Does Timing of Implant Placement Affect Implant Therapy Outcome in the Aesthetic Zone? A Clinical, Radiological, Aesthetic, and Patient-Based Evaluation

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ABSTRACT

Purpose: To compare five different implant treatment protocols in the anterior maxilla, including immediate, early, and delayed implant placement, as well as implant placement in conjunction with simultaneous guided bone regeneration and implant placement 3 months following horizontal autologous bone block grafting.

Material and Methods: Aesthetic indices used included the Pink Esthetic Score (PES), Papilla Index (PI), Subjective Esthetic Score (SES), and White Esthetic Score (WES). Subjective evaluation of implant aesthetics was performed using a visual analogue scale (VAS). The VAS consisted of a 10 cm–long line representing the degree of discontent (0%) or satisfaction (100%).

Results: A total of 153 implants in 153 patients (80 women, 73 men) were evaluated after a mean follow-up of 4.5 ± 2.9 years. Mean peri-implant bone loss was 1.6 ± 0.9 mm and not affected by treatment protocol, time after implant placement, or crown length. Papilla presence, by contrast, differed significantly between the protocols: Papilla formation was more pronounced following delayed and immediate implant placement. No statistical significance was found among treatment modalities with regard to PES, SES, or WES. Longer crowns were associated with lower PES and PI ratings and correlated with greater midfacial recession. SES was also influenced by time after implant placement and keratinized mucosa. Patient satisfaction differed significantly among treatment protocols, favoring immediate implant placement. Agreement between objective and subjective aesthetic ratings was low.

Conclusion: The present study suggests that comparable clinical, radiological, and aesthetic results can be achieved with all treatment protocols. Gingival recession, however, seems to occur in the long term irrespective of the technique used.

KEY WORDS: aesthetics, anterior maxilla, autologous bone grafts, PapilIa Index, patient satisfaction, Pink Esthetic Score, single-tooth implants, Subjective Esthetic Score, treatment protocols, White Esthetic Score

INTRODUCTION

Single-tooth implant treatment in the aesthetic zone has become a viable treatment option with regard to function and aesthetics. However, aesthetic complications following implant therapy might impair overall subjective and objective satisfaction due to deficient papillae,[1,2] mucosal discoloration,[3] contour deficiency,[4] and gingival midfacial recession.[4–6] While implant-crown morphology and color can be optimized, achieving satisfactory soft tissue aesthetics still remains a challenging and unpredictable task as a result of differing surgical protocols.[5,7–9] An optimal treatment combination should take into account all determinants of patient satisfaction.

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Patients' increasing appreciation of aesthetics and demand for short-duration implant therapy have become the subject of growing interest with regard to treating the anterior maxilla. Thus, implant protocols have been revised to combine the goals of immediate implant placement on the one hand and the benefit of immediate loading on the other. While immediate implant placement carries the advantages of fewer surgical interventions, thus shortening total treatment time, it can also offer – in cases of immediate restoration – immediate aesthetic results.[10,11] However, as this strategy cannot take into account bone remodeling, periimplant soft tissue may undergo dynamic alterations with regard to papilla formation and midfacial soft tissue position.[5,12,13] Furthermore, in such cases the maxilla sustains an increased risk of implant failure when combined immediate implant placement and immediate loading are applied.[14,15] In cases of insufficient bony width, simultaneous and/or staged lateral bone grafting procedures are often considered mandatory to enable proper implant placement.[16] Consequently, buccal soft and hard tissue contours may undergo substantial change, thus influencing periimplant soft tissue aesthetics in the long term.

As the timing of implant placement as well as the need for grafting procedures may influence the final aesthetic outcome, the lack of within-study comparison of different treatment approaches was addressed in recent studies.[11,16] Therefore, the aim of this study was to compare different implant treatment modalities using multiple aesthetic indices. In addition, radiological assessment and patient-based evaluation were performed.

MATERIALS AND METHODS

Patient Selection

In the period 2008 to 2011, patients with single-tooth implants in the aesthetic zone were retrospectively scheduled for a follow-up visit. In cases of multiple implants in one patient, the implant closest to the midline was selected.[17] Thus, 153 implants in 153 patients were available for evaluation.

Inclusion criteria were as follows:

1 Single-tooth implant placement in the maxillary aesthetic zone (regions 14–24).
2 Implant in situ for at least 1 year.
3 Immediate, early, or delayed implant placement.
4 Implant placement with simultaneous guided bone regeneration (GBR) or following lateral autologous onlay block grafting.
5 Releasing incisions only in case of augmentative procedures.
6 Natural opposing dentition.

