

Case Series

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

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Background: To validate the concept of early implant placement for use in the esthetically sensitive anterior maxilla, clinical trials should ideally include objective esthetic criteria when assessing outcome parameters.

Methods: In this cross-sectional, retrospective 2- to 4-year study involving 45 patients treated with maxillary anterior single-tooth implants according to the concept of early implant placement, a novel comprehensive index, comprising pink esthetic score and white esthetic score (PES/WES; the highest possible combined score is 20), was applied for the objective esthetic outcome assessment of anterior single-tooth implants.

Results: All 45 anterior maxillary single-tooth implants fulfilled strict success criteria for dental implants with regard to osseointegration, including the absence of peri-implant radiolucency, implant mobility, suppuration, and pain. The mean total PES/WES was 14.7 ± 1.18 (range: 11 to 18). The mean total PES of 7.8 ± 0.88 (range: 6 to 9) documents favorable overall peri-implant soft tissue conditions. The two PES variables facial mucosa curvature (1.9 ± 0.29) and facial mucosa level (1.8 ± 0.42) had the highest mean values, whereas the combination variable root convexity/soft tissue color and texture (1.2 ± 0.53) proved to be the most difficult to fully satisfy. Mean scores were 1.6 ± 0.5 for the mesial papilla and 1.3 ± 0.5 for the distal papilla. A mean value of 6.9 ± 1.47 (range: 4 to 10) was calculated for WES.

Conclusions: This study demonstrated that anterior maxillary single-tooth replacement, according to the concept of early implant placement, is a successful and predictable treatment modality, in general, and from an esthetic point of view, in particular. The suitability of the PES/WES index for the objective outcome assessment of the esthetic dimension of anterior single-tooth implants was confirmed. However, prospective clinical trials are needed to further validate and refine this index. *J Periodontol* 2009;80:140-151.

KEY WORDS

Case series; clinical trial; dental implants; outcome assessment; single-tooth implants.

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Implant therapy in partially edentulous patients has become a well-established treatment modality, in general, and anterior single-tooth replacement has become a highly predictable solution, in particular. Numerous studies¹⁻⁵ have reported similar implant survival and success rates for implants inserted in the esthetic zone compared to those placed in other segments of the jaws. However, the current literature is scarce when it comes to objective outcome evaluation from an esthetic point of view.⁶⁻²¹ Not infrequently, one has to thoroughly search the text of clinical studies that report on anterior maxillary implants to extract relevant esthetics-related information.

Although some publications^{6,14,16,22} have highlighted the impact of the height of the patient's smile line on esthetics, other studies^{7,23-25} paid particular attention to the influence of the presence or absence of interproximal gingival papillae after implant therapy. An index to assess the size and volume of interproximal papillae adjacent to single-tooth implants, termed the papilla index, was proposed.²³ The index defined five distinct levels, ranging from the complete absence of papillary tissue (index score 0) to hyperplastic papillae (index score 4). This index was used for the esthetic examination of 25 single-tooth implants, reporting a significant spontaneous regeneration of papillae after a mean follow-up period of 18 months compared to the peri-implant soft tissue conditions present at the time of insertion of the restorations. The investigator concluded that the proposed index was suitable for the scientific assessment of soft tissue contours adjacent to single-tooth implant restorations.

More recently, several additional attempts have been made to implement objective criteria for assessing the esthetic dimension of a fixed implant restoration located in the anterior region of the mouth.²⁶⁻²⁸ Meijer et al.²⁶ published the aesthetic implant crown index consisting of criteria related to the implant restoration itself and those associated with the surrounding soft tissues. Fürhauser et al.²⁷ made an excellent proposal in the form of an index termed the pink esthetic score (PES), focusing essentially on the soft tissue aspects associated with an anterior implant restoration. They identified seven distinct soft tissue parameters: the presence or absence of mesial and distal papillae, the level and curvature of the line of emergence of the implant restoration from the mucosa at the facial aspect, facial soft tissue convexity (in analogy to a "root eminence"), and the color and texture of the facial marginal peri-implant mucosa. The investigators assigned the same weight to each of the seven parameters, i.e., 2, 1, or 0, which results in a maximum possible score of 14.

Implant dentistry has constantly evolved toward the simplification of clinical procedures and shortened treatment times, such as flapless surgery, immediate

implant placement, and immediate implant restoration. Studies^{17,21,29} that have applied these protocols mostly report similar short- and mid-term implant survival and success rates compared to more traditional treatment approaches. However, when it comes to their implementation in the anterior maxilla, these protocols may lead to less favorable results from an esthetic point of view, e.g., recession of the peri-implant mucosa. To validate or reject such novel implant protocols for use in the esthetically sensitive anterior maxilla, clinical trials should routinely include objective esthetic criteria when assessing outcomes. These criteria should comprehensively embrace the pertinent elements of the so-called pink and white esthetics in the form of an easy-to-use index.

