Retrospective analysis of survival rates and marginal bone loss on short implants in the mandible

Keywords: fixed prosthodontics, short implants, vertical bone loss

Abstract

Objectives: Short implants have become an interesting alternative to bone augmentation in dental implantology. Design of shorter implants and longer surveillance times are a current research issue. The goal of this study was to show the survival rates of short implants below 9 mm in the partly edentulous mandibular premolar and molar regions with fixed prosthetics. Marginal vertical and 2D bone loss was evaluated additionally. Different implant designs are orientationally evaluated.

Material and Methods: A total of 247 dental implants with fixed prosthetics (crowns and bridges) in the premolar and molar region of the mandible were evaluated; 47 implants were 9 mm or shorter. Patient data were evaluated to acquire implant survival rates, implant diameter, gender and age. Panoramic X-rays were analysed for marginal bone loss.

Results: Average surveillance time was 1327 days. Cumulative survival rate (CSR) of short implants was 98% (1 implants lost) compared to 94% in the longer implants group without significance. Thirty-five of the short implants were Astratech®/C211 (0 losses) and 12 were Camlog® Screw Line Promote Plus (1 loss). Early vertical and two-dimensional marginal bone loss was not significantly different in short and regular length implant group with an average of 0.6 mm and 0.7 mm² in short implants on the observation period.

Conclusions: Within the limitations of this study, we conclude that short implants with a length of 9 mm or less have equal survival rates compared with longer implants over the observation period of 1–3 years.

Dental implants are a proven modality for treating completely and partially edentulous patients [Branemark et al. 1977]. More than a thousand different implant designs have been developed during the last decade [Esposito et al. 2007]. Primary stability depends mainly on the osseous design of the implant including the functional length, besides surgical technique and properties of local bone [Glauser et al. 2004; Toyoshima et al. 2011]. The loss of teeth leads to bone resorption limiting the use of regular length implants of 10 mm or above [Cawood & Howell 1988; Solar et al. 1998; Vinter et al. 1993]. The use of conventional dental implants in the partial edentulous mandible may be complicated by severe bone loss. One way to avoid grafting procedures was described by Krekmanov et al. and Aparicio et al. using tilted implants [>15° inclination with respect to the occlusal plane] [Aparicio et al. 2001; Krekmanov et al. 2000]. The 5-year success rates for tilted and axial dental implants were 98% [tilted] and 93% [axial] in one study [Krekmanov et al. 2000], and 95.2% [tilted] and 91.3% [axial] in another study [Aparicio et al. 2001]. Other authors reported similar cumulative survival rates (CSR) for tilted implants in the range of 95–96% [Calandriello & Tomatis 2005; Malo et al. 2005].

Short implants (<10 mm) are another interesting alternative to avoid difficult tilted implant placement and advanced surgical bone augmentation in atrophic jaws [Menchero-Cantalejo et al. 2011; Neldam and Pinholt 2010]. Finite element models of implants showed a load induction in the first mm of bony embedding implying the possibility of using short implants below 10 mm of functional length [Fanuciu et al. 2004; Koca et al. 2005; Tepper et al. 2002]. Recent studies showed 1–3 year survival rates above
implants in the period between January 2006 and November 2008. The inclusion criteria were partial dentate mandible, patient’s informed consent and fixed prosthetic rehabilitation. Exclusion criteria were edentulous patients, implant treatment of the maxilla and treatment with removable prosthesis on implants. Forty-seven implants were 9 mm or shorter (see Fig. 1). Patient data were evaluated to acquire CSR, implant diameter, gender and age. Demographic and anamnesis data were recorded from patients’ records. The short implants were used for single crowns or bridge reconstructions with or without connection to regular length implants. Definition of the experimental groups deduced from the evaluated implants (see Tables 1 and 2): Since implants were not paired, a randomization was done. We compared short implants \( (n = 47) \) with regular length implants \( (n = 179) \) in one evaluation and excluded all cases with bone augmentation in this part. Short implants \( (n = 47) \) were compared with regular length implants with bone augmentation \( (n = 21) \) in another analysis.

**Outcome criteria**
The primary outcome criteria were implant survival and success rate according to the novel criteria of the 7th European Workshop on Peridontology [Lang & Berglundh 2011]. Marginal bone loss in the evaluated initial bone remodelling phase was therefore considered as physiological. The former criteria of Albrektsson and co-workers [Albrektsson et al. 1986] were considered as less actual.

