Aesthetic outcome of single-tooth implant restorations following early implant placement and guided bone regeneration: crown and soft tissue dimensions compared with contralateral teeth

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Abstract

Objectives: The aim of this study was to compare crown and soft tissue dimensions of single-tooth implant restorations following early implant placement and guided bone regeneration (GBR) with contralateral non-restored teeth.

Material and methods: Twenty-seven patients treated by one and the same surgeon and prosthetist to restore a single-tooth gap with a class I bone defect in the premaxilla by means of an implant-supported restoration were reviewed. Patients were examined at least 6 months following placement of the crown. All implants had been inserted 6–8 weeks following tooth extraction in conjunction with GBR. At evaluation, crown dimensions, soft tissue dimensions, clinical conditions and patients’ aesthetic satisfaction were assessed by one clinician who had not been involved in the treatment.

Results: Implant-supported crowns were not significantly longer than contralateral teeth and midfacial soft tissues showed comparable levels after on average 21 months of function. Our data also indicated significant papilla loss especially at the distal aspect of the implants. As the patient’s aesthetic appreciation was favourable in 88% of the cases, this appeared to be of trivial importance.

Conclusions: Favourable aesthetics may be achieved for single-tooth implant restorations following early implant placement and GBR. The impact of the latter on papilla levels, however, remains to be determined in longitudinal studies.

Single-tooth replacement by means of an implant-supported restoration has become a viable treatment option [Creugers et al. 2000; Romeo et al. 2002; Wennström et al. 2005; Levin et al. 2006]. Highly predictable results in terms of osseointegration and straightforward restorative procedures excluding the need to sacrifice a sound tooth structure may explain this evolution. Still, achieving an aesthetically optimal result is not self-evident as this is determined by a number of factors: tooth-related factors such as tooth dimensions, form and colour contribute to aesthetics as well as soft tissue-related factors including inter-dental and midfacial soft tissue dimensions, texture and colour. Complexity increases when the buccal bone lacks volume to safely imbed the implant, thereby making a staged surgical approach inevitable including bone augmentation. This is apparent when part of the buccal bone wall is missing upon extraction of the failing tooth. However, recent findings suggest that extensive resorption of even intact buccal plates is a common phenomenon following tooth removal [Schropp et al. 2003; Araujo & Lindhe 2005]. In addition,
immediate implant placement has no impact on this remodelling process, making it a potentially risky procedure for aesthetic failure if patients are not well selected [Botticelli et al. 2004; Araujo et al. 2005; De Rouck et al. 2008b]. Clearly, the vast majority in clinical practice do not qualify for such an approach. In these patients, early implant placement, usually combined with guided bone regeneration (GBR) in the aesthetic zone, can be pursued with the following advantages: first, a 6- to 8-week time span following tooth extraction ensures that bone resorption – which is an inevitable event – will have occurred by extent. Thereby, the actual bone volume can be more accurately assessed during implant surgery and bone augmentation. Second, postponing implant placement by 6–8 weeks allows the soft tissues to heal, thereby facilitating primary wound closure. This is imperative when bone augmentation is simultaneously performed. Even though early implant placement combined with GBR has become a well-documented technique [Hämmerle & Lang 2001; Zitzmann et al. 2001; Juodzbalys et al. 2007], insights in terms of aesthetic results are very scarce.

To our knowledge, crown and soft tissue dimensions of single-tooth implant restorations following early implant placement and GBR have never been compared with contralateral natural teeth. These teeth can, however, be considered the ultimate reference in terms of symmetry and therefore aesthetics. The aim of this study was to document this on the basis of 27 treated patients.

Material and methods

Patient selection
Subjects were retrospectively recruited among those who had been treated for dental implants by one and the same surgeon [J.C.] and prosthodontist [T.D.R.] between 2002 and 2007 at the Dental Clinic of the Free University of Brussels [VUB]. Patients in supportive care [one to two times a year] fulfilling the following eligibility criteria were asked to come in for clinical and radiographic examination:

1. one single-tooth implant restoration in the aesthetic zone [15–25] in situ;
2. implant placed in an early healing stage, that is between 6 and 8 weeks following tooth removal;
3. GBR performed in conjunction with implant surgery using Bio-Oss® [Geistlich Biomaterials, Medipus, Rixensart, Belgium: 0.25–1 mm] and Bio-Gide® [Geistlich Biomaterials, Medipus: 25 × 25 mm] to eliminate a class I bone defect [Seibert 1983];
4. non-restored contralateral tooth; and
5. implant restoration at least 6 months completed.

Forty-two patients had been treated between 2002 and 2007 to restore a single-tooth gap with a class I bone defect by means of early implant placement and GBR. Fifteen patients were excluded because of the following: patient rejection (n = 4), restored contralateral tooth (n = 8), and implant restoration <6 months completed (n = 3). Twenty-seven patients [mean age: 50 years; SD: 10; range 27–73] were compliant with supportive care, met the eligibility criteria and agreed to analysis. Nine of the subjects were men, and 18 were women. The average number of months between connection of the restoration and the recall appointment was 21 months [SD: 17; range 6–68]. Out of the 27 qualifying single-tooth implant restorations, 10 (37%) were in a central incisor position, six (22%) in a lateral incisor position, four (15%) in a canine position, six (22%) in a first premolar position and one in a second premolar position.

Surgical procedure
A case is shown in Fig. 1 illustrating the surgical procedure. In all patients, implant surgery was preceded by screening and a comprehensive clinical and radiographic examination performed by two experienced clinicians [J.C./T.D.R.]. Thereupon, a treatment plan was proposed to the patient. The surgical procedure always included antibiotic and analgesic therapy [Amoxicillin/Clavulanic acid 500 mg and Ibuprofen 600 mg], both started 1 h pre-operatively. Oral disinfection was performed using a 0.2% chlorhexidine digluconate mouthwash [Corsodyl®, GlaxoSmithKline, Genval, Belgium]. A mucoperiosteal flap was prepared as follows: sulcular incisions at both teeth facing the single-tooth gap were connected via a palatally oriented crestal incision. In addition, two buccal releasing incisions at the para-median aspect, more specifically at the distal line-angle of both adjacent teeth, were performed. Following full-thickness flap elevation, all patients received a commercially available implant [Nobelreplace tapered TiUnite®, Nobel Biocare, Göteborg, Sweden], inserted according to the manufacturer’s instructions. Special attention was paid to a correct selection and three-dimensional positioning of the implant as described by Buser et al. [2004]. In the mesiodistal dimension, a distance of the implant shoulder to the neighbouring teeth of about 2 mm was pursued. As a result, implants had a diameter of 3.5 mm in a lateral incisor position and 4.3 mm in all other positions. In the orofacial dimension, the implant shoulder was positioned palatal to the point of emergence at the adjacent teeth. In the apicocoronal dimension, the implant shoulder was located 1–2 mm below the cemento-enamel junctions at the facial aspect of the adjacent teeth. Implant length varied from 10 to 16 mm. Following installation, multiple bone perforations were performed in the buccal bone wall and the peristium was released. In case of buccal dehiscence, autogenous bone chips (usually harvested from the base of the alveolar process and/or the nasal spine) were placed in direct contact with the exposed area of the implant. Bovine bone granulæ [Bio-Oss®, Geistlich Biomaterials, Medipus: 0.25–1 mm] soaked in blood were applied above. If no implant exposure had occurred, GBR only included the application of bovine bone granulæ soaked in blood. The site was deliberately overbuilt and the graft was covered by two or more layers of a commercially available collagen membrane [Bio-Gide®, Geistlich Biomaterials, Medipus: 25 × 25 mm]. Primary tension-free wound closure was finally achieved by means of multiple single sutures [Vicryl® 5/0, Johnson & Johnson, St-Stevens-Woluwe, Belgium]. Post-operative instructions included cryotherapy during the first 24 h, continued antibiotic and analgesic treatment for 5 days and oral disinfection for 2 weeks. Sutures were removed at 2 weeks post-operatively.

