Single-Tooth Implants with Different Neck Designs: A Randomized Clinical Trial Evaluating the Aesthetic Outcome

Laurens den Hartog, DDS, PhD;* Gerry M. Raghoebar, DDS, MD, PhD;†
James J. Huddleston Slater, DDS, PhD;‡ Kees Stellingsma, DDS, PhD;§ Arjan Vissink, DDS, MD, PhD;¶
Henny J. A. Meijer, DDS, PhD**

ABSTRACT

Aim: To evaluate the aesthetic outcome of single-tooth implants in the aesthetic zone with different neck designs from a professional's and patient's perception.

Materials and Methods: Ninety-three patients with a missing anterior tooth in the maxilla were randomly assigned to be treated with an implant with a smooth neck, a rough neck with grooves or a scalloped rough neck with grooves. Implants were installed in healed sites. One year after definitive crown placement (18 months post-implant placement), photographs were taken and the aesthetic outcome was assessed according to two objective aesthetic indexes: pink esthetic score/white esthetic score (PES/WES) and implant crown aesthetic index (ICAI). A questionnaire was used to assess the aesthetic outcome and general satisfaction from a patient's perception. Standardized radiographs were taken to measure marginal bone level changes.

Results: One implant was lost. Although there was a significant difference in marginal bone loss between the different implant neck designs (smooth neck 1.19 ± 0.82 mm, rough neck 0.90 ± 0.57 mm, scalloped neck 2.01 ± 0.77 mm), there were no differences in aesthetic outcome. According to the professional's assessments using PES/WES and ICAI, 79.3% and 62% of the cases showed acceptable crown aesthetics, and 59.8% and 56.5% of the cases showed acceptable mucosa aesthetics. Overall, patients were satisfied about the aesthetics of the mucosa (81.5%) and crown (93.3%), and general patient satisfaction was high (9.0 ± 1.0 out of a maximum of 10). According to the professional's assessment, a pre-implant augmentation procedure was associated with less favorable aesthetics of the mucosa.

Conclusion: This study shows that the aesthetics of single-tooth implants in the maxillary aesthetic zone appears to be independent of the implant neck designs applied but dependent on the need for pre-implant surgery.

KEY WORDS: aesthetics, dental implant, esthetics, implant neck, single tooth, soft tissue

INTRODUCTION

The focus of attention in contemporary implantology has shifted from implant survival towards the quality of implant survival. Particularly in the anterior region, the aesthetic outcome has been considered to be of significance for the overall treatment success.[1–3] Both the

*Department of Oral and Maxillofacial Surgery, University Medical Center Groningen and University of Groningen, Groningen, the Netherlands; †Department of Oral and Maxillofacial Surgery, University Medical Center Groningen and University of Groningen, Groningen, the Netherlands; ‡Department of Oral and Maxillofacial Surgery and Center for Dentistry and Oral Hygiene, Department of Oral Health Care and Clinical Epidemiology, University Medical Center Groningen and University of Groningen, Groningen, the Netherlands; §Department of Oral and Maxillofacial Surgery, University Medical Center Groningen and University of Groningen, Groningen, the Netherlands; ¶Department of Oral and Maxillofacial Surgery, University Medical Center Groningen and University of Groningen, Groningen, the Netherlands; **Department of Oral and Maxillofacial Surgery and Center for Dentistry and Oral Hygiene, Department of Prosthodontics, University Medical Center Groningen and University of Groningen, Groningen, the Netherlands

Reprint requests: Dr. Laurens den Hartog, Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, Hanzeplein 1, PO Box 30.001, 9700 RB Groningen, the Netherlands; e-mail: l.den.hartog@kchir.umcg.nl

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appearance of the implant crown and the peri-implant mucosa contribute to the final aesthetic outcome.[2,4]

The level of the peri-implant mucosa is an important aspect determining the aesthetic outcome.[2,4] The level of the peri-implant marginal bone has been associated with the level of the peri-implant mucosa.[5–7] After implant placement, it is accepted that some peri-implant marginal bone loss will occur.[8] Hence, loss of peri-implant marginal bone might affect the level of the peri-implant mucosa and, with that, the final aesthetic outcome.

The design of the implant neck is considered to be of relevance for preservation of marginal peri-implant bone.[6,9,10] It has been reported that an implant neck with a roughened surface or with retention elements might result in less marginal peri-implant bone resorption than a traditional smooth implant neck (Figure 1, A and B).[9–11] As a consequence, the neck of novel implant designs are often provided with a roughened surface and retention elements to induce maximum bone preservation, particularly when to be applied in aesthetically sensitive cases. Apart from the capacity of a rough implant neck to preserve marginal peri-implant bone, it has been suggested that an implant neck with a scalloped implant platform might preserve marginal peri-implant bone, especially at the proximal side (Figure 1C).[12,13] Such a scalloped implant neck would mirror the alveolar ridge curvature, which is lower on the facial and oral aspects but rises in the proximal areas. Relative to the bone crest, the implant-abutment interface at the proximal aspect is located at a more coronal position compared with common flat-platform implant designs, possibly leading to more marginal bone preservation.