Exclusion criteria were as follows:

1 Connective tissue grafts.
2 Evidence of occlusal overload due to bruxism.
3 Untreated periodontal disease.

Five different implant treatment protocols were available for analysis. Assessments were performed by clinical, radiological, aesthetic, and patient-based evaluation. All patients were informed about the aim of the study and signed an informed consent form. The study protocol was approved by the Ethics Committee of Vienna (Nr 442/2008).

Surgical Protocols

All implants (Brånemark® MK-III and Nobel Replace™ Tapered, Nobel Biocare®, Gotebörg, Sweden) were inserted according to manufacturers' recommendations and placed in a three-dimensionally favorable position.[7] Implant treatment protocols included immediate, early, and delayed implant placement (IIP, EIP, DIP) as well as implant placement in conjunction with simultaneous GBR or 3 months after lateral autologous bone block grafting (ABG) in a staged procedure.

In cases of immediate implant placement, the tooth was removed atraumatically and immediately replaced by an implant if the site of interest met the following criteria: (1) absence of any pathology, (2) intact facial bone, (3) sufficient bone width, (4) absence of severe soft tissue recession, and (5) absence of mucosal discoloration. The gap between socket wall and implant was not filled, and implants were provisionally restored. None of the implants were immediately loaded to allow for undisturbed healing. If the implant did not reach primary stability of 25 Ncm, submerged healing was applied.

In addition to immediate implant insertion protocols, early (6 to 8 weeks following tooth removal) and delayed (at least 6 months following tooth removal) implant placement were used. No tissue grafts were performed using these protocols, and no vertical releasing incisions were made during flap elevation.

In cases of minor buccal bone deficiency observed during implant placement, GBR was simultaneously applied to augment the facial aspect. Peripheral autologous bone chips combined with deproteinized bovine bone material (Bio-Oss® 0.25–1 mm, Geistlich Biomaterials, Wolhusen, Switzerland) were placed and covered with a resorbable membrane (Bio-Gide® 25 × 25 mm, Geistlich Biomaterials). Flap elevation included vertical releasing incisions with periosteal slitting to compensate for the additional bone volume and to guarantee tension-free closure. After a 3-month healing period, a second-stage procedure was performed.

In cases of major orofacial bone deficiency and insufficient bone width (less than 4 mm), bone grafting was performed prior to implant placement using autologous bone blocks. Bone harvesting sites involved the ramus mandibulae,[18] mandibular symphysis,[19] or iliac crest[20] in cases of severe deficiencies. Flap elevation included vertical releasing incisions with periosteal slitting to compensate for the additional bone volume and to guarantee tension-free closure. After a 3-month healing period, the implant was placed. Two days prior to implant surgery, patients were advised to start using chlorhexidine digluconate mouthwash (0.2% Chlorhexamed, GlaxoSmithKline Pharma GmbH, Vienna, Austria) and for 1 week thereafter. For all surgical procedures, antibiotic prophylaxis (amoxicillin 875 mg and clavulanic acid 125 mg; Augmentin®, GlaxoSmithKline Pharma GmbH, Vienna, Austria) was administered starting 1 day prior to surgery, with a dosage of two tablets a day for 5 continuous days. In case of intolerance, clindamycin 300 mg three times a day (Dalacin® C, Pfizer Corporation Austria GmbH, Vienna, Austria) was prescribed. Mefenamic acid (Parkemed®, Pfizer Corporation Austria GmbH Austria) or dexibuprofen (Seractil®, Gebro Pharma GmbH, Fieberbrunn, Austria) were prescribed as analgesics.

Clinical and Radiological Assessment

All patients were examined by the same clinician, assessing the following variables:

- Presence of plaque: The Modified Plaque Index[21] was applied, using the following scoring system: 0 = no plaque; 1 = nonvisible thin film of plaque that can be detected by scraping the tooth surface with a probe; 2 = visible plaque; 3 = massive plaque that fills the interdental space.
- Probing depth: Peri-implant probing was performed to the nearest 0.5 mm using a manual probe.
- Bleeding on probing: Scores of 0 (no bleeding) and 1 (bleeding) were used to record the presence or absence of peri-implant bleeding.
- Recession: The amount of midfacial recession was recorded at the midfacial buccal aspect of the implant to the nearest 0.5 mm (in comparison with the contralateral tooth).
- Height of the buccal keratinized mucosa: The height of the buccal keratinized mucosa was measured at the midfacial aspect and was defined as the distance between soft tissue margin and mucogingival junction.
- Gingival biotype: Visual inspection was perfomed, and tissue biotype was classified as either thin or thick.
- Interproximal bone levels: Periapical radiographs taken with a paralleling device and a plastic x-ray holder at the recall examination were compared with radiographs taken at baseline to assess interproximal bone levels at the mesial and distal aspect. An assessment of marginal bone levels was performed with printed radiographs using a precision slide-jaw caliper to the nearest 0.1 mm. The magnification factor for each radiograph was individually assessed by comparison of radiological and actual implant lengths. Differences between interproximal bone levels at baseline and follow-up were used to compute peri-implant bone loss.
- Horizontal implant-tooth distance (HITD): The horizontal implant-tooth distance was measured from the level of the implant shoulder to the mesial and distal aspects of the adjacent teeth.[22]
- Crown length (CL): The crown length was defined as the distance between the incisal edge of the implant crown and the implant shoulder.

