Four-unit fixed dental prostheses replacing the maxillary incisors supported by two narrow-diameter implants - a five-year case series

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Abstract
To determine the survival rate of 10 four-unit fixed dental prostheses (FDPs) replacing the four maxillary incisors, supported by 20 narrow-diameter implants (NDIs), (2) to assess the incidence of mechanical and biological complications, and (3) to evaluate bone level changes longitudinally after final FDP insertion

Reference

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Key words: case series, clinical study, esthetics, implant-supported fixed dental prostheses, maxillary incisors, narrow-diameter implants

Abstract

Objectives: (1) To determine the survival rate of 10 four-unit fixed dental prostheses (FDPs) replacing the four maxillary incisors, supported by 20 narrow-diameter implants (NDIs), (2) to assess the incidence of mechanical and biological complications, and (3) to evaluate bone level changes longitudinally after final FDP insertion.

Materials and methods: Ten patients (six women, four men), mean age 49.4 ± 12.6 years, were treated with a four-unit anterior maxillary FDP (six screw-retained; four cemented). Biological parameters, eventual technical complications, radiographic measurements, and study casts were assessed at 1 (baseline), 3, and 5 years after implant placement. A multilevel logistic regression test was performed on clinical parameters and bone level changes (significance level \( P < 0.05 \)).

Results: The 5-year implant and FDP survival rate was 100%. Mean modified plaque index (mPI) values were 0.03 and 0.02 at 3 and 5 years, significantly lower when compared to mPI (0.11 ± 0.31) at 1 year. Mean modified sulcus bleeding index (mSBI) was 0.08, 0.08, and 0.15 over time. Probing depth (PD) values were 1.57, 1.64, and 2.03 mm. Statistically significant differences were found between 1 vs. 5 year (\( P = 0.0003 \)) and 3 vs. 5 year (\( P = 0.001 \)). Keratinized mucosa (3.65 mm) remained stable during observation period. DIB mean values were 2.01 ± 0.34, 2.13 ± 0.13, and 2.17 ± 0.38 mm. Patient satisfaction based on visual analog scale revealed favorable fulfillment of overall treatment and esthetic expectations.

Conclusions: Two NDIs supporting a four-unit FDP to replace the four missing maxillary incisors may be considered a predictable treatment modality.

The replacement of the four maxillary incisors by means of an implant-supported prosthesis is challenging from an esthetic and biomechanical point of view (Vailati & Belser 2007). In contrast to the long-term studies related to esthetic single-tooth replacement (Buser et al. 2013a; Chappuis et al. 2015), little has been reported on implant-supported multiunit fixed dental prostheses (FDPs) (Zarb & Zarb 2002; Krennmair et al. 2011). Open questions focus on the ideal number, dimension, and localization of the implants (Vailati & Belser 2007; Krennmair et al. 2011), because reports in the literature are inconclusive on their esthetic outcomes, particularly with respect to the implanto soft tissue contours (Belser et al. 2004a; Mitranı et al. 2005).

Different treatment alternatives were first described in detail by Vailati and Belser (Vailati & Belser 2007). These authors stated that consecutive single-implant rehabilitation of the four maxillary incisors is limited by anatomic parameters, with the notable disadvantage that the small interimplant distances (Tarnow et al. 2000; Belser et al. 2004a) may increase both marginal bone resorption and loss of papilla (Tarnow et al. 1992; Choquet et al. 2001; Martin et al. 2007; Chen & Buser 2012). The currently recommended strategy is to limit the number of implants, to avoid adjacent implants, and to position the implants next to natural teeth to benefit from tissue support provided by these structures [Belser et al. 2004b]. This clinical concept, based on a biological-prosthetic approach, has been primarily derived from clinical experience and prostodontic principles, rather than from formal scientific evidence.

One possible option proposed by Vailati and Belser (Vailati & Belser 2007) is the
insertion of two narrow-diameter implants (NDIs) at the lateral incisor sites to support a four-unit FDP, comprising two central ovate pontics. In the described context, NDIs placed in the position of the lateral incisors offer both a distinct biological and an aesthetic advantage, due to their small dimension. They allow to respect the minimal interproximal distance (i.e., 1.5 mm) to the adjacent natural canines without interfering with the future embrasure between the lateral incisor implant crown and the central incisor pontic. Although the NDI was originally designed for small single-tooth gaps (Buser et al. 2000, Romeo et al. 2006), it was progressively used to support multiunit FDPs replacing the maxillary and mandibular incisors (Cordaro et al. 2006), especially in patients with high aesthetic expectations. However, clinical data using this type of implants to support multiunit FDPs in case of extended edentulous spaces in the anterior maxilla are still scarce.