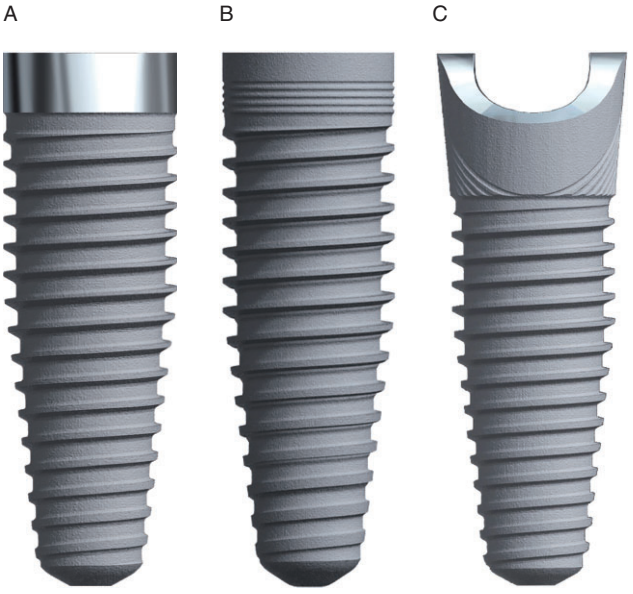

Figure 1 (A) Implant with a 1.5-mm smooth ("machined") implant neck (Replace Select Taperered, Nobel Biocare AB). (B) Implant with a moderately rough implant neck with grooves (NobelReplace Groovy, Nobel Biocare AB). (C) Implant with a scalloped moderately rough implant neck with grooves from a facial point of view (NobelPerfect Groovy, Nobel Biocare AB).

To assess the aesthetic outcome of implant therapy, both the opinions of the professional and patient have to be considered. From a professional's perception, the aesthetic outcome should be explored using an objective rating instrument. Such an instrument will facilitate a thorough analysis of the final result to improve surgical or prosthetic treatment aspects. Furthermore, it can be of value to assess treatment strategies longitudinally or to identify host factors. Recently, two instruments have been introduced to measure the aesthetics of the crown and mucosa, namely the implant crown aesthetic index (ICAI)[4] and the pink esthetic score/white esthetic score (PES/WES).[2]

As the patient is the final user of implant therapy, the opinion of the patient is also of importance.[14] A method to assess the subjective aesthetic outcome from a patient's perspective is the use of questionnaires.[15–17]

Inherent to the recent shift towards the quality of implant survival, only a few studies on anterior implant therapy inquired into the aesthetic outcome[1,3] and, to our best knowledge, no clinical trials have yet been published addressing the aesthetic outcome of different implant neck designs. Furthermore, little is known about predisposing factors associated with the final aesthetic outcome. Therefore, the aim of this trial was to evaluate the aesthetic outcome of anterior single-tooth implants with three different neck designs from a professional's and patient's perception. In addition, peri-implant marginal bone level changes were assessed.

MATERIALS AND METHODS

Patients

All patients with a single missing tooth in the maxillary aesthetic zone (incisor, canine, or first premolar) who were referred for implant treatment to the Department of Oral and Maxillofacial Surgery (University Medical Center Groningen, University of Groningen, Groningen, the Netherlands) were considered for inclusion. Patients had to be at least 18 years of age. The width of the

diastema was at least 6 mm and was neighbored with natural teeth. Oral hygiene had to be adequate (modified plaque index and modified sulcus bleeding index scores ≤ 1).[18] Exclusion criteria were smoking, American Society of Anesthesiologists (ASA) score ≥ III,[19] presence of an active periodontal disease as expressed by probing pocket depths ≥4 mm and bleeding on probing (index score ≥ 2), and a history of radiotherapy to the head and neck region.

Study Design

The study protocol of this prospective randomized clinical trial was approved by the Medical Ethical Committee of the University Medical Center Groningen and written informed consent was obtained from all eligible patients before enrolment. Patients were included between January 2005 and February 2008. By means of a specifically designed locked computer program, patients were randomly assigned to one of three study groups to be treated with an implant:

- a 1.5-mm smooth ("machined") implant neck (Replace Select Tapered, Nobel Biocare AB, Göteborg, Sweden) – "smooth" group (Figure 1A);
- a rough implant neck with grooves (NobelReplace Tapered Groovy, Nobel Biocare AB) – "rough" group (Figure 1B);
- a scalloped rough implant neck with grooves (NobelPerfect Groovy, Nobel Biocare AB) – "scalloped" group (Figure 1C).

Randomization by minimization[20] was used to minimize differences between the treatment groups with regard to the following variables: age (≤30 years, >30 years), location of the implant site (central or lateral incisor, canine or first premolar), and whether or not a pre-implant augmentation procedure in a separate session was indicated beforehand. The surgeon that inserted the implants was informed about the allocation on the day of surgery.

Intervention Procedure

Implants were inserted in healed sites at least 3 months after tooth removal. When bone volume was insufficient for implant placement, a bone augmentation procedure was carried out in a separate session. As a grafting material, autogenous intra-oral bone was used together with anorganic bovine bone (Geistlich Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) covered with a collagen membrane (Geistlich BioGide). Implants were inserted 3 months after the augmentation procedure.

