CLINICAL ORAL IMPLANTS RESEARCH

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Esthetic evaluation of single-tooth implants in the anterior maxilla following autologous bone augmentation

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Abstract

Objectives: Autologous bone augmentation to rebuild compromised alveolar ridge contour prior to implant placement allows for favorable three-dimensional implant positioning to achieve optimum implant esthetics. The aim of the present study was to evaluate peri-implant soft tissue conditions around single-tooth implants following bone grafts in the esthetic zone of the maxilla.

Materials and methods: Sixty patients underwent autologous bone augmentation of deficient maxillary sites prior to placement of 85 implants in the esthetic zone. In case of multiple implants per patient, one implant was randomly selected. Objective evaluation of 60 single-tooth implants was performed using the Pink-Esthetic-Score (PES) and Papilla Index (PI) and supplemented by subjective patient evaluation, as well as clinical and radiologic examination.

Results: Objective ratings of implant esthetics were satisfactory (median PES: 11, median PI: 2) and significantly correlated with high patient satisfaction (mean VAS score: 80%). Both esthetic indices demonstrated respectable levels of inter- as well as intra-observer agreement. Poor implant esthetics (low PES and PI ratings) were significantly associated with increased anatomic crown height, while no influence of horizontal implant-tooth distance could be found.

Conclusions: The present investigation indicates that favorable esthetic results may be achieved in the augmented anterior maxilla. However, bony reconstruction of compromised alveolar ridges does not guarantee optimum implant esthetics.

Rehabilitation of single tooth gaps in the esthetic zone by means of dental implants remains a therapeutic challenge for both surgeon and prosthodontist (Phillips & Kois 1998; Chang et al. 1999; Kan et al. 2003; Belser et al. 2004a; Buser et al. 2008). The buccal cortical plate of the alveolar process may be resorbed after or even prior to tooth extraction due to inflammatory disease or trauma. Consequently, bone augmentation procedures to rebuild deficient ridge contours are mandatory to enable dental implant placement (von Arx & Buser 2006). Autogenous bone still represents the gold standard in ridge augmentation procedures and can be harvested either intraorally from the chin, mandibular ramus and maxillary tuberosity or extraorally from the iliac crest (Cordaro et al. 2002, 2011; McCarthy et al. 2003; Raghoebar et al. 2003; Roccuzzo et al. 2004). While being advantageous for their osteogenic properties, autologous bone grafts carry the inherent disadvantage of donor site morbidity (Nkenke et al. 2001, 2002, 2004; Pommer et al. 2008). It is well established that peri-implant soft tissue appearance is dependent upon the underlying bone topography (Bianchi & Sanfilippo 2004) and that the shape of buccal bone defects has an influence on the development of gingival recession (Kan et al. 2007). Sufficient bone volume, favorable three-dimensional implant positioning, and stable peri-implant soft tissue conditions are considered prerequisites to achieve long-term implant esthetics (Buser et al. 2004; Grunder et al. 2005; Chen & Buser 2009).

Besides implant function, soft tissue esthetics represent a major aspect of implant success and may be a main motivating factor for the patients' decision to implant therapy in the esthetic zone (Pjetursson et al. 2005). Due to high implant survival and success rates (Jemt 2008; Tonetti et al. 2008) evaluation of the esthetic outcome has become the focus of scientific interest in the anterior maxilla. Outcome of dental implant treatment is frequently described in terms of clinical and

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radiologic aspects (Stellingsma et al. 2003) using success criteria generally based on defined thresholds of objective clinical parameters, such as radiologic crestal bone loss, implant mobility and probing depths (Karoussis et al. 2003; Misch et al. 2008). Subjective patient satisfaction is considered insufficiently in the current literature (den Hartog et al. 2008), illustrated by the fact that less than 2% of the publications on oral implants deal with patient-centered issues (Pjetursson et al. 2005). The assessment of patient-based outcome measures was reiterated in the fourth European Workshop on Periodontology (Lang et al. 2002); however, analysis of patients' opinion on implant esthetics in augmented jawbone is still scarce. The aim of the present study was to evaluate peri-implant soft tissue around single-tooth implants following bone augmentation procedures in the esthetic zone of the maxilla. Both objective assessment using the Pink Esthetic Score (Fürhauser et al. 2005) and the Papilla Index (Jemt 1997) as well as subjective evaluation of patient satisfaction (Belser et al. 2004b; Pjetursson et al. 2005) were performed.

