Extra short dental implants supporting an overdenture in the edentulous maxilla: a proof of concept

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Abstract

Objectives: This study investigates the outcome of short implants additionally placed with longer implants to support a maxillary overdenture.

Materials and methods: Twelve patients received six implants to support a maxillary overdenture. Only one patient still had two molars in the maxilla, while the others had no remaining teeth. The status of the opposing arch was diverse. The distal implant in each quadrant was 6 mm in height (S) and the middle implants ranged between 10 and 14 mm (L). All implants were placed following a one-stage procedure and early loaded (6 weeks). Clinical and radiological parameters were assessed 6, 12 and 24 months after loading.

Results: One short implant failed 2 weeks after surgery, probably due to early mobilization by the provisional prosthesis. The mean bone loss on the rough part of the implant was 0.7 mm (S) vs. 1.3 mm (L) during the first year and 0.3 mm (S) vs. 0.2 mm (L) during the second year after loading. The mean implant stability quotient values were 67 (S) vs. 70 (L) at placement and 75 (S) vs. 78 (L) after 1 year. At the 2-year follow-up, all prostheses were still stable and comfortable.

Conclusion: An overdenture on six implants, of which two have a reduced length, might represent a successful treatment option. No significant difference could be found between both implant lengths at 2 years’ follow-up. However, bone loss with short implants may increase the likelihood of failure.

Today, implant treatment can be short, simple, cost-effective and highly predictable. In particular, practitioners want to rehabilitate most patients without implementing advanced surgical techniques, such as alveolar augmentations or sinus grafting.

The increase in patient comfort for patients wearing an overdenture vs. a complete denture is striking, especially for those who suffer from lack of stability and retention. In particular, practitioners want to rehabilitate most patients without implementing advanced surgical techniques, such as alveolar augmentations or sinus grafting.

Osteotome sinus floor elevation is performed when the residual bone height is 4 mm or more. Conventional sinus floor elevation can be performed when the residual bone height is <4 mm (Zitzmann & Scharer 1998; Khoury 1999; Tawil & Mawla 2001). The implants are placed together with the inlay, except when the residual bone height is extremely reduced (Wallace 2006), in which case the implants will be placed at a later stage when the inlay has healed. Recent publications showed that, even without using a filling material, comparable successful results can be obtained (Lundgren et al. 2004; Thor et al. 2007).

A risk of perforation of the Schneiderian membrane exists [19.5%; range between 0% and 58%] (Pettersson et al. 2008). Studies have shown a good level of success (>90% after 12 months), but sometimes, patients refuse the treatment due to the multiple surgical procedures, high costs and longer treatment duration.
Another technique is the use of the tilted implants inclined before the sinus, but only a few studies are available in the literature (Krekmanov et al. 2000; Aparicio et al. 2001; Malo et al. 2006; Aghiardi et al. 2010).

The use of short implants may be a suitable alternative in situations with reduced alveolar height. Some have hesitated to use these implants due to the perception of a higher risk of failure compared with longer implants for both fixed restorations (Jaffin & Berman 1991; Jemt & Lekholm 1993; Wyatt & Zarb 1998; Naert et al. 2002a, 2002b), as well as maxillary overdentures (Engquist et al. 1988; Jemt 1993; Jemt & Lekholm 1995; Chan et al. 1998).

More recent studies have suggested that short implants (7 --to <10 mm) can reach the same level of success as longer ones for the fixed partial dental prostheses (Griffin & Cheung 2004; Renaud & Nisand 2005; Fugazzotto 2008). Even longer term follow-ups (e.g. 3 years; Bernard et al. 1995, 7 years: Nedir et al. 2004) reported retrospectively that short implants (8--9 mm long) were not less successful compared with implants >10 mm long in the posterior region with fixed partial dental prostheses. One explanation for the good outcome may be the implant surface characteristics. The first studies used turned surfaces, while more recent studies, with better results, report on rougher surfaces (e.g. SLActive, TiUnite). Indeed, das Neves et al. (2006) reviewed the results of 33 studies of 16,344 implants, and assessed failure rates over time. A failure rate of 4.8% was reported, and there was no correlation between implant length and success or failure, except for 7 mm, turned surface implants with an external hex, placed in poor bone quality; however, this implant is no longer representative of current practice and the respective results are a poor indicator for the use of short implants. A new chemically modified titanium surface, SLActive, has been developed. Compared with the conventional SLA surface, this new surface showed enhanced bone formation, significantly increased cellular activity and proliferation of vascular structures in the first 14 days following implantation, as demonstrated by histological and immunohistochemical evaluation (Schwarz et al. 2007a). This increase in early cellular activity increases the degree of bone apposition to the chemically modified SLA surface in the early healing stages. This evidence suggests increased implant stability in the critical early osseointegration period. The present study will, to our knowledge, be the first one to assess the outcome of short implants with a moderately rough implant surface, placed for a planned maxillary overdenture design.