At implant surgery, a slightly palatal crest incision with extensions through the buccal and palatal sulcus of the adjacent teeth and a divergent relieving incision at the distal tooth were made. A minimal mucoperiosteal flap was prepared to expose the alveolar ridge. The implant site was prepared by using a surgical template that was fabricated in the dental laboratory, based on the prospective implant crown in its ideal position. With respect to the corono–apical position of the implants, the shoulder of the implant was placed at a depth of 3 mm apical to the most apical aspect of the surgical template for optimal emergence profile. For the scalloped implants, the mid-facial part of the scalloped implant shoulder was taken as reference. The proximal peaks of the scalloped implants were aligned towards the proximal bone, facing the adjacent teeth. Cases, in which the implant neck remained uncovered after proper corono–apical positioning or in which the bone wall thickness facially to the implant was <2 mm, were locally augmented. For this procedure, autogenous bone chips collected during implant bed preparation and anorganic bovine bone (Geistlich Bio-Oss) were used and subsequently covered with Geistlich BioGide. The wound was closed with Ethilon 5–0 nylon sutures (Johnson & Johnson Gateway, Piscataway, NJ, USA).

During the healing phase, patients were wearing a removable partial denture that did not interfere with the wound. After 3 months, implants were uncovered and a screw-retained provisional crown was fabricated by means of an engaging temporary abutment and composite (Solidex, Shofu Inc., Kyoto, Japan). After a provisional phase of 3 months (i.e., 6 months post-implant placement), a definitive crown was made consisting of an individually fabricated zirconia abutment for the smooth and rough groups (Procera, Nobel Biocare AB) and individualized titanium abutments (Procera) for the implants in the scalloped group because zirconia abutments were not available for these implants. A zirconia Procera coping was luted over the titanium abutments in order to create an abutment with a zirconia outside. Depending on the location of the screw access hole, crowns were cement-retained by means of a zirconia Procera coping or screw-retained by fusing porcelain directly to the abutment. Cemented-retained crowns were cemented with glass ionomer cement (Fuji Plus, GC Europe, Leuven, Belgium). In seven patients the

contralateral tooth received a new all-ceramic zirconia crown (Procera) in the same procedure (two in the smooth group and rough group, three in the scalloped group). For more details regarding product specifications, we refer to a previous clinical report.[21]

All surgical procedures were performed by a single experienced surgeon. The prosthetic procedure was accomplished by two experienced prosthodontists and all crowns were fabricated by one dental technician.

Aesthetic Assessment

The aesthetic outcome was assessed on digital photographs that were taken 1 year after placement of the definitive crown (18 months after implant placement) (camera: Fuji-film FinePix S3 Pro, Tokyo, Japan). The implant and adjacent dentition were captured on one photograph, which was centered at the midline. Of implants that replaced a lateral incisor, canine or first premolar, two additional photographs were taken on which the implant and contralateral tooth were centered.

The ICAI[4] and the PES/WES[2] were used to determine the aesthetics of the peri-implant mucosa and implant crown. Both indexes were used, to allow for comparison with data from other studies. Both indexes are composed of aesthetically related items based on the anatomic form, color, and surface characteristics of the implant crown and peri-implant soft tissue.

The ICAI contains nine items of which five are related to the crown and four are related to the peri-implant mucosa. For each item, penalty points of 0, 1, and 5 can be given as representing no, minor and major deviations compared with the contralateral tooth *and* adjacent dentition. The total score for crown and mucosa leads to the following corresponding judgment about the aesthetic outcome: (1) 0 penalty points, excellent; (2) 1 or 2, satisfactory; (3) 3 or 4, moderate; and (4) 5 or more, poor aesthetics (note: one item with a major deviation leads to poor aesthetics). In this study, the ICAI was slightly modified and has been used to analyze the aesthetics of the crown (ICAI crown) and the aesthetics of the mucosa (ICAI mucosa) separately.

The PES/WES contains ten items, five for crown and five for mucosa. In contrast to the ICAI, the PES/WES rewards items with points instead of utilizing penalty points. Taking the contralateral tooth as a reference, on each item 0, 1, or 2 points can be assigned representing major, minor, or no discrepancies. The highest possible score for the crown (WES) and for the mucosa (PES) is 10. A threshold of clinical acceptability has been defined for the PES/WES, which is set at 6 points for the WES and 6 points for the PES.

Measurements were done by two observers that were blinded to the group allocation. The intraobserver agreement of the ICAI and PES/WES has been shown to be acceptable in the studies in which these indexes were introduced.[2,4]

Patient Satisfaction

Patient satisfaction was assessed using a self-administered questionnaire. The questionnaire comprised of four questions regarding patient's aesthetic satisfaction with the color and shape of the crown and mucosa. These questions could be answered on a 5-point rating scale ranging from "very dissatisfied" (score 1) to "very satisfied" (score 5). Furthermore, patients were asked to mark their general satisfaction on a 10-cm visual analogue scale (VAS) having end phrases "very dissatisfied" (0) on the left end and "very satisfied" (10) on the right end.