The aims of this longitudinal prospective case series study were [1] to determine the survival rate of 10 four-unit fixed dental prostheses supported by 20 anterior maxillary NDIs through a clinical observation time of 5 years, [2] to assess the incidence of mechanical and biological complications, and [3] to evaluate peri-implant bone level changes longitudinally after final FDP insertion.

Materials and methods

Study design

This case series was performed at the Division of Fixed Prosthodontics and Biomaterials, University Clinics of Dental Medicine, University of Geneva, as part of a doctoral thesis (Moráquez et al. 2015). Ten patients restored with a four-unit anterior maxillary FDP participated in this prospective study. The patient’s history before implant placement included failing tooth-borne conventional fixed restorations that needed replacement. The study protocol was approved by the Human Research Ethics Commission of the University Hospitals of Geneva (Ref. 14-006). Informed consent was obtained from all patients prior to their inclusion into the study.

The patients [six female and four male] with a mean age of 49.4 ± 12.6 years (range 32–68 years) were treated with 10 metal–ceramic FDPs replacing the four maxillary incisors. Among these, nine prostheses were supported by 18 tissue-level NDIs (narrow neck implants: 3.5–∅ 3.3 mm; Straumann Institute, Basel, Switzerland) and one by two tissue-level NDIs (regular neck 4.8–∅ 3.3 mm; Straumann Institute, Basel, Switzerland) inserted at the sites of the lateral incisors. Eighteen implants (8 of 10 mm length; 10 of 12 mm length) were placed according to the concept of early implant placement (including five with simultaneous facial contour augmentation), while two implants (12 mm length) were placed using a delayed approach. All implants were loaded following a conventional protocol. After a provisional phase (6–9 months), six screw-retained multiunit FDPs (torqued to 35 Ncm) and four cemented multiunit FDPs [temporary cement; Temp-Bond, Kerr] were inserted. To avoid cement excess in the peri-implant tissues, dental floss (Johnson & Johnson Reach Dental Floss,) was used between interproximal contacts and, below ovoid pontics [Oral-B Super Floss]. Eight patients were non-smokers and two patients were light smokers (< 10 cigarettes/day).

Clinical examination

The clinical examination was performed 1 [baseline], 3, and 5 years after implant surgery. Eventual technical complications (chipping of the ceramic, screw loosening, loss of retention) were recorded, and analysis of biological parameters was performed as indicated in detail below. In addition, radiographic evaluation and cast analysis were carried out at the time intervals. To standardize clinical and radiographic measurements by one examiner (OM), the baseline was established at 1 year after implant placement. FDPs were not removed at any time between the points of evaluation.

Biological parameters

Modified plaque index [mPI], modified sulcus bleeding index [mSBI], and probing depth [PD in mm] at six aspects around the implants (Mombelli et al. 1987) were assessed. In addition, the width of the facial keratinized mucosa (KM) was measured on the mid-facial aspect of each implant [in mm].

Radiographic examination

Standardized periapical radiographs were taken at 1, 3, and 5 years using silicone bite blocks. The radiographic linear distance from the implant shoulder to the first bone-to-implant contact [DIB] was used to calculate the marginal bone levels at the mesial and distal sites of the implants. For each implant and examination interval, the DIB value was calculated as the average of the obtained mesial and distal values (Weber et al. 1992). These measurements were obtained using the ImageJ 1.48v program (Wayne Rasband National Institutes of Health, USA). The digitized images were calibrated by setting the scale to the known distance between two implant threads (1 mm) [Fig. 1]. The radiographic readings were performed by one calibrated examiner who was not involved in the surgical or prosthetic treatment of the patients. In addition, a frequency analysis of the difference between DIB values from the 1-, 3-, and 5-year examination was performed ([Δ DIB3 to Δ DIB5]) [Buser et al. 1999]. A negative Δ DIB indicated bone loss between two examinations.

Cast analysis

Impressions were taken at 1, 3, and 5 years to produce study casts of the maxilla. The mid-facial height of each implant crown [IC]
was measured to identify potential changes in clinical crown height or mucosal recession between time intervals.

**Patient satisfaction based on questionnaire and related visual analog scale**

Patient satisfaction was assessed using a 100-mm visual analog scale (VAS). The patients were asked to answer two questions by drawing a vertical mark on a horizontal line to indicate the esthetic and overall treatment satisfaction at the first recall examination. The scale varied from 0 (very unsatisfied) to 10 (very satisfied) on the following questions: “Did the final esthetic result correspond to your initial expectations?” and “How do you evaluate the overall treatment result?”