Aesthetic and Patient-Based Evaluation

Objective evaluation of implant aesthetics was performed by two observers based on standardized intraoral photographs using four aesthetic indices: Pink Esthetic Score (PES), Papilla Index (PI), Subjective Esthetic Score (SES), and White Esthetic Score (WES). Photographs were obtained with a digital camera and

100 mm macro lens with ring flash. Photographs were taken centered on the contact region between the upper central incisors, while a gauge was placed near the incisal edge to assess soft tissue deviations to the nearest 0.5 mm. In the case of premolars, additional photographs were made if the mesial or distal peri-implant papilla was not visible for PES evaluation. For the purpose of quality assessment, observer blinding was used to evaluate the aesthetic outcome among different treatment protocols.[10]

The PES[23] includes a total of seven variables (mesial papilla, distal papilla, level of soft tissue margin, soft tissue contour, alveolar process deficiency, soft tissue color, and soft tissue texture). Evaluation of soft tissue around implant-supported single teeth is performed by giving a score of 0 to 2 for each variable (0 representing the poorest and 2 the best result). The maximum score of 14 points reflects perfect peri-implant soft tissue aesthetics.

The PI[24] assesses the height of the interproximal gingival papillae adjacent to implant-supported single-tooth restorations using a score of 0–4: 0 = no papilla present; 1 = less than half of the papilla height is present and a convexity of the adjacent tissue is noted; 2 = more than half of the papilla height is present, but not to the full extent of the contact point (papilla is not in complete harmony); 3 = the papilla fills the entire proximal space and is in good harmony; 4 = the papilla is hyperplastic. Thus, complete papilla formation achieves 3 points.

The SES[4] is used to evaluate midfacial soft tissue recession based on the vertical change in the mucosal margin position following restoration of the implant: I = midfacial recession of 0.5 mm or less and labial tissue fullness in harmony with the adjacent teeth; II = midfacial recession between 0.5 and 1 mm and labial tissue fullness in harmony with the adjacent teeth; III = midfacial recession between 1 and 1.5 mm and/or deficient labial tissue; IV = midfacial recession greater than 1.5 mm and/or deficient labial tissue.

The WES[25] focuses on implant-crown aesthetics, assessing 5 variables by comparison with the contralateral tooth (general tooth form; outline and volume of the clinical crown; color, which includes the assessment of hue and value; surface texture; translucency and characterization) using a grading scale ranging from 0 (worst) to 2 (perfect outcome). A maximum score of 10 reflects perfect implant-crown-related aesthetics.

Subjective evaluation of implant aesthetics was performed using a visual analogue scale (VAS) as recommended for evaluation of patient satisfaction.[26]

Statistical Analysis

In cases of patients with multiple implants, the implant closest to the midline was selected. Thus, 153 implants in 153 patients were available for evaluation. Prior statistical analysis data were visually inspected to check whether distribution was normal or skewed. The Kruskal-Wallis test was used to compare interval-scaled variables, and if the level of significance was reached, pairwise Mann-Whitney *U*-tests were performed. Fisher's exact test was adopted to compare the distribution of categorical variables between treatment modalities. 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. To account for multiple testing (factors influencing aesthetics and peri-implant bone loss), Bonferroni correction was applied. Intra- and interexaminer reliability were assessed using kappa statistics. All tests were two-sided, and $p < .05$ was considered significant. Statistical analyses were performed using the statistical package SPSS (version 20; IBM, Armonk, NY, USA).

RESULTS

A total of 153 implants in 153 patients (80 women, 73 men) with a mean age of 37 ± 17 years at the time of implant placement were eligible for evaluation and met the inclusion criteria. Fifteen patients (9.8%) were smokers.

Implant treatment protocols included immediate implant placement in 17% of the cases ($n = 26$). Early and delayed implant placements were performed in 23% ($n = 35$) and 9% ($n = 13$), respectively. Simultaneous implant placement with guided bone regeneration was performed in 10% ($n = 15$), while ABG prior to implant placement was necessary in 41% ($n = 64$) of the patients.