Restorative procedure
After an osseointegration period of 3 months, the implant was uncovered by means of a punch technique and an appro-
appropriate healing abutment was connected, followed by 2–3 weeks of soft tissue healing. Thereupon, an open tray impression coping (Nobel Biocare) was attached and a pre-selected disposable tray (Coe, disposable impression tray, GC America, Alsip, IL, USA) was appropriately perforated. The implant impression was made using a polyether impression material (Impregum Pentamix, 3M ESPE, Seefeld, Germany). Special attention was paid to an accurate replication of the soft tissue architecture. On the master model, the final configuration of the restoration was defined by means of a wax-up, thereby basically copying the clinical crown of the contralateral tooth irrespective of the underlying implant position and inclination. After this preparatory step, the technician selected the appropriate aesthetic titanium abutment (Aesthetic Abutment, Nobel Biocare) on the basis of the implant angulation and depth of the implant shoulder in reference to the midfacial soft tissue margin. A distance of the latter to the abutment–crown interface of about 1 mm was pursued to avoid deep cementation of the crown. (Precious) metal–ceramic restorations were fabricated in all cases. The minor palatal position of the implant in reference to the point of emergence at the adjacent teeth enabled the ceramist to ensure a flat to a slightly concave emergence profile of the cosmetic porcelain. No attempt was made to condition the soft tissues by means of a provisional crown in any of these patients. All restorations were cemented using temporary cement (Temp-Bond, Kerr, Sca-fati, Italy). Oral hygiene instructions were reinforced following installation of the implant-supported crown.

Clinical examination
At the recall appointment, the following variables related to crown dimensions, soft tissue dimensions and clinical conditions were recorded at both the implant-supported restoration and the contralateral tooth by one and the same trained clinician who had not been involved in the surgical/restorative procedures [I.W.]:

Crown dimensions
All recordings were made using a measuring rod to the nearest 0.1 mm [Fig. 2].
- **Clinical crown length**: the distance from the midfacial soft tissue margin to the incisal edge.
- **Crown width**: the widest mesio-distal dimension between the marginal ridge mesial and the distal convexity on the facial aspect of the crown.
- **Facio-palatal crown dimension**: the widest distance at the cervical third of the crown between the facial and the palatal aspect of the crown.

Soft tissue dimensions
All recordings were made using a periodontal probe (CP 15 UNC, Hu-Friedy, Chicago, IL, USA) to the nearest 0.5 mm.
- **Keratinized mucosa width**: the distance between the midfacial gingival margin and the mucogingival junction.
- **Midfacial soft tissue level**: the distance of the midfacial soft tissue margin at the crown to a line connecting the midfacial soft tissue margin of the two adjacent teeth. If the level at the crown

Fig. 1. Case illustrating the surgical procedure. (a) Clinical view before removal of tooth 11. (b) Full-thickness mucoperiosteal flap with two releasing incisions and insertion of a 4.3 × 16 mm implant at 8 weeks following tooth extraction. Although the buccal wall was intact at the time, extensive bone loss had occurred within a 2-month time frame. (c) Harvesting of autogenous bone chips from the nasal spine to cover the exposed area of the implant. (d) Application of bovine bone particles soaked in blood on top of the autogenous bone chips following multiple buccal wall perforations and release of the periosteum. (e) Collagen membrane applied in a double layer to cover and stabilize the particles. (f) Result after 6 months of function.

Fig. 2. Measuring rod used to record crown dimensions to the nearest 0.1 mm. The facio-palatal dimension is measured at the cervical third of the crown.
was located apical to this line, a negative value was scored. If the level at the crown was located coronal to this line, a positive value was attached.

- **Papilla height**: the distance of the top of the papilla (mesial and distal) to a line connecting the midfacial soft tissue margin of the two adjacent teeth.

### Clinical conditions

- **Plaque score**: percentage of visible plaque measured on four sites per implant and tooth (mesial, midfacial, distal, and palatal) at the soft tissue margin.
- **Probing depth**: measured to the nearest 0.5 mm at four sites per implant and tooth (mesial, midfacial, distal, and palatal) using a manual probe (CP 15 UNC, Hu-Friedy).
- **Bleeding on probing**: percentage of bleeding on probing measured at four sites per implant and tooth (mesial, midfacial, distal, and palatal).