Change in Marginal Bone Level

After implant placement and 1 year after placement of the definitive crown (18 months post-implant placement), standardized digital intra-oral radiographs were taken according to a long-cone paralleling technique according to the procedure as described by Meijndert and colleagues[22] Marginal bone level changes were measured using specifically designed software. All measurements were performed by one examiner. The radiographic examination could not be blinded because the type of implant neck could be derived directly from the radiographs. The reliability of the photographic examination was assessed using 14 randomly selected radiographs from each study group that were measured by two examiners and by one examiner twice with a 2-week interval.

Data Analysis

ICAI crown scores, ICAI mucosa scores, PES scores, and WES scores were analyzed separately. To assess the interobserver agreement of both aesthetic evaluation instruments, linear weighted kappa (κ) values were calculated. The intraobserver and interobserver agreement for the radiographic assessment was expressed as the 95% limits of agreement,[20] representing the interval containing

95% of the differences between the observations to be compared. In addition, the intraclass correlation coefficient was calculated.

Per patient, ICAI and PES/WES scores of both observers were averaged. For the ICAI, the average score was subsequently transposed to the corresponding judge (i.e., excellent, satisfactory, moderate, poor aesthetics). For between-group comparisons, Kruskal–Wallis tests were used followed by post hoc Mann–Whitney tests in case of statistical significance. One way analysis of variance was conducted for between-group comparisons of marginal bone level changes. To identify factors associated with the aesthetic outcome, multiple regression analysis were performed. The following factors were explored: implant type, age, gender, and whether or not a pre-implant augmentation procedure was performed. Correlations between the aesthetic outcome and patient's aesthetic satisfaction were determined with Spearman's correlation tests.

In all analyses, a significant level of 0.05 was chosen. Data were analyzed using the Statistical Package for Social Sciences (version 16.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Patients

A total of 93 patients were included. Details regarding patient characteristics are depicted in Table 1. One implant in the smooth group was lost 5 months after implant placement. The implant survival rate at 18 months after implant placement was 96.8% for the smooth group (1 implant lost) and 100% for the rough and scalloped study groups. All patients attended the follow-up visit at 1 year after definitive crown placement.

Aesthetic Assessments

The PES/WES showed a satisfactory interobserver agreement. A weighted κ-value of 0.69 was calculated for the PES and a value of 0.62 was calculated for the WES. The ICAI showed satisfactory interobserver agreement for the soft-tissue assessment (κ-value 0.64), whereas moderate agreement was found for the assessment of the crown (κ-value 0.39). Because of this moderate agreement, the ICAI crown assessment was not used in the correlation and regression analyses.

There were no differences between study groups regarding the aesthetic outcome of the crown and peri-implant mucosa (Table 2). Furthermore, a per-item analysis of both indexes showed no differences between study groups. According to the PES/WES, in 59.8% of the cases the mucosa showed acceptable aesthetics (PES score ≥ 6) and in 79.3% of the cases the aesthetics of the crown were acceptable (WES score ≥ 6) (Figures 2 and 3). According to the ICAI, 56.5% of the cases showed satisfactory mucosa aesthetics (satisfactory and excellent combined) and 62% showed satisfactory crown aesthetics (Figures 2 and 3). For both indexes, the crown item "color of the crown" showed the lowest score and most penalty points. According to the WES, 69% of the crowns showed a discrepancy in color and according to the ICAI this percentage was 68% (mean values of both observers). The soft tissue item "level of the labial mucosa" showed the most penalty points of the ICAI (54% showed deviation) and the second lowest score of the PES (61% showed deviation). The PES-item "root convexity, soft tissue color and texture" was assigned the lowest score (76% showed deviation).

Multivariate linear regression analyses revealed that a pre-implant augmentation procedure was significantly associated with a lower PES score and ICAI mucosa score (regression coefficient, respectively, 1.27 and 0.55

TABLE 1 Baseline Characteristics per Study Group

Variable	Smooth Group ($n = 31$)	Rough Group ($n = 31$)	Scalloped Group ($n = 31$)
Mean age (years) ± standard deviation (range)	37.2 ± 12.9 (18–60)	40.1 ± 14.4 (18–67)	40.1 ± 17.2 (19–80)
Male/female ratio	15/16	17/14	14/17
Implant site location I1/I2/C/P1	20/7/1/3	18/8/3/2	18/6/3/4
Augmentation before implant surgery*	12	11	10

*Implants were installed after 3 months.

TABLE 2 PES, WES, ICAI Mucosa, and ICAI Crown Scores per Study Group and for the Whole Study Population

	Smooth ($n = 30$)*	Rough ($n = 31$)	Scalloped ($n = 31$)	Overall ($n = 92$)
PES				
Mean ± SD	6.0 ± 1.9	6.3 ± 1.7	6.6 ± 1.6	6.3 ± 1.7
Range (0–10)	1.5–9.5	3.5–9.5	3.5–9	1.5–9.5
WES				
Mean ± SD	7.2 ± 1.5	7.4 ± 1.6	7.2 ± 1.6	7.3 ± 1.5
Range (0–10)	4.5–9.5	4–10	4.5–10	4–10
ICAI mucosa				
Excellent	2 (6.7%)	0 (0%)	0 (0%)	2 (2.2%)
Satisfactory	14 (46.7%)	15 (48.4%)	21 (67.7%)	50 (54.3%)
Moderate	8 (26.7%)	6 (19.4%)	4 (12.9%)	18 (19.6%)
Poor	6 (20%)	10 (32.3%)	6 (19.4%)	22 (23.9%)
ICAI crown				
Excellent	1 (3.3%)	1 (3.2%)	1 (3.2%)	3 (3.3%)
Satisfactory	17 (56.7%)	18 (58.1%)	19 (61.3%)	54 (58.7%)
Moderate	10 (33.3%)	10 (32.3%)	7 (22.6%)	27 (29.3%)
Poor	2 (6.7%)	2 (6.5%)	4 (12.9%)	8 (8.7%)