**Material and Methods**

**Patients and implants**
A total 247 dental implants in 216 patients (120 females with 141 implants and 96 males with 106 implants) with fixed prosthetics (crowns and bridges) in the premolar and molar regions with fixed prosthetics (crowns and bridges). Marginal vertical and 2D bone loss was evaluated additionally.

**Surgical Procedures**
All surgeries were performed under local anaesthesia with open flap access to the bone. Osteotomy preparations of implant sites were performed with low speed high-torque drill units \( (800 \text{ rpm}) \) using intense irrigation with a cold saline solution. A standard non-submerged healing abutment was used. All implants were loaded 3 months after implant placement.

**Statistics**
The Kaplan-Meier survival function was used for the description of CSR. A Gehan-Breslow–Wilcoxon test was conducted to compare the CSR criteria between the group with the long and the short implants. The unpaired \( t \)-test with Mann–Whitney test was applied to compare both groups with regard to peri-implant bone loss. \( P \)-values <0.05 were termed significant. The analyses were conducted using Prism version 4.0d [Graphpad Inc., San Diego, CA, USA].

**Results**
We evaluated implants in the mandibular side teeth area only. Average surveillance time was 1327 days. Intraosseous insertion depth of the AstraTech\textsuperscript{®} implants was complete, always resulting in a functional length corresponding to the product length on the package. Intraosseous length of Camlog\textsuperscript{®} Promote Plus was measured immediately after surgery and used as initial value for all bone loss calculations. CSR of short implants was 98\% \( (1 \text{ implant lost}) \) compared to 94\% in the longer implants group [see Figs 1 and 3, Table 1]. The difference was not significant in the Gehan–Breslow–Wilcoxon
failures amongst short implants occurred in the Camlog® Screw Line Promote Plus group (1 loss). The lost Camlog® Screw Line Promote Plus implant (6/9 mm) was inserted with extreme short intrasosseous length (5.5) (see Fig. 1).

Excluding the 21 implants with bone augmentation at regular length implants (2 losses) showed that longer implants had only one failure later than 200 days [591 days] after insertion. The short implant was lost 35 days after insertion.

Vertical marginal bone loss after 3 months of observation was not significantly different in short and regular length implant group in the unpaired t-test with Mann–Whitney test ($P = 0.0831$). Average vertical bone loss in the short implants group was 0.95 mm over the observation period (see Fig. 4). The two-dimensional bone loss was, on average, 0.84 mm$^2$ in the short implants group (see Fig. 5). The difference between the two groups was not significant in the unpaired t-test with Mann–Whitney test ($P = 0.2656$).

Twenty-one normal length implants were used in combination with bone augmentation and resulted in two failures. CSR of these implants was 95% compared with 98% at the short implants under observation. The bone loss between the groups was not significantly different for vertical ($P = 0.9601$) and 2D measurement ($P = 0.3230$) in the unpaired t-test with Mann–Whitney test (see Figs 6 and 7).
A clinical follow-up was possible in 15 of the short implant patients. Only one was a patient with a Camlog® implant and marginal bone loss of 5-6 mm in the posterior molar region after 50 months. The other implants were all Astratech® with an average surveillance time of 40 months and a marginal bone loss of 2 mm in mean.

Discussion

The data showed no significant difference between the CSR of short and normal length implants in the mandibular side teeth area after a mean surveillance time of 1327 days. There was also no significant difference between the CSR of short implants compared with augmented normal length implants. Marginal bone loss around short implants was also not significantly different amongst the groups.

From the technical view, implant-crown relationships that exceed the 1:1 ratio are harmful for the implant (Misch et al. 2006). This is one aspect limiting the acceptance of short implants regardless of the positive study results so far. Therefore, some authors conclude that short implants fail more often when evaluating machinized implants (Bahat 1993, Friberg et al. 1991; Jemt et al. 1996; Nevins & Langer 1993; Snaauwaert et al. 2000; van Steenbergh et al. 1990; Wyatt & Zarb 1998). Other studies evaluated short-textured implants with the same negative conclusion (De Bruyn et al. 1999; Testori et al. 2001).

