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Immediate single-tooth implants in the anterior maxilla: a 1-year case cohort study on hard and soft tissue response

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Abstract

Aim: The objective of the present study was to assess implant survival rate, hard and soft tissue response and aesthetic outcome 1 year after immediate placement and provisionalization of single-tooth implants in the pre-maxilla. All patients underwent the same strategy, that is mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material between the implant and the socket wall and the connection of a screw-retained provisional restoration.

Material and Methods: Thirty consecutive patients were treated for single-tooth replacement in the aesthetic zone by means of immediate implant placement and provisionalization. Reasons for tooth loss included caries, periodontitis or trauma. At 6 months, provisional crowns were replaced by the permanent ones. Clinical and radiographic evaluation was completed at 1, 3, 6 and 12 months to assess implant survival and complications, hard and soft tissue parameters and patient's aesthetic satisfaction.

Results: One implant had failed at 1 month of follow-up, resulting in an implant survival rate of 97%. Radiographic examination yielded 0.98 mm mesial, respectively, 0.78 mm distal bone loss. Midfacial soft tissue recession and mesial/distal papilla shrinkage were 0.53, 0.41and 0.31 mm, respectively. Patient's aesthetic satisfaction was 93%.

Conclusions: The preliminary results suggest that the proposed strategy can be considered to be a valuable treatment option in well-selected patients.

Key words: dental implants; hard tissue; immediate implantation; immediate loading; maxilla; single-tooth; soft tissue

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The prosthetic rehabilitation of a single maxillary anterior tooth with an implant-supported fixed prosthesis is an accepted concept. The original Brånemark protocol suggested 3 months of soft and hard tissue healing following tooth removal and an additional 3–6-month load-free osseointegration period (Albrektsson et al. 1981, Branemark 1983). This leads to many months of waiting with an uncomfortable removable partial denture and several surgical interventions. Based on the aforementioned concerns, patients occasionally prefer a traditional, sometimes destructive, bridge construction.

In the last decade, Implant Dentistry has evolved considerably: the original protocol has been modified by several investigators to include one-stage surgery (Becker et al. 1997), immediate post-extraction implant placement (Lazzara 1989, Werbitt & Goldberg 1992, Polizzi et al. 2000) and immediate provisionalization (Gomes et al. 1998, Ericsson et al. 2000). Studies have been published in which these three approaches are combined (De Rouck et al. 2007). Most of these reports focused, however, on implant survival and preservation of hard tissues, with much less attention to the soft tissue architecture. Needless to say, the aesthetic success of a restoration

Conflict of interest and source of fundings statements

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is determined by the harmony of the hard and soft tissues (Touati 1995, Grunder et al. 1996).

In this study, single-tooth replacement was performed by means of muco-periosteal flap elevation, immediate post-extraction implant placement, insertion of a grafting material and the connection of a screw-retained provisional restoration. The rationale of this treatment concept and its outcome on hard and soft tissues following a 1-year study period are discussed in this paper.

Material and Methods

Patient selection

This study included 30 consecutively treated cases in 30 different patients at the Dental Clinic of the Free University in Brussels (VUB). Patients were selected during a screening visit on the basis of inclusion and exclusion criteria.

Inclusion criteria were as follows:

1. At least 18 years old.
2. Good oral hygiene.
3. Presence of a single failing tooth in the anterior maxilla (15–25) with both neighbouring teeth present.
4. Ideal soft tissue contour at the facial aspect of the hopeless tooth in perfect harmony with the surrounding teeth.
5. Normal to thick-flat gingival biotype.
6. Adequate bone height apical to the alveolus of the failing tooth ($\geqslant$5 mm) to ensure primary implant stability of at least 35 N cm.

Exclusion criteria were as follows:

1. Systemic diseases.
2. Smoking ($\geqslant$10 cigarettes a day).
3. Bruxism, lack of posterior occlusion.
4. Non-treated periodontal diseases.
5. Presence of active infection (pus, fistula) around the hopeless tooth.
6. Loss of the labial crest after extraction of the failing tooth.

Surgical procedure

Following screening, comprehensive clinical and radiographic examination was performed by two experienced clinicians (J. C./T. D. R.) and impressions were taken of both jaws for model analysis. Thereupon, a treatment plan was proposed. All patients consented to the planned treatment strategy, which was reviewed and approved by the ethical board.

One hour pre-operatively, patients were advised to start antibiotic and analgesic therapy (Amoxicillin 500 mg and Ibuprofen 600 mg). Oral disinfection was performed using a 0.2% chlorhexidine digluconate mouthwash (Corsodyl, GlaxoSmithKline, Genval, Belgium).

Teeth scheduled for immediate replacement were systematically removed following minimal mucoperiostal flap elevation (Fig. 1a and b). Periotomes were used to extract as atraumatically as possible. Immediate implant placement (Nobelreplace tapered TiUnite®, Nobel Biocare, Göteborg, Sweden) was performed if the labial crest was intact. Special attention was paid to the correct selection and three-dimensional positioning of the implant. In the orofacial dimension, the implant shoulder was positioned palatal to the point of emergence at adjacent teeth. In the mesiodistal dimension, a distance of the implant shoulder to the neighbouring teeth of about 2 mm was pursued. In the apico-coronal dimension, the implant shoulder was positioned 1 mm subcrestally or about 4 mm below the outline of the peri-implant mucosa (Fig. 1b). In order to obtain primary implant stability of at least 35 N cm, which was considered to be a pre-requisite for immediate provisionalization in this study, surgical sites were frequently underprepared. Following confirmation of the primary stability using a Torque Controller (Nobel Biocare), implant impression was made (Fig. 1c). The final implant position was recorded using radio-opaque and sterile vinylpolysiloxane material (Elite implant® medium, Zhermack, Badia Polesine, Italy). After ensuring that no impression material had remained at the surgical site, a cover screw was attached to the implant and grafting materials (Bio-Oss® 0.25–1 mm, Geistlich Biomaterials, Wolhusen, Switzerland) soaked in blood were inserted to fill the void between the implant and the alveolus. Particles were gently condensed and applied to the level of the implant shoulder. All voids were grafted irrespective of their width. Finally, the cover screw was replaced by an appropriate healing abutment and the wound was closed by means of single sutures (Vicryl® 5/0, Johnson & Johnson, St-Stevens-Woluwe, Belgium). Post-operative instructions included avoidance of the surgical site while brushing and eating, the use of a 0.2% chlorhexidine mouthwash two times a day for 2 weeks and antibiotic therapy for 5 days (Amoxicillin 500 mg three times a day). If necessary, analgesic therapy (Ibuprofen 600 mg maximum three times a day) was continued. All surgical procedures were performed by one and the same surgeon (J. C.).

Fabrication of the provisional restoration

Using the implant impression taken at the time of surgery, an individualized screw-retained provisional crown was fabricated in the dental laboratory. In brief, an engaging titanium temporary abutment (Nobel Biocare) served as a carrier for an appropriate hollowed denture tooth (Fig. 1d). Selection of the latter was principally driven by the design and colour of the failing tooth. Autopolymerizing acrylic resin (Palavit® 55 VS, Heraeus Kulzer, Hanau, Germany) was used to bond the temporary abutment and the denture tooth and for designing the cervical portion of the restoration. As a model of the opponent jaw was available, the provisional restoration was adjusted to clear centric and eccentric contacts before polishing procedures. All temporary crowns were fabricated by one and the same prosthodontist (T. D. R.).

Connection of the provisional and permanent restoration

Approximately 3 h following implant installation, the healing abutment was removed by the prosthodontist and the provisional restoration was tightened at 15 N cm onto the fixture. In order to avoid contamination, all restorations had been provided with 1% chlorhexidine digluconate gel at the abutment screw level. The clinician made sure that the provisional restoration was cleared of all contact in centric occlusion and during eccentric movements in order to avoid full functional loading of the implant during healing. Avoidance of the site while eating for an 8-week period was recommended. Figure 1e shows an example of a provisional restoration after 3 months of follow-up.

After 6 months, the provisional restoration was replaced by a permanent cemented restoration. Therefore, a standard implant impression was made using a polyether impression material (Impregum Penta®, 3M ESPE, Seefeld, Germany) and an open tray impression

coping (Nobel Biocare). Special attention was paid to an accurate replication of the soft tissue architecture. A standard aesthetic titanium abutment (Esthetic Abutment, Nobel Biocare) was used to connect the permanent metal–ceramic restoration. Cementation was performed using temporary cement (Temp-Bond® NE, Kerr, Scafati, Italy). In Fig. 1f, an example of a permanent restoration after a follow-up period of 1 year is shown.

All prosthetic procedures were conducted by one and the same prosthodontist (T. D. R.) and all permanent restorations were fabricated in one and the same dental laboratory (Dental Art, Zottegem, Belgium).

Implant survival and complications

At each re-assessment, namely after 1, 3, 6 and 12 months of follow-up, implant survival and complications were evaluated. The criteria for successful osseointegration according to Smith & Zarb (1989) were adopted. These criteria essentially include major bone loss, radiolucency, mobility, pain, discomfort and/or neurosensory changes. All biologic and prosthodontic complications were recorded during the study period.

Hard tissue parameters

Immediately following connection of the provisional restoration and after 3, 6 and 12 months, a peri-apical radiograph was taken using the long-cone paralleling technique and an X-ray holder (XCP Bite Block, Dentsply Rinn, Elgin, IL, USA). An occlusal jig (Futar® D Fast, Kettenbach Dental, Eschenburg, Germany) was used to standardize the angulation and position of the film in relation to the implant and X-ray beam. All radiographs were scanned (300 dpi) and digitized (SprintScan 35 Plus, Polaroid, Cambridge, MA, USA). Changes in marginal bone levels at the mesial and the distal aspect of the implant were based on the exact distance between three implant threads as provided by the implant manufacturer (Nobel Biocare). The appropriate software (Vixwin 2000 v1.11, Dentsply Gendex, Lake Zurich, Switzerland) was used to calculate bone-level changes over time. All radiographs were analysed by two clinicians (J. C./T. D. R.).

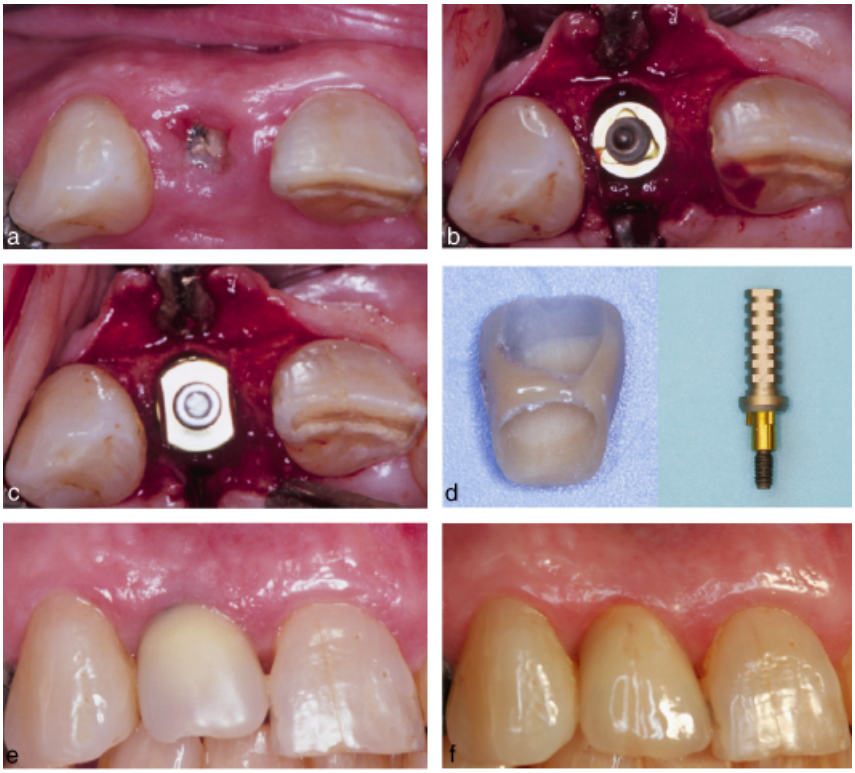

Fig. 1. (a) Fracture of tooth 12 near the level of the alveolar crest. (b) Minimal mucoperiosteal flap reflection, tooth extraction and restoration-driven implant placement (Nobelreplace tapered TiUnite® diameter 4.3 mm–length 16 mm). (c) Connection of a standard impression coping for the open tray impression technique. (d) Autopolymerizing acrylic resin is used to bond an appropriate hollowed denture tooth (left) and a temporary titanium abutment (right). (e) Labial view of the provisional screw-retained restoration after 3 months of follow-up. (f) Labial view of the permanent cemented restoration after 1 year. Note some additional fill of the mesial interdental space between the 3- and the 12-month follow-up visit.