The aim of this study was to define a novel comprehensive index for the objective outcome assessment of the esthetic dimension of anterior maxillary single-tooth implants and to apply this index for the outcome assessment of 45 maxillary anterior single-tooth implants that had been inserted according to the concept of early implant placement.

MATERIALS AND METHODS

Definition of a New Esthetic Index: PES/White Esthetic Score (WES)

To comprehensively assess the long-term performance of maxillary anterior single-tooth implants from an esthetic point of view, a suitable index has to satisfy the following criteria: pertinence, inclusion of the relevant peri-implant soft tissues and the specifically restoration-inherent parameters, definition of a threshold of clinical acceptability, ease of use, and reproducibility.

As a consequence, the authors modified a previously published peri-implant soft tissue index²⁷ (PES) and combined it with a novel implant restoration index developed for this study (WES).

PES. In contrast to the original proposal, the PES comprises the following five variables (Fig. 1; Table 1): mesial papilla, distal papilla, curvature of the facial mucosa, level of the facial mucosa, and root convexity/soft tissue color and texture at the facial aspect of the implant site.

A score of 2, 1, or 0 is assigned to all five PES parameters. The two papillary scores (mesial and distal) are assessed for the complete presence (score 2), incomplete presence, (score 1), or absence (score 0) of papillary tissue. The curvature of the facial soft tissue line, also defined as the line of emergence of the implant restoration from the soft tissues, is evaluated as being identical (score 2), slightly different (score 1), or markedly different (score 0) compared to the natural control tooth and, thus, provides a natural symmetrical or disharmonious appearance. The level of the facial peri-implant mucosa is scored by

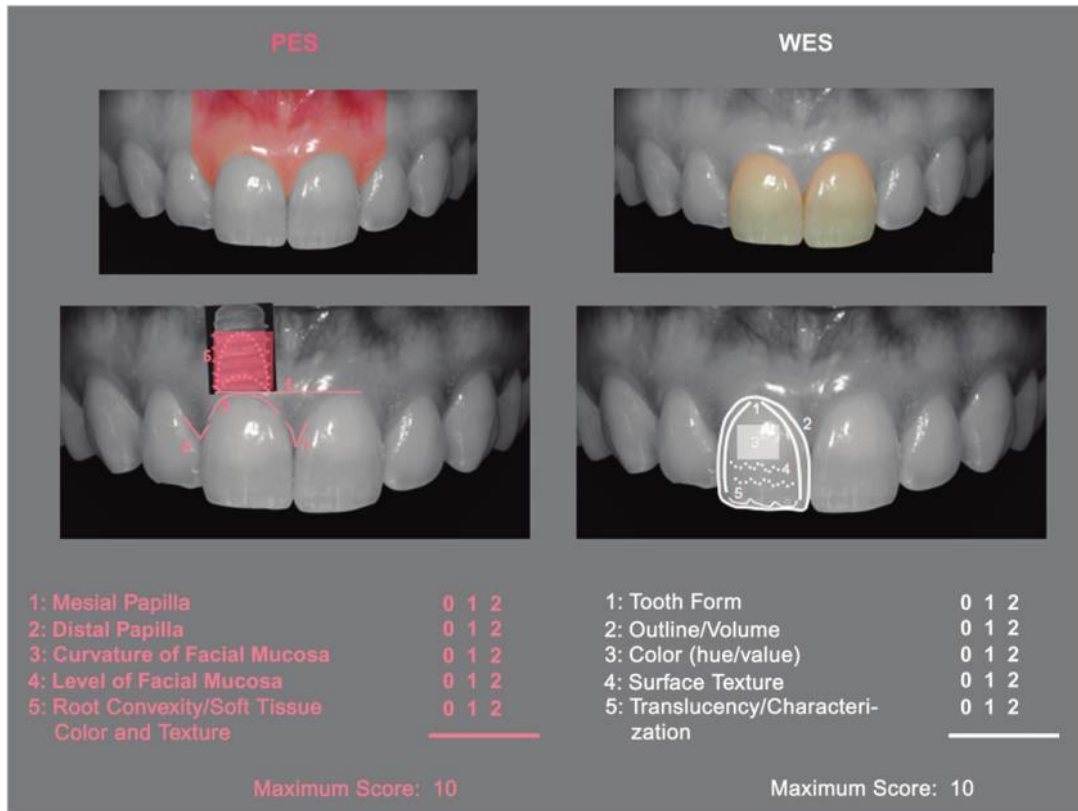


Figure 1.