Other studies including implants with rough surfaces in the following years showed better CSR outcomes (Table 3). Several studies with lower patient numbers, shorter surveillance times or singular data analysis support these results and show good CSR and limited marginal bone loss of short dental implants equal to regular length implants (Anitua & Orive 2010; Felice et al. 2010; Grant et al. 2009; Rossi et al. 2010; Sanchez-Garcés et al. 2010). CSR should also be compared with implant survival rates of sinus inlay and crestal onlay grafting techniques (Renouard & Nisand 2006). Short implants of 10 mm or shorter showed survival rates of 90% equaling the rates known from sinuslift augmentation as described for the severely resorbed maxilla with Branemark implants (Renouard & Nisand 2005). A prospective study compares the outcomes of short implants compared with vertical ridge augmentation and presents the data updates continuously (Felice et al. 2009, 2010). The data showed similar bone loss in both groups and less complications in the short implant group. A 3-year follow-up of Osseotite implants in a retrospective, multicentre study with 311 short implants of 8.5 mm or less functional length in 188 patients showed a CSR of 95.8% during 3 years of follow-up (Goene et al. 2005). Other 1–3 years survival rates above 90% in both jaws have been mentioned above (Friberg 2008; Friberg et al. 2002; Renouard & Nisand 2005, 2006). A meta-analysis evaluated 33 longitudinal studies comparing advanced surgery vs. short implants [7, 8.5, or 10 mm] in 16,344 implant placements with a total of 786 failures (4.8%). Implants of 7 mm failed at a rate of 9.7%, whereas 10-mm implants showed 6.3% failure rate. Among the risk factors, poor bone quality in association with short implants seemed to be relevant to failure. Greater diameter of 4 mm and more appeared to minimize failure (das Neves et al. 2006). This failure rate of short implants below 10% equals the complication rate of vertical bone augmentation with any current method in maxilla or mandibula (Bornstein et al. 2008; Esposito et al. 2008; Nevins & Langer 1993). A meta-analysis of 43 studies on sinus floor elevation [34 open technique of Boyne] showed an average survival rate of 91.8% (Wallace & Froum 2003). Other studies showed similar results with survival rates between 83% and 96% over 8–12 years (Clayman 2006, Emmerich et al. 2005; Ferrigno et al. 2006). Randomized controlled clinical data are lacking (Neldam and Pinholt 2010).

As the cumulative survival rate (CSR) is often used for this purpose, CSR of short implants was compared with those of longer implants. As Menchero-Cantalejo et al. (2011) pointed out in their recent meta-analysis, the majority of studies examining short implants do not provide data on CSR with respect of the implant location. Therefore, we compared short and long implants in the middle and posterior position of the mandible only.

Recently, the length definition was changing and short implants are considered being shorter than 10 mm of functional intrasosseous length as the major load induction in the bone of the jaws was shown in the upper 5 mm (Fanuscu et al. 2004; Koca et al. 2005; Tepper et al. 2002). Current prospective clinical research is focusing on super short implants even below 5 mm. However, amongst shorter implants, there is a better outcome in the longer ones showing that the initial loading force in the upper 5 mm is not the only factor for success (Hagi et al. 2004).

Malo et al. evaluated 408 short Branemark implants in 237 patients with severely atrophic maxilla and mandibula comparing 7 and 8.5 mm Branemark implants [Malo et al. 2007]. There were 131 implants of 7-mm length and 277 implants of 8.5-mm length. The survival rate of the longer short implants was slightly better with marginal bone loss of 1 mm after 1 year, and 1.8 mm after 5 years in the 7-mm implants, and a marginal vertical bone loss of 1.3 mm after 1 year, and 2.2 mm after 5 years in the 8.5-mm implants.

A rough surface showed advantages in short implants compared with smooth machined implants in a study with 4891 implants [Feldman et al. 2004]. Overall 5-year CSR was evaluated for machined-surfaced (n = 2597) and dual acid-etched Osseotite implants (n = 2294 implants) with 0.7% difference, which is not statistically significant. The difference was 7.1% in the posterior maxilla and 8.5% in the anterior maxilla and significant in both analyses in short implants 10 mm or less.

A meta-analysis further evaluated this aspect in a targeted review of 12 studies with short endosseous dental implants [7 mm or shorter] in partially edentulous patients (Table 3) (Hagi et al. 2004). The results showed that implant geometry is of importance. The surface roughness is also of significance when comparing rough surfaced with textured implants. The textured implants had lower CSR in the maxilla than in the mandible. This analysis includes several older studies (Bahat 1993; Gunne et al. 1999; Jemt & Lekholm 1993; van Steenbergh et al. 1990; De Bruyn et al. 1999; Testori et al. 2001). There are several reviews showing limited comparability of current studies, but confirm the good outcomes described above.