*One implant was lost.
SD = Standard deviation; PES = pink esthetic score; WES = white esthetic score; ICAI = implant crown aesthetic index.

for PES and ICAI). The factor age contributed significantly to the outcome of WES (regression coefficient –0.048), whereas implant type and gender were not associated with the aesthetic outcome.

Patient Satisfaction

Patient satisfaction was high (Table 3) and there were no between-group differences. General patient satisfaction scores using VAS ranged from 5.5 to 10.

Figure 2 Implant in right central incisor position. Mean pink esthetic score 9, mean white esthetic score 9. Satisfactory mucosa (1 penalty point) and satisfactory crown aesthetics (1 penalty point) according to implant crown aesthetic index. Minor deviations were noted regarding the items soft tissue texture and general tooth form (mesiodistal width).

Figure 3 Implant in right central incisor position. Mean PES score 6, mean WES score 7.5. Satisfactory mucosa (2 penalty points) and satisfactory crown aesthetics (2 penalty points) according to implant crown aesthetic index. Minor deviations were noted regarding the soft tissue items mesial papilla, distal papilla, level of the labial mucosa and curvature of the facial mucosa and to the crown items general tooth form (mesiodistal width) and color.

TABLE 3 Patient Satisfaction per Study Group and for the Whole Study Population

	Number of Patients Being Satisfied (%) *			
	Smooth ($n = 30$)†	Rough ($n = 31$)	Scalloped ($n = 31$)	Overall
Color of the crown	28 (93.3%)	30 (96.8%)	28 (90.0%)	86 (93.3%)
Shape of the crown	28 (93.3%)	31 (100%)	29 (93.5%)	88 (95.7%)
Color of the gums	26 (86.7%)	27 (87.1%)	26 (83.9%)	79 (85.9%)
Shape of the gums	24 (80.0%)	27 (87.1%)	24 (77.4%)	75 (81.5%)
General patient satisfaction (VAS score; mean ± SD)	8.8 ± 1.1	8.9 ± 1.0	9.1 ± 0.8	9.0 ± 1.0

*Measured on 5-point scale (4 or 5 equals satisfied).
†One implant was lost.
VAS = visual analogue scale; SD = standard deviation.

Patient's aesthetic satisfaction with the appearance of the mucosa (color and shape) was correlated with the outcome of PES. The outcome of all questions was correlated with general patient satisfaction.

Change in Marginal Bone Level

The assessment of the reliability of the radiographic examination revealed an intraobserver difference of –0.01 ± 0.25 mm (limits of agreement: –0.50 and 0.50 mm) and an interobserver difference of 0.08 ± 0.31 mm (limits of agreement: –0.69 and 0.54 mm). Intraclass correlation coefficient of 0.99 and 0.96 were calculated for the intraobserver and interobserver agreement, respectively, signifying high levels of agreement.

The amount of marginal bone loss from implant placement to 1 year after definitive crown placement (equals 18 months post-implant placement) is presented in Table 4. The mean marginal bone loss (mesial and distal sides combined) was 1.19 ± 0.82 mm in the smooth group, 0.90 ± 0.57 mm in the rough group, and 2.01 ± 0.77 mm in the scalloped group and was significantly different.

TABLE 4 Mean Marginal Bone Loss (mm) at Mesial and Distal Implant Sides from Implant Placement to 1 Year after Definitive Crown Placement (Equals 18 Months after Implant Placement)

	Smooth ($n = 30$)*	Rough ($n = 31$)	Scalloped ($n = 31$)
Mesial of implant	1.10 ± 0.83	0.91 ± 0.66	2.01 ± 0.74†
Distal of implant	1.27 ± 1.09	0.90 ± 0.77	2.00 ± 1.01†

*One implant was lost.
†$p < .05$.
SD = standard deviation.

DISCUSSION

This clinical trial evaluated the aesthetic outcome of single-tooth implants in the anterior dentition with three different neck designs as an independent factor, using two established indexes for rating the objective aesthetic outcome and a questionnaire to subjectively evaluate the aesthetics from a patient's perception. Although there were significant differences in radiographic marginal bone loss between the three implant neck designs included in this trial, no differences in aesthetic outcome were observed. Patient satisfaction was high and it revealed that there was a discrepancy between the patient's aesthetic satisfaction and the objective aesthetic outcome according to the indexes.