Materials and methods

Subject sample

Records at the Department of Oral Surgery (Medical University of Vienna) were retrospectively screened for patients provided with implants (Nobel Biocare™; Nobel Biocare, Gothenburg, Sweden) in the esthetic zone of the maxilla (upper incisors, canines and first premolars) following bone augmentation. Patients were scheduled for a recall visit and subjected to clinical and radiologic examination as well as subjective and objective evaluation of implant esthetics, if they fulfilled the following inclusion criteria: (1) single tooth implant restoration in the esthetic zone *in situ* for at least 1 year (Fig. 1a), (2) horizontal ridge augmentation using autologous bone blocks (Fig. 1b) prior to implant placement (Fig. 1c), and (3) conventional healing protocol (at least 3 months after augmentation as well as implant surgery). Bone augmentation surgery was considered in cases of less than 6 mm bone width. The study protocol was approved by the Ethics Committee of the Medical University of Vienna and patients gave their informed consent.

Clinical and radiologic assessment

The following variables were assessed clinically: height of the buccal keratinized mucosa (measured at the midfacial aspect), modified plaque index (Mombelli et al. 1987), bleeding-on-probing (4-point measurement), and peri-implant pocket depths (mesial, buccal, distal, palatal). In addition, patient- and implant-related factors such as age and gender, tobacco use, reason for tooth loss, implant site, length, diameter and healing modality (submerged vs. non-submerged) as well as height and type of prosthetic restoration (screw-retained vs. cemented) were recorded. Intraoral (periapical) radiographs were taken at follow-up visits and compared with the radiographs taken after implant placement (baseline). Radiographic bone loss was computed using an individual magnification factor determined by comparison of actual and radiographic implant length. Furthermore, anatomic crown height (measured from the incisal edge to the head of the implant), crown-to-implant ratio (Blanes 2009) and horizontal implant-tooth distance (HITD) at the level of the implant neck (Gastaldo et al. 2004) were determined.

Esthetic and patient-based evaluation

Objectively, the esthetic outcome was evaluated using standardized intraoral photographs of implant supported single crowns and adjacent peri-implant soft tissue. The Pink Esthetic Score (PES) and Papilla Index (PI) were assessed twice at an interval of 4 weeks by both a surgeon and a prosthodontist. The PES awards a total of seven variables (Fig. 4) with a score of 0 to 2. The maximum score of 14 points reflects perfect implant esthetics (Fürhauser et al. 2005). Peri-implant papilla height (Fig. 5) was assessed based on the PI (Jemt 1997). Patient satisfaction was assessed using the Visual Analog Scale (VAS) recommended as a subjective measure of implant esthetics (Belser et al. 2004b). The VAS consists of a 10 cm long line representing the spectrum of agreement between 0% (indicating total discontent) and 100% (indicating total satisfaction). Furthermore, patients were asked whether they would repeat the treatment, if necessary, and whether they would recommend it to others (Pjetursson et al. 2005; Dierens et al. 2009).

Statistical analysis

Sixty patients received a total of 85 single tooth implants. In patients with more than one implant, one implant was randomly selected to guarantee independence of observation. Continuous data are shown as mean and standard deviations in case of normally distributed data, and as median and interquartile range (IQR) otherwise. Differences between groups were tested using Wilcoxon rank-sum tests. Categorical data are described with absolute and relative frequencies. Associations between ordered categorical data were tested with a trend version of the Chi-square test assuming equal distances between groups. In case of sparse data, an exact version was used. Associations between metric data or ordinal data are described and tested by the nonparametric Spearman correlation coefficient (r_S). Means of mesial and distal measurements were used if not stated otherwise. Intra-observer agreement for PES and PI measurements was assessed using weighted kappa, where a value of 0 can be interpreted as no agreement (observed conformities may be explained by pure chance) and a value of 1 represents perfect agreement. Agreement among raters (inter-observer agreement) was assessed by Kendall's coefficient of concordance for ordinal responses. Statistical analyses were performed using SAS® statistic software (Version 9.2; Cary, NC, USA). All tests were two-sided and