Table 2. Data of overall results

<table>
<thead>
<tr>
<th>Results after 1327 days mean surveillance time</th>
<th>Short implants &lt;10 mm</th>
<th>Implants &gt;10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over all</td>
<td>47</td>
<td>200</td>
</tr>
<tr>
<td>Losses</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Survival rate (%)</td>
<td>98</td>
<td>94</td>
</tr>
<tr>
<td>Losses premolar region</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Losses molar region</td>
<td>1</td>
<td>7</td>
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<tr>
<td>Average survival time of lost implants (days)</td>
<td>30</td>
<td>135</td>
</tr>
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</table>

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in general [Neldam and Pinholt 2010; Raviv et al. 2010].

The data show a good clinical outcome even though a high number of short implants were reconstructed without mechanical connection to regular length implants. However, we consider that a combination with regular length implants is recommended as mentioned by other authors, and in complying with finite element studies [Fanuscu et al. 2004; Koca et al. 2005; Strietzel & Reichart 2007; Tepper et al. 2002].

Conclusions

Within the limits of this study, we conclude that short implants with a length of 9 mm or less have equal survival rates compared with longer implants over the observation period of 1–3 years in the mandibular molar and premolar region. Combining short implants with regular length implants in fixed prosthetic constructs is a recommendable option.

References


Table 3. Cumulative survival rates of short implants in various studies

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Study design</th>
<th>Number of implants</th>
<th>Short implants</th>
<th>Long implants</th>
<th>Survival rate of short implants</th>
<th>Survival rate of long implants</th>
<th>Follow up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artzi et al. (2006)</td>
<td>Prospective cohort</td>
<td>248</td>
<td>89</td>
<td>159</td>
<td>75% (8 mm)</td>
<td>97.9% (13 mm)</td>
<td>5–10 years</td>
</tr>
<tr>
<td>Winkler et al. (2000)</td>
<td>Prospective cohort</td>
<td>2917</td>
<td>951</td>
<td>1966</td>
<td>Survival ranged from 66.7%</td>
<td></td>
<td>3 years</td>
</tr>
<tr>
<td>Renouard and Nisand (2005)</td>
<td>Retrospective cohort</td>
<td>96</td>
<td>96</td>
<td>–</td>
<td>94.6%</td>
<td></td>
<td>2 years</td>
</tr>
<tr>
<td>Goene et al. (2005)</td>
<td>Retrospective cohort</td>
<td>311</td>
<td>311</td>
<td>–</td>
<td>95.8%</td>
<td></td>
<td>3 years</td>
</tr>
<tr>
<td>Renouard and Nisand (2006)</td>
<td>Review</td>
<td>3173</td>
<td>2141 (6.9 mm)</td>
<td>1032</td>
<td>95.9%</td>
<td></td>
<td>3–144 months</td>
</tr>
<tr>
<td>Friberg (2008)</td>
<td>Retrospective cohort</td>
<td>506</td>
<td>–</td>
<td>–</td>
<td>90.3% (7 mm)</td>
<td>93.7% (10 mm)</td>
<td>7 years</td>
</tr>
<tr>
<td>Malo et al. (2007)</td>
<td>Retrospective cohort</td>
<td>408</td>
<td>408</td>
<td>–</td>
<td>93.6%–94.6%</td>
<td></td>
<td>5 years</td>
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<tr>
<td>Feldman et al. (2004)</td>
<td>Prospective cohort</td>
<td>4891</td>
<td>2015 (10 mm or less)</td>
<td>2876</td>
<td>95.7% (8 mm)</td>
<td>97.1% (8.5 mm)</td>
<td>5 years</td>
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<tr>
<td>Hagi et al. (2004)</td>
<td>Review</td>
<td>4107</td>
<td>2597 (machined)</td>
<td>1218 (machined-surfaced)</td>
<td>91.6 (machined-surfaced)</td>
<td>93.8 (machined-surfaced)</td>
<td>1–5 years</td>
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<td></td>
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<td></td>
<td>1379 (machined-surfaced)</td>
<td>1497 (dual-acid-etched)</td>
<td>97.7 (dual-acid-etched)</td>
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<td>1218 (machined- surfaced)</td>
<td>797 (dual-acid-etched)</td>
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<td>1218 (machined- surfaced)</td>
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<td>764</td>
<td>3343</td>
<td>Mandibular (67–100%)</td>
<td>Mandibular (90.1–98.1%)</td>
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