of implants (Nicolaou et al. 2013). Very few studies (Deporter et al. 2001a, Rossi et al. 2010) have reported the primary stability of short implants, as assessed by different methods. Qualitative analysis suggested that short implants performed similar to longer implants as revealed by Periotest Values and Resonance Frequency Analysis. However, insufficient data and a lack of standardization did not allow us to draw definitive conclusions.

The limited data available in the present systematic review failed to identify quantitatively any association between implant failure and increased crown-to-implant ratio (C/I ratio). Two original studies (Deporter 2001a, Tawil et al. 2006) evaluated the clinical C/I ratio by means of measurements on working casts. Rossi et al. (2010) found that the mean clinical C/I ratio, as measured in radiographs (which truly consid-
ereder the endosseous portion of the implant), increased up to the 2-year follow-up. In other words, the clinical C/I ratio, which should be considered for conclusions, is not a constant along the time and the influence of this aspect may be altered over time. A qualitative analysis suggested that the C/I ratio has no significant effect on crestal bone levels and that a C/I ratio of 1.5 or greater is not detrimental to the success of a short implant. Special care should be taken when developing the patient’s occlusal pattern, properly adjusting the occlusion and avoiding contact in lateral movements. Thus, a more favourable force orientation and load distribution can be achieved and the C/I ratio may not be a major biomechanical risk factor.

In the case of conventional fixed prosthodontic restorations, it is generally recommended that a ratio of two lengths of root structure embedded in healthy bone should be used for one length of crown (i.e. c/r ratio = 1.2 or 0.5). If this is not possible, an increased number of abutment teeth should be used (Rokni et al. 2005). This law has been extrapolated to the implant dentistry for many years. Particularly in the posterior region of the jaws, where there is limited bone height and short implants are used, a very outsized crown needs to be fabricated to reach occlusion. This results in a higher C/I ratio. A C/I ratio >1:1 is considered harmful for any implant (Romeo et al. 2006), and C/I ratios between 0.5 and 1 have been proposed to prevent crestal bone loss and eventually implant failure. Nevertheless, recent evidences from a systematic review (Blanes 2009) and a clinical study (Blanes et al. 2007b) showed that implant restorations with C/I ratios >2 may not influence implant survival rate and the incidence of prosthetic complications. The introduction of the surface treatment of short implants has been suggested to largely offset the existence of inadequate crown-implant ratios (Menchero-Cantalejo et al. 2011).

Strategy and strength of evidence

A modified validity tool with the addition of nine items has been used for the quality assessment in the present review (Telleman et al. 2011). The inclusion of items addressing issues not explored in the original version of the chart has been discussed and decided among the review team in an attempt to increase its scope and identify possible methodological biases. The quality assessment revealed a moderate methodological quality and a high unconfornity of the studies included. However, the interpretation of these findings should be done with caution, as long as our chart has not been validated elsewhere and thus may present some potential limitations. Moreover, the results were obtained from observational studies and the highest level of evidence (randomized controlled study) has not been achieved. This is in agreement with previous reviews (Renouard & Nisand 2006, Kotsovilis et al. 2009, Monje et al. 2013), when no RCTs assessing the outcomes of short implants have been found. There is controversy over the validity of evidence from non-randomized studies; they are more susceptible to selection, performance, detection, attrition and publication bias (Pommer et al. 2011).

Although no specific randomized controlled trials meeting the eligibility criteria of the present review have been found, some studies that were excluded from the data compilation and meta-analysis are noteworthy. In these clinical trials, short implants were randomly placed in non-augmented bone and were compared to longer implants placed in vertically augmented mandibles (Felice et al. 2010, Esposito et al. 2011a) and maxillae (Cannizzaro et al. 2009, Pieri et al. 2012). The results indicate that when the bone height over the mandibular canal or below the maxillary sinus is reduced, short implants present good and similar results in the short- and mid-term to longer implants placed in vertically augmented bone. The studies agreed that short implants could be an interesting alternative to vertical augmentation since the treatment is faster, cheaper and associated with a lower incidence of complications. Even promising, these preliminary post-loading results must be confirmed by trials with larger sample sizes and longer follow-ups.