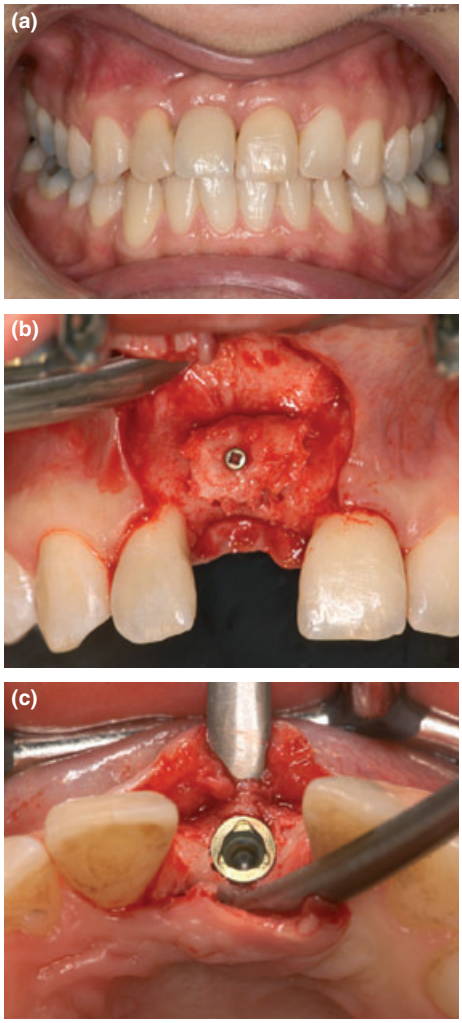

Fig. 1. Implant esthetics (a) following autologous bone augmentation (b) prior to implant placement (c).

$P \leq 0.05$ was considered significant. No adjustments for multiple comparisons were made as this study is of rather exploratory nature.

Results

Following horizontal ridge augmentation using autologous bone grafts, 60 single-tooth implants were placed in the anterior maxilla. At the time of implant surgery, the age of the patients (37 females and 23 males) ranged between 19 and 79 years (mean age: 36.8 years). Time between implant placement and follow-up visit ranged from 1.2 to 8.1 years (mean: 4.1 ± 1.9 years). Ten female and five male patients were smokers (25%). Reasons for anterior tooth loss included trauma (30%), aplasia (28%), crown/root fractures (18%) and endodontic failure (24%). Five implants were shorter than 13 mm (8.3%), 43 implants were 13 mm in length (71.7%), and the remainder were longer. An implant diameter of 3.5 mm was used in 33.3% and 4.3 mm in 48.3% of cases. Non-submerged implant healing was recorded in 23%. Single-tooth implant crowns showed a mean anatomic height of 10.5 ± 0.9 mm and were screw-retained in 28% of implants and cemented otherwise. The majority of implants (70%) were placed in incisor positions (Fig. 2). The proportions of central incisors, lateral incisors, canines, and first premolars were 41%, 18%, 12% and 29% of screw-retained and 46%, 28%, 14% and 12% of cemented implant crowns, respectively, without significant differences in distribution ($P = 0.255$; exact chi-square trend test).

All 60 implants fulfilled established success criteria (Smith & Zarb 1989). The mean height of the buccal keratinized mucosa measured 3.7 ± 1.2 mm and mean probing depths of 4.0 ± 1.1 mm were recorded. Bleeding on probing was seen in 57% of sites and associated with higher pocket depths ($P < 0.01$; exact chi-square trend test). No signs of plaque could be seen around 24 implants (40%) while a plaque index of 1, 2, and 3 was found in 27 (45%), 8 (13%), and 1 (2%) cases, respectively. Bleeding on probing was significantly correlated with high plaque index values ($P < 0.01$; exact chi-square trend test). Radiologic peri-implant bone loss was 1.3 ± 0.7 mm showing no correlation to duration of follow-up ($r_s = 0.11$, $P = 0.404$), presence of plaque ($r_s = -0.11$, $P = 0.395$), pocket depth ($r_s = 0.13$, $P = 0.319$), or crown-to-implant ratio ($r_s = 0.15$, $P = 0.247$). Horizontal distances from the implant neck to the adjacent mesial and distal tooth were 2.3 ± 1.0 mm and 2.0 ± 0.7 mm, respectively (range: 0.5–4.6 mm) demonstrating no correlation to peri-implant bone loss (mesial: $r_s = 0.04$, $P = 0.744$, distal: $r_s = -0.09$, $P = 0.488$; Spearman correlation).