Guide for the use of PES/WES based on the virtual presentation of an optimal single-tooth implant restoration.

comparison to the contralateral tooth in terms of an identical vertical level (score 2), a slight (≤ 1 mm) discrepancy (score 1), or a major (≥ 1 mm) discrepancy (score 0). Finally, the proposed index combines three additional specific soft tissue parameters as one variable: the presence, partial presence, or absence of a convex profile (in analogy to a root eminence) on the facial aspect, as well as the related mucosal color and surface texture. The latter two elements basically reflect the presence or absence of an inflammatory process, which, in turn, may adversely affect the appearance of an anterior single-tooth implant restoration. To attain a score of 2 for this combination variable, all three parameters are more or less identical compared to the control tooth. A value of 1 is assigned if two criteria are fulfilled, whereas a score of 0 is assigned if none or only one parameter matches the control site.

The five described parameters (5×2) add up, under optimum conditions, to a score of 10; the threshold of clinical acceptability was set at 6.

WES. The WES specifically focuses on the visible part of the implant restoration itself (i.e., the part of the implant crown that emerges from the peri-implant mucosa) and is based on the five following parameters: general tooth form; outline and volume of the

clinical crown; color, which includes the assessment of the dimension's hue and value; surface texture; and translucency and characterization (Fig. 1; Table 1).

A score of 2, 1, or 0 is assigned to all five parameters. Thus, in case of an optimum implant restoration, a maximum total WES of 10 is reached. All five parameters are assessed by direct comparison with the natural, contralateral reference tooth, estimating the degree of match or eventual mismatch. In the case of an optimum duplication of the esthetically relevant features inherent to the control tooth, a maximum WES score of 10 is possible. Again, the threshold of clinical acceptance was set at a score of 6.

Hence, the highest possible combined PES/WES score is 20, which represents a close match of the peri-implant soft tissue conditions and the clinical single-tooth implant crown compared to the respective features present at the contralateral natural tooth site. To facilitate the objective appreciation of some of the parameters, the fabrication of study casts, in addition to standardized clinical photographs, is indispensable. The clinical photographs are primarily used to assess general tooth/crown form, tooth/crown color, incisal translucency and characterization, as well as soft tissue color, curvature, and level. The study cast

Table 1.
Detailed Description of PES/WES

PES			
Parameter	Absent	Incomplete	Complete
Mesial papilla	0	I	2
Distal papilla	0	I	2
	Major Discrepancy	Minor Discrepancy	No Discrepancy
Curvature of facial mucosa	0	I	2
Level of facial mucosa	0	I	2
Root convexity/soft tissue color and texture	0	I	2
Maximum total PES score			10
WES			
Parameter	Major Discrepancy	Minor Discrepancy	No Discrepancy
Tooth form	0	I	2
Tooth volume/outline	0	I	2
Color (hue/value)	0	I	2
Surface texture	0	I	2
Translucency	0	I	2
Maximum total WES score			10

evaluation completes the PES/WES assessment, facilitating the objective appreciation of crown outline, volume, and surface texture, in addition to root convexity and soft tissue texture.

Clinical Study

Patient population. Forty-five patients of a cohort of 49 who had been treated consecutively at the Department of Oral Surgery and Stomatology, University of Bern, between 2001 and 2004 with maxillary anterior single-tooth implants, according to the concept of early implant placement,³⁰ were included in this cross-sectional retrospective study. The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000. All included patients had to sign an informed consent form. Four patients were not able to participate in the follow-up examination. Thus, the group consisted of 16 female and 29 male patients, with a mean age of 39.9 years (range: 17 to 81 years); the implant sites included 26 central incisor, 11 lateral incisor, three canine, and five first premolar positions. The specific patient-selection process and related data set were described in more detail in a recent publication.³¹

Surgical and Reconstructive Treatment Protocol

The concept of early implant placement is defined by a postextraction healing period of 4 to 8 weeks prior to implant insertion, to allow for soft tissue healing; it was described in detail in previous publications.^{30,31}

In this study, screw-type titanium implants^{||} with a sand-blasted acid-etched surface and a regular neck

diameter of 4.8 mm were inserted according to established surgical principles.³⁰ Because all implants were placed in the anterior maxilla, a 1.8-mm machined neck was chosen. After a healing period of 6 to 12 weeks, depending on the volume of the peri-implant bone defect to be regenerated with the guided bone regeneration technique, osseointegration was confirmed clinically and radiographically; subsequently, the prosthetic procedures were initiated. All implants were restored for a transient period of 1 to 3 months with screw-retained provisional implant crowns, based on prefabricated titanium copings, prior to the permanent reconstruction by means of porcelain-fused-to-metal crowns. Because the vast majority of patients had been referred from private practices to the Department of Oral Surgery and Stomatology, University of Bern, for the placement of the implants, the subsequent prosthetic procedures were mostly carried out by the referring general practitioners. Consequently, the implant crowns were mainly fabricated in regional private dental laboratories. Therefore, this cohort of single-tooth implant crowns is likely to be heterogeneous in design, but it represents the current status of implant prosthodontics in private practice.