Another reason for a higher failure rate, previously reported for short implants, might be the limited number of implants supporting the superstructure, due to a limited amount of bone. There is no consensus about the number of implant supporting an overdenture, but a recent systematic review revealed that a maxillary overdenture, supported by six implants, splinted with a bar, is the most successful treatment regarding the survival of both the implants and the prostheses (Slot et al. 2010).

If short implants are predictable, their use may have the following consequences: restricting the need for sophisticated and expensive computer-ized radiographic methods, restoration-driven rather than surgically driven placement (tilted implants), reducing the surgically demanding procedures such as sinus lifts and bone grafting, avoiding the occurrence of sensation disturbance and making surgery easier by not having to place the longest implants. The acceptance of implant treatment by the patient is much higher when the surgical intervention is less invasive (Walton & MacEntee 2005).

This prospective pilot study aimed to test the outcome of short 6 mm moderately rough implants, in the edentulous maxilla, when combined in primary splinted bar-supported overdenture treatment, without grafting.

Material and methods

Patients

Consecutively, 12 healthy patients in need of a full-arch treatment in the maxilla were recruited. Exclusion criteria included alcohol or drug abuse, psychiatric problems, uncontrolled diabetes or uncontrolled systemic disease, intravenous bisphosphonates. Based on a multi-slice CT scan (MSCT), the patient was included if six implants could be placed in the maxilla without the need for bone augmentation. The required height for the most distal implant in both quadrants was ± 6 mm. From a prosthetic point of view, the patient had to have at least 8 mm of vertical height from the crest of the mucosa to the plane of occlusion or top of the acrylic of the denture was available. This space is needed for the abutment, a conical cap, a retentive acrylic for the attachment, the CrCo framework and the resin teeth.

If tooth extraction was still required in the maxilla, a healing period of 6 months was respected before implant insertion. Periodontal treatment of the remaining teeth in the mandible was performed in the meantime. Smokers were not excluded, but were requested to reduce or to refrain from smoking.

The patients were followed for 2 years after receiving their prosthetic restorations. Follow-up visits were scheduled at 2 weeks, 6, 12 and 24 months after prosthesis placement.

Surgery

Based on the results of the MSCT scan images, six implants were planned without using a software planning tool. The four middle implants were at least 10 mm in length (long implants: L) and the two end implants were 6 mm in length (short implants: S).

Under local anesthesia and under sterile conditions, a crestal incision was made and implants with a chemically modified grit-blasted and acid-etched surface and a smooth collar of 1.8 mm (SLActive Standard Plus, Institut Straumann AG, Basel, Switzerland) were installed following the guidelines as defined by Buser et al. (2000). Mucoperiostal flaps were raised to identify the anterior borders of the maxillary sinuses and the incisive canal. An inter-implant distance of at least 8 mm was respected where possible, to allow retention clips for the removable supra-structure. The implants were placed perpendicular to the plane of occlusion where possible.

By mental navigation (MSCT) and exploration of the sinus, the short implants were placed in a respective bone height of 6 mm at positions 16–17 and 26–27.

If one of the six implants did not reach primary stability [insertion torque <15 N cm], all implants were installed in a two-stage procedure. In the case of one-stage surgery, healing abutments were placed immediately.

The patient was not able to wear the temporary removable prosthesis during the first week. Antibiotics [amoxicillin 500 mg, 3 × [d]] were prescribed for 4 days, and painkillers were taken as required. The patient was asked to rinse twice a day with a chlorhexidine solution 0.12%

Bone quality was evaluated subjectively (Lekholm & Zarb 1985). Implant sites were under-prepared for the short implants to achieve maximal primary stability.