The main reasons for tooth loss included trauma, aplasia, and caries, in 64 (42%), 30 (20%), and 36 (23%) cases, respectively. A significantly higher percentage of patients who lost a tooth following trauma required ABG (47%; $p < .001$). No statistical significance could be discerned when comparing different treatment protocols with regard to gender ($p = .547$) or smoking habits ($p = .379$).

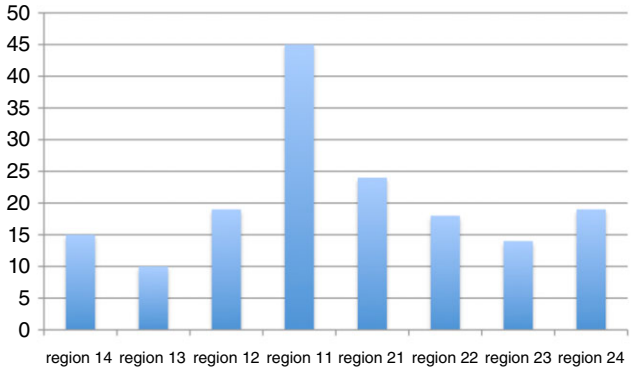

Figure 1 Distribution of single-tooth implants in the maxillary aesthetic zone.

Implant lengths of 10 mm and 13 mm were used in 4% ($n = 6$) and 72% ($n = 110$) of the cases, respectively; the remainder were 15 mm ($n = 11$), 16 mm ($n = 24$), or 18 mm ($n = 2$) in length. Diameters were 3.3 mm ($n = 3$), 3.5 mm ($n = 53$), 3.8 mm ($n = 29$), 4.0 mm ($n = 3$), 4.3 mm ($n = 60$), and 5.0 mm ($n = 5$) in 2%, 35%, 19%, 2%, 39%, and 3% of the cases, respectively. Wider implant diameters were used in cases of immediate implant placement compared with other treatment modalities ($p < .008$).

Implants were placed in central and lateral incisor positions in 58 (38%) and 37 (24%) cases, as well as in canine and premolar positions in 24 (16%) and 34 (22%) cases (Figure 1). Fifty percent ($n = 32$) of the bone grafts were performed in central incisor positions ($p = .020$). Implant-supported crowns were cemented in 105 cases (69%) and screw-retained otherwise. A submerged healing protocol was applied in 64% ($n = 84$) of the implants, and a transmucosal approach was applied in the remainder. Healing modality differed between treatment protocols ($p = .003$): the majority of immediate implants were subjected to transmucosal healing (69%), while submerged healing was favored in the vast majority of cases in all other treatment protocols (EIP 71%, DIP 83%, GBR 90%, ABG 68%). No statistical significance could be found between different treatment protocols in terms of implant length ($p = .138$) or prosthetic restoration ($p = .094$).

Clinical and Radiological Assessment

No plaque was present in 55% ($n = 71$) of the implants, while plaque scores of 1, 2, and 3 were recorded in 34% ($n = 43$), 8% ($n = 10$), and 3% ($n = 4$), respectively. Mean pocket depth was 3.6 ± 1.2 mm (range 1.0–7.5 mm), while bleeding on probing was present in 33% of the implants. Half of the implants (50%) showed no recession, while the remainder showed recession ranging from 0.5 to 5 mm at the midfacial aspect (median 0 mm, IQR 0–1 mm). A mean height of 4.1 ± 1.4 mm was measured for midfacial keratinized mucosa, while thick and thin gingival biotypes were found in 58% ($n = 89$) and 42% ($n = 64$), respectively. No significant differences between implant protocols were found in terms of plaque ($p = .235$), pocket depth ($p = .675$), bleeding on probing ($p = .323$), keratinized mucosa ($p = .137$), or tissue biotype ($p = .266$).

After a mean follow-up of 4.5 ± 2.9 years, peri-implant bone loss of 1.6 ± 0.9 mm was measured. The lowest amount of bone loss (1.2 ± 0.6 mm) was observed following EIP. Bone loss in the DIP and IIP groups was 1.4 ± 0.8 mm and 1.5 ± 0.8 mm, respectively. Greater bone loss was observed in the GBR (1.7 ± 0.7 mm) and ABG (1.8 ± 0.9 mm) groups. Significant differences were found between EIP and GBR groups ($p = .032$), as well as between EIP and ABG ($p = .001$).