Clinical Follow-Up Examination

The 45 patients were recalled in 2006 as part of their routine annual recall program. A clinical examination was performed and radiographs were taken according to a well-established protocol, generally applied to

^{||} Straumann Dental Implant System, Institute Straumann, Basel, Switzerland.

Table 2.
Detailed PES and WES of All 45 Included Implants

Patient	Implant Site	PES						WES						Total PES + WES
		Mesial Papilla	Distal Papilla	Curvature of Facial Mucosa	Level of Facial Mucosa	Root Convexity, Soft Tissue Color and Texture	Total PES	Tooth Form	Tooth Volume/Outline	Color (hue/value)	Surface Texture	Translucency and Characterization	Total WES	
1	9	1	1	1	2	1	6	1	1	1	1	2	6	12
2	10	1	2	2	2	0	7	1	1	1	1	1	5	12
3	9	2	2	1	2	2	9	1	1	2	1	2	7	16
4	8	2	1	2	2	1	8	1	1	2	2	1	7	15
5	9	2	1	2	2	2	9	1	1	2	1	2	7	16
6	12	1	1	2	2	1	7	2	1	2	2	2	9	16
7	9	2	1	2	2	2	9	2	1	2	1	1	7	16
8	8	2	1	1	2	1	7	1	1	1	1	1	5	12
9	10	1	1	1	2	2	7	1	1	1	1	1	5	12
10	7	2	1	2	1	1	7	2	1	2	1	2	8	15
11	9	2	1	2	2	1	8	2	1	1	1	1	6	14
12	7	2	1	2	1	2	8	2	1	2	2	2	9	17
13	5	2	1	2	2	1	8	1	1	1	1	1	5	13
14	7	1	2	2	1	1	7	1	1	2	1	1	6	13
15	6	1	1	2	2	1	7	1	2	1	1	1	6	13
16	8	2	1	2	2	1	8	1	1	0	1	1	4	12
17	6	1	2	2	2	0	7	1	1	1	1	2	6	13
18	10	1	1	2	1	1	6	1	1	2	2	2	8	14
19	12	1	1	2	2	2	8	1	2	2	1	1	7	15
20	8	2	1	2	2	1	8	2	2	1	2	2	9	17
21	7	1	1	2	2	1	7	1	1	1	1	2	6	13
22	7	1	2	2	2	1	8	1	1	2	1	2	7	15
23	8	2	1	2	2	1	8	1	1	2	2	2	8	16
24	10	1	1	2	2	1	7	1	1	2	2	2	8	15
25	9	2	2	2	2	1	9	2	1	2	1	2	8	17
26	8	2	1	2	2	1	8	2	1	1	2	1	7	15
27	9	2	1	2	2	1	8	1	2	1	1	2	7	15
28	8	1	1	2	1	1	6	1	1	2	1	2	7	13
29	9	2	2	2	2	1	9	1	1	2	1	2	7	16

Table 2. (continued)
Detailed PES and WES of All 45 Included Implants

Patient	Implant Site	PES						WES						Total PES + WES
		Mesial Papilla	Distal Papilla	Curvature of Facial Mucosa	Level of Facial Mucosa	Root Convexity, Soft Tissue Color and Texture	Total PES	Tooth Form	Tooth Volume/Outline	Color (hue/value)	Surface Texture	Translucency and Characterization	Total WES	
30	8	1	1	2	2	1	7	1	2	2	2	2	9	16
31	12	2	1	2	1	1	7	1	1	2	1	2	7	14
32	9	2	2	2	2	1	9	1	1	1	1	2	6	15
33	9	2	1	2	1	1	7	2	1	2	1	1	7	14
34	7	1	1	2	2	1	7	1	1	1	1	1	5	12
35	9	1	1	2	2	2	8	1	1	2	2	1	7	15
36	8	2	2	2	1	2	9	2	1	2	2	2	9	18
37	5	1	1	2	2	2	8	2	2	2	2	2	10	18
38	9	2	2	2	2	1	9	2	2	2	1	2	9	18
39	9	2	1	2	2	1	8	1	1	2	1	2	7	15
40	8	2	1	2	1	2	8	1	1	1	1	1	5	13
41	11	1	2	2	2	1	8	1	2	2	2	2	9	17
42	10	2	1	2	2	2	9	1	2	1	1	2	7	16
43	9	2	1	2	2	0	7	1	1	1	0	1	4	11
44	9	2	2	2	1	1	8	1	1	1	1	1	5	13
45	9	2	2	2	2	1	9	2	1	2	1	2	8	17
	Mean	1.60	1.29	1.91	1.78	1.18	7.76	1.29	1.20	1.56	1.27	1.60	6.91	14.67

determine implant survival and implant success.³²⁻³⁵ At the time of recall, six patients had their implant restorations for 4 years, 16 patients had theirs for 3 years, and 23 patients had theirs for 2 years.