With regard to the aesthetic outcome of the peri-implant mucosa, no differences were notified between the three implant neck designs. Furthermore, none of the separate soft tissue items showed differences between the study groups. Beforehand, we hypothesized that the design of the implant neck might have an effect on the level of the peri-implant mucosa because there might be differences in marginal bone loss between the implant neck designs included. However, using both indexes, such an effect could not be shown in our study, despite between group differences in marginal bone loss. One reason for this might be that the amount of peri-implant marginal bone resorption brought about a clinical effect that was too little to be observed with the indexes. A second reason might be attributed to the role of the periodontium of the adjacent teeth. It is

assumed that the bone level next to the adjacent teeth is highly related to at least the future level of the papillae.[23,24] Possibly, the periodontium also acts on other aesthetically related aspects as the level of the facial mucosa. A third reason for not observing between-group differences in soft tissue levels despite differences in marginal bone loss might be ascribed to the preoperative situation. It could be that the level of the mucosa before implant placement was more relevant to the future level of the peri-implant mucosa than the amount of bone loss around the implant neck.

The aesthetic assessment of the crown did not reveal differences between study groups. We believe that the implant necks we investigated are of less importance for the final crown aesthetics. Implants in the study groups were restored according to the same procedure. The only difference was that for the implants in the scalloped group, titanium abutments had to be used instead of zirconia abutments in the smooth and rough group. However, the titanium abutments were modified by means of a zirconia layer. Besides, all crowns in this study were all ceramic.

As a result from the recent introduction of the PES/WES and ICAI, published studies using these indexes for aesthetic evaluation are scarce. Only a few studies could be identified that reported the aesthetic outcome of anterior single tooth replacements using the PES/WES[2,25–27] or a modification of the PES/WES[28] and only one study could be found using the ICAI.[29] To our best knowledge, these are the only available instruments to rate the aesthetics of both crown and mucosa. In the first study on the PES/WES,[2] the reproducibility of this index was analyzed on the basis of 45 maxillary single-tooth implants installed according to an early implant placement procedure. A mean PES score of 7.7 ± 1.3 was reported and no implant scored lower than 6 points, the predefined level of clinical acceptability. In a second study from the same research group,[25] a PES score of 8.1 ± 1.75 was reported for 20 early placed implants and only one case showed less than 6 points. In our study, the aesthetics of the mucosa were judged with a mean score of 6.3 and 40.2% of the cases scored less than 6 points, thus were clinical unacceptable. Most likely, a less favorable preoperative situation was the underlying factor for these lower PES scores. In our study, all implants were inserted in healed extraction sites and teeth had already been extracted at the first consultation without having opportunities to perform socket preservation techniques. It is known that after tooth removal, the walls of the alveolus undergo substantial resorption at the facial aspect, affecting the soft tissue anatomy.[30,31] Early implant placement and simultaneous guided bone regeneration, according to which the implants in the abovementioned studies were inserted, might favor the facial soft tissue anatomy. For instance, it was demonstrated in these studies that the level of the contralateral reference tooth was identical in 77.8% (35 of 45)[2] and 90% (18 of 20)[25] of the cases. In our study, however, this item showed the second lowest score of all items and in 34 of 92 patients (37%) the level of the mucosa was identical.

The less favorable preoperative situation in our study is also reflected in the frequency of pre-implant augmentation procedures, necessary to allow for proper implant installation 3 months later. In our study, a pre-implant augmentation procedure was needed in one-third of the patients and the regression analyses showed that this procedure was significantly associated with a lower PES score. A study to the aesthetic outcome of anterior single-tooth implants installed after a separate augmentation procedure, confirmed the negative effect of a pre-implant placement augmentation procedure on the appearance of the mucosa.[29]

With regard to the assessments of the implant crown, in the study by Belser and colleagues[2] crowns were judged with a mean WES score of 6.9 ± 1.5, which is in line with the score of 7.3 ± 1.5 as we observed. However, in the other study from the same research group,[25] the mean WES score was 8.7 ± 1.0. It was argued that this higher WES score could be explained by the fact that only one dental technician was involved having excellent expertise in the field of esthetic restorations versus multiple joining technicians in the other study. Compared with our study, this difference in white aesthetics might be explained from the fact that in our study the contralateral tooth received a new crown less frequently (in the study by Buser and colleagues,[25] 5 of 20 contralateral teeth received a new crown, in our study 7 of 92). Because the contralateral tooth serves as a reference tooth in assessing the white aesthetics, it is easier to reach a higher aesthetic judge when these teeth are provided with a new crown too, particularly on the variables color, translucency, and texture. Furthermore, it should be realized that the less favorable pink aesthetics we observed could affect the outcome of the white aesthetics. Less voluminous papillae for instance or an

undercontoured alveolar process might be compensated by overcontouring the anatomy of the crown. Regarding the color of the crown, this will remain a challenging item to fulfill without any discrepancy. In our study and in the study by Buser and colleagues,[25] this item showed the lowest appreciation. It should be realized, however, that the aesthetics were assessed on photographs. It might be that in a direct assessment of the patient, the color of the crown shows more favorable resemblance with the adjacent dentition.