Mean mesial and distal horizontal implant-tooth distances of 2.3 ± 1.2 mm and 1.8 ± 1.1 mm, respectively, were measured. No influence of HITD on peri-implant bone loss was observed ($r_s = -0.06$, $p = .471$). A mean value of 11.7 ± 2.4 mm was recorded for crown length. No difference was found between different treatment protocols in terms of horizontal implant-tooth distance ($p = .072$) or crown length ($p = .071$).

Among the factors tested for effect on marginal bone levels (time after implant placement, crown-fixation, implant protocol, HITD, crown length), no significant influence was observed for time after implant placement ($r_s = 0.12$; $p = .145$), crown-fixation ($p = .132$), implant protocol ($p = .017$), HITD ($r_s = -0.06$; $p = .471$), or crown length ($r_s = -0.04$; $p = .698$) at a Bonferroni-corrected significance level of $p = .01$.

Aesthetic and Patient-Based Evaluation

Objective evaluation of peri-implant soft tissue aesthetics using the PES yielded overall scores ranging from 2 to 14 (median 11, IQR 9–12). Detailed PES scores for each implant treatment protocol are given in Table 1. Intra- and interexaminer reliability was assessed as fair to substantial based on the criteria defined by Landis and Koch.[27] Intra-examiner reliability on the basis of kappa ranged from 0.343 ($p < .001$; soft tissue texture) to 0.756

TABLE 1 Aesthetic Scores by Implant Protocol

	IIP ($n = 26$)	EIP ($n = 35$)	DIP ($n = 13$)	GBR ($n = 15$)	ABG ($n = 64$)
Time after implant placement (months), median	56	54	58	46	42
Pink Esthetic Score					
Mean ± SD	10.7 ± 2.4	10.4 ± 2.2	11.2 ± 2.0	9.5 ± 2.2	10.2 ± 2.1
Median	11.0	11.0	11.0	10.0	11.0
Range	5–14	6–13	7–14	5–13	2–14
Satisfactory (10–14)	77%	71%	85%	67%	75%
Unsatisfactory (0–9)	23%	29%	15%	33%	25%
Papilla Index					
Mean ± SD	2.0 ± 0.7	1.7 ± 0.8	2.5 ± 0.5	1.7 ± 0.8	1.7 ± 0.6
Median	2.0	1.5	2.5	2.0	2.0
Range	0–3	0–3	1–3	0–3	0–3
Satisfactory (2–3)	77%	46%	92%	60%	55%
Unsatisfactory (0–1)	23%	54%	8%	40%	45%
Subjective Esthetic Score					
Good (I) (<0.5 mm)	65%	66%	77%	53%	70%
Acceptable (II) (0.5–1.0 mm)	27%	14%	15%	40%	19%
Poor (III–IV) (>1.0 mm)	8%	20%	8%	7%	11%
White Esthetic Score					
Mean ± SD	8.8 ± 1.7	9.1 ± 1.4	8.8 ± 1.2	9.0 ± 1.0	9.2 ± 1.0
Median	9.5	10.0	9.0	9.0	9.0
Range	4–10	3–10	6–10	7–10	7–10
Satisfactory (7–10)	88%	97%	92%	100%	100%
Unsatisfactory (0–6)	12%	3%	8%	0%	0%

IIP = immediate implant placement; EIP = early implant placement; DIP = delayed implant placement; GBR = guided bone regeneration and simultaneous implant placement; ABG = autologous bone grafting and implant placement in a staged procedure.

($p < .001$; mesial papilla). Kappa values from 0.188 ($p < .001$; soft tissue color) to 0.687 ($p < .001$, mesial papilla) were calculated for interexaminer reliability.

Evaluation of peri-implant papilla presence resulted in a median PI score of 2 (IQR 1–2) for both the mesial and distal aspects. Papilla presence differed significantly among implant protocols ($p = .001$). Papilla formation was more pronounced following DIP and IIP (Table 1). Treatment protocols involving grafting (GBR, ABG) showed inferior Papilla Index scores (1.7 ± 0.7 vs 1.9 ± 0.8) when compared with conventional protocols (IIP, EIP, DIP), with statistical significance at $p = .04$. By the SES, 67% ($n = 103$) of all implants showed good aesthetic results with a score of I. Scores of II, III, and IV were recorded in 21% ($n = 32$), 5% ($n = 7$), and 7% ($n = 11$) of cases, respectively.

With regard to crown-related parameters, the overall WES ranged from 3 to 10 (median 9, IQR 8–10). Table 1 provides detailed information sorted by implant protocol. No statistically significant difference was found among treatments modalities regarding PES ($p = .140$), SES ($p = .755$), or WES ($p = .731$).