As reported in a recently published study,³¹ the following standard soft tissue and radiographic parameters were assessed: modified plaque index, modified sulcus bleeding index, probing depth (PD), the distance between the implant shoulder and the mucosal margin (DIM), clinical attachment level (sum of PD+DIM), and the distance between the implant shoulder and the first discernible bone-implant contact.

Evaluation of Esthetic Treatment Outcome

PES/WES analysis. For this purpose, all implant crowns located in the position of canines (three crowns), lateral incisors (11 crowns), or central incisors (26

crowns) were photographed with a digital camera,^{¶#} making sure that the contralateral tooth was also completely and symmetrically represented. Additional standardized clinical photographs (×1 magnification) were taken at each implant site and at the contralateral tooth. For the 26 central incisor implants, the photograph was centered at the midline to facilitate the subsequent analysis, which is primarily based on symmetry. The photographic approach was slightly modified for the five first premolar single-tooth implants involved in the study. These standardized photographs had to include a full representation of the second premolar, which served as the reference. Finally, a pair of study casts, produced in type IV stone, was fabricated for each of the 45

¶ Fuji S2 Pro, Fujifilm Holding, Tokyo, Japan.
 # Nikon 105 mm Macro lens, Nikon, Tokyo, Japan.

Table 3.
Summarized PES and WES of the 45 Included Implants

PES						
	Mesial Papilla	Distal Papilla	Curvature of Facial Mucosa	Level of Facial Mucosa	Root Convexity/Soft Tissue Color and Texture	Total Score (maximum 10)
Maximum	2	2	2	2	2	9
Minimum	1	1	1	1	0	6
Mean	1.6	1.3	1.9	1.8	1.2	7.8
SD	0.50	0.46	0.29	0.42	0.53	0.88
WES						
	Tooth Form	Tooth Volume/Outline	Color (hue/value)	Surface Texture	Translucency/Characterization	Total Score (maximum 10)
Maximum	2	2	2	2	2	10
Minimum	1	1	1	1	0	4
Mean	1.3	1.2	1.6	1.3	1.6	6.9
SD	0.46	0.40	0.55	0.50	0.50	1.47

patients to facilitate a direct, objective assessment related to the PES/WES index.

The PES/WES analyses were performed by one experienced prosthodontist (LG) who had not been involved in the prosthetic treatment of any of the patients enrolled in the study. To reduce bias and to ensure optimum reproducibility, the evaluation was carried out twice on different days. In the few cases of diverging scores, the examiner carefully reevaluated the photographs and study casts prior to making her decision. To further reduce the risk for an inconsistency in scoring, a third PES/WES evaluation was scheduled on a different date, this time with the participation of a second prosthodontist (UCB). Each implant site was scored together, following the order of the 10 PES/WES parameters. In case of differences, a short discussion was engaged in until a consensus between the two examiners was reached. Again, in case of divergent scores, which were extremely rare at this stage, the two examiners debated until a final consensus was reached. At this point, the general principle of retaining the lower of the two litigious scores was implemented to avoid any trend toward too favorable results.

Patient Questionnaire and Related Visual Analog Scale (VAS) Analysis

A questionnaire comprising three items addressing specific esthetically related aspects of the treatment was sent to all 45 patients 1 month after the follow-

up examination. Each question included a VAS, permitting the patient to precisely mark on a calibrated horizontal line his or her specific degree of satisfaction with the aspect of the single-tooth implant treatment. The questionnaires were accompanied by simple and precise instructions for use.

The first question asked the patient to judge retrospectively the overall treatment protocol regarding the inherent therapy and the length of treatment. The associated scale reached from “unbearable” to “diligent and easy to support.” The second question asked whether the treatment result fulfilled the patient’s general expectations. Here, the range of possible answers went from “totally unsatisfied” to “fully satisfied.” Finally, the third question addressed specifically the patient’s satisfaction with the treatment outcome from an esthetic point of view; the range of possible answers went from “totally unsatisfied” to “completely satisfied.” The questionnaires were analyzed according to the published guidelines³⁶ related to a testing technique for measuring subjective or behavioral phenomena.

