Short dental implants: An emerging concept in implant treatment

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Objective: Short implants have been advocated as a treatment option in many clinical situations where the use of conventional implants is limited. This review outlines the effectiveness and clinical outcomes of using short implants as a valid treatment option in the rehabilitation of edentulous atrophic alveolar ridges. Data Sources: Initially, an electronic search was performed on the following databases: Medline, PubMed, Embase, Cochrane Database of Systematic Reviews, and DARE using key words from January 1990 until May 2012. An additional hand search was included for the relevant articles in the following journals: International Journal of Oral and Maxillofacial Implants, Clinical Oral Implants Research, Journal of Clinical Periodontology, International Journal of Periodontics, Journal of Periodontology, and Clinical Implant Dentistry and Related Research. Any relevant papers from the journals’ references were hand searched. Articles were included if they provided detailed data on implant length, reported survival rates, mentioned measures for implant failure, were in the English language, involved human subjects, and researched implants inserted in healed atrophic ridges with a follow-up period of at least 1 year after implant-prosthesis loading. Conclusion: Short implants demonstrated a high rate of success in the replacement of missing teeth in especially atrophic alveolar ridges. The advanced technology and improvement of the implant surfaces have encouraged the success of short implants to a comparable level to that of standard implants. However, further randomized controlled clinical trials and prospective studies with longer follow-up periods are needed. (Quintessence Int 2014;45:499–514; doi: 10.3290/j.qi.a31539)

Key words: implant-supported prostheses, posterior edentulous jaws, short dental implant, success rate, surface topography

The utilization of endosseous dental implants as one of the treatment modalities for tooth loss has increased recently, especially with the introduction of new, improved implant designs and surface topography that support and provide predictable results for both fixed and removable prostheses. For many years, the trend was to use longer and wider implants where possible for successful outcomes, on the basis that these implants provide greater surface area for bone contact which, in turn, increases implants’ anchorage and enhances their long-term survival. In addition, longer implants were thought to distribute the occlusal loads more efficiently since they would provide a favorable implant to crown ratio. However, in certain clinical situations with major anatomical limitation such as maxillary sinus pneumatization and/or reduced alveolar bone height as a result of tooth extraction, placing longer implants is not always a
straightforward procedure. In relation to the location, posterior areas of both maxillary and mandibular arches demonstrate lower bone quality and quantity than the anterior areas. Anatomical structures, such as the inferior dental nerve and maxillary sinus, may further limit the existing available bone at the implant insertion site. From the biomechanical and restorative aspects, it was also noted that teeth or restorations located closer to the temporomandibular joint, are subjected to greater occlusal bite forces of approximately ≥ 500 N in comparison to forces in the anterior regions (≤100 N). Hence the optimal number of implants is critical to support the prosthesis, so as to reduce biomechanical stresses. The existence of teeth adjacent to the implant site may complicate the situation where tooth drifting encroaches into the available space for the proposed implants, hence reducing the number of supporting implants. This situation sometimes creates insufficient prosthesis support, which could result in high biomechanical stresses on implants.

When placing dental implants in the posterior regions of the mouth with inadequate bone height, other interventions or adjunctive treatments may need to be considered. One of the suggested solutions is surgical intervention with augmentation of the resorbed ridge bone, such as guided bone regeneration, bone grafts, distraction osteogenesis, sinus floor elevation, surgical intervention with nerve displacement, or placement of implants in a tilted position.

Although these techniques have proved to have some degree of success over years, there are insufficient data regarding which procedure provides better outcomes when each procedure is compared to another. They are also case sensitive and have the disadvantages of high cost and morbidity, are time-consuming, and could increase the treatment and recovery periods.

A predictable alternative treatment modality, utilizing short implants as an adaptation procedure for the extremely resorbed ridge, has been advocated. These authors described the use of short implants without the need for complicated surgical procedures.

The rationale for placement of short implants especially in bone of adequate density is that the highest magnitude of stress is concentrated in the crestal 5 mm of the bone-implant interface. Lum had shown that the occlusal stresses that were applied to the implants were primarily distributed to the crestal bone regardless of the implant length, resulting in less subjected stresses to the apical part of the implant. Therefore, any increase of implant length, such as the use of implants of 10 mm instead of 7 mm in length, might not provide any significant improvement to its anchorage. Finite element analyses have also supported this concept and demonstrated that implant length might not be the principal factor influencing the occlusal loads to the bone-implant interface, and other factors such as poor bone density and posterior location in the oral cavity with compromised curve of Spee or occlusal plane are probable contributing factors influencing implant success. It has been also suggested that the diameter of implants plays a more considerable role in distribution of occlusal forces than implant length. Moreover, with increasingly predictable outcomes and good clinical success of short implants in regions of reduced alveolar ridges, the need for ridge augmentation procedures and related donor site morbidity is reduced.