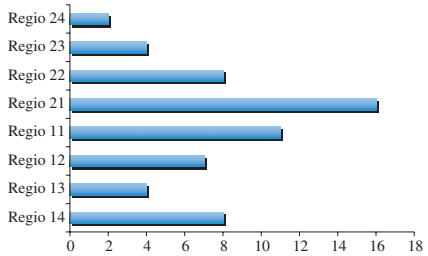

Fig. 2. Distribution of 60 maxillary implants in the esthetic zone.

Objective evaluation of implant esthetics resulted in a median Pink-Esthetic-Score (PES) of 11 (IQR: 8-12) and a median Papilla Index (PI) of 2 (IQR: 2-3) for both the mesial and distal papilla. Nonparametric descriptive statistics were used due to asymmetry of distribution in the PES histogram (Fig. 3). A significant positive correlation between the two esthetic indices was observed ($r_s = 0.53$, $P < 0.001$). Inter-observer agreement was generally higher for the PES (92%) compared with the PI (85%). Kappa values of intra-observer variability ranged from 0.70 to 1.00 for the PES and from 0.86 to 0.94 for the PI (Table 1). Among the 7 PES variables, PES-5 (alveolar process deficiency) and PES-7 (soft-tissue texture) demonstrated the lowest degree of intra-observer agreement (0.70 and 0.78, respectively) compared with all other variables (0.80–0.91) that may be explained by negligible rating frequencies of PES = 0 (Fig. 4, red bars) in these two PES variables (Kraemer et al. 2002). PI ratings of the mesial vs. distal papilla (Fig. 5) showed no significant difference ($P = 0.966$; Wilcoxon signed rank test); neither did PES-1 vs. PES-2 ($P = 0.547$; Wilcoxon signed rank test). Sites of large implant-tooth distances (≥2.5 mm) did not show significantly different esthetic results compared to those with HITD < 2.5 mm (mesial: $P = 0.721$; distal: $P = 0.876$; exact chi-square trend test).

Among the factors to influence implant esthetics (Table 2), significant inverse correlations of anatomic crown length on PES ($r_s = -0.36$, $P < 0.001$) and PI ($r_s = -0.55$, $P < 0.001$) were observed. No impact of smoking ($P = 0.394$; Wilcoxon rank-sum test) or duration of follow-up ($r_s = -0.17$, $P = 0.185$) could be found. Subjective evaluation of implant esthetics revealed a mean VAS score of 80% and demonstrated moderate but significant correlations to PES ($r_s = 0.42$, $P = 0.001$) as well as PI scores ($r_s = 0.30$, $P = 0.019$). No significant differences between screw-retained and cemented crowns were seen regarding subjective patient satisfaction ($P = 0.162$; Wilcoxon rank test) as well as objective PES ($P = 0.235$; Wilcoxon rank test) and PI ($P = 0.268$; Wilcoxon rank test) ratings. All patients claimed that they would repeat the treatment and recommend it to others.

Discussion

The present evaluation of anterior maxillary single-tooth implants following autologous bone augmentation yielded esthetic results

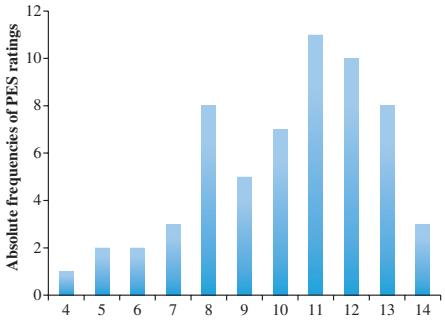

Fig. 3. Histogram illustrating skewed frequency distribution of PES (Pink Esthetic Score) ratings in the esthetic zone.