Statistical Analyses

The implemented statistical analysis aimed at detecting any significant correlations between the total PES/WES scores and the responses to questions 2 and 3, because they were more directly related to the esthetic indices than was question 1. A linear regression analysis was conducted to compare separately the VAS response to questions 2 and 3 to the total PES/

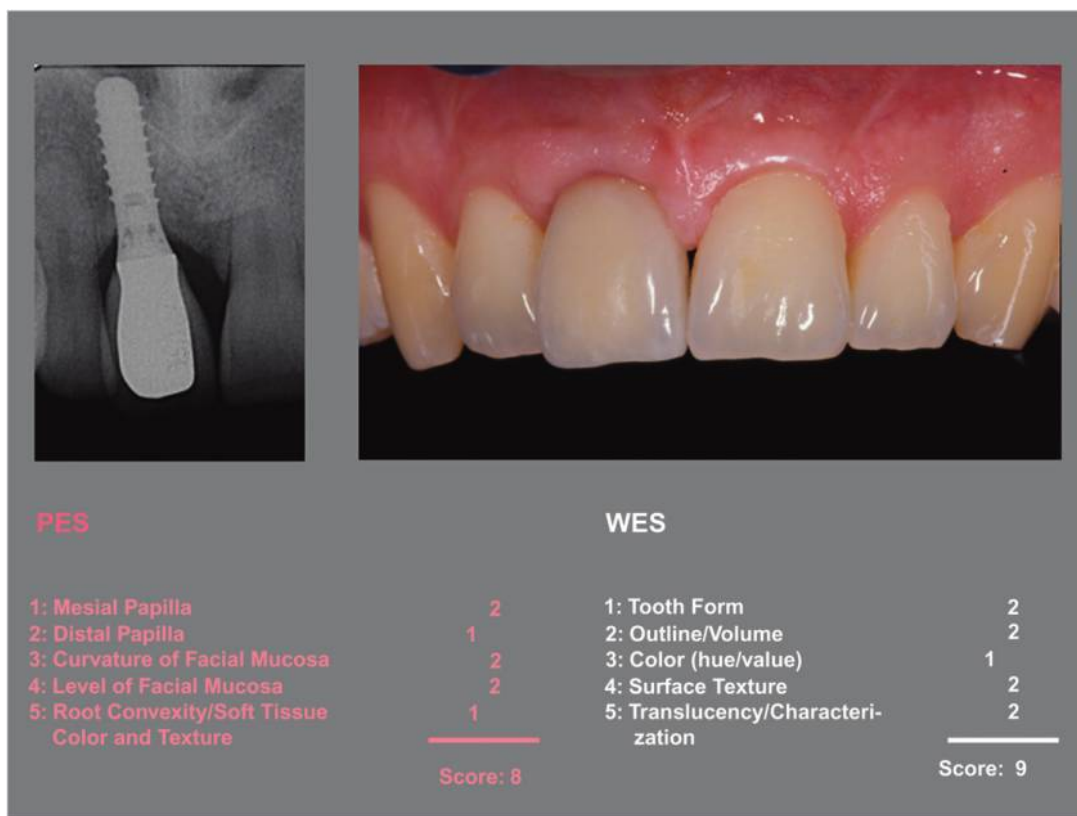


Figure 2.

Clinical and radiographic aspect of a single-tooth implant at the right central incisor location with high PES/WES.

WES score. All analyses were performed using computer software.**

RESULTS

Standard Soft Tissue and Radiographic Parameters

All 45 anterior maxillary single-tooth implants fulfilled the strict success criteria defined by Buser et al.,³² i.e., status of stable osseointegration, including the absence of peri-implant radiolucency, implant mobility, suppuration, and pain. The detailed analysis of the relevant clinical and radiographic parameters of this retrospective, cross-sectional case series was reported in a separate publication.³¹

Evaluation of Esthetic Treatment Outcome

PES/WES analysis. The detailed PES/WES scores of the 45 examined single-tooth implants are presented in Table 2, whereas the summarized scores, including the standard deviations, are shown in Table 3. The mean total PES/WES was 14.7 ± 1.18 (range: 11 to 18). Only one of 45 anterior single-tooth implants had an overall score <12, (11), which corresponds, from an esthetic point of view, to a treatment outcome slightly below the defined threshold of clinical acceptability.

The mean total PES was 7.8 ± 0.88 (range: 6 to 9). The two PES parameters facial mucosa curvature (1.9 ± 0.29) and facial mucosa level (1.8 ± 0.42) had the highest mean values, whereas the combination variable root convexity/soft tissue color and texture (1.2 ± 0.53) was the most difficult to satisfy; only 11 of 45 implant sites attained the maximum value of 2. For the papillary area, mean scores of 1.6 ± 0.5 for the mesial papilla and 1.3 ± 0.46 for the distal papilla were reached. For the total PES, none of the 45 single-tooth implants scored <6.