Among the factors tested for their effect on aesthetics (time after implant placement, crown-fixation, implant protocol, implant diameter, crown length, keratinized mucosa, healing modality, tissue biotype), the following significant differences remained after Bonferroni correction ($p = .006$): Crown length influenced PES, PI, and SES ratings; higher crown lengths were associated with lower PES ($r_s = -.29$; $p < .001$) and PI ($r_s = -.30$; $p < .001$) and correlated with higher midfacial recession ($r_s = 0.29$, $p < .001$). Papilla presence was influenced by the implant protocol ($p = .001$; Table 1) and tissue biotype ($p = .003$). Higher PI scores were observed in cases of thick tissue biotype (2.02 ± 0.63) as compared with thin tissue biotype (1.67 ± 0.73). The amount of midfacial recession

was influenced by time after implant placement ($r_s = 0.28$; $p = .001$) and presence of keratinized mucosa ($r_s = 0.36$; $p < .001$). Time after implant placement did not influence PES ($r_s = –0.16$; $p = .044$) or PI ($r_s = 0.04$; $p = 0.652$) ratings. PES, PI, and SES were not influenced by crown-fixation (PES: $p = .229$; PI: $p = .731$; SES: $p = .064$), implant diameter (PES: $r_s = 0.00$, $p = .974$; PI: $r_s = 0.01$, $p = .888$; SES: $r_s = 0.09$, $p = .247$) or healing modality (PES: $p = .033$; PI: $p = .007$; SES: $p = .036$). Presence of keratinized mucosa did not influence PI ratings ($r_s = 0.10$; $p = .227$). PES and SES scores were not influenced by the implant protocol (PES: $p = .140$; SES: $p = .755$) or tissue biotype (PES: $p = .053$; SES: $p = .519$).

Patient satisfaction using the Visual Analogue Scale following different implant treatment protocols was 95% for IIP, 84% for EIP, 80% for DIP, 75% for GBR, and 79% for ABG. Patient satisfaction differed significantly among treatments ($p < .001$). IIP was preferred compared with all other implant protocols ($p = .017$ vs EIP, $p = .007$ vs DIP, $p < .001$ vs GBR, $p < .001$ vs ABG). Agreement between subjective (VAS) and objective aesthetic ratings was low (VAS vs PES: $r_s = 0.18$, $p = .027$; VAS vs PI: $r_s = 1.21$, $p = .010$; VAS vs SES: $r_s = –0.21$, $p = .009$; VAS vs WES: $r_s = 0.08$, $p = .358$).

DISCUSSION

In the present study, comparably favorable aesthetics were achieved following different implant treatment protocols. According to the classification proposed by Chen and colleagues,[28] satisfactory aesthetics (PES 10–14) were observed in 67% to 85% of the cases, which corresponds to recent literature: satisfactory results have been reported in 65% to 100% of cases[17,28–31] following IIP (present study: 77%), while 62% and 45–68% of patients were satisfied following EIP and DIP,[32,33] respectively (present study: EIP: 71%; DIP: 85%). In the present investigation, PES ratings of delayed and immediate implants showed slightly superior aesthetics compared with early implants in combination with GBR or ABG. Similar results were recently reported showing slightly superior aesthetics in delayed implants compared with early implants.[32] These interesting findings may possibly be explained by the fact that healed jawbone offers optimal soft and hard tissue conditions. Nevertheless, bone availability can be reduced dramatically by resorptive alterations occuring after tooth extraction, thus complicating implant therapy.[34]

However, it should be kept in mind that the presence of different peri-implant soft tissue conditions at the baseline might have favored one treatment protocol over another.[29] Standardized photographs and three-dimensional radiographs taken at baseline would therefore be helpful to allow comparisons among different time points while peri-implant soft tissue undergoes dynamic alteration.[30,33,35,36]

The scarcity of quality reports on aesthetic outcome[10] and the need for comparative analyses among different treatment protocols in order to avoid biased results from interstudy comparisons have been highlighted recently.[11,16] The present study submits, for the first time, five different implant protocols in a within-study comparison using multiple aesthetic ratings. Among these, the PI was used to offer a more detailed analysis on papilla presence, as this can be considered as a major determining factor for subjective patient satisfaction. Interestingly, papilla formation following DIP was observed to be superior as compared with IIP and EIP. However, this result should be interpreted with caution owing to the small sample of implants placed using the delayed approach ($n = 12$). However, a recent comparison of early- and delayed-placed implants favored the latter in terms of complete papilla formation (55% versus 64% based on PES subscores). The delayed approach might offer some advantages over IIP, as enhanced peri-implant bone remodeling has been reported in conjunction with IIP.[37,38] In that scenario, papilla formation in the interproximal embrasures could be impaired, as it is not possible to predict the amount of peri-implant bone resorption. In comparison, a delayed protocol would therefore benefit from peri-implant stable hard tissue conditions to support peri-implant soft tissue. A detailed literature comparison of different implant protocols based on PES and PI is given in Tables 2 and 3, showing complete papilla formation in 13% to 80% of cases.