As was expected from other studies, patient satisfaction was high.[1,16,17] Although the outcome of PES was correlated to patient satisfaction with the appearance of the mucosa, most of the patients were satisfied with the appearance of the mucosa (>80%) and even more patients were satisfied with the appearance of the crown (>93%). This discrepancy, between the aesthetic outcome from a professional's and patient's perception, has been demonstrated in earlier studies.[14,29,32] This difference might be explained by the finding that factors considered by professionals to be relevant for the esthetic outcome may not be of decisive importance for patient's aesthetic satisfaction.[32] Furthermore, it might be that for the final appreciation of the patient, the preoperative situation plays a role of significance and gives weight to the final judgment. When the preoperative situation is compromised and patient's expectations are realistic, patients might be satisfied even when the aesthetic outcome, according to an objective index taking only the final result into consideration, is poor. The high general patient satisfaction we observed might be deduced from the patient's appreciation with the aesthetics, because the outcome of all questions was correlated with general patient satisfaction. However, it should be noticed that also other aspects as function and comfort might contribute to general patient satisfaction.

With respect to the reproducibility of the ICAI, controversial degrees of intraobserver and interobserver agreement have been reported. At the introduction of the ICAI, two prosthodontists showed acceptable intraobserver and interobserver agreement. Gehrke and colleagues,[33] however, reported poor to moderate reliability for the ICAI when applied by different professionals including prosthodontists. In our study, the ICAI was slightly modified and was used to generate a separate judgment for the crown and mucosa instead of an overall judgment. It was found that the reliability of the mucosa assessment was acceptable and of the crown assessment was moderate. Apparently, the crown is more prone to disagreement than the mucosa. We believe that this moderate reproducibility might be caused by the scoring system of the ICAI and the corresponding final judgment. Namely, when an item deviates majorly in the observers' eyes, the aesthetics will be judged automatically as being poor. However, when this deviation is minor according to another observer, large differences in final judgment will occur. Furthermore, the ICAI is based on comparing the implant crown with the contralateral tooth and the adjacent dentition as well. This might lead to more variation in observer interpretation. Because the PES/WES applies a different scoring system and the contralateral tooth is the only reference, this index might be less sensitive for disagreement and subsequently showed higher reliability. However, this might also lead to shortcomings because a major discrepancy on an item yet might lead to acceptable aesthetics and in some cases it would be more plausible to involve the adjacent dentition in the analyses as well (for instance when the contralateral tooth shows compromised aesthetics). More studies would be helpful to further develop a reproducible and valid aesthetic index, which should be commonly applied in implant research.

In conclusion, this study shows that there were no differences in aesthetic outcome between the different implant necks of single-tooth implants applied in the aesthetic zone, despite significant differences in peri-implant marginal bone loss. According to the most reproducible index (the PES/WES), the aesthetics of the peri-implant mucosa was judged as being not acceptable in 40% of the cases whereas 20% of the implant crowns were not aesthetically acceptable. However, patient's aesthetic satisfaction regarding color and shape of crown and mucosa was high. It should be realized that in this study all implants were installed in healed sites at least 3 months after extraction and one third of the cases had to be augmented before implant placement. Because we found that the need for a pre-implant augmentation procedure has a detrimental effect on the objective aesthetic outcome of the mucosa, this underlines the need to prevent a separate augmentation procedure, possibly by extracting hopeless teeth in an earlier stage or by performing socket preservation techniques.