Prosthetic procedure

After 1 week, the denture was adjusted and relined with a tissue conditioner [CoeComfort, Kerr America Inc., Chicago, IL, USA]. This was repeated every 4 weeks. The impressions on the implant level were taken 3 weeks after implant placement, which made early loading (6 weeks after implant placement) possible. Abutments (synOcta, Institut Straumann AG) were installed with a screw-re-tained bar construction on top. All abutments were torqued up to 15 N cm for long implants, while those on short implants were manually torqued. If an implant was a spinner, a further 6-week healing period was respected. After 6 months, all synOcta abutments were torqued to 35 N cm. A gold alloy bar [Cendres & Metaux, Biel, Switzerland], with an egg-shaped profile, was used in all patients to connect the implants. The retention was provided by four or five Au alloy clips within the horse.
shoe-shaped, CoCr-reinforced, removable prosthesis. The bars were without extensions. The teeth of the overdentures were composite resin ones (Fig. 1d–g). A balanced occlusion and articulation pattern – in maximal intercuspidation, lateral and protrusive movements – was opted for. Patients were instructed to clean the bar with an electrical toothbrush and to use interdental brushes (Fig. 1h).

After 1 year, the bar was removed to record broken set screws, loose or broken abutments.

All prosthetic complications such as activation or replacement of the clips, untightening of the abutment/gold screw, fractures of prosthesis of components and relining that occurred during the follow-up period were recorded as well.

Clinical recordings
Implant stability was measured using two devices: Periotest (Siemens AG, Bensheim, Germany) and Osstell™ (Integration Diagnostics, Savedalen, Sweden). Measurements were taken immediately after implant insertion, at 6 and 12 months after loading. Each time, the final abutments were torqued to 35 N cm.

Pockets (PPD) and recessions (Rec) were measured at six sites per implant at each visit. The implant shoulder was used as a reference. A negative recession value means a subgingival positioning of the implant. Bleeding on probing was registered and scored as absent (=0) or present (=1). Gingival hyperplasia was evaluated based on a comparison of intra-oral slides taken at the 2-year recall and those taken after placement of the bar.

Radiographic follow-up
Radiographs were taken after implant placement, at loading, and 6, 12 and 24 months after loading to calculate bone loss over time. A film holder-beam aiming device (Rinn, XPC Instruments, Elgin, IL, USA) was used, with the film placed parallel to the implants. Threads had to be clearly visible; if needed, the device was stabilized using soft bite wing flaps (Emmenix-Flap, Hegew Werken, Duisburg, Germany). The known distance between the threads was used for the calibration of each radiograph. All radiographic analyses were performed by a single investigator blinded to the protocol at the University of Bern. Radiographic bone-level measurements were estimated as the distance from the implant shoulder to the first visible bone-to-implant contact (BIC). Bone-level data reported in this article are measured by taking the smooth/rough interface of the implants as a reference point, which is located 1.8 mm apical from the implant shoulder. A negative bone-level value means a subcrestal positioning of the reference point.

Success criteria
Success was defined based on clinical and radiographic findings using previously published validated criteria for Straumann implants (Buser et al. 1990). An implant was considered as successful if there was lack of mobility, absence of peri-implant radiolucency, absence of recurrent peri-implant infection with suppuration, absence of continuous or recurrent pain or structural failure of the implant.

Statistical analyses
Each measured variable, assessed at a certain time, was considered as a separate variable. A linear mixed model was built with patient as a random factor and implant length as a fixed factor. First, all-pairwise comparisons were constructed and P-values were corrected according to Tukey’s multiple comparison procedure. Afterwards, all long implants were compared with the short implant and P-values were corrected.
according to Dunnett's multiple-comparison procedure. Finally, the average of the long implants was compared with the short implant. As only one comparison was made per variable, no correction for simultaneous hypothesis testing was made. The residual values of all models showed a normal quantile plot and equal variability for the different implant lengths. The comparison between groups of patients (smoking, antagonist, parodontitis) was made in a similar fashion. Also, here, as only two groups were compared with each other, no correction for simultaneous hypothesis testing was made. The relation between clinical parameters was assessed by a linear regression and the Spearman rank correlation coefficient, for which each time, the corresponding P-values were calculated. S-plus 7 for Linux software was used for all statistical analyses.

**Results**

**Patients**

Twelve patients (mean age 58.6 years, range 47.7–71.3 years, five women and seven men) were followed for 2 years. Six of the patients were smokers. The main reason for tooth extraction was periodontitis [10/12 patients] and two patients were already edentulous in the maxilla, when they entered the study. Bone loss > 50% at mandibular teeth was present in 5/10 patients. The status of the opposing arch was the opposing denture on two teeth [n = 1], implant-supported fixed dental prosthesis [n = 1] or overdenture on two implants [n = 1], full/shortened dental arch [n = 9] [Table 1]. In the latter, only one patient was wearing a lower removable prosthesis for distal tooth replacement.