The retrospective design of the present study must be considered a limitation; however, as patients were treated consecutively, it may offer additional insights (especially for the practitioner), as the study reflects daily life performance. Strict patient selection criteria may be associated with favorable aesthetic results[11] compared with inclusion of complex patient cases presenting with challenging soft and hard tissue deficiencies that may impair aesthetic outcome.[43] It is obvious that good results can be obtained by choosing patients with

TABLE 2 Pink Esthetic Score Results Reported in Literature following Different Treatment Protocols according to the Classification Proposed[28]

	Implant Protocol	Follow-Up (Years)	Mean PES ± SD	Satisfactory Aesthetics (PES 10–14) (%)	Unsatisfactory Aesthetics (PES 0–9) (%)
Juodzbalys & Wang 2007[31]	IIP	1	11.1 ± 1.3	100	0
Lai et al. 2008[33]	DIP	0.7–1	9.5 ± 2.3	45	55
Chen et al. 2009[28]	IIP	2.2	11.0 ± 1.7	78	22
Buser 2009 JP[39]*	EIP + GBR	1	8.1 ± 1.2*	—	—
Belser 2009[25]*	EIP	2–4	7.8 ± 0.9*	—	—
Cosyn et al. 2010[32]†	EIP	2.5	9.9 ± 1.9	62	38
	DIP	2.5	10.4 ± 2.1	68	32
Hof et al. 2011[16]	ABG	4.2	11.5 ± 0.7	60	40
Cosyn et al. 2012[17]†	IIP	2.5	10.9 ± 2.4	65	35
	EIP	2.5	9.7 ± 2.2	66	33
	GBR	2.5	10.1 ± 2.0	47	53
	ABG	2.5	9.0 ± 1.7	38	62
Noelken et al. 2012[29]	Various	5.4	10.5	67	33
Noelken et al. 2013[30]†	IIP	2.3	11.3 ± 1.8	91	9
Pieri et al. 2013[40]†	ABG	5	8.6 ± 1.6	17	83
Present study	IIP	4.7	10.7 ± 2.4	77	23
	EIP	4.5	10.4 ± 2.2	71	29
	DIP	4.8	11.2 ± 2.0	85	15
	GBR	3.8	9.4 ± 2.2	67	33
	ABG	3.5	10.2 ± 2.1	75	25

*Objective aesthetic assessment based on the modified Pink Esthetic Score index[25] (a score of 10 reflects perfect outcome).
†Additional data supplied by the authors (listed in Acknowledgments section).
PES = Pink Esthetic Score; IIP = immediate implant placement; EIP = early implant placement; DIP = delayed implant placement; GBR = guided bone regeneration and simultaneous implant placement; ABG = autologous bone grafting and implant placement in a staged procedure.

optimal soft tissue conditions as compared with choosing patients suffering from trauma or periodontal disease.[29] In the present study 42% of the patients had lost their teeth due to trauma, with subsequent extensive hard tissue defects. This explains the necessity of ABG to rebuild hard and soft tissue contours prior to implant surgery in the majority of cases.

The level of soft tissue margin seems to be determined by hard tissue level and soft tissue thickness,[44,45] whereas a thin tissue biotype might favor apical displacement of soft tissue margin.[5,6] In the present study, no difference with regard to tissue biotype in midfacial tissue recession was observed among different timing protocols. However, this has to be interpreted with caution, as categorization of tissue biotype was performed on visual inspection, which has been shown to be unpredictable.[46] The evidence of the importance of keratinized mucosa around dental implants still remains limited and controversial in dental literature.[47] In the present investigation, reduced heights of keratinized mucosa were significantly associated with increased apical displacement of midfacial soft tissue position. However, it has to be noted that in the present study assessment of midfacial recession was performed by comparison with the contralateral tooth. Thus, the midfacial soft tissue position of the contralateral tooth may not have reflected ideal soft tissue conditions in all cases. Similar results were presented in a prospective study[48] showing that the presence of keratinized mucosa of at least 2 mm in height decreased the probability of midfacial recession. The largest amount of recession was observed within the first 6 months. Interestingly, in the present study, long observation periods were significantly associated with apical soft tissue displacement. This might especially be of importance following immediate implant placement, when bone remodeling is still continuing.[37,38] A recent study reported the presence of continuous soft tissue recession, while, by contrast,

TABLE 3 Papilla Presence Reported in Literature Based on Pink Esthetic Score and Papilla Index Ratings