The term “short implant” is subjective, with no consensus in the literature concerning its definition. Some authors defined it as “implants no longer than 7 mm”, while others defined an implant of length 10 mm as a short implant. Furthermore, the possibility of placing implants at different levels in the bone provides another way of defining a short implant: any implant with a calculated length of 8 mm or less completely submerged in bone is considered a short implant. However, since the minimal length for proven predictable success was always 10 mm, implants of this length are commonly considered to be standard length, and so any implant below 10 mm is referred as a short implant.

This paper evaluates the outcomes from published articles in order to review the efficiency and feasibility of using short implants as a treatment modality in the reha-
bilitation of patients with missing teeth, especially where severe resorption of the alveolar ridges has resulted.

**DATA SOURCES**

The following databases were accessed for the literature search: Medline, PubMed, Embase, Cochrane Database of Systematic Reviews, and DARE (Database of Abstracts and Reviews of Effectiveness) to identify all the studies that had been conducted on any implant system below 10 mm and that had been published between January 1990 and May 2013. The search also included studies not listed in the basic search but that had been cited by the identified studies.

An additional hand search was accomplished for six related peer-reviewed dental journals: *International Journal of Oral and Maxillofacial Implants*, *Clinical Oral Implants Research*, *Journal of Clinical Periodontology*, *International Journal of Periodontics*, *Journal of Periodontology*, and *Clinical Implant Dentistry and Related Research*, that were published between January 2000 and June 2010, by using the key words as well as the lists of references of all suitable papers and review studies. Relevant unpublished studies or articles were also identified by using the Google search engine using the same key words.

The terms or key words used in this search were “short dental implants”, “short implants”, “dental implants” [MeSH term], AND “short implants”, “dental implants” [MeSH term], AND “short length”, “dental implants” [MeSH term], AND “length”, “endosseous dental implant or implantation” [MeSH term] AND “short length”.

**Sources selection**

The first author created a search strategy in which all the titles and abstracts of the studies were examined and relevant studies selected. The selection criteria included:

- all types of human clinical studies specifically designed to investigate short implants with less than 10 mm in length of any system that were placed in healed alveolar ridge
- studies with reported implant survival rates as well as criteria for implant failure
- studies with mentioned mean follow-up period of at least 1 year after implant loading with the prosthesis.

In this review, a wide range of inclusion criteria to obtain general findings were included without differentiating implant type, surgical procedure technique, patient characteristics, or prostheses type.

**REVIEW**

In recent years, some authors have published comprehensive literature overviews on short implants either in the form of narrative or structured reviews in order to examine feasibility of their clinical use.

Hägi et al.\(^3\) reported that short implants of 6 and 7 mm length with press-fit shape and sintered porous surface topography demonstrated the best performance, with a lower failure rate. It was concluded that surface geometry plays a major role in performance of dental implants of lengths 7 mm or less. Das Neves et al.\(^1\) analyzed the treatment outcome of longitudinal studies using Brånemark and compatible implants of 7, 8.5, and 10 mm in length, and based on the results they recommended that short implants could be used as an alternative treatment to advanced bone augmentation surgeries.

Renouard and Nisand\(^4\) reviewed 53 studies in which 13 studies were devoted to short implants while 21 studies provided data on the implant length. The authors noted higher failure rates in older studies, which involved machined-surface implants placed in inferior bone quality and restricted anatomical sites. However, more recent studies reported survival rates for short implants similar to those of long implants. Furthermore, Misch et al.\(^3\) retrospectively reviewed 745 short (less than 10 mm in length) implants that were placed in the posterior mandible of partially edentulous patients. A high survival rate of 98.9% was reported for short implants.

Recently, two reviews have been published in which short implants were compared with conventional
implants. The first one was by Kotsovilis et al., who conducted his meta-analysis to answer the question: “Is there a significant difference in survival between short (≤ 8 or < 10 mm) and conventional (≥ 10 mm) rough-surface dental implants placed in totally or partially edentulous patients?” This meta-analysis included 37 articles and concluded that the placement of rough-surface short implants was as effective a treatment modality as long rough-surface implants. The second review, by Romeo et al., concluded that short and standard implants have a similar survival rate. Nevertheless, some important confounders needed to be identified in future studies as they might be contributing factors on the success of short implants.

Telleman et al. conducted a systematic review that evaluated the survival rate of short (< 10 mm) implants in partially edentulous patients and concluded that short implants can be successfully used in these patients with better prognosis in the mandible of non-smokers. A systematic review by Annibali et al. evaluated clinical studies which use implants of less than 10 mm length, to determine the success of short implant-supported prosthesis in the atrophic alveolar ridge. They found a higher cumulative survival rate for implants with a rough surface, which leads to the conclusion that the provision of short implants with prostheses in patients with atrophic jaws seems to be a successful treatment modality in the short term; however, more clinical studies are needed to support the long-term assessment.

Advantages of using short implants

The option of short dental implant treatment is of benefit to both patient and surgeon. For the patient, the use of short implants results in an avoidance of autogenous bone grafting surgery to compensate for the pneumatization of the sinus and/or loss of available bone height at the crest prior to implant placement (Figs 1 and 2). Maxillary sinus augmentation is a surgically invasive procedure and associated with many complications that may affect the final outcome of the implant surgery. The most frequent complication is the perforation of the sinus membrane. Schwartz-Arad et al. evaluated the prevalence of complications for sinus augmentation procedures and the impact of these complications on the implant survival. They found that membrane perforation was the most frequent complication, and it occurred in 44% of the cases. However,
membrane perforation did not seem to significantly affect the implant survival rate, which was 95.5% after 7 years.

Chiapasco et al\textsuperscript{12} reviewed the clinical publications from 1966 to 2005 that evaluated the success of different techniques for ridge augmentation and the survival rate of dental implants placed after ridge augmentation. They included studies with a minimum follow-up of 6 months which evaluated one of the following procedures:

- guided bone regeneration
- onlay bone grafts
- inlay grafts
- bone splitting for ridge expansion
- distraction osteogenesis
- revascularized flaps.

Their analysis revealed that the success rates of surgical procedures ranged from 60% to 100% for guided bone regeneration, 92% to 100% for onlay bone grafts, 98% to 100% for ridge expansion techniques, 96.7% to 100% for distraction osteogenesis, and 87.5% for revascularized flaps. Survival rates for implants ranged from 92% to 100% with guided bone regeneration, 60% to 100% with onlay bone grafts, 91% to 97.3% with ridge expansion, 90.4% to 100% with distraction osteogenesis, and 88.2% with revascularized flaps. They found no superiority of one procedure to another in offering better outcomes. Therefore it is advantageous to avoid these advanced complicated surgical procedures with their associated negative sequelae like donor site morbidity for the bone graft and sensory alterations of the mental nerve for nerve transposition procedures.\textsuperscript{14,17} The avoidance of surgical procedures also saves the patient significant time and money, and eliminates pain/discomfort related to the surgical procedures as well as the presurgical diagnostic radiography.\textsuperscript{29,31}

Grant et al\textsuperscript{14} evaluated the overall success rate of short implants (8 mm in length) placed in the partially or completely edentulous mandible and restored with fixed or removable prostheses. A total of 124 patients were included in the study, with placement of 335 short implants, and the survival rate obtained was 99% in the mandible. It was concluded that short implants provide a predictable treatment alternative to bone grafting and nerve lateralization for the atrophic mandible. Esposito et al\textsuperscript{37} supported the same conclusion with a randomized control trial that compared 6.3-mm-
long implants to longer implants placed in vertically augmented atrophic posterior mandibles, and evaluated if this was a suitable alternative treatment option. The study included 60 partially edentulous patients who were assigned to two groups to receive either 1 to 3 short or longer implants placed in vertically augmented bone. All patients were followed for up to 3 years after loading. Results showed that there were statistically significantly more complications in augmented patients. Short implants experienced statistically significantly less bone loss than long implants. It was concluded that short implants could be a valid alternative to vertical augmentation and provide faster and less expensive treatment with less morbidity.

A recent prospective clinical study of Stellingsma et al. compared the clinical and radiographic results of three groups of implant treatment in combination with overdenture prostheses in patients with extremely resorbed mandibles. The three treatment groups were: a transmandibular implant, augmentation of the mandible with an autogenous bone graft and the placement of four implants, and the placement of four implants (8 to 11 mm in length) only. Postoperative complications, implant survival, periodontal indices, change in bone height, and prosthetic complications were assessed during a 10-year evaluation period. After 10 years they found significantly fewer implants were lost in the implant-only group. The cumulative 10-year implant survival rate of the transmandibular implants was 76.3%, and the augmentation group 88%, in comparison with the group provided with short endosseous implants (98.8%). It was concluded that the use of short implants in combination with overdentures in the extremely resorbed mandible seems to be the first choice of treatment because of the low morbidity, high survival rate, and favorable periodontal parameters. In addition, the surgery can be done in an outpatient setting which will reduce the cost of treatment.

On the other hand, benefits to the surgeon include the shorter bone preparation at the implant site required when placing smaller implants, to provide direct access for water irrigation and reduce the possibility of bone overheating. The short osteotomy site also helps to position the implant in the proper angulation to the load since the basal bone beyond the original alveolar ridge is not always located in the long axis of the missing tooth. Another advantage, reported by Stellingsma et al., is the possibility of placing short implants in an outpatient clinic under local anesthesia, unlike the augmentation procedures that should be carried out under general anesthesia and usually involve a morbidity of the donor area. Nedir et al. reported a 7-year analysis of titanium plasma-sprayed (TPS; Straumann) and sand-blasted, large-grit, acid-etched (SLA; Straumann) implants placed in a private practice and loaded for at least 1 year. In the posterior mandible and maxilla, the mean implant length was 9.90 and 9.74 mm respectively. They concluded that shorter implants did not fail more than longer ones; the only three implants which failed were 10 mm and 12 mm long, and thus the cumulative success rate was 99.4%. The study results also indicated the predictable and safe use of short implants in a private practice, which can make implant treatment simpler and accessible to a higher number of patients and practitioners.