**Surgical and prosthetic procedure**

No serious adverse events occurred. A total of 72 implants were placed (24 S and 48 L). All short implants had a diameter of 4.1 mm, while for the longer implants, 11/48 (23%) had a diameter of 3.3 mm and 37/48 (77%) had a diameter of 4.1 mm (Table 2). Most implants were placed in type III and IV bone (76% and 56% of S and L implants, respectively; Table 3).

During implant insertion, there were no spinners, and for all implants, the initial stability was above 15 N cm, resulting in a one-stage procedure and elastomer impressions after 3 weeks.

One short implant was lost 2 weeks after implant insertion, probably due to mobilization by the provisional prosthesis. The implant was removed and a suprastructure was provided on the remaining five implants. Two implants (one S and one L) in another patient spanned during healing cap removal. An additional healing of 6 weeks was therefore respected before continuing the prosthetic part. After 2 years, all overdentures functioned successfully. Gold screw untightening occurred in two patients. A relaxing and adaptation of the occlusion was needed in one patient. Replacement and activation of the retention clips was not needed during the entire follow-up. Neither broken set screws nor abutment screws have been detected, or fracture of overdentures.

**Clinical measurements**

Implant stability quotient at placement was not different between both subsets of implants at any of the subsequent visits. The values increased between implant insertion and 6 months and remained stable afterwards. The Periotest changes were less pronounced over time, except for the short implants again between implant insertion and 6 months.

The pocket probing depth, recession, bleeding on probing and plaque index did not differ significantly between the subgroups (Table 4). At the 2-year follow-up, mucosal hyperplasia was seen in 4/12 patients.

Five patients needed additional oral hygiene instructions. In 3/4 patients, the gingival hyperplasia almost disappeared, while for one patient, excision of the fibrous tissue was needed.

**Radiographic evaluation**

Bone level and bone loss have been presented in cumulative percentage figures. The line on the graph displays for each point the proportion of points that are smaller than or equal to the point itself. It should be clear that the graph starts at near zero, and increases to a value of 100. The

Table 1. Description of the patient population

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Smokers</th>
<th>Oral hygiene</th>
<th>Parafunction</th>
<th>UJ</th>
<th>LJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>Good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Bad</td>
<td>Bruxism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Bad</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>No</td>
<td>Very good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Yes</td>
<td>Good</td>
<td>Sucking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Yes</td>
<td>Moderate</td>
<td>Sucking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>No</td>
<td>Very good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>No</td>
<td>Very good</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Number of implants with respective diameter and length in mm

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length 6</th>
<th>Length 10</th>
<th>Length 12</th>
<th>Length 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>4.1</td>
<td>24</td>
<td>2</td>
<td>7</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 3. Percentage of short (S) and long (L) implants placed in bone characterized by quality I, II, III and IV (Lekholm & Zarb 1985)

<table>
<thead>
<tr>
<th>% Bone quality</th>
<th>Bone quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Implant</td>
<td>S</td>
</tr>
<tr>
<td>L</td>
<td>13</td>
</tr>
</tbody>
</table>

UJ, upper jaw; LJ, lower jaw; I, implant; T, teeth; BL, bone loss; perio, periodontitis; pros, prosthetic; PT, periodontal treatment; RPD, removable partial denture; NA, not applicable.
Table 4. Overview of the results for clinical parameters (mean, median, range) for short (S) and long (L) implants

<table>
<thead>
<tr>
<th></th>
<th>Impl Ins</th>
<th>6 months</th>
<th>12 months</th>
<th>24 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISQ BuccoOral</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>65.9 (66, 44–84)</td>
<td>75.7 (77, 63–88)</td>
<td>74.1 (75, 57–85)</td>
<td>–</td>
</tr>
<tr>
<td>L</td>
<td>68.5 (68, 41–86)</td>
<td>77.8 (76, 53–85)</td>
<td>76.6 (80, 39–86)</td>
<td>–</td>
</tr>
<tr>
<td>ρ</td>
<td>0.23</td>
<td>0.97</td>
<td>0.83</td>
<td>–</td>
</tr>
<tr>
<td>ISQ MesioDistal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>68.3 (71, 52–82)</td>
<td>75.2 (78, 60–85)</td>
<td>75.1 (75, 63–83)</td>
<td>–</td>
</tr>
<tr>
<td>L</td>
<td>72.2 (73, 32–83)</td>
<td>79.3 (78, 63–85)</td>
<td>79.1 (81, 39–90)</td>
<td>–</td>
</tr>
<tr>
<td>ρ</td>
<td>0.92</td>
<td>0.16</td>
<td>0.99</td>
<td>–</td>
</tr>
<tr>
<td>PTV units</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>–7.7 (–4, –8 to +0)</td>
<td>–4.5 (–5, –6 to +0)</td>
<td>–4.7 (–5, –6 to +0)</td>
<td>–</td>
</tr>
<tr>
<td>L</td>
<td>–5.9 (–5, –7 to +1)</td>
<td>–4.5 (–5, –6 to +0)</td>
<td>–4.5 (–6, –6 to +0)</td>
<td>–</td>
</tr>
<tr>
<td>ρ</td>
<td>0.03</td>
<td>0.8</td>
<td>0.36</td>
<td>–</td>
</tr>
<tr>
<td>PPD (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>–</td>
<td>2.9 (2.8, 2 to +5)</td>
<td>3.1 (3, 1 to +6)</td>
<td>3.2 (3, 1 to +6)</td>
</tr>
<tr>
<td>L</td>
<td>–</td>
<td>3.2 (2.9, 2 to +7)</td>
<td>3.6 (3.2, 2 to +8)</td>
<td>3.5 (3.2 to +8)</td>
</tr>
<tr>
<td>ρ</td>
<td>–</td>
<td>0.95</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>Rec (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>–</td>
<td>–0.9 (–0.5, –2 to +0.3)</td>
<td>–0.9 (–0.8, –3 to +0)</td>
<td>–0.8 (–0.5, –2 to +0)</td>
</tr>
<tr>
<td>L</td>
<td>–</td>
<td>–1.3 (–1, –3 to +0)</td>
<td>–1.1 (–1, –3 to +0)</td>
<td>–0.9 (–0.3, –3 to +0)</td>
</tr>
<tr>
<td>ρ</td>
<td>–</td>
<td>0.87</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>BOP (% sites)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>–</td>
<td>26</td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td>L</td>
<td>–</td>
<td>27</td>
<td>44</td>
<td>28</td>
</tr>
<tr>
<td>ρ</td>
<td>–</td>
<td>1</td>
<td>0.99</td>
<td>1</td>
</tr>
</tbody>
</table>

P-value has been corrected for simultaneous hypotheses (n = 18) testing.
Pimpl Ins, implant insertion; ISQ, implant stability quotient (measured with the Osstell device); PTV, perio test value; PPD, probing pocket depth; Rec, gingival recession; BOP, bleeding on probing.

A detailed analysis of bone loss per implant is presented in Figs. 2 and 3. Short implants were placed slightly deeper than long ones [Fig. 2], with a mean bone level at placement of –0.8 mm [range –1.8 to +0.2, confidence interval [CI] –1 to 0.5] [S] vs. –0.2 mm [range –1.8 to +1, CI –0.5 to +0.2] [L], with the smooth–rough interface of the implant serving as the reference point for the measurements.

Bone loss after 1 year was 0.7 mm [range 0 to +2.1, CI 0.06 to +1.3] [S] vs. 1.3 mm [range 0 to +5.1, CI 0.6 to +1.9] [L] [P > 0.05]. Additional bone loss during the second year was 0.3 mm [range 0 to 2.2, CI 0.1 to +0.6] [S] vs. 0.2 mm [range 0 to 1.8, CI 0 to +0.4] [L].

A detailed analysis of bone loss per implant is presented in Fig. 4. Short implants did not show more bone loss compared with longer implants. Bone loss of more than 1.5 mm during the first year of loading was seen at 4/23 (17%) for the S implants and 12/48 (25%) for L implants [Fig. 4]. Ongoing bone loss of >1 mm during the second year was observed at 3/23 (13%) S and 3/48 (6%) L implants [Table 5]. The implants with remarkable bone loss were especially located in the anterior and canine positions.