### Patient’s aesthetic satisfaction

Patients were asked to express their satisfaction in reference to the aesthetic outcome on the basis of a 10 cm visual analogue scale labelled with ‘not at all satisfied’ at the zero point and ‘completely satisfied’ at the right end point. A staff member (I.W.), who had not been involved in the treatment, was charged with presenting the following question: ‘How would you rate your satisfaction with respect to the aesthetic outcome of your treatment?’

### Statistical analysis

For all variables, the mean values and standard deviations were calculated. The Wilcoxon signed ranks test was used to compare implant-related with tooth-related data. The level of significance was set at 5% for each comparison.

### Results

#### Post-operative complications

Post-operative complications included temporary swelling of the upper lip and haematoma formation in practically all patients. Pain was a relatively uncommon complication, which may be related to intensive analgesic therapy. Wound dehiscence did not occur following tension-free closure in these subjects. In one patient, bovine bone particles perforated the mucosa after 6 weeks. Spontaneous closure was re-established after removal of the granulae and antiseptic therapy for 1 week (chlorhexidine spray 0.2% twice a day).

### Implant success

Based on the clinical and radiographic criteria for success proposed by Smith & Zarb (1989), all implants were successful at the time of evaluation.

#### Crown dimensions

Table 1 shows the crown dimensions for implant-supported restorations and contralateral teeth. Clinical crown length was not significantly different between implant crowns and teeth ($P = 0.266$). The mean disparity in the crown width of 0.2 mm, however, nearly reached the level of significance ($P = 0.056$). The facio-palatal dimension was on average 0.4 mm smaller for implant-supported crowns when compared with contralateral teeth ($P \leq 0.001$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Implant-supported crowns</th>
<th>Contralateral teeth</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical crown length (mm)</td>
<td>10 (1.7)</td>
<td>9.7 (1.5)</td>
<td>0.3 (1.1)</td>
</tr>
<tr>
<td>Crown width (mm)</td>
<td>7.8 (1.4)</td>
<td>7.6 (1.2)</td>
<td>0.2 (0.6)</td>
</tr>
<tr>
<td>Facio-palatal crown dimension (mm)</td>
<td>7.5 (0.8)</td>
<td>7.9 (1.1)</td>
<td>−0.4 (0.5)*</td>
</tr>
</tbody>
</table>

*Highly significant difference: $P \leq 0.001$

#### Soft tissue dimensions

Table 2 presents the data describing soft tissue dimensions at implant-supported crowns and contralateral teeth. The width of the keratinized mucosa was comparable at implants and teeth ($P = 0.673$). The midfacial soft tissue level was also similar for both ($P = 0.362$).

A borderline significant difference ($P = 0.053$) was found in the mesial papilla height between implant crowns and contralateral teeth showing a shorter papilla by on average 0.4 mm at implant restorations. The distal papilla was on average 1 mm shorter at implant restorations in comparison with the corresponding site at contralateral teeth ($P \leq 0.001$).

#### Clinical conditions

The clinical conditions in terms of plaque score, probing depth and bleeding on probing at implant restorations and teeth are
depicted in Table 3. As all were well-compliant patients in supportive care, the data indicated low mean plaque levels (<20%). Furthermore, the percentage of plaque-harbouring sites was equal at implants and teeth \(P = 0.305\).

In contrast, probing depth was on average 0.9 mm greater at implants when compared with contralateral teeth \(P < 0.001\). Probing depth never exceeded 5 mm at implant sites.

The mean percentage of bleeding sites on probing was relatively high at implants (27%). Only 9% of the tooth sites showed bleeding. The difference was highly statistically significant \(P = 0.001\).

**Patient’s aesthetic satisfaction**

Patient’s aesthetic satisfaction, as determined by a visual analogue scale, indicated a mean score of 88%, with a range from 69% to 98%.

**Discussion**

Implant aesthetics is considerably receiving attention from the scientific community. This is not surprising as patients have become more demanding in terms of aesthetics. For a restoration to be successful, it should closely resemble what once existed in nature from a functional and an aesthetic point of view. In this way, the original data related to the healthy natural tooth and its gingival architecture are essential when studying aesthetics of single-tooth implant restorations as these data characterize the ultimate treatment objective. Actually, however, original tooth- and soft tissue-related data are lacking in the vast majority of clinical cases, often because the tooth has already been removed when implant surgery is planned. Even if the failing tooth is still *in situ*, crown and/or soft tissue dimensions are seldom intact as a result of pathologic conditions. Chang et al. (1999) used the healthy contralateral natural tooth instead of the failing tooth to study the aesthetic treatment outcome of single-tooth implant restorations. This may be appropriate as aesthetics is all about harmony and symmetry with the surrounding teeth and soft tissues. The goal of the present study was to evaluate the crown and soft tissue dimensions of single-tooth implant restorations following early implant placement and GBR using the method described by Chang et al. (1999). As GBR has become a standard procedure especially in the maxilla, accurate documentation on the aesthetic treatment outcome is clearly essential.

This study indicated comparable clinical crown length for implant-supported restorations and contralateral teeth. In line with this observation, our data showed similar midfacial soft tissue levels at implant crowns and teeth. These favourable midfacial soft tissue levels may have been the result of a strict orofacial implant position characterized by a slightly palatal shoulder location in relation to the point of emergence at the adjacent teeth. Alternatively, a buccal shoulder position may result in considerable midfacial soft tissue recession as shown by Evans & Chen (2008). Also, the apicocoronal implant position may be relevant in this respect. Even though a biologic width of 3–4 mm will be established, deep implant shoulders increase peri-implant inflammation, possibly contributing to excessive bone loss and in turn soft tissue recession (Hermann et al. 2001; Brüggini et al. 2006). Another reason why favourable midfacial soft tissue levels were found at implant crowns in our study could be related to the fact that one-third of the tooth replacements were central incisors. As the operated neighbouring tooth was the contralateral control in these cases, recession could have masked a possible disparity in midfacial soft tissue levels at implant crowns and teeth, thereby favourably influencing the results at implant crowns. On the other hand, the mean difference in the clinical crown length between implant-supported restorations and contralateral teeth was hardly affected when the central incisor sites were excluded from the analysis. In fact, the difference even slightly decreased from 0.3 to 0.1 mm, thereby substantiating our earlier conclusion. In the report by Chang et al. (1999), crowns supported by implants were on average 1 mm longer than clinical crowns of contralateral teeth and midfacial soft tissue levels seemed to be more apically positioned at implant restorations. Chang et al. (1999) included data on single-tooth implants that had been conventionally inserted without bone augmentation. These findings substantiate the relevance of GBR in optimizing aesthetics at the midfacial aspect of single-tooth implant restorations in the maxilla. By and large, however, augmentation procedures do not seem to prevent remodelling of the peri-implant tissues. Grunder (2000) evaluated soft tissue stability around 10 single-tooth implants, which had been installed following a surgical protocol including GBR and connective tissue grafting, and described significant midfacial soft tissue recession pointing to an average 0.6 mm after 1 year of function. Interestingly, this apical displacement of the soft tissue margin is of a magnitude comparable to the amount of recession that can be anticipated at single-tooth implants inserted using a standard surgical approach without simultaneous augmentation (Bengazi et al. 1996; Small & Tarnow 2000; Cardaropoli et al. 2006). In this regard, immediate implant insertion is also not superior to implant placement into healed sites, as a number of studies on immediately placed single-tooth implants have indicated midfacial soft tissue recessions between 0.5 and 0.75 mm after 1 year of function (Kan et al. 2003a; Cornelini et al. 2005; De Rouck et al. 2008a). Evidently, minor midfacial soft tissue recession in the early phase of healing, possibly as a result of adaptation to adequate biological dimensions, seems to be an inevitable phenomenon at implant-supported restorations irrespective of the treatment modality, at least when a flap has been raised during implant surgery.

In contrast to our results, a poor aesthetic treatment outcome as rated by a clinician has recently been reported for single-tooth replacements using different bone augmentation procedures (Meijndert et al. 2007). In this regard, one should realize that these patients had undergone bone augmentation before implant surgery as the residual hard tissue support did not allow for a simultaneous approach. Clearly, the starting point of these subjects had to have been less favourable than the one of our patients showing class I bone defects. At least based on the cases we treated likewise in our centre, most of them showed excessive horizontal as vertical bone loss and/or bone resorption at one or both adjacent teeth. These conditions make an ideal soft tissue outline biologically impossible. More accurate data on the aesthetics of these complex cases treated in...
a staged approach, for instance using the method by Chang et al. [1999], are needed in the future.

Besides midfacial soft tissue levels, interproximal papillae are of particular concern in terms of the aesthetic treatment outcome. This study indicated papilla loss at both the mesial as well as the distal aspect of single-tooth implant restorations, which is in accordance with other studies [Chang et al. 1999; Kan et al. 2003a; De Rouck et al. 2008a]. The borderline significant difference in mesial papilla height should be interpreted with some caution since one-third of the tooth replacements were central incisors in this study. Obviously, the mesial papilla is shared between the tooth and the implant in these cases, thereby masking possible differences. This may be substantiated by the fact that the mean difference in mesial papilla height between implant-supported restorations and contralateral teeth was increased from 0.4 to nearly 0.6 mm following exclusion of the central incisor sites. When comparing the results of this study concerning papilla height with what has been earlier reported by Chang et al. [1999], it is striking that our data showed by and large 0.5–1 mm shorter papillae. These findings suggest a possible impact of GBR on neighbouring papillae. Another explanation could be a difference in the time span between crown installation and clinical examination, which was on average 38 months in the study by Chang et al. [1999] and 21 months in the present study. In this regard, an increase in papillary soft tissue volume can be expected over time [Jemt 1997; Chang et al. 1999; Grunder 2000; Cardaropoli et al. 2006]. It is strongly believed that the presence of papillae surrounding an implant-supported restoration is principally driven by the level of the alveolar bone and the presence of supracrestal fibers on the neighbouring teeth [Choquet et al. 2001; Kan et al. 2003b]. To what extent such papilla regeneration over time occurs following GBR needs to be elucidated in longitudinal studies. Longitudinal data would also be of interest to monitor the bucco-lingual dimension of the ridge following GBR.

Despite partial papilla loss, patient’s aesthetic satisfaction was on average 88%. This appreciation by the patient seems to be relevant in assessing the aesthetic outcome as there is not necessarily a correlation between the clinician’s evaluation and the patient’s opinion [Meijndert et al. 2007].

At present, the impact of the restorative procedure on the aesthetic outcome of single-tooth implants placed according to the present protocol is unclear. Very recently, instant provisionalisation of immediate single-tooth implants has been shown to optimize midfacial aesthetics [De Rouck et al. 2009]. However, this may not hold true for single-tooth implants placed according to a conventional surgical approach without simultaneous bone augmentation, thereby questioning the need for soft tissue conditioning in standard cases [Hall et al. 2007]. In this study, provisional crowns were not installed to condition soft tissues.

In spite of the fact that there were no significant differences in the presence of plaque between implant restorations and teeth, probing induced significantly more bleeding around implants. This is, however, not an uncommon finding [Chang et al. 1999; Lorenzoni et al. 1999; Roos-Jansaker et al. 2006; Ozkan et al. 2007] as a result of an ‘inflammatory cell infiltrate’ possibly induced by microleakage at the implant–abutment interface [Piattelli et al. 2003; Broggini et al. 2006] and the subgingival position of a restoration border [Jemt & Pettersson 1993]. Probing depth was also considerably higher around implants when compared with contralateral teeth, which can be considered a normal phenomenon especially around two-piece implants [Lekholm et al. 1986; Apse et al. 1991; Proussaefs et al. 2002].

In conclusion, early implant placement in conjunction with GBR at single-tooth gaps with class I bone defects did not result in significant displacement of midfacial soft tissue levels, at least not in comparison with corresponding levels at contralateral teeth. Our data also indicated significant papilla loss, especially at the distal aspect of single-tooth implants. The impact of the GBR on papilla levels is currently unclear and needs to be evaluated in longitudinal studies. We wish to emphasize that this is a cross-sectional exploratory study using soft tissue levels at intact contralateral teeth as a reference. The fact that these reference levels may not be fully stable over time can be considered a drawback. However, we believe this is of minor importance as aesthetics is all about harmony and symmetry at any given point in time. At least after, on average, 21 months of function, these restorations and their surrounding soft tissues appeared to be aesthetically satisfying.

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References