Table 1. **Intra- (weighted κ) and inter-observer agreement (Kendall's coefficient of concordance for ordinal responses) of PES (Pink Esthetic Score) and PI (Papilla Index) ratings**

Variable	Intra-observer agreement of prosthodontist ratings	Intra-observer agreement of surgeon ratings	Inter-observer agreement (prosthodontist vs. surgeon)
PES total	0.93	0.83	0.92
PES1: mesial papilla	0.95	0.80	0.87
PES2: distal papilla	0.84	0.98	0.87
PES3: level of soft-tissue	0.96	0.87	0.90
PES4: soft-tissue contour	0.93	0.83	0.81
PES5: alveolar process	0.92	0.70	0.71
PES6: soft tissue color	0.95	0.91	0.82
PES7: Soft tissue texture	1.00	0.78	0.72
PI mesial	0.86	0.94	0.83
PI distal	0.91	0.92	0.85

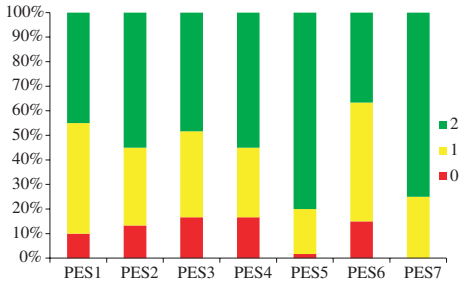

Fig. 4. Frequency distribution of PES (Pink Esthetic Score) ratings: each of the seven variables (PES1 = mesial papilla, PES2 = distal papilla, PES3 = level of soft-tissue margin, PES4 = soft-tissue contour, PES5 = alveolar process deficiency, PES6 = soft-tissue color and PES7 = soft-tissue texture) was rated from 0 (poor outcome) to 2 (optimum result).

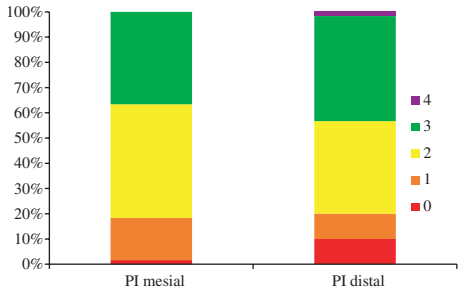

Fig. 5. Frequency distribution of mesial and distal Papilla Index (PI) ratings: 0 = no papilla present, 1 = less than half of the papilla height present (convex nature of the adjacent tissue), 2 = more than half of the papilla height present, but not to the full extent of the contact point (papilla not in complete harmony), 3 = papilla fills the entire proximal space and is in good harmony, 4 = papilla is hyperplastic (Jemt 1997).

comparable to those reported for implants placed in original jawbone without two-stage augmentation procedures (Table 3). Pink esthetic scores of 10 to 12 have been described to represent good esthetic results, while scores of 13 and 14 indicate optimum implant esthetics (Chen et al. 2009). Thus, 60% of implants in the present investigation can be considered to show satisfactory esthetics, while a rate of 88% has been reported for immediate implant placement (Chen et al. 2009). Chi-square comparison would indicate no significant difference between these two study results ($P = 0.131$); however, immediate protocols may not have been an option in most patient cases of the present study. Significant differences may also be suspected between literature results of immediate (Chen et al. 2009) vs. delayed implant placement (Lai et al. 2008) in the non-augmented anterior maxilla ($P < 0.001$). Between-study comparison of implant esthetics following bone augmentation (present study) and results of delayed implant placement without previous augmentation surgery (Lai et al. 2008) yielded a difference of borderline significance ($P = 0.041$); however, the authors would like to stress the fact that these results have to be interpreted with caution. Within-study comparison of different treatment protocols is needed to clarify potential differences in esthetic outcome.