Soft tissue parameters

At 1, 3, 6 and 12 months of follow-up, the *clinical condition* of the implant-restoration was recorded by means of the following parameters:

1. *Plaque score*. A dichotomous score was given (0 = no visible plaque at the soft tissue margin; 1 = visible plaque at the soft tissue margin) at four sites per implant (mesial, midfacial, distal, palatal).
2. *Probing depth*. It was measured to the nearest 0.5 mm at four sites per implant (mesial, midfacial, distal, palatal) using a manual probe (CP 15 UNC, Hu-Friedy®, Chicago, USA).
3. *Bleeding on probing*. A dichotomous score was given (0 = no bleeding; 1 = bleeding) at four sites per implant (mesial, midfacial, distal, palatal).

At each of the re-assessments, oral hygiene was reinforced.

Before tooth removal and at 1, 3, 6 and 12 months of follow-up, *soft tissue dimensions* were measured as follows:

1. *Papilla levels*. The levels were recorded by means of an acrylic stent provided with direction grooves by two clinicians (Fig. 2). A papilla level (mesial papilla level–distal papilla level) is defined as the distance between the top of the groove and the top of the papilla measured to the nearest 0.5 mm using a manual probe (CP 15 UNC, Hu-Friedy®).
2. *Midfacial mucosa level*. The level of the peri-implant mucosa at the midfacial aspect of the tooth/restoration was measured using the same acrylic stent provided with a central direction groove by two clinicians. The midfacial level is defined as the distance between the top of the groove and the first contact with the peri-implant mucosa measured to the nearest 0.5 mm using a manual probe (CP 15 UNC, Hu-Friedy®).

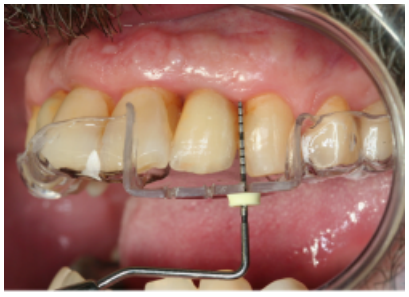

Fig. 2. Acrylic stent with three direction grooves to determine the outline of the soft tissues at the mesial, distal and midfacial aspect of the restoration.

Patient's aesthetic satisfaction

At the end of the study period, patients were asked to express their satisfaction with 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 was not 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

Data analysis was performed using the patient as the experimental unit. For all parameters, the mean values per subject and per visit were calculated, if applicable. The changes over time of these variables were examined by means of repeated measures one-way analysis of variance (ANOVA). The level of significance was set at 5%.

Results

From the 32 patients who had been scheduled from May 2005 to June 2006, 30 (14 men, 16 women; mean age of 54 with a range from 24 to 76) were actually treated for single-tooth replacement in the aesthetic zone by means of immediate implant placement and provisionalization. Two patients had to be excluded during surgery as loss of the labial crest occurred after extraction of the failing tooth. Table 1 shows the tooth types and reasons for tooth loss: more than half were incisors and the most prevalent reason for failure was tooth fracture. Thirty screw-type tapered implants with a micro-roughened body and a machined collar (Nobelreplace tapered TiUnite®: diameter 4.3 mm–length 10 mm: two implants; diameter 4.3 mm–length 13 mm: eight implants; diameter 4.3 mm–length 16 mm: 14 implants; diameter 5 mm–length 13 mm: two implants; diameter 5 mm–length 16 mm: four implants) were inserted. The bone gap between the alveolus and the implant platform that was filled with Bio-Oss® particles had an average orofacial dimension of 1.38 mm (range 0–4 mm) at the midfacial aspect of the implant. Table 2 shows the distribution of the gap width sorted per tooth type.

During the 12-month observation period, one patient was lost to follow-up after 3 months.