	Implant Protocol	Follow-Up (Years)	Complete Papilla by PI (PI = 3) (%)	Complete Papilla by PES (PES1 + PES2 = 2) (%)
Jemt and Lekholm 2003[41]	ABG	2	39	—
Juodzbalys and Wang 2007[31]	IIP	1	36	42
Palatella et al. 2008[12]	IIP	2	39	—
	EIP	2	50	—
Lai et al. 2008[33]	DIP	0.7–1	—	53
Kan et al. 2009[42]	IIP (connective tissue graft)	2.2	80	—
Chen et al. 2009[28]*	IIP	2.2	—	58
Buser et al. 2009[39]	EIP + GBR	1	—	48
Belser et al. 2009[25]	EIP	2–4	—	44
Cosyn et al. 2010[32]	EIP	2.5	—	55
	DIP	2.5	—	64
Cosyn et al. 2011[11]	IIP	3	—	52
Cosyn et al. 2012[17]	IIP	2.5	—	60
	EIP	2.5	—	56
	GBR	2.5	—	32
	ABG	2.5	—	23
Noelken et al. 2012[29]*	Various	5.4	—	15
Noelken et al. 2013[30]*	IIP	2.3	—	31
Pieri et al. 2013[40]*	ABG	5	—	29
Present study	IIP	4.7	27	50
	EIP	4.5	19	36
	DIP	4.8	42	65
	GBR	3.8	13	30
	ABG	3.5	13	23

*Additional data supplied by the authors (listed in Acknowledgments section).
PES = Pink Esthetic Score; PI = Papilla Index; IIP = immediate implant placement; EIP = early implant placement; DIP = delayed implant placement; GBR = guided bone regeneration and simultaneous implant placement; ABG = autologous bone grafting and implant placement in a staged procedure.

papillae regenerated over time.[36] Long-term results remain controversial as soft tissue aesthetics may become enhanced or impaired depending on PES/PI and SES ratings, respectively.[11,29,35,40]

Assessment of patient satisfaction has become an important issue in implant dentistry, as it determines overall implant success. In the present study, a significantly higher subjective patient satisfaction rate following IIP was confirmed compared with all other implant protocols. This is not surprising, as a longer healing time prior to prosthetic restoration of the implant is regarded as a major drawback by patients.[49] A comparison of patients' attitudes towards early and delayed implant protocols favored the former in terms of patient satisfaction with the overall implant treatment.[50] However, this difference could not be confirmed after 5 years.[51] Patients' preference for IIP might be explained by the psychological expectation of immediate tooth replacement with immediate aesthetics,[10,11] as well as reduction of morbidity and surgical interventions.[52] Despite all the advantages of this implant protocol, it carries an increased risk of implant failure in case of immediate loading, especially in the maxilla.[14,15] Although patients appear to accept an implant failure rate of 10% in case of continuous temporization,[53] it is imperative to have prior discussions that cover all potential risks, such as implant failure, impaired papilla presence, midfacial recession, and discoloration. If patients are provided with realistic expectations, this will result in improved subjective satisfaction.[54,55]

A recent review focusing on cemented and screw-retained restorations reported similar outcomes for both implant-supported crown fixation methods[56]; however, the aesthetic outcome was not considered. In the present study, slightly higher PES values were recorded for screw-retained single crowns (10.7 vs 10.1). Similar

results have been found recently for both restoration options.[57] In a direct comparison, a higher incidence of technical complications was seen in screw-retained crowns (24% versus 12%), while cemented single-tooth crowns were more prone to peri-implant bone loss.[56] This finding is in line with the results of the present study, in which higher bone loss was observed in cases of cemented crowns. This might be attributed to the presence of excess cement in the peri-implant sulcus and may be especially likely if implants are placed in a subcrestal position in an effort to optimize aesthetics.[58] Furthermore, as screw-retained crowns are retrievable, complications can be handled more easily as compared with cemented reconstructions.[56] However, it should be kept in mind that screw-retained crowns require optimal three-dimensional prosthetic-driven implant positioning. Any deviation from an ideal implant position might result in aesthetic shortcomings.[59]

The results of the present study suggest that comparable clinical, radiological, and overall aesthetics can be achieved following different implant timing protocols. However, longer observation periods favor apical displacement of midfacial soft tissue irrespective of the treatment protocol. Crown length may be regarded a major determining factor affecting soft tissue aesthetics, as it significantly influenced PES, PI, and SES ratings. In order to investigate potential differences among different protocols it seems valuable to separately document the effect on soft tissue aspects in future studies (e.g., PI, SES) as assessment of overall aesthetics using PES may camouflage minor soft tissue changes.

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