For the WES, the mean total was 6.9 ± 1.47 (range: 4 to 10). Of the 45 implant crowns examined, nine (20%) scored slightly below the threshold of 6.

Figures 2 and 3 are the clinical photographs and the radiographs of two representative examples: one central incisor single-tooth implant with a total PES/WES of 17 (corresponding to an excellent overall esthetic outcome) and one central incisor with a total score of 12 (less favorable esthetic outcome, corresponding to the threshold level of clinical acceptability). Although these two examples are distinctly different from an esthetic point of view, they are both compatible with strict implant success criteria.³²

** SAS 9.1, SAS Institute, Cary, NC.



Figure 3.

Clinical and radiographic aspect of a single-tooth implant at the left central incisor location with low PES/WES.

Patient Questionnaire and Related VAS Analysis

Thirty-nine (86%) of 45 patients returned the completed questionnaires. Despite the clear instructions for use, one questionnaire was filled out incorrectly; 38 could be analyzed. Of these 38 patients, 27 had a higher PES than WES.

Question 1 asked for general feedback of the patient's subjective satisfaction with the treatment protocol. Thirty-four patients located their satisfaction with the overall treatment procedure distinctly above the 60% mark on the VAS, which led to a mean score of $85.2\% \pm 16.2\%$ (range: 51.2% to 100%). Questions 2 and 3, which specifically addressed the treatment outcome, led to a highly positive, but less differentiated, patient feedback; this was demonstrated by the fact that none of the answers was <60% and that only one answer to question 2 and three answers to question 3 were <80%.

Eight of nine patients who had a total WES <6 answered the questionnaire. The comparison of the objective evaluation by the examiners and the subjective answers by the patients demonstrated their satisfaction as >94% for questions two and three. A similar picture was present when one looked at the lower one-third of the total PES/WES compared to question

3; the lowest satisfaction score was 91%, whereas the related total PES/WES score was <13.5.

The linear regression analysis did not reveal any statistically significant correlations between the total PES/WES and the VAS response to questions 2 and 3. This confirms the fact that the patient's perception of dental restorations from an esthetic point of view frequently differs significantly from that of dental professionals. Only when looking separately at the response to question 3 by four of 38 patients, giving VAS scores of 75 to 82 (Fig. 4), could one detect a moderately strong correlation between PES/WES and VAS response (correlation coefficient: 0.82; $P = 0.1798$).

DISCUSSION

This retrospective, cross-sectional study presented the esthetic outcomes of 45 anterior maxillary single-tooth implants inserted according to the concept of early implant placement. The esthetic outcomes were assessed with a new comprehensive PES/WES index. The mean total PES/WES of 14.7 indicated an overall successful esthetic outcome; only one crown scored <12, which was defined as the threshold of clinical acceptability.

The PES (mean score of 7.8) was clearly higher than the corresponding WES (mean score of 6.9). This is not surprising, because the PES is mainly influenced by the local anatomy and the applied surgical procedure to regenerate the peri-implant bone defects routinely present in postextraction implant sites. Hence, the routine and skills of the implant surgeon play an important role in the esthetic outcome of peri-implant soft tissues. The procedures in this retrospective study were carried out by an experienced implant surgeon (DB). None of the 45 single-tooth implants scored <6, which confirms the high predictability of the surgical protocol used in this study. The main goal of the applied surgical protocol is a predictable contour augmentation of the facial bone wall to support esthetically pleasing soft tissue contours, in particular the avoidance of mucosal recession. The two PES variables facial mucosa curvature and facial mucosa level showed high scores (mean score of 1.9 and 1.8, respectively), indicating that this goal was achieved with high predictability.

The scores for the mesial and distal papillae (mean scores of 1.6 and 1.3, respectively) were slightly less favorable. However, the height of peri-implant papillae primarily depends on the bone level height at adjacent root surfaces, as shown in two clinical studies.^{7,25} Because the present study was a retrospective case-series study without a control arm,³¹ the influence of the timing of implant placement (immediate versus early versus late), the design and type of implant used, and the type of surgical access flap chosen on the soft tissues and, therefore, the PES data, cannot be judged. In future studies, it would be of interest to use the PES/WES to evaluate the benefit of different papilla-preservation flap designs when placing dental implants in the esthetic zone using guided bone regeneration procedures.^{37,38}

The combination variable root convexity/soft tissue color and texture showed the lowest mean score

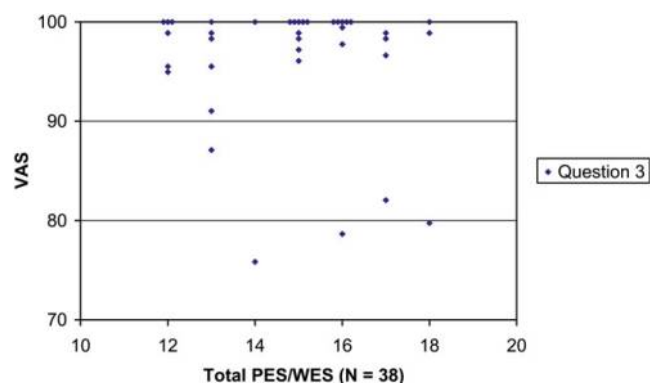


Figure 4.