Implant survival and complications

At 1-month follow-up, one of the implants had failed (tooth location 21; diameter 5 mm–length 16 mm) as pain, discomfort and implant mobility occurred. The reason for this early loss was unclear. Besides this one early failure, all implants remained well integrated based on the criteria for successful osseointegration proposed by Smith & Zarb (1989), resulting in a 97% cumulative implant survival rate after 1 year of function. With reference to complications within this observation period, one permanent crown had lost retention at 8 months of follow-up and was re-cemented.

Hard tissue parameters

Table 3 shows the changes in the mesial and distal bone levels at 3, 6 and 12 months of follow-up in relation to the time point of connecting the provisional restoration. The largest amount of bone loss was observed in the first 3 months: 0.58 mm mesially and 0.47 mm distally. Thereafter, diminished loss was observed. After 1 year of function, radiographic examination yielded 0.98 mm mesial bone loss, respectively, 0.78 mm distal bone loss.

Soft tissue parameters

In Table 4, the *clinical conditions* of the implant restorations are shown. Throughout the study period, plaque scores remained low (<20%). In fact, 82% of the subjects demonstrated plaque scores of maximum 25%. About half of the sites exhibited bleeding on probing. A trend towards a reduction in probing depth from 3.90 to 3.46 mm was found. There were no significant

Table 1. Tooth types and reasons for failure

Tooth types	Reasons for failure				
	fracture	caries/endodontic	periodontal	root resorption	total
Incisors	8	4	5	2	19
Canines	0	1	0	1	2
Pre-molars	2	4	2	1	9
Total	10	9	7	4	30

Table 2. Width of the gap between implant and bony wall according to the extracted tooth type

Tooth types	0–1 mm	1.1–2 mm	2.1–3 mm	3.1–4 mm	Total
Incisors	10	9	0	0	19
Canines	1	1	0	0	2
Pre-molars	3	3	1	2	9
Total	14	13	1	2	30

Table 3. Changes in marginal bone levels in relation to the time point of connecting the provisional restoration

Location	Month 3	Month 6	Month 12
Mesial bone level (mm)	0.58 ± 0.41	0.85 ± 0.52	0.98 ± 0.50
Distal bone level (mm)	0.47 ± 0.65	0.66 ± 0.70	0.78 ± 0.55

Mean ± SD.

Table 4. Clinical conditions of implant restorations at different time intervals

Parameter	Month 1	Month 3	Month 6	Month 12
Plaque score (%)	17 ± 22	19 ± 21	18 ± 23	17 ± 18
Probing depth (mm)	3.90 ± 0.83	3.76 ± 0.67	3.64 ± 0.76	3.46 ± 0.69
Bleeding on probing (%)	54 ± 30	49 ± 19	46 ± 23	41 ± 16

Mean ± SD.

Table 5. Inter-examiner reproducibility of soft tissue dimensions

Parameter	Paired samples *t*-test	Pearson's correlation coefficient	Identical scoring (%)
Papilla levels (mm)	NS	0.994 ($p \leqslant 0.001$)	81
Midfacial mucosa level (mm)	NS	0.995 ($p \leqslant 0.001$)	86

NS, non-significant.

Table 6. Changes in soft tissue dimensions in relation to the pre-operative status

Parameter	Month 1	Month 3	Month 6	Month 12
Mesial papilla level (mm)	− 0.50 ± 0.73*	− 0.64 ± 0.76*	− 0.50 ± 0.75*	− 0.41 ± 0.71†
Distal papilla level (mm)	− 0.33 ± 0.83†	− 0.50 ± 0.78*	− 0.41 ± 0.85†	− 0.31 ± 0.83
Midfacial mucosa level (mm)	− 0.43 ± 0.68*	− 0.48 ± 0.80†	− 0.54 ± 0.77*	− 0.53 ± 0.76†

*Highly significant soft tissue loss in comparison to the pre-operative status: $p \leqslant 0.005$.
†Significant soft tissue loss in comparison to the pre-operative status: $0.005 < p \leqslant 0.05$.
Mean ± SD.

differences in any of the parameters over time.

Table 5 indicates high agreement among both clinicians for recording *soft tissue dimensions*. Identical scoring was found in more than 80%.

Table 6 depicts the dimensional changes of the soft tissue outline around the implant restorations in relation to the status before tooth extraction. The largest reductions in papilla height were found at 3 months of follow-up, pointing to a mean loss of 0.64 mm ($p < 0.001$) for mesial papillae and 0.50 mm ($p = 0.005$) for distal papillae. Although there were no significant differences in papilla height among the different time points, a trend towards some recovery following 3 months of healing was apparent: at 1 year of follow-up, the average papilla loss was 0.41 mm ($p = 0.035$) at the mesial aspect of the restoration, respectively, 0.31 mm ($p > 0.05$) at its distal aspect. In Fig. 1e and f the phenomenon is illustrated.

The largest alterations in the midfacial level of the peri-implant mucosa occurred during the first month of healing, pointing to a mean loss of 0.43 mm ($p = 0.002$). At the 1-year follow-up visit, the midfacial soft tissue recession was on average 0.53 mm ($p = 0.011$). There were no significant changes in midfacial soft tissue levels in the different time intervals.

Patient's aesthetic satisfaction

Patient's aesthetic satisfaction, as determined by a visual analogue scale, indicated a mean score of 93%, with a range from 82% to 100%.

Discussion

The study involved a method for immediate replacement of a hopeless tooth with an implant-supported fixed prosthesis. For the patient, this appears to be an inviting strategy: it is a one-stage procedure and eliminates the need for a removable partial denture in the early stages of healing. Thus, the patient benefits from immediate aesthetics and comfort. From a clinical point of view, the procedure also has its advantages. These are mainly related to time gain as post-extraction healing and osseointegration coincide.

Based on the short-term results of the present study, immediate single-tooth implants in the anterior maxilla may be considered to be a successful treatment strategy with a cumulative implant survival rate of 97% after 1 year of function. This result is comparable to other short-term studies using the same protocol ($\geqslant$94%) (Hui et al. 2001, Calvo Guirado et al. 2002, Lorenzoni et al. 2003, Kan et al. 2003a, Cornelini et al. 2005, Barone et al. 2006). Studies with longer observation periods yielded survival rates of $\geqslant$93% (Groisman et al. 2003, Norton 2004, Tsirlis 2005, Degidi et al. 2006, Ferrara et al. 2006). Interestingly, these survival rates are in line with data published for implants inserted according to the standard protocol ($\geqslant$93%) (Goodacre et al. 1999, Noack et al. 1999, Krennmair et al. 2002, Romeo et al. 2002, Levin et al. 2006). Hence, the time span from extraction to implant placement does not seem to be the pivotal factor in attaining osseointegration. In contrast, the macro- and microstructure of the implant may be more relevant. In this study, screw-type tapered implants with a micro-roughened body and a machined collar were used. This selection seemed evident as more bone-to-implant contact is found around screw-type implants in comparison with cylindrical implants (Vandamme et al. 2007) and high primary stability can be achieved easily with a tapered implant design (O'Sullivan et al. 2004). In addition, micro-roughened implants have shown significant biomechanical advantages over machined implants: as a result of contact osteogenesis and increased bone-to-implant contact, the former benefit from rapid bone apposition and superior anchorage (Cosyn et al. 2007). Finally, we used implants with a standard machined collar in this study as the additional value of a micro-textured collar is currently unclear (Cosyn et al. 2007). Besides these geometrical implant aspects, osseointegration was further optimized as follows: first, primary implant stability of at least 35 N cm was pursued and considered to be a pre-requisite for immediate provisionalization. This seemed appropriate because the study of Ottoni et al. (2005) revealed a correlation between placement torque and survival of single-tooth implants: nine out of 10 failing implants were placed with an insertion torque of only 20 N cm. Appropriate initial insertion torque was advocated by the

authors to proceed with early loading (Ottoni et al. 2005). Second, provisional restorations were cleared of all contacts to avoid micro-movements, which are sufficient to jeopardize the osseointegration process (Brunski 1993, Brunski et al. 2000). Interestingly, the need for these precautions has been questioned recently by Lindeboom et al. (2006) as they found no significant differences in any parameter between immediately loaded and immediately non-loaded provisionalized implants.

Radiographic examination 1 year after implant placement revealed a mean bone loss of 0.98 mm mesially and 0.78 mm distally, which is in agreement with other studies on the current concept (Lorenzoni et al. 2003, Tsirlis 2005). These data are slightly different from the peri-implant bone changes following the conventional two-stage procedure in healed sites (Adell et al. 1986, Naert et al. 2002). These findings contribute to the current theory that crestal bone changes are dependent on the location of the micro-gap irrespective of submerged or non-submerged implant placement (Hermann et al. 2000, Cosyn et al. 2007). In contrast, three studies on immediate implantation and provisionalization presented limited bone loss, yielding <0.50 mm after 1 year of function (Kan et al. 2003a, Norton 2004, Cornelini et al. 2005). Kan et al. (2003a) even observed several implants with bone gain, a phenomenon that was not observed in the present study. This could be explained by a difference in the surgical technique.

In spite of the fact that plaque levels remained low throughout the study ($<20\%$), nearly half of the sites bled upon probing. This is, however, not an uncommon feature around implants (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 micro-leakage at the implant–abutment interface (Broggini et al. 2003, Piattelli et al. 2003) and the subgingival position of a restoration border (Jemt & Pettersson 1993). A relatively high mean probing depth of about 3.5 mm after 1 year of function was found in this study, which can be considered to be a normal phenomenon around two-piece implants as described by others (Lekholm et al. 1986, Apse et al. 1991, Proussaefs et al. 2002). An interesting observation was the decreasing trend in probing depth between 1 month of follow-up (3.90 mm) and study termination (3.46 mm). Similar pocket shrinkage was reported by Proussaefs et al. (2002) from 3.6 mm at 3 months to 3.2 mm at 12 months of follow-up and earlier literature (Apse et al. 1991).

Even though ample reports have been published on immediate implant insertion and provisionalization for replacing maxillary anterior teeth, few have documented the aesthetic treatment outcome (De Rouck et al. 2007). Hence, one of the objectives of this prospective study was to monitor changes in soft tissue dimensions. Usually, a reference line connecting the midfacial gingival level of the two teeth adjacent to the implant restoration is used for this purpose (Chang et al. 1999, Kan et al. 2003a, Cornelini et al. 2005). As midfacial gingival levels may be liable to variation, especially when mucoperiosteal flaps are reflected, an acrylic stent with fixed reference points was used in this study. This method proved highly reproducible.

In the present investigation, significant reductions in papilla height were found, reaching a maximum of 0.64 mm ($p<0.001$) on average for mesial papillae, respectively, 0.50 mm ($p=0.005$) for distal papillae at 3 months of follow-up. Soft tissue swelling may have limited papilla loss in the early stages of healing explaining less discrepancy in relation to the pre-operative status at 1 month of follow-up. Interestingly, our 3-month data on papilla loss seem considerably higher in comparison with what has been described earlier by Kan and co-workers (2003a). They reported only 0.33 mm mean loss for mesial papillae, respectively, 0.25 mm for distal papillae at 3 months following single-tooth replacement in the incisor–cuspid maxillary region by means of immediate implant insertion and provisionalization. This disparity can be explained by the flapless surgical approach in their study, resulting in less tissue trauma. However, as the present study and the report by Kan et al. (2003a) indicate comparable levels of papilla loss after 1 year of function, yielding approximately 0.5 mm for mesial papillae and 0.3 mm for distal papillae, a possible impact of the surgical technique seems negligible in the longer run. In this regard, it has been well documented that the presence of a papilla adjacent to a single-tooth implant restoration is principally driven by the level of the alveolar bone on the neighbouring tooth (Choquet et al. 2001, Kan et al. 2003b). An interesting observation in our study is the increase in papilla height between the 3-month and the 1-year visit. Although this was not statistically consolidated by our data, the fact that distal papilla levels were not significantly different from pre-operative levels at the 1-year re-assessment is indicative of the phenomenon. This observation appears to be in line with earlier reports demonstrating an increase in papillary soft tissue volume during the first year of function of single-tooth implant restorations (Chang et al. 1999, Grunder 2000, Cardaropoli et al. 2006).

In this study, significant midfacial soft tissue recession of 0.53 mm in the first year of function was found, which is in agreement with a report by Kan et al. (2003a) indicating 0.55 mm following a similar strategy. Cornelini et al. (2005) described 0.75 mm midfacial soft tissue loss within the same time frame. Other studies have been published on soft tissue topography following single-tooth implant placement in healed sites demonstrating comparable levels of midfacial recession in the first year of function, yielding to 0.6 mm (Grunder 2000, Cardaropoli et al. 2006). By on average 3 years of follow-up, midfacial soft tissue loss of about 1 mm has been described for conventional single-tooth implant restorations (Chang et al. 1999). These data appear to be slightly different for multiple-unit implant reconstructions (Bengazi et al. 1996, Small & Tarnow 2000). In addition, long-term studies have demonstrated ongoing soft tissue shrinkage up to 1.7 mm, at least in fully edentulous patients (Adell et al. 1986, Apse et al. 1991). These findings indicate that remodelling is an inevitable and continuous event, making long-term soft tissue monitoring a necessity. At least in the first year of function, our data demonstrate limited loss at the midfacial aspect, which may be explained as follows: first, patients with a thin-scalloped biotype were excluded in this study. As the risk for aesthetic complications is considerably high in these subjects, hard tissue conditioning and/or periodontal plastic surgery are often necessary. These procedures are delicate and require a staged approach. Second, Bio-Oss® particles were systematically enclosed between the implant and the socket wall. Even though resorption of

the alveolar ridge inevitably occurs following tooth extraction (Schropp et al. 2003, Araujo & Lindhe 2005), it has been shown that significantly more buccal bone can be preserved when the extraction socket is filled with a grafting material exhibiting a low substitution rate such as Bio-Oss® (Nevins et al. 2006). As the immediate insertion of an implant has no impact whatsoever on the dimensional changes of the extraction socket (Botticelli et al. 2004, Araujo et al. 2005), it is conceivable that this bone substitute induces an analogue effect if incorporated between an implant and the socket wall. Evidently, this issue should be investigated in controlled clinical studies. Because of the promising properties of Bio-Oss® in this field and because this grafting material does not seem to interfere with osseointegration (Polyzois et al. 2007), we choose to apply it at all times in this study even though the necessity of this procedure in small bone gaps can be considered to be a matter of debate. Finally, screw-retained instead of cemented provisional restorations were used in this study. This may be the reason why no complications were reported during the provisional stage. In contrast, fistulae have been described when using cemented provisional restorations (Kan et al. 2003a).

A flapless surgical technique for anterior implant placement has been earlier advocated for optimal aesthetic results (Kan et al. 2000). An advantage of a flapless approach in immediate implant cases is the preservation of blood supply of the buccal socket wall. Still, the clinical relevance of this argument is not well understood. Moreover, our results after 1 year of function on soft tissue topography at the midfacial and the papilla level appear to be, by no means, inferior to those published previously on flapless implant surgery (Kan et al. 2003a). High patient aesthetic satisfaction may reinforce these results. Consequently, raising a flap or not does not seem to be the pivotal factor in achieving aesthetic results. The rationale for reflecting minimal mucoperiosteal flaps in this study was threefold: first, it facilitates tooth removal, which can be quite delicate, especially when the tooth is fractured or in case of root resorption. Note that these were the reasons for tooth loss in nearly half of our cases. Second, a flap allows the clinician to inspect the buccal socket wall properly for fenestrations and/or dehiscencies. Third, flapless surgery increases the risk of perforation, making it a risky procedure when implant placement is not computer navigated. Other precautions for flapless implant surgery in the aesthetic region have been described recently (Oh et al. 2007).

On the basis of the preliminary results of this study, single-tooth replacement by means of mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material and the connection of a screw-retained provisional restoration can be considered to be a valuable treatment option. The presented protocol also offers many advantages for the patient as for the clinician. However, careful patient selection and treatment planning appear to be of critical importance in achieving a predictable treatment outcome. Evidently, further research is needed to monitor hard and soft tissue changes on a long-term basis.

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Clinical Relevance

Scientific rationale for the study: Ample studies have been published on immediate placement and provisionalization of single-tooth implants in the pre-maxilla. However, no data have been reported on this concept combining mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material and immediate connection of a screw-retained restoration.

Principal findings: The cumulative implant survival rate was 97% in a group of 30 patients. Soft tissue recession was limited to <0.5 mm after 1 year of follow-up.

Practical implications: For well-selected cases, this strategy appears to be a valuable option. The main advantages include time gain and immediate aesthetics and comfort.