**Data analysis**

To analyze all parameters measured at 1, 3, and 5 years after implant surgery, multilevel logistic regression for binary variables (mPI) and multilevel regression for continuous variables (PD) were used. The multilevel model techniques were chosen to account for the non-independence of the data, namely that data stemming from sites of the same implant are more similar than data from different implants, and data from implants of the same patient are more similar than data from different patients. Technically, a random intercept was included at the patient level in the multilevel models. Conditions of applications, including conditional normality, were checked using residual plots. Patient satisfaction parameters were expressed using mean values [± standard deviation]. All analyses were performed using R v3.1.0 program [R Foundation for Statistical Computing, Vienna, Austria], and the confidence level was 95% [P < 0.05].

**Results**

All ten patients recruited attended the 1- (baseline), 3-, and 5-year follow-up examinations. The 5-year survival rate of the 10 examined four-unit FDPs and 20 NDIs was 100%. None of the FDPs presented biological or technical complications such as chipping of the ceramic, loosening of the screw/abutment, loss of retention, or failure between the first and fifth year.

**Biological outcomes**

Detailed results of peri-implant soft tissue parameters are listed in Table 1. All implants were still firmly integrated, without suppurration in the peri-implant sulcus. The patients exhibited very good oral hygiene with mean mPI values of 0.03 and 0.02 at the 3- and 5-year examination, respectively. These results showed statistically significant differences compared to the mean mPI value (0.11 ± 0.31) obtained at the 1-year follow-up. The peri-implant soft tissues appeared clinically healthy with little tendency to bleed after probing. The mean mSBI were 0.08, 0.08, and 0.15 at the 1-, 3-, and 5-year follow-ups, showing no significant difference between examinations. The mean PD was 1.57 mm at the 1-year examination. These values slightly increased to 1.64 and 2.03 mm during the follow-up period. The mean PD values were statistically different between the 1- vs. 5-year [P = 0.0003] and 3-vs. 5-year examination [P = 0.001]. The mean KM value at the 5-year follow-up was 3.65 mm, showing a stable and wide band of KM on the facial aspect of the implant crowns. There were no differences between the 3- and 5-year follow-ups.

**Radiographic bone level outcomes**

The radiographs obtained of each implant did not reveal any signs of continuous peri-implant radiolucency during the entire observation period [Fig. 2].

The mean DIB value [Table 2] after 1 year was 2.01 ± 0.34, 2.13 ± 0.13 mm [range 1.75–2.8 mm] after 3 years, and 2.17 ± 0.38 mm [range 1.65–3.05 mm] after 5 years. The differences between the mean DIB values for the three time points analyzed were not statistically significant [DIB 1–3 year: P = 0.12; DIB 1–5 year: P = 0.06; DIB 3–5 year: P = 0.31]. The frequency analysis of the 20 implants evaluated between the 1- and 3-year follow-up (Δ DIB 1–3 year) showed that all the implants exhibited either a slight bone gain or bone loss between +0.50 and –0.74 mm [Fig. 3]. Similar results were found between the 1- and 5-year examination (Δ DIB 1–5 year) within +0.75 and –0.75 mm of bone gain or loss. The maximum bone loss was –0.75 mm for one implant [Fig. 4].

**Cast analyses**

Clinical implant crown height values remained stable over 5 years. The mean IC values were 13.06 mm (SD 1.83 mm), 12.49 mm (SD 3.09 mm), and 13.96 mm (SD 1.90 mm) at the three time points [Table 3]. The differences between IC values of the three examinations were not statistically significant [IC 1–3 year: P = 0.74; IC 1–5 year: P = 0.95; IC 3–5 year: P = 0.82]. The mean distance measured between the mesial surfaces of the canines was 35.35 mm (SD 1.96 mm; range 32.5–39.5 mm).

**Patient satisfaction**

The patient feedback based on VAS analyses revealed an overall treatment satisfaction of 96.9% [SD 0.51], and an esthetic satisfaction of 92.7% [SD 0.96].

**Discussion**

The results of this prospective case series indicate that the use of two NDIs placed at the lateral sites may be sufficient to support a four-unit FDP as a predictable modality to replace four missing maxillary incisors. The examined implants maintained successful tissue integration during the entire 5-year examination period as documented by both biological and radiographic parameters.

The standard soft tissue parameters mPI, mSBI, PD as well as KM values revealed healthy peri-implant soft tissues. Patients showed significant improvement in plaque control at the 3- and 5-year follow-up, compared to the 1-year examination. Concerning PD values, the measurements slightly increased from the 1-year follow-up, showing some differences at the 3- and 5-year examination. None of the other parameters showed statistically significant differences over time. The mean values obtained are in accordance with data from long-term studies evaluating...
bone-level [Buser et al. 2011; 2013a; Sanz et al. 2015] and tissue-level [Buser et al. 2013b] implants supporting single crowns in the esthetic zone.