Discussion

A good success percentage, both for implants 100% for L and 97.9% for S implants (criteria Buser et al. 1990) as well as for the overdenture (100%) was obtained after 2 years.
The outcome of short implants is comparable to the results reported previously on implants, placed after sinus lift procedures and loaded after 2–6 months. These survival rates for the latter technique ranged between 95.6% and 100% for implants and 100% for the overdenture (mean follow-up: 12–22 months) [Raghoebar et al. 2003, 2005, 2006]. For the latter procedure, long-term analysis [10 years] showed a survival rate of 86.1% for implants and 74.4% for maxillary overdentures [Visser et al. 2009]. Loss of implants occurred during the healing phase or the first year of loading.

The present mean bone level was 0.7 mm (S) and 1.3 mm (L) at 1 year and 1 mm (S) and 1.5 mm (L) at 2 years. Other studies (2.8 mm turned neck) on an SLActive surface in an overdenture design are not available. Less bone loss (Ganeles et al. 2008; Morton et al. 2010), especially compared with the long implants in the present study, has been reported for SLActive implants supporting a fixed partial restoration, which might not be extrapolated to implants supporting an overdenture. In general, the mean bone loss for a bar-retained overdenture on four to six implants is reported to range between 0.3 and 0.7 mm [Naert et al. 1998; Zitzmann & Marinello 2000; Raghoebar et al. 2003]. In the present study, most bone loss was observed for the longer implants in the anterior region, which stabilized after the first year [Table 5]. One should realize that most patients [10/12] lost their teeth due to terminal periodontitis, and that in 4/5 patients, the remaining teeth were affected by bone loss. Excessive bone loss was localized in three patients, who had poor oral hygiene and were heavy smokers, both factors increasing the risk for peri-

![Fig. 3. Cumulative percentage of mean bone level per implant (reference smooth/rough surface) for short and long implants (a) at loading, (b) 6 months of loading, (c) 12 months of loading, (d) 24 months of loading.](image1)

![Fig. 4. Cumulative percentage of mean bone loss per implant on the rough implant surface. (a) During the first year of loading. (b) During the second year of loading.](image2)
implantitis (Heitz-Mayfield 2008; Heitz-Mayfield & Huynh-Ba 2009). Significantly more bone loss for implants, in the premolar and anterior regions compared with the molar regions, supporting fixed full dental prostheses has been reported previously, which may be due to more vertical loading forces (Bergqvist et al. 2009). In the present study, parafunction (clenching and bruxing during the day time, and grinding the bar during night) was found in one patient, in whom smoking, stress and susceptibility to periodontitis were also present. Another reason might be further resorption of the anterior jaw bone, leading to dehiscences, with circumferential bone loss, but there is not enough evidence for this as yet.

In general, short implants were unintentionally placed deeper (Fig. 2), but no increased bone loss was found (Fig. 5). Several previous studies indicated that bone loss is greater the deeper the rough/smooth interface is placed (Hammerle et al. 1996; Hermann et al. 2000; Hartman & Cochran 2004; Alomrani et al. 2005), but no such correlation was found in the present study.

Because different criteria for success and survival have been used in previous studies, it is difficult to compare with those results, but our data were comparable with previous reports on delayed, early or immediate loading protocols, which ranged between 94.4% and 100% (Zitzmann & Mariniello 2000; Raghoebarsing et al. 2003; Pieri et al. 2009). For most implants in the present study (65/72), it was possible to apply the early loading protocol, even in quality 4 bone. Only in one patient were two implants spinners, both a short and a long implant. Therefore, all six implants had to undergo a prolonged healing time. This had no consequences on further treatment, which makes it a predictable therapy.

There is a lack of a common definition of “short” implants, and most studies are not explicitly designed to evaluate short implants specifically. To our knowledge, this is the first study that has compared the outcome of additionally placed short implants with the outcome of longer implants, supporting a maxillary overdenture. Engquist et al. (1988) documented a two to three times higher failure rate when shorter implants of 7 or 10 mm were placed in the treatment of an overdenture. This higher failure rate has been confirmed by another 3- and 5-year follow-up (Jemt 1993; Jemt & Lekholm 1995). Those studies report on machined implant surfaces.

Previously, a significantly higher failure rate of machined implants (16% vs. 3.5%) has been reported for type IV bone quality compared with type I and II (Jemt et al. 1996; Goodacre et al. 2003). Studies with the chemically modified SLA surface have shown good success in immediate and early loading, although only reporting on partially edentulous patients, where 41.8% were placed in bone quality III and IV, with no failures in bone quality IV (Ganeles et al. 2008; Zöllner et al. 2008). The high success rates achieved, also for overdentures in the present study, may also be due to the improved wettability of this implant surface, where a better osteogenic response increased BIC (Buser et al. 2004; Schwarz 2007a, 2007b; Wall et al. 2009). Earlier stability versus conventional SLA in the critical first weeks of healing has also been demonstrated (Oates et al. 2007). These factors may therefore improve the success rate in early or immediate loading in sites with poor bone quality (type III and IV) and reduced bone height. Indeed, most implants in the present study were placed in type III and IV bone (76% and 56% of S and L implants), with satisfying results.

Unlike the mandible (McGill Consensus meeting, Montréal, 2003), there is no consensus today regarding the number of implants for a maxillary overdenture. However, a recent systematic review revealed that a maxillary overdenture, supported by six implants, which are connected with a bar, is the most successful treatment regarding the survival of both the implants and the overdenture (Slot et al. 2010).

Two additional short implants, as proposed by the present proof of concept, implicate an additional cost for the patient. The effectiveness against the costs might be an increase of the overdenture stability, due to the wider spread of the implants within the arch. A second advantage might be that it will prevent further posterior bone resorption, implicating less relinings of the prosthesis. There is no literature available today to argument these thoughts.

Shorter restoration times have become more widely accepted and practiced in recent years.
Typically, provisional restorations in partially edentulous patients are placed out of occlusion. The current protocol allowed loading after 6 weeks by a final overdenture. The results suggest that even in bone quality IV, a successful treatment can be expected with two additional short implants, early loaded, supporting an overdenture. The lower bone quality/density may be compensated by early splinting of all implants. Early loading in the present study avoided frequent relining during the first weeks when compared with immediate loading by the final overdenture [Pieri et al. 2009]. Prosthetic complications were limited. Previous reports also mentioned higher incidences of clip problems (17% retention, 22% fracture of clip) [Jemt et al. 1992]. Replacement of the clip has been mentioned as the most frequent requirement for repeated repair [Allen et al. 1997], while this was not needed in the present study. The low need for retightening the retainers during the 2-year observation period is in line with Kiener et al. [2001].

One of the limitations of this study is the lack of information on the forces applied by different opposite arch conditions. Because the patient population of the present study was limited, it was not possible to evaluate the influence of the applied forces of the opposing arch status on bone loss around the maxillary implants. For example, most patients had an antagonistic shortened arch with a history of periodontitis, which limits the possibility for achieving a fully balanced articulation, which might have a negative effect. It also remains an open question whether a full-fixed bridge on implants might result in stronger forces/more load of the maxillary implants. Because of a limited patient group, it was not possible to analyze the influence of confounding factors. In this group, confounding factors (e.g. smoking, diabetes and genetic predisposition), socio-economic conditions (including the social security system) and local risk factors (oral hygiene, SPT, number of teeth lost, remaining deep pockets) were comparable for both implant lengths.

Mucositis and gingival hyperplasia may be a disadvantage of overdentures [Jemt et al. 1996; Eckfeldt et al. 1997; Watson et al. 1997]. In the present study, 4/12 (33%) patients showed gingival hyperplasia compared with 22.5% in the study of Pieri et al. [2009]. This is often the case, when the space between the bar and the oral mucosa is limited. Often, short abutments are chosen to avoid bulky overdentures.

There might be a concern when excessive bone loss occurs at such short implants. The present protocol allows to remove the short implant(s), without a consequence on the prosthetic level, if four remaining implants survive. As there is not yet a consensus for the treatment of peri-implantitis, the removal of the implant might be the best solution to save the other implants from infection. Of course, it is not the intention of the placement of two extra implant, to loose them in the future. The removal of a short implant will be easier compared with long implants. A combination of 6 mm implants was suggested with longer implants for partial edentulism [Nedir et al. 2004], which may also explain the success of this treatment. Recent studies have shown that maximum bone stress is almost independent of implant length [Pierrisnard et al. 2003] and that implant width may be more important than length [Anitua et al. 2010].

Conclusion

This prospective study showed that short implants can be a successful alternative to bone augmentation techniques for this treatment concept, also in quality type III or IV bone. Clinical parameters for extra short implants of 6 mm were comparable to longer implants. If bone loss occurs on a short implant, a relatively larger portion is affected compared with longer implants, which may hamper the long-term success.

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References


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Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1.** CONSORT 2010 checklist of information to include when reporting a randomised trial*.

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