ESTHETIC EVