Early loading of single crowns supported by 6-mm-long implants with a moderately rough surface: a prospective 2-year follow-up cohort study

**Key words:** dental implants, early loading, implant length, prospective cohort, short implants, SLActive surface

**Abstract**

**Aim:** To evaluate prospectively the clinical and radiographic outcomes after 2 years of loading of 6 mm long moderately rough implants supporting single crowns in the posterior regions.

**Material and methods:** Forty SLActive Straumann® short (6 mm) implants were placed in 35 consecutively treated patients. Nineteen implants, 4.1 mm in diameter, and 21 implants, 4.8 mm in diameter, were installed. Implants were loaded after 6 weeks of healing. Implant survival rate, marginal bone loss and resonance frequency analysis (RFA) were evaluated at different intervals. The clinical crown/implant ratio was also calculated.

**Results:** Two out of 40 implants were lost before loading. Hence, the survival rate before loading was 95%. No further technical or biological complications were encountered during the 2-year follow-up. The mean marginal bone loss before loading was $0.34 \pm 0.38$ mm. After loading, the mean marginal bone loss was $0.23 \pm 0.33$ and $0.21 \pm 0.39$ mm at the 1- and 2-year follow-ups. The RFA values increased between insertion (70.2 ± 9) and the 6-week evaluation (74.8 ± 6.1). The clinical crown/implant ratio increased with time from 1.5 at the delivery of the prosthesis to 1.8 after 2 years of loading.

**Conclusion:** Short implants (6 mm) with a moderately rough surface loaded early (after 6 weeks) during healing yielded high implant survival rates and moderate loss of bone after 2 years of loading. Longer observation periods are needed to draw more definite conclusions on the reliability of short implants supporting single crowns.

In replacing missing teeth, osseointegrated implants have become a viable option, especially in the restoration of single tooth gaps (Lang & Salvi 2008). In the posterior regions, however, the location of anatomical structures, i.e. the inferior alveolar nerve and the maxillary sinus, may limit the availability of a sufficient bone volume to install oral implants. Such situations may require additional and complex surgical interventions to augment insufficient bone volume. Obviously, this will result in prolonged treatment times, and consequently, additional morbidity and costs.

An alternative therapy in situations with limited amounts of bone available is the installation of short implants, defined as implants with a length of ≤ 10 mm [e.g. Friberg et al. 1991; Jemt & Lekholm 1995; Feldman et al. 2004; Renouard & Nisand 2006]. The use of short implants simplifies the restoration of posterior segments of dentition substantially [ten Bruggenkate et al. 1998; Arlin 2006], and minimizes...

Especially in severely resorbed mandibles or maxillae, the placement of short implants may lead to a crown-to-implant (C/I) ratio that may be considered as being unfavorable (for a review, see Blanes 2009). It should be noted, however, that finite element analysis indicated the maximum bone strain to be essentially independent of implant length and bicortical anchorage [Pierresnard et al. 2003].

Clinical outcomes of short implants have been discussed and controversial results have been reported. According to some studies, short implants failed more frequently than long implants [Bahat 1993; Winkler et al. 2000; Naert et al. 2002; Weng et al. 2003]. Other authors, however, although admitting increased failure rates with shorter implants, suggested that short implants still presented with “adequate” survival rates [Van Steenberghe et al. 1990; Friberg et al. 1991; Jemt 1991; Lekholm et al. 1999]. Eventually, implant length was stated to not significantly influence survival rates at all [Buser et al. 1997; Brocard et al. 2000; Testori et al. 2001; Romeo et al. 2002; Stellingsma et al. 2003]. The reason for these controversial results may be found in the fact that smooth machined implant surfaces were compared with moderately rough or rough surface implants of equal length.

In recent years, numerous implant manufacturers opted to produce implants with surface modifications, and in general, rougher surfaces than hitherto propagated. This also led to the production of shorter implants. In a multicenter clinical study [ten Bruggenkate et al. 1998] 6 mm implants with a rough surface (TPS) were studied. The survival of 6 mm implants was comparable with that of longer implants. Even though in that study a number of single crowns were included, the authors recommended to splint short implants in the prosthetic restoration. Nevertheless, the number of studies on very short implants with clearly characterized surfaces is limited.

The aim of the present study was to evaluate prospectively the clinical and the radiographic outcomes after 2 years of loading of 6 mm implants with moderately rough (SLActive) supporting single crowns in the posterior regions.

Material and methods

Patient selection

All treatments were carried out by a single practitioner in a private dental practice in Bologna, Italy, in strict collaboration with the Special Surgery Unit, Department of Dental and Stomatological Sciences, University of Bologna, Italy, during a period between October 2006 and July 2007. Approval for the study by the local Ethical Committee and written consent by the patients were obtained.

To be recruited for the study, the patients had to meet the following inclusion criteria: Being

- at least 18 years of age;
- in good general health;
- willing to participate for the duration of the study;
- willing to provide informed consent;
- partially edentulous in the posterior region (premolars and molars);
- free from soft tissue, alveolar bone or dental pathologies; and
- dentate in the opposing jaw to obtain occlusal contacts.

Patients were excluded if they presented with

- uncontrolled diabetes mellitus;
- alcoholism;
- systemic immune disorders;
- insufficient bone quantity to place an implant of 6 mm length;
- previous implant and/or graft installation at the surgical site; and
- pregnancy.

Smoking and bruxism were recorded but were not considered as a contraindication to treatment. Patients were advised that smoking is associated with an increased risk of implant failure.

Thirty-five consecutively treated patients [22 females and 13 males; 28–70 years old (mean age 51), 10 of whom were heavy smokers (≥ 10 cigarettes/day), none with bruxism, in need of restorative treatment due to missing single or multiple premolars or molars were recruited.

Forty Straumann SLActive-modified surface implants, with a length of 6 mm [19 with a diameter of 4.1 mm, regular neck, and 21 with a diameter of 4.8 mm, wide neck], were installed according to the manufacturer’s recommendation.

Basic examination

Before enrollment in the study, patients were examined regarding periodontal disease, caries and bone availability at the experimental sites. They all received an appropriate treatment before implant installation.

- The following parameters were recorded for each patient:
  - Full-mouth plaque scores [O’Leary et al. 1972],
  - Full-mouth bleeding on probing [Lang et al. 1986] and
  - Number of periodontal pockets categorized in probing depth (PPD) = 4–5, 6–8 and ≥ 9 (Table 1).

Standardized intraoral radiographs were obtained, using individually fabricated film holders.

Surgical procedures

The surgical treatments were performed under local anesthesia [Articain with

| Table 1. Clinical conditions and radiographic bone levels at the various visits, from implant insertion to the 2-year follow-up (n = 38) |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | Plaque (%)      | BoP (%)         | Number of pockets ≥ 4 mm in categories | Radiographic bone level (mm) |
|                 |                 |                 | 4–5 6–8 ≥ 9 | M D |
| Implant insertion | 8               | 14.4            | 5 9 4         | 1.39 (0.8) 1.86 (0.87) |
| Prosthesis delivering | 8.5            | 15              | 5 9 4         | 1.77 (0.85) 2.15 (0.91) |
| 1 year | 8.7            | 15.9            | 6 9 4         | 2.01 (0.8) 2.36 (0.78) |
| 2 years | 8.7            | 15.9            | 6 9 4         | 2.24 (0.84) 2.57 (0.87) |
included 1 g amoxicillin (Amoxicillina®) and sutured to allow a transmucosal healing (Fig. 1a–b).

The final insertion torque and the resonance frequency analysis (RFA) values (Deng et al. 2008) were obtained at the time of surgery [Table 2].

A healing abutment was screwed onto the implant, and the flaps were repositioned and sutured to allow a transmucosal healing [Fig. 1a–b].

Medications prescribed to all patients included 1 g amoxicillin (Amoxicillin®), Merck Pharma, Milan, Italy) twice daily for 5 days; 600 mg Ibuprofen (Brufen®, Abbott S.R.L., Latina, Italy) as needed; and chlorhexidine mouthwashes 0.20% twice daily for 1 week.

No removable prosthesis was allowed during the healing phase. After a week, the sutures were removed. The wound was professionally cleaned after 1, 2 and 4 weeks. Any surgical complications were recorded [infection, pain, other adverse events] and, at the 6-week visit, RFA was again assessed [Table 2].

Restorative treatment

After about 6 weeks of healing, a synOcta® abutment was placed on the implants and tightened to 35 N cm, impressions were taken and a fixed prosthesis of gold palladium alloy and porcelain was fabricated and delivered to the patients after about 1 week [Fig. 1c–d]. All restorations were checked for adequate occlusal contact, and the framework fit was assessed using a pressure spot indicator paste. A standardized X-ray utilizing an individual template was obtained at the delivery of the prosthesis.

Follow-up protocol

Reexaminations were performed after 6–12 and after 24 months following placement of the crown. At each visit, implant survival and complications were evaluated, and the following parameters were assessed at each implant: plaque and bleeding scores in a dichotomous manner, and PPD at four aspects were obtained [Table 1]. Standardized intra-oral radiographs, utilizing an individual template, were obtained at the 1- and 2-year follow-ups [Fig. 2a–d].

Radiographic measurements

Measurements on radiographs were performed using a magnifying gradient index lens (Scale Lupe × 10, West Chester, PA, USA). Bone loss around the implants was assessed at mesial and distal aspects [Table 1]. According to a previous study (Blanes et al. 2007), the distance evaluated on radiographs from the working cusps to the margin of the implants was considered as the anatomical crown. The anatomical crown-to-implant ratio [anatomical C/I ratio] was then calculated considering the length of the implant being 6 + 2.8 mm [polished neck]. The clinical crown length was obtained by adding the extent of bone loss to the anatomical crown at the mesial and distal aspects. The clinical crown-to-implant ratio [clinical C/I ratio] was calculated by dividing the clinical crown length by the total length of the endosseous portion of the implant [8.8 mm minus bone loss] at the mesial and distal aspects. A mean value was calculated subsequently for each implant.

Data analysis

All variables evaluated at different periods were included in the analyses. The primary outcome variables were implant loss and peri-implant bone-level changes. Differences regarding radiographic bone-level changes at the various reexaminations and RFA were analyzed using Student’s t-test for paired observations. The level of significance was set at α = 0.05. Data from the clinical evaluations were considered as descriptors; the mean values and SD were calculated. A Pearson’s correlation coefficient was applied to test significant correlations among bone density, insertion torque and RFA. The level of significance was set at α = 0.05.

Table 2: Bone morphology type, insertion torque in N cm and RFA (ISQ) (n = 38)

<table>
<thead>
<tr>
<th>Bone morphology type</th>
<th>Insertion torque (N cm)</th>
<th>RFA (ISQ)</th>
<th>RFA (ISQ)</th>
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<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
<td>≤ 15 15 &lt; x ≤ 35 ≥ 35</td>
<td>Mean</td>
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<tr>
<td></td>
<td>8 24 8 0 17 11 10 70.2 (9) 42–84 74.8 (6.1)</td>
<td>60–84</td>
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*Difference from baseline statistically significant (P<0.01).
Results

Forty implants were installed, 19 (48%) of 4.1 mm diameter, regular neck, and 21 (52%) of 4.8 mm diameter, wide neck. Two implants with 4.1 mm diameter, one in a molar and the other in a premolar position, were lost before loading (early failure). Hence, the survival rate after healing (6 weeks) was 95%. All the 38 remaining implants were stable at abutment connection, carried out at 35 N cm without pain or rotation. No implants were lost after loading at the 2-year follow-up. Hence, the 2-year survival rate remained at 95%. No probing depth > 5 mm was detected at any implant sites.

Fourteen premolar (35%) and 26 molar regions (65%) were used. Twenty-five implants (63%), six in the premolar and 19 in the molar sites, were placed in the mandible, and 15 (37%) were installed in the maxilla. Eight of those were premolar and seven were molar sites in the maxilla. Ten implants, eight in the molar and two in the premolar regions, represented the last element of the dentition.

Bone morphology according to the criteria of Lekholm & Zarb (1985) was used to attribute implant sites as follows: eight Type 1 (20%), 24 Type 2 (60%), eight Type 3 (20%) and zero Type 4 (0%) (Table 2).

The mean values of the insertion torque were ≤ 15 N cm at 17 implants, between 15 and 35 N cm at 11 implants, and ≥ 35 N cm at 10 implants (Table 2).

The RFA mean value at implant insertion was 70.2 ± 9 (range 42–84), and at the 6-week evaluation, it was 74.8 ± 6.1 (range 60–84), with a mean increase of 4.6 ± 6.3 between the two time points (Table 2). This difference was statistically highly significant (P = 0.0001).

A positive correlation was found between insertion torques and RFA values, while negative correlations were found between bone morphology and insertion torques and between bone morphology and RFA values.

The mean values, standard deviation and range of clinical crown length and C/I ratios are reported in Table 3.

The mean anatomical crown length was 8.9 ± 1.7 mm (range 5.8–12.7 mm), the anatomical C/I ratio was 1 ± 0.2 (range 0.7–1.4). The mean length of the clinical crown as well as the clinical C/I ratio increased from the time of delivery of the prosthesis to the 2-year follow-up: 10.5 ± 1.9–11.3 ± 2.1 and 1.5 ± 0.3–1.8 ± 0.6 mm, respectively.

The mean bone level around implants at the mesial and distal aspects is reported in Table 1. The bone loss between the various intervals is reported in Table 4. Almost all implants (35 out of 38) showed bone loss between implant insertion and the 2-year follow-up period [mean value 0.75 ± 0.71]. Bone loss was observed between loading and the 2-year follow-up visit at 29 out of 38 implants (0.43 ± 0.49).

Discussion

The present prospective cohort study demonstrated that short 6 mm implants loaded in an early phase of the healing (after...
6 weeks] support single crowns with a high degree of implant survival and a minimal loss of marginal alveolar bone after 2 years. However, an initial failure rate of 5% was encountered during the pre-loading phase (two implants out of 40). This is twice as high as that reported in a systematic review (Berglundh et al. 2002) on complications in implant therapy. While there was an initial implant failure rate of 2–3%, single tooth replacement only yielded an initial failure rate of 0.8% before loading [Berglundh et al. 2002]. In a more recent systematic review on single crowns supported by implants [Jung et al. 2008], the initial failure rate for implants before loading was 1.9%. These rates refer to implants of “normal” length, i.e. >8 mm and are obviously much lower than the failure rate of the present study. However, it has to be kept in mind that the loss of one implant in the present study already constitutes 2.5%, as the size of the cohort is small (n = 40). Hence, the study is certainly underpowered to claim a reliable initial failure rate for short implants. Because both patients who each lost an implant were heavy smokers, the failure rate may have been determined by a confounding risk factor. In addition, one of the failing implants had been placed into very dense cortical bone, while the other failing implant was inserted with a very low torque (<15 N·cm), with a low ISQ value (42) and a Type III morphology of bone. It may be anticipated, therefore, that these implants failed as a result of overheating the parent bone in the former or a lack of primary stability in the latter case.

In the present study, the abutment connection was performed with a torque of 35 N·cm after 6 weeks of healing, and neither pain nor rotating implants were noted. This is in agreement with other studies that applied similar torques to the same implant system after the same healing period [Cochran et al. 2002; Rocuzzo et al. 2008]. In those studies, however, implants longer than 6 mm and with a conventional SLA surface were placed while, in the present, 6 mm implants with an SLActive® surface were used. It was recently suggested that osseointegration may have occurred slightly more rapidly in implants with an SLActive®-modified surface compared with the standard SLA surface of the Straumann® implant [Buser et al. 2004].

SLA and SLActive® surfaces are in the category of a moderately rough surfaces that has been identified to be a surface category resulting in superior BIC% and faster osseointegration than mildly rough or smooth machined surfaces [for a review, see Wennemer & Albrektsson 2000]. An animal study on the sequential events during the healing process in non-submerged implants has clearly documented that smooth surface implants lag behind moderately rough surface implants during the osseointegration process [Abrahamsson et al. 2004]. This was revealed both by BIC% as well as the proportion of woven or lamellar bone, especially during the first 4–6 weeks of healing.

In the present study, no implants were lost after loading and during the 2-year period of follow-up. This is in agreement with other clinical studies that reported a high success rate on single crowns supported by implants with an SLActive-modified surface [Ganeles et al. 2008; Zöllner et al. 2008]. Moreover, it is in agreement with studies that reported a high success rates and using short implants (for a review, see Renouard & Nisand 2006). For instance, 6 mm Straumann® implants with a moderately rough surface were used and a success rate of 94% was reported after 2 years of loading [Arlin 2006]. However, it should be mentioned that a substantially lower success rate (<80%) was presented for 7 mm implants with a machined surface after 3 and up to 6 years of follow-up [i.e. Winkler et al. 2000; Weng et al. 2003]. Again, the surface configuration of the implants may be the more significant factor than implant length in determining survival.

Statistically significant correlations were found between bone morphology, insertion torques and initial ISQ values in the present study. The ISQ mean value after 6 weeks was higher compared with the initial registration, and the difference was statistically significant. This is in agreement with other human studies [Zhuang et al. 2007; Lai et al. 2008] in which implants with an SLA surface were used. Decreasing ISQ values up to 4 weeks and increasing values thereafter are a common phenomenon of RFA during osseointegration [Han et al. 2010; Sim & Lang 2010]. Regarding the C/I, it has been suggested [Blanes et al. 2007] that the fulcrum of the lever arm acts on the marginal bone due to the rigidity of the C/I connection and the elasticity of the bone. Concern was expressed that this may eventually lead to marginal bone resorption. Hence, the calculation of the C/I ratio was to be performed using the clinical and not the anatomical crown (C). This represents the distance between the cusp of the crown and the most coronal contact of the bone to the implant. Consequently, the clinical implant length (L) is measured from the most coronal contact point of the bone to the implant (B) to the apex of the implant. An initial C/I of 1.77 was reported for standard implants. In the present study, the clinical C/I ratios increased during the evaluation period from 1.5 at delivery of the prosthesis to 1.8 after 2 years of loading. Consequently, the lever arm increased accordingly. Studies that used mathematical models [Iplikcioglu & Akca 2002; Pierrisnard et al. 2003] reported that the longer the lever arms, the greater the marginal mechanical strain around dental implants. This, in turn, means that marginal bone levels could be affected with time. However, the recent systematic review [Blanes 2009] was unable to confirm this hypothesis.

Bone resorption around implants from the time of implant insertion to the 1-year follow-up was 0.56 ± 0.50 mm. This low rate of marginal bone resorption during the first year after implant installation is in agreement with other studies that report similar data [e.g. Luongo et al. 2005; Ganeles et al. 2008]. Moreover, in the present study, a rate of bone resorption of 0.23 ± 0.33 mm was observed during the first year and 0.21 ± 0.39 mm was observed during the second year of function. This, again, is substantially higher than the rate of bone loss reported [0.03 ± 0.02 for the first 2 years] for standard [Astra Tech] implants with a moderately rough surface [Wennström et al. 2005]. However, it should be emphasized that the margin of the implant was located 2.8 mm from the border of the SLA rough/smooth surface interface at the time of implant installation. This, in turn, means that radiographically, the bony margin was still located above the border of the rough/smooth interface after 2 years. The major bone-level changes have been documented to occur during the first year of loading at implants installed in healed
longer observation periods [Wennström et al. 2005] as well as at implants installed immediately into extraction sockets [Botticelli et al. 2008]. In the present study, most bone resorption occurred during the pre-loading period (0.34 ± 0.38). The remodeling around the marginal bone still seemed to be ongoing at the second year of follow-up and hence, longer observation periods would be desirable for evaluation of resorptive and remodeling processes.

The results of the present cohort study suggest that installation of 6 mm implants with an SLActive®-modified surface yielded high implant survival rates and moderate loss of bone after 2 years of loading. Longer observation periods are needed to draw more definite conclusions on the reliability of short implants supporting single crowns.

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References


Rossi et al. Early loading of short implants