Factors influencing the survival rate of short implants

Many factors have been reported in the literature to affect the use and prognosis of short implants.

Jaw and bone quality

The jaw bone and bone density were suggested by Friberg et al. to be the most influential factor on implant survival. Good bone quality is usually reported as a prerequisite for primary implant stability. Turkylmaz et al. also reported the influence of bone quality on the primary stability and survival rate of dental implants.

Many studies supported the strong relation between bone quality and implant failure, and explained that negative association by the higher rate of implant loss in the edentulous maxilla than mandible was due to the poorer bone quality of the maxilla. Misch reported a higher failure rate of implants of less than 10 mm in length. He suggested a number of fac-
tors as possible explanations for the low success rate, which included that implants were placed in the posterior maxillary regions into bone of poor quality, subjected to great chewing forces, and that the crown lengths were excessively increased in relation to the implant length.

Herrmann et al evaluated the patient, implant, and treatment characteristics to identify possible prognostic factors for implant failure. The study consisted of 487 implants and showed significant differences regarding implant failures as a result of bone quality, jaw shape, implant length, treatment protocol, and combinations of bone-related characteristics. It was concluded that approximately two out of three patients with a combination of poor bone quality and low bone height experienced implant failure. Moreover, the combination of short implant length and poor bone quality was reported to reduce the implant stability during implant placement and the healing period.

Smoking and systemic alterations
Smoking has been reported as a risk factor for implant success. The literature reports different factors that explain the negative impact of tobacco smoking on implant outcomes. The effect of tobacco smoking is exerted over the microcirculation, resulting in reduced nutrition of gingival and bone tissues. The local absorption of nicotine produces vasoconstriction, which might compromise healing during the first stages of repair of the implant bed. Smoking may have an adverse effect on fibroblast function, interfere with chemotaxis and phagocytosis in neutrophils, and negatively influence immunoglobulin production by lymphocytes. In addition, this may render smokers susceptible to more infection following surgery and may cause delayed healing. Further, nicotine enhances the release of arginine vasopressin, a powerful vasoconstrictive hormone that acts on the peripheral vasculature and may cause thromboembolic problems.

Schwartz-Arad et al conducted a study to compare the incidence of smoking complications and the survival rate related to dental implants among both smokers and nonsmokers. The study included 959 implants placed in 261 patients who were divided into three groups: nonsmokers, mild smokers (up to 10 cigarettes/day), and heavy smokers (more than 10 cigarettes/day). The overall failure rate was 2% for nonsmokers and 4% for all smokers, and complications were found more in the smoking group than in the nonsmoking group. It was concluded that a reduction in smoking will decrease complications with dental implants. Anitua et al also reported a correlation between smoking and lower implant survival rates.

With regards to short implants, Strietzel and Reich-ard demonstrated low implant survival in smokers, especially in patients who smoked more than 10 cigarettes/day. Hence, the authors stressed the careful use of short implants in smokers. When short implant prognosis was evaluated in partially edentulous patients, Telleman et al found that short implants placed in patients who did not smoke had a higher chance of long-term survival than in smokers. Furthermore, Haas et al stated that “smoking is a risk factor for both implant failures and periodontal inflammation or pocket development around the implants, and therefore this habit needs to be controlled, mainly during the osseointegration periods of short implants”.

Systemic alteration, especially that resulting from diabetes mellitus, was reported by Graves et al and Preshaw et al to affect the host response to bacterial action in a way that increases the risk for periodontal disease and peri-implantitis.

Implant design and surface topography
The introduction of new implant systems with advanced surface topography and chemistry has been reported in many studies to increase the survival rates of short implants to values comparable to those reported for long implants (Table 1).

Different parameters have been used in the literature to describe implant surface roughness or topography. However, the height-descriptive two-dimensional parameters (profiles) Ra, Rq, Rz, and Rt or their three-dimensional counterparts Sa, Sq, Sz, and St are the most commonly used parameters. The Ra (Sa) is the...
arithmetic mean height deviation of the profile (Ra) or surface (Sa). It is a robust and stable height descriptive parameter around which most of the published studies centered the discussion, even if the other parameters were reported. However, it was noted that height parameters alone are not enough for a proper description of a surface, which minimally needs to include one height as well as at least one spatial or hybrid parameter, such as Sds% (the density of summits of a surface) and Sdr (the developed surface ratio).

The optimal bone response for a surface with Sa level between 1 and 2 μm and Sds of 50% (moderate roughness) has been reported. The mechanism behind this response is still unknown, but it was hypothesized that the poor osseointegration with the polished surface is due to the low friction with surfaces that provide low retention, and also cells flattening out on the surface, which prevents their nutrition. Moderate roughness is optimal due to the perfect fit to connective tissue and bone cells. Very rough surfaces may leave such a distance between peaks that cells perceive them as smooth surfaces. In addition, the retention of the very rough surfaces may also be poor mechanically because only the peaks come into contact with the bone.

Initially, implants were developed with a turned smooth surface; however, the surface microtopography is now altered by various techniques, such as acid-etching, grit blasting, and titanium plasma-spraying, which results in a rough and increased implant surface. Furthermore, recent developments have reached the level of nanotopography.

Wennerberg and Albrektsson evaluated the effect of titanium surface topography on bone integration. It was concluded that surface topography (or surface roughness) does influence bone response at the

<table>
<thead>
<tr>
<th>Study (year)</th>
<th>Type of study</th>
<th>No. of short implants</th>
<th>Length of implants (mm)</th>
<th>Surgical protocol</th>
<th>Prosthesis type</th>
<th>Mean follow-up (years)</th>
<th>Success/survival rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friberg et al82 (2000)</td>
<td>Retrospective</td>
<td>Rough 0</td>
<td>260 Brånemark</td>
<td>6–7</td>
<td>2 stages</td>
<td>Fixed/removable</td>
<td>8</td>
</tr>
<tr>
<td>Bahat42 (2000)</td>
<td>Retrospective</td>
<td>Rough 0</td>
<td>313 Brånemark</td>
<td>6</td>
<td>2 stages</td>
<td>Fixed</td>
<td>5–12</td>
</tr>
<tr>
<td>Testori et al11 (2001)</td>
<td>Prospective multicenter</td>
<td>153 Osseotite 0</td>
<td>≤10</td>
<td>2 stages</td>
<td>Fixed</td>
<td>3.6</td>
<td>97.5</td>
</tr>
<tr>
<td>Naert et al45 (2002)</td>
<td>Longitudinal 0</td>
<td>1,129 Brånemark</td>
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<td>2 stages</td>
<td>Fixed</td>
<td>16</td>
<td>81.5</td>
</tr>
<tr>
<td>Testori et al19 (2002)</td>
<td>Prospective multicenter</td>
<td>158 Osseotite 0</td>
<td>≤10</td>
<td>2 stages</td>
<td>Fixed</td>
<td>3</td>
<td>98.4 (maxilla) 97.5 (mandible)</td>
</tr>
<tr>
<td>Tawil et al47 (2003)</td>
<td>Prospective</td>
<td>Rough 0</td>
<td>269 Brånemark</td>
<td>≤10</td>
<td>2 stages</td>
<td>Fixed</td>
<td>1–7.5</td>
</tr>
<tr>
<td>Goené et al79 (2005)</td>
<td>Retrospective multicenter</td>
<td>311 Osseotite 0</td>
<td>7–8.5</td>
<td>2 stages</td>
<td>Fixed</td>
<td>3</td>
<td>95.8</td>
</tr>
<tr>
<td>Romeo et al12 (2006)</td>
<td>Longitudinal</td>
<td>265 SLA/TPS Straumann 0</td>
<td>8</td>
<td>NS</td>
<td>Fixed/removable</td>
<td>6.4</td>
<td>97.9</td>
</tr>
<tr>
<td>Deporter et al13 (2008)</td>
<td>Case series multicenter</td>
<td>26 Sintered porous 0</td>
<td>5</td>
<td>2 stages</td>
<td>Fixed</td>
<td>1–8</td>
<td>85.7 (maxilla) 100 (mandible)</td>
</tr>
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<td>Anitua et al16 (2008)</td>
<td>Retrospective</td>
<td>532 0</td>
<td>7–8.5</td>
<td>2 stages/1 stage</td>
<td>Fixed</td>
<td>5</td>
<td>99.2</td>
</tr>
<tr>
<td>Grant et al14 (2009)</td>
<td>Retrospective</td>
<td>355 0</td>
<td>8</td>
<td>2 stages</td>
<td>Fixed</td>
<td>2</td>
<td>99</td>
</tr>
</tbody>
</table>
micrometer level and might influence it on a nano-
-meter level.

In addition to increasing the implant surface area
and associated bone-to-implant contact, surface treat-
ments were found to accelerate the osseointegration
process, and thus allow for early prosthesis installa-
tion.31 This can also compensate for any inadequate
crown/implant ratios.68 It was noted that the main
reported reason for high failure rates in older studies is
that implant surfaces were machined, externally hexed,
or screw type. Another proposed reason was less bone-
to-implant contact due to the reduced implant surface
provided by short implants in comparison to longer
implants with the same diameter.75,76 An alternative
view was reported in recent studies with a high clinical
performance rate for short implants. It was mainly
attributed to advances in implant design and surface
topography, which ensured better primary stability and
larger bone-to-implant surface contact, together with
the application of strict surgical protocols and adapted
prosthetic restorations. Some studies reported the
implant system used as an additional important fac-
tor.28,31,77-80

In a study by Deporter et al,77 sintered porous sur-
faces (SPS) were used as a means to increase osseointe-
gration in their ultra-short implants. Hägi et al30 noted
implant surface topography and geometry as one of
the important modulating factors for implant success
for implants of 7 mm or less.

Goené et al79 demonstrated that the use of
Osseotite (Biomet 3i) implants with greater surface area
in comparison to machined-surface implants could
explain the high survival rates in those short implants,
which were found to be equivalent to longer (> 10 mm)
implants of the same design.

Furthermore, longitudinal studies of rough-surface
implants found high cumulative success rates ranging
between 97.5%81 for 36 months’ follow-up and 99.5%58
for 12 months’ and 24 months’ follow-up.14

Prosthetic factors
Many studies still considered prosthetic factors, such as
occlusal overloading, unfavorable crown/implant ratio,
splinting, occlusal table, cantilever length, implant sys-
tem, opposing dentition, and bruxism as risk factors
that compromise the longevity of short implants.18,42,44-47,52,82,83 For that reason, Misch17 suggested
optimizing the function of short implants through mea-
sures that might help to reduce the excessive mechani-
cal loading on surrounding bone as well as to distrib-
ute the forces over the prosthetic area evenly. He
demonstrated that lateral forces on the posterior
implant-supported prostheses can be reduced by
respecting and applying the anterior guide with
removal of cantilevers of the restorations in any direc-
tion, or applying measures that enhance the use of
supporting surface area such as placement of more
implants, increasing implant diameter, using implant
designs with greater surface area, or increasing the
functional surface area by implant crown splinting.

Tawil et al84 also evaluated the influence of some
prosthetic factors on the survival and complication
rates of short implants. The study included 262 short
machined-surface Brånemark implants that were
placed in 109 patients and followed up for a mean of 53
months. It was reported that peri-implant bone loss did
not correlate with the crown/implant ratio or occlusal
table and these values do not seem to be major risk fac-
tors in 39 cases of favorable loading. The authors sup-
ported the use of short implants if the force orientation
and load distribution are favorable and parafunctional
habits are controlled.

In the literature, there is a considerable debate on
the influence of crown/implant ratio on short implant
success. Based on the fact that each crown has to be
constructed to reach the occlusal plane, the use of
short implants definitely causes a higher crown/
implant ratio, which might increase the risk of bio-
mechanical complications (Fig 3). Some studies
reported the negative influence of this increase in
crown/implant ratio especially in cases of severe ridge
resorption. They considered increased crown height as
a vertical cantilever which results in higher peri-implant
bone stress,85 and, eventually, led to crestal bone loss or
implant failure86 or complication in the prosthetic
components.87 However, recent studies on the impact
of the crown/implant ratio on bone loss of the alveolar crest reported no influence on crestal bone loss, and reported crown/implant ratio is not a suitable predictor of implant survival (Table 2).28,88,89 Rokni et al90 demonstrated that in the case of short implants of 5 or 7 mm in length, neither the crown/root ratio nor the estimated implant surface area had any influence on the crestal bone loss because it was noted to remain stable during the loading period of those implants, while for long implants of 9 or 12 mm in length, increased bone loss (≥ 0.2 mm) was reported.90 In another study by Schulte et al,89 the authors calculated the crown/implant ratio. The results showed a high survival rate with crown/implant ratios ranging from 0.5:1 to 3:1, leading to the conclusion that crown/root ratio rules associated with natural teeth should not be considered for either prospective implant sites or existing implant restorations.

Splinting of short implant crowns for better distribution of occlusal loads is highly recommended in the literature due to direct and stiff implant connection to surrounding bone and unfavorable crown/implant ratio.17 Yilmaz et al91 measured and compared the strain generated by splinted and non-splinted implant

Table 2

<table>
<thead>
<tr>
<th>Study (year)</th>
<th>Type of study</th>
<th>No. of implants</th>
<th>Type of implants</th>
<th>Length of implants (mm)</th>
<th>Prosthesis type</th>
<th>Type of C/I ratio</th>
<th>Range of C/I ratio</th>
<th>Mean follow up (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nedir et al19 (2004)</td>
<td>Prospective</td>
<td>528</td>
<td>Rough, TPS/SLA</td>
<td>≤ 11</td>
<td>Fixed</td>
<td>Clinical</td>
<td>1–2</td>
<td>1</td>
</tr>
<tr>
<td>Rokni et al90 (2005)</td>
<td>Prospective</td>
<td>199</td>
<td>Sintered porous</td>
<td>5–12</td>
<td>Fixed</td>
<td>Clinical</td>
<td>0.8–3</td>
<td>4</td>
</tr>
<tr>
<td>Schulte et al89 (2007)</td>
<td>Retrospective</td>
<td>889</td>
<td>Bicon</td>
<td>&lt; 10</td>
<td>Fixed</td>
<td>Clinical</td>
<td>0.5–3</td>
<td>2.3</td>
</tr>
<tr>
<td>Tawil et al84 (2006)</td>
<td>Prospective</td>
<td>262</td>
<td>Machined solid</td>
<td>≤ 10</td>
<td>Fixed</td>
<td>Anatomical</td>
<td>&lt;1–&gt;2</td>
<td>4.5</td>
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</tbody>
</table>

Figs 3a to 3e  Clinical pictures and radiographs of patient treated with two short implants of 8 mm length (Ankylos system) placed in positions of right mandibular first and second molars, and restored with single metal-ceramic crowns. The digital radiographs demonstrate implants with high crown/implant ratio. (a) Stage-one surgery; (b) stage-two surgery; (c) crown installation; (d) 6 months after loading; (e) 12 months after loading.
crowns for short implants. Data showed evidence of increased load sharing for splinted prostheses regardless of the direction the load was applied. It was concluded that splinting short implants may distribute the strain more evenly during functional loading. Katranji et al\textsuperscript{92} evaluated the sinus augmentation complications and the different management methods that might reduce these negative effects and increase the long-term success of implant prostheses in posterior maxilla. They found that splinted implants have the ability to distribute stress levels evenly across the prosthesis framework and minimize the stress transmitted to the bone. This helps to preserve the bone level around implants placed in augmented sinuses.

Many studies report correlations between prosthetic factors, occlusal overload, and short implant failure, but some recent investigations have failed to prove this association.\textsuperscript{80,84,93}

Success/survival of short implants

It has been a rule in implant dentistry that the success rate increases by increasing the implant length, even though there is no evidence in the literature concerning the linear relationship between implant length and success.\textsuperscript{94}

In the past, a higher failure rate was documented for shorter implants than for longer implants (Table 3).\textsuperscript{40,42,44,45,48,49,51,95-98} Only three short implant failures were reported by van Steenberghe et al\textsuperscript{49} out of 120, with 7-mm-long implants giving an overall survival rate of 97.5%. Friberg et al\textsuperscript{40} also evaluated the overall survival rate of 4,641 implants 7 mm in length, which was found to be 94.5%. A 10-year prospective multicenter study that was conducted to compare the survival rates of short implants with those of longer ones, reported an overall survival rate of 93.5% for 7-mm-long implants in comparison to 91.5% for 13-mm-long implants.\textsuperscript{44} Yet Wyatt and Zarb,\textsuperscript{97} Winkler et al,\textsuperscript{98} and Herrmann et al\textsuperscript{51} reported the lowest overall survival rate for short implants. In the first study, of the 12 implants placed three of them were lost, leading to an overall survival rate of 75% for 7-mm-long implants. In the second study, of 43 implants placed 11 were lost, giving a percentage of 74.4% for the overall survival rate for the same length implants. The last study reported an overall survival rate of 78.2% for 7-mm-long implants.

In recent publications, highly successful results were reported for short implants, with a collective survival rate of 99.1%. A low incidence of biological and biomechanical complications after a mean follow-up period of 3.2 ± 1.7 years was also reported.\textsuperscript{24,99-101}

In an extensive review\textsuperscript{16} that included 33 studies, published between 1980 and 2004, with implants of 7, 8.5, or 10 mm in length, the overall success rate was 95.2%. Although poor bone quality was found to be related to failure, using implants with a diameter of 4 mm helped to reduce failure in situations of poor bone quality. Thus it was concluded that short implants can be used as a valuable alternative to bone augmentation procedures. The implants used showed survival rates comparable with those obtained for long implants.\textsuperscript{4}

Gentile et al\textsuperscript{28} evaluated the survival rate of short Bicon dental implants (5.7 mm long), and compared it to implants of greater length from the same system (8 mm and longer). No difference was found in the survival rates between the groups of short and long implants. A similar success rate with implants measuring 10 mm or less and longer implants was also reported by Testori et al.\textsuperscript{81}

The survival rates of machined-surface short implants were compared with those of long implants and the results showed cumulative survival rates of 81.5% for short implants and 97.2% for long implants.\textsuperscript{45} A 97.7% survival rate for single or double Brånemark implants with a length between 6 and 18 mm and a mean observation period of 37 months was reported.\textsuperscript{102}

In another study, Bahat\textsuperscript{42} also examined free standing or splinted Brånemark implants with lengths ranging between 6 and 20 mm, and observed a survival rate of 94.4% after 5 years in the posterior region of the maxilla. Friberg et al\textsuperscript{82} retrospectively followed the treatment outcome of patients with severely atrophic edentulous mandibles that were rehabilitated with short (6 to 7 mm) Brånemark implants and reported
<table>
<thead>
<tr>
<th>Study (year)</th>
<th>Type of study</th>
<th>No. of implants</th>
<th>Type of implants</th>
<th>Length of implants (mm)</th>
<th>Prosthesis type</th>
<th>Survival/success rate (%)</th>
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<td>Prospective multicenter</td>
<td>485</td>
<td>Implant innovations/rough</td>
<td>≤10</td>
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<td>98.2</td>
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<td>8</td>
<td>Fixed/removable</td>
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<td>Implant innovations/machined</td>
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<td>HA-coated</td>
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<td>Bicon</td>
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<td>Fixed</td>
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<td>Retrospective</td>
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<td>Bicon</td>
<td>NS</td>
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<td>98.2</td>
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<tr>
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<td>Bicon</td>
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<td>26</td>
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<td>5</td>
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</table>

HA, hydroxyapatite; NS, not specified.
high success, with a cumulative survival rate of 95.5% at 5 years and 92.3% at 10 years follow-up. Ivanoff et al.\textsuperscript{103} found that 8-mm-long and 5-mm-diameter implants failed 25% of the time in the maxilla and 33% of the time in the mandible, while the 10-mm and 12-mm implants that were 5 mm in diameter reported no mandibular failure and a 10% failure in the maxilla.

A Medline search of 13 studies related to implant failure and implant length was published by Goodacre et al.\textsuperscript{50} in 2003. The reports included 2,754 short implants and 3,015 implants greater than 10 mm in length. The resultant failure rate was 10% for short implants compared to 3% for longer implants. Similar results were found by Minsk et al.\textsuperscript{104} who reported clinical results for screw-type short dental implants over a 6-year period. In their report, implants of 7 mm to 9 mm in length reported a 16% failure rate with an overall survival rate of 91.3% for all lengths. An overall rate of failure of 9% for all implants in a study by Weng et al.\textsuperscript{48} was demonstrated, even though 60% of those failures were for implants of 10 mm or less in length. A 100% survival rate was reported for porous short implants for a mean functional period of 11 months.\textsuperscript{105} while 100% cumulative success rate was reported for short hydroxyapatite-coated screw-retained implants (6 mm diameter \times 8 mm length).\textsuperscript{99}

Furthermore, Misch\textsuperscript{31} retrospectively evaluated 273 patients who were treated with 745 short implants (7 or 9 mm long) in the posterior mandibular partially edentulous regions and discovered a survival rate of 98.9%. Another retrospective clinical study of all patients treated between 2000 and 2007 who received implants shorter than 10 mm showed cumulative survival rates for all implants in function ranging from 98.1% to 99.7%.\textsuperscript{106} The authors concluded that, if short implants (6 to 9 mm) were utilized appropriately, they could result in cumulative survival rates similar to those reported for longer implants.

The clinical effectiveness of dental implants of different sizes was evaluated and compared between TPS and SLA implants of 8 mm and 10 mm in length over a 14-year period.\textsuperscript{106} In this study, the cumulative survival rates were 97.9% for TPS implants, and 97.1% for the latter. Grant et al.\textsuperscript{104} reported a survival rate of 99% for 335 short implants (8 mm long) placed in the posterior mandible with a follow-up period up to 2 years post implant placement. Mufu and Chapman\textsuperscript{107} prospectively evaluated the cumulative survival rates in 168 patients who received 432 Bicon implants after a period of 4 years to be 90.0% in the maxilla and 96.8% in the mandible. Retrospective analysis of Bicon short implants placed in 294 subjects between 1992 and 2004 with a mean follow-up period of 2.3 years was investigated, and results indicated a survival rate of 98.2%.\textsuperscript{99} The results of a 10-year uncontrolled retrospective analysis of 1,889 short implants placed and loaded in 327 patients demonstrated an overall survival estimate of 98.2% at 1 year and 96.9% at 5 years after fixture placement.\textsuperscript{108}

Regarding the use of short implants as a sole alternative to the vertical augmentation of atrophic posterior mandible and placement of standard implants, Felice et al.\textsuperscript{109} placed 60 short implants in one group and in the other 61 standard implants after vertical bone augmentation of the atrophic ridge. The implants were followed for 1 year after loading. The results showed no significant differences in bone loss between the two groups, but the augmentation procedure had the disadvantages of a longer healing period, need for further technical skills, increased treatment costs, and postoperative paresthesia of the inferior alveolar nerve in a highly statistically significant manner. The study results support the efficacy of using short implants as an alternative treatment to standard implants with bone augmentation. However, the follow-up period was short, so more research is needed to evaluate the long-term variation in the success rate.

**CONCLUSION**

The literature illustrates that short implants (< 10 mm) seem to be a valid alternative, with reasonable evidence of high success rates compared to the surgical augmentation procedures in the treatment of atrophic alveolar ridges. The high failure rates reported in older studies were mainly for machined-surface implants.
placed in areas with poor bone quality. However, improvements were documented using rough-surface implants with improved implant surface topography, regardless of the implant location or type of prosthetic restorations. The prognosis of short implant placement has been reported retrospectively to be comparable to that of standard implants in recent times, which understandably was found to be better in the mandible rather than in the maxilla. However, there is still a dearth of data on the prospective long-term success and survival of these short implants, particularly with respect to occlusal loading, crown/implant ratio, and in situations of less than optimal bone quality.

REFERENCES