REFERENCES

1. Den Hartog L, Slater JJ, Vissink A, Meijer HJ, Raghoebar GM. Treatment outcome of immediate, early and

conventional single-tooth implants in the aesthetic zone: a systematic review to survival, bone level, soft-tissue, aesthetics and patient satisfaction. J Clin Periodontol 2008; 35:1073–1086.
2. Belser UC, Grutter L, Vailati F, Bornstein MM, Weber HP, Buser D. Outcome evaluation of early placed maxillary anterior single-tooth implants using objective esthetic criteria: a cross-sectional, retrospective study in 45 patients with a 2- to 4-year follow-up using pink and white esthetic scores. J Periodontol 2009; 80:140–151.
3. Annibali S, Bignozzi I, La Monaca G, Cristalli MP. Usefulness of the aesthetic result as a success criterion for implant therapy: a review. Clin Implant Dent Relat Res 2009 [Epub ahead of print].
4. Meijer HJ, Stellingsma K, Meijndert L, Raghoebar GM. A new index for rating aesthetics of implant-supported single crowns and adjacent soft tissues-the implant crown aesthetic index. Clin Oral Implants Res 2005; 16:645–649.
5. Bengazi F, Wennstrom JL, Lekholm U. Recession of the soft tissue margin at oral implants. A 2-year longitudinal prospective study. Clin Oral Implants Res 1996; 7:303–310.
6. Hermann JS, Cochran DL, Nummikoski PV, Buser D. Crestal bone changes around titanium implants. A radiographic evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. J Periodontol 1997; 68:1117–1130.
7. Hermann JS, Buser D, Schenk RK, Schoolfield JD, Cochran DL. Biologic Width around one- and two-piece titanium implants. Clin Oral Implants Res 2001; 12:559–571.
8. Laurell L, Lundgren D. Marginal bone level changes at dental implants after 5 years in function: a meta-analysis. Clin Implant Dent Relat Res 2011; 13:19–28.
9. Lee DW, Choi YS, Park KH, Kim CS, Moon IS. Effect of microthread on the maintenance of marginal bone level: a 3-year prospective study. Clin Oral Implants Res 2007; 18:465–470.
10. Bratu EA, Tandlich M, Shapira L. A rough surface implant neck with microthreads reduces the amount of marginal bone loss: a prospective clinical study. Clin Oral Implants Res 2009; 20:827–832.
11. Shin YK, Han CH, Heo SJ, Kim S, Chun HJ. Radiographic evaluation of marginal bone level around implants with different neck designs after 1 year. Int J Oral Maxillofac Implants 2006; 21:789–794.
12. Wohrle PS. Nobel Perfect esthetic scalloped implant: rationale for a new design. Clin Implant Dent Relat Res 2003; 5 (Suppl 1):64–73.
13. Kan JY, Rungcharassaeng K, Liddelow G, Henry P, Goodacre CJ. Periimplant tissue response following immediate provisional restoration of scalloped implants in the esthetic zone: a one-year pilot prospective multicenter study. J Prosthet Dent 2007; 97:S109–S118.
14. Esposito M, Grusovin MG, Worthington HV. Agreement of quantitative subjective evaluation of esthetic changes in implant dentistry by patients and practitioners. Int J Oral Maxillofac Implants 2009; 24:309–315.
15. Levi A, Psoter WJ, Agar JR, Reisine ST, Taylor TD. Patient self-reported satisfaction with maxillary anterior dental implant treatment. Int J Oral Maxillofac Implants 2003; 18:113–120.
16. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent 2003; 23:313–323.
17. Pjetursson BE, Karoussis I, Burgin W, Bragger U, Patients LNP. satisfaction following implant therapy. A 10-year prospective cohort study. Clin Oral Implants Res 2005; 16:185–193.
18. Mombelli A, van Oosten MA, Schurch E Jr, Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987; 2:145–151.
19. Smeets EC, de Jong KJ, Abraham-Inpijn L. Detecting the medically compromised patient in dentistry by means of the medical risk-related history. A survey of 29,424 dental patients in The Netherlands. Prev Med 1998; 27:530–535.
20. Altman DG. Practical statistics for medical research. London: Chapman & Hall, 1991.
21. Den Hartog L, Raghoebar GM, Stellingsma K, Meijer HJ. Immediate loading and customized restoration of a single implant in the maxillary esthetic zone: a clinical report. J Prosthet Dent 2009; 102:211–215.
22. Meijndert L, Meijer HJ, Raghoebar GM, Vissink A. A technique for standardized evaluation of soft and hard peri-implant tissues in partially edentulous patients. J Periodontol 2004; 75:646–651.
23. Choquet V, Hermans M, Adriaenssens P, Daelemans P, Tarnow DP, Malevez C. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. J Periodontol 2001; 72:1364–1371.
24. Romeo E, Lops D, Rossi A, Storelli S, Rozza R, Chiapasco M. Surgical and prosthetic management of interproximal region with single-implant restorations: 1-year prospective study. J Periodontol 2008; 79:1048–1055.
25. Buser D, Halbritter S, Hart C, et al. Early implant placement with simultaneous guided bone regeneration following single-tooth extraction in the esthetic zone: 12-month results of a prospective study with 20 consecutive patients. J Periodontol 2009; 80:152–162.
26. Cho HL, Lee JK, Um HS, Chang BS. Esthetic evaluation of maxillary single-tooth implants in the esthetic zone. J Periodontal Implant Sci 2010; 40:188–193.

27. Buser D, Wittneben J, Bornstein MM, Grütter L, Chappuis V, Belser UC. Stability of contour augmentation and esthetic outcomes of implant supported single crowns in the esthetic zone. 3-Year results of a prospective study with early implant placement post extraction. J Periodontol 2010 [Epub ahead of print].
28. Cosyn J, Eghbali A, De Bruyn H, Dierens M, De Rouck T. Single implant treatment in healing versus healed sites of the anterior maxilla: an aesthetic evaluation. Clin Implant Dent Relat Res 2010 [Epub ahead of print].
29. Meijndert L, Meijer HJ, Stellingsma K, Stegenga B, Raghoebar GM. Evaluation of aesthetics of implant-supported single-tooth replacements using different bone augmentation procedures: a prospective randomized clinical study. Clin Oral Implants Res 2007; 18:715–719.
30. Schropp L, Isidor F, Kostopoulos L, Wenzel A. Patient experience of, and satisfaction with, delayed-immediate vs. delayed single-tooth implant placement. Clin Oral Implants Res 2004; 15:498–503.
31. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. J Clin Periodontol 2005; 32:212–218.
32. Chang M, Odman PA, Wennstrom JL, Andersson B. Esthetic outcome of implant-supported single-tooth replacements assessed by the patient and by prosthodontists. Int J Prosthodont 1999; 12:335–341.
33. Gehrke P, Degidi M, Lulay-Saad Z, Dhom G. Reproducibility of the implant crown aesthetic index–rating aesthetics of single-implant crowns and adjacent soft tissues with regard to observer dental specialization. Clin Implant Dent Relat Res 2009; 11:201–213.