Clinical long-term data on anterior maxillary implant-retained FDPs are scarce. The clinical data published by Krennmair et al. (Krennmair et al. 2011) in a retrospective study using two standard diameter implants to replace the four maxillary incisors are in line with the mean clinical values obtained in this study.

The DIB values obtained from the 20 implants indicated overall stable peri-implant bone crest levels on the mesial and distal aspects. As stated in previous studies [Buser et al. 2013b; 1999], mean DIB values alone are not indicative of the stability of peri-implant bone crest levels, because some implants will lose or gain bone over time. Thus, frequency analyses of ΔDIB values were calculated between 1-, 3-, and 5-year examinations. In the present study, all of the implants exhibited either a slight bone gain or loss within −0.75 and 0.75 mm. These results are in line with previous studies presenting a frequency analysis of ΔDIB values [Bornstein et al. 2005; Buser et al. 2013b; 1999]. The favorable clinical and radiographic results were also confirmed by the cast analyses.

Concerning patient satisfaction, it would be essential to create a white and pink esthetic index for multiunit implant reconstructions that allows the assessment of esthetic outcomes with objective parameters [Benic et al. 2012]. Such an “objective” analysis, correlated with the “subjective” evaluation of the patient, would help clinicians to identify parameters that make restorations more esthetically pleasing for the patient [Annibali et al. 2012].

Different treatment options for the replacement of the four maxillary incisors with an implant-supported FDP were first discussed by Vailati and Belser (Vailati & Belser 2007), including the proposal to routinely use only two NDIs positioned at the lateral incisor sites. However, only case reports [Vela-Nebot et al. 2011; Petropoulou et al. 2013] and a

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**Table 2. Radiographic bone level outcomes of the 20 implants (DIB; mm)**

<table>
<thead>
<tr>
<th>Examination period</th>
<th>1 year</th>
<th>3 years</th>
<th>5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.01</td>
<td>2.13</td>
<td>2.17</td>
</tr>
<tr>
<td>SD</td>
<td>0.34</td>
<td>0.30</td>
<td>0.38</td>
</tr>
<tr>
<td>Median</td>
<td>2.00</td>
<td>2.08</td>
<td>2.20</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.50</td>
<td>1.75</td>
<td>1.65</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.70</td>
<td>2.80</td>
<td>3.05</td>
</tr>
</tbody>
</table>

No statistically significant differences among DIB (distance from the implant shoulder to the first bone-to-implant contact) values were found over the course of 5 years (DIB 1–3 year: \( P = 0.12 \); DIB 1–5 year: \( P = 0.06 \); DIB 3–5 year: \( P = 0.37 \)).

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**Fig. 2.** Patients 2 and 10 with screw-retained fixed dental prostheses at 5-year follow-up.

**Fig. 3.** Frequency analysis of ΔDIB 1–3 year [in mm]. A negative value reveals bone loss between the time intervals.
This study examined 10 patients where two NDIs were used at the lateral incisor sites to support an FDP replacing the four maxillary incisors. The occlusal analysis revealed an overjet that varied between 2 and 7 mm (mean 3.9 mm), and an overbite between 2 and 6 mm (mean 3.2 mm). Furthermore, three patients presented bilateral canine guidance, six patients showed bilateral group function, whereas one patient exhibited a right canine guidance and left group function. Although reasonable concerns have been raised about the lower mechanical strength of the NDI (Schwarz 2000; Zinssi et al. 2004), particularly in case of non-ideal occlusal schemes, no mechanical complications or failures were observed in this 5-year clinical study. These results are in agreement with recent reviews (Klein et al. 2014) that concluded that survival rates of NDIs appear to be similar compared to those of regular-diameter implants. Moreover, clinical studies including NDIs with a new titanium-zirconium alloy (TiZr) (Barter et al. 2012; Ioannidis et al. 2015) have shown promising results that point to an incremental gain in the mechanical properties of this type of implants. Further, in patients with high esthetic expectations and limited horizontal bone volume, NDIs seem to be a choice with a predictable long-lasting biological result.

Conclusions

The 5-year survival rate of both the examined 4-unit anterior metal-ceramic FDPs and the supporting implants was 100%.

The clinical and radiographic parameters of all 20 implants remained stable throughout the observation period. No technical complications were registered during the entire study duration. The investigated treatment approach in general and the esthetic outcome in particular were favorably perceived, as expressed by a high degree of patient satisfaction. Within the limitations of this prospective case series study, two soft tissue-level NDIs supporting a four-unit FDP to replace the four missing maxillary incisors may be considered a predictable treatment modality, including the potential of becoming the treatment of choice. However, additional well-controlled clinical studies based on larger patient populations are needed to confirm these favorable data.

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Conflict of interests

The authors declare no conflict of interest related to the study.

References