Finally, statistical analyses in this review were restricted to implant-based failure data and this limitation is in agreement with recently published systematic reviews with meta-analysis (Kotsovilis et al. 2009, Pommer et al. 2011, Telleman et al. 2011, Monje et al. 2013). The authors would have preferred to perform a patient-based analysis, as events (implant loss) tend to cluster within the same patients. However, the use of patient-based statistical analysis was hampered by the lack of adequate patient-based failure data and to the fact that some of the studies included in this review are not exclusively about short implants.

On the other hand, the present systematic review applied meticulous strategies of searches, screenings, data compilation and analysis to prevent or minimize bias. No restrictions to the database, language and year of publication were applied. This may have contributed to the high number of references found. Contact with the authors allowed the obtaining of some missing, unpublished, or unclear data in a form compatible for meta-analysis. Furthermore, some exclusion criteria were used to prevent potential confounders and, therefore, systematic bias. For instance, we thought convenient to not include retrospective studies; we opted for selecting only those prospectively designed. Consequently, no significant heterogeneity among selected studies was found in the meta-analyses for the outcomes FP and PFP, as well as no evidence of publication bias existed. On the other hand, the studies presented high and very high heterogeneity for the outcomes BFP and MBL respectively. This inconsistency may be explained by the lack of standardization on how the outcomes are assessed and reported. In the case of MBL, subgroup analysis and meta-regressions had a greater relevance, because they assess every single co-variable that may be responsible for the overall very high heterogeneity.

Conclusion

Within the limitations of the present systematic review with meta-analysis, it is suggested that single crowns supported by short implants are an
acceptable and predictable option in the short- and long-term treatment of the atrophic jaws. It should be considered as an advanced bone augmentation surgery, with a favourable advantage/risk ratio. Low failure proportions (5.9%), low incidence of biological and prosthetic complications (3.8% and 2.8% respectively) and minimal bone loss are reported after a mean follow-up period of 40 ± 33.72 months. Some advantages of the technique can be listed: (1) avoid the need for bone grafting to place longer implants; (2) less postoperative morbidity; (3) reduced treatment time; (4) reduced costs; and (5) restricting the need of sophisticated computerized radiographic exams.

In summary, it can be concluded that:

- the installation of single crowns supported by short dental implants in the maxilla has a better prognosis over installation in the mandible;
- surface topography and surgical technique did not affect the failure proportion and incidence of biological complications of short implants;
- peri-implantitis, heavy smoking and persistent periodontal disease are RKF for the loss of a short implant;
- the actual effect of systemic disease, bone quality and primary stability on the prognosis of short implants supporting single crowns in the posterior region of the jaws remains unknown;
- increased C/I ratios of short implant-supported single crowns did not influence marginal bone loss and cannot be associated with increased implant failure rates and the occurrence of technical complications;
- surgical handling of the recipient site is critical for short implants, as long as it may seriously compromise implant stability.

Recommendations for further research

In spite of the increasing number of papers on short implants being published, it must be noted that the overall levels of evidence provided by the literature are still insufficient. Randomized controlled trials specifically addressing single crowns supported by short implants placed in original jawbone compared with those of longer implants placed in augmented bone, with longer follow-up times and larger samples are necessary to validate the current findings. Furthermore, it is desirable that future studies could address, in a patient-based analysis, factors such as minimal length, prosthetic design, implant stability, bone quality, smoking status and presence of bruxism that may lead or not to an increased risk of failures and/or complications.

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References


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Clinical Relevance

Scientific rationale for the study: There is a lack of evidences on the prognosis of single crowns supported by short implants in the posterior region of the jaw.

Principal findings: Single crowns supported by short implants in the posterior region show a high predictability, with a low incidence of failures and complications.

Practical implications: Clinicians can safely use short implants to support single crowns for the rehabilitation of partially edentulous patients. However, comparisons to longer implants associated to bone augmentation prior to placement are limited and the treatment option that shows better results in the long term is still unknown.