Correlation between total PES/WES and VAS responses of the 38 patients to question 3.

(1.2) of all five PES parameters. It might be difficult to attain a maximum score for this parameter because it consists of three different aspects to be fulfilled. Clinical experience with future studies will show if this particular parameter tends to exhibit low scores compared to the other four PES parameters.

The WES was clearly less favorable than the PES. This observation is also documented by the fact that 20% of the crowns scored below the threshold of 6, which is the level of clinical acceptability from the examiner's point of view. It is possible that the WES component of the applied esthetic index is too rigorous, because all patients accepted the insertion of their implant crowns during therapy. The patient's perception of dental restorations from an esthetic point of view frequently differs significantly from that of dental professionals, which is confirmed by reports from the literature.^{39,40} This observation was also made in the present study by comparing the PES/WES and the results of the questionnaire. For example, eight patients with a WES score <6 expressed their satisfaction as >94% for questions 2 and 3. A similar picture was present when the lowest one-third of the total PES/WES were compared to question 3; the lowest satisfaction score was 91% in this subgroup, whereas the related total PES/WES score was <13.5.

An additional contributing factor for the less favorable WES was that >20 dental technicians were involved in the treatment of these 45 patients. With such a high number of technicians involved, it is clear that not all of them offered the same level of quality from an esthetic point of view. This assumption is supported by the results of a parallel, prospective case-series study⁴¹ on 20 patients, which tested the same treatment approach. The WES analysis showed clearly higher scores (mean score of 8.65), and it is reasonable to assume that this was directly linked to the fact that all 20 crowns were fabricated by the same technician. However, this study, which was carried out exclusively in a university setting, may not represent the reality of current prosthetic performance in daily private practice.

When it comes to the simplicity and reproducibility of the PES/WES index, one should keep in mind that the originally published PES²⁷ used seven independent variables and assigned identical importance or "weight" to each of them, thus having a maximum possible score of 14. However, it is questionable whether the described parameters 5 to 7, addressing peri-implant soft tissue color, texture, and facial convexity, are, from a purely esthetic point of view, equally important as parameters 1 to 4, which relate to a direct comparison to the soft tissue status around the natural control tooth. Because we considered these three parameters to be of lesser importance compared to the rest of the index criteria when it came

to the overall esthetic performance of an anterior single-tooth implant, we decided to combine these into one variable, basically assigning each of them only 33% of their original relative “weight.” Furthermore, the modified PES index now seems easier to apply for non-calibrated clinicians because of the lower number of parameters. The five described PES parameters add up to a total score of 10; in the authors’ opinion, this number has the merit of traditionally reflecting an excellent performance, is easier to remember than most other numbers, and permits the arbitrary setting of a threshold of clinical acceptability (usually 60% of a maximum possible score) at 6.

In analogy, a similar scoring system to assess the white esthetics (WES) of the restorations was proposed and evaluated in the present study. Hence, the highest possible combined PES/WES score is 20, which refers to an identical match of the peri-implant soft tissue conditions and the clinical single-tooth implant crown with the respective features at the contralateral natural tooth.

The present retrospective study demonstrated the applicability and reproducibility of the newly proposed PES/WES index. The PES/WES index also fulfilled other important characteristics of such a scoring system, i.e., inclusion of the relevant peri-implant soft tissues and the specifically restoration-inherent parameters, definition of a threshold of clinical acceptability, ease of use, and reproducibility. Nevertheless, future prospective studies, ideally with one surgeon, prosthodontist, and dental technician, are needed to evaluate this index to more clearly define its strengths or eventual shortcomings and to establish it as an integral part of studies assessing implant success in the maxillary anterior zone.

CONCLUSIONS

This retrospective study demonstrated that anterior maxillary single-tooth implant replacement, according to the concept of early implant placement, is a successful and predictable treatment modality from an esthetic point of view. The suitability of the PES/WES index for the objective outcome assessment of the esthetic dimension of anterior single-tooth implants was confirmed. However, prospective clinical trials are needed to further validate and refine this index. Ideally, these studies should also compare the influence of the timing of implant placement (immediate versus early versus delayed), the design and type of the implant used, and the type of surgical access flap on the PES/WES.

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