In evaluating treatment outcomes of implants in the anterior maxilla, both objective implant esthetics and patient satisfaction should be considered. In the present investigation, patient satisfaction was significantly correlated with objective ratings by professionals. By contrast, other objective measures such as the Implant Crown Aesthetic Index (ICA) failed to appropriately reflect subjective patient opinion with regard to validity and reproducibility (Gehrke et al. 2008). Although the esthetic indices (PES, PI) used in the present study demonstrated respectable levels of inter- as well as intra-observer agreement, both of them revealed only moderate correlation with patient satisfaction. Future research may explore the success criteria of implant esthetics from the patients' perspective.

Studies indicate that the presence of peri-implant papilla seems to be dictated by the attachment level of the adjacent teeth (Grunder 2000; Choquet et al. 2001; Kan et al. 2003) and the horizontal implant-tooth distance (HITD): distances lower than 2.5 mm may result in papilla absence (Gastaldo et al.

Table 2. **Factors tested for influence (Spearman's *r*, *indicating statistical significance) on esthetic index values (PES = Pink Esthetic Score, PI = Papilla Index) and patient satisfaction (VAS = Visual Analog Scale)**

	PES		PI		VAS	
	r_s	*P*	r_s	*P*	r_s	*P*
Pocket depth	0.06	0.669	−0.07	0.577	−0.09	0.493
Plaque index	−0.18	0.174	−0.08	0.524	0.04	0.778
Implant length	−0.07	0.618	−0.17	0.201	0.01	0.915
Implant diameter	0.14	0.291	0.09	0.469	−0.19	0.140
Anatomic crown height	−0.36	0.001*	−0.55	<0.001*	−0.08	0.443
Horizontal implant- tooth distance	−0.07	0.612	0.04	0.747	0.02	0.867
Marginal bone loss	−0.03	0.815	−0.25	0.06	−0.14	0.274

Table 3. **Comparison of literature results evaluating the esthetic outcome of maxillary implants in the esthetic zone following different treatment modalities: Pink esthetic score (PES) mean (± SD) and median (interquartile range) and percentage distribution of outcome categories (satisfactory/unsatisfactory esthetic result)**

	Fürhauser et al. 2005	Lai et al. 2008	Juodzbalys & Wang 2007	Chen et al. 2009	Cosyn et al. 2010	Present study
Treatment concept	Various treatment concepts	Delayed implant placement, no bone augmentation	Immediate implant placement, simultaneous socket augmentation	Immediate implant placement, no bone augmentation	Early or delayed implant placement, no bone augmentation	Second stage implant placement following bone augmentation
Follow-up	No data	0.7–1 year	1 year	2.2 years	2.5 years	4.2 years
Mean PES (± SD)	9.5 ± 3.8	9.5 ± 2.3	11.1 ± 1.3	11.0 ± 1.7	10.2 ± 2.0	11.5 ± 0.7
Median PES (IQR)	–	9 (8–11)	11 (10–12)	11 (10–12)	11 (8–12)	11 (8–12)
Satisfactory esthetic result (PES = 10–14)	56%	45%	100%	88%	65%	60%
Unsatisfactory esthetic result (PES = 0–9)	44%	55%	0%	22%	35%	40%

2004), while papillae were found to be present in cases of HITD between 2.5 and 4 mm (Lops et al. 2008; Romeo et al. 2008). In the present study, however, no significant difference was observed between these two groups. In agreement with previous investigations (Cooper et al. 2001; Ryser et al. 2005; Palmer et al. 2007), it can therefore be suggested that HITD may not be the major determining factor for peri-implant papilla presence. The present study also confirms the finding that peri-implant papilla presence may not be strictly correlated with marginal bone loss (Degidi et al. 2008). Anatomic height of the implant crown, by contrast, was found to affect implants esthetics, showing highly significant correlation with both PES and PI ratings.

In conclusion, objective as well as subjective evaluation of maxillary implants following bone augmentation in the esthetic zone yielded satisfactory results. Future research is indicated to compare implant esthetics in augmented sites to immediate implants as well as delayed implant placement without bone augmentation. However, it should be kept in mind that long-term implant survival and success rates may be compromised in augmented bone (Rocchietta et al. 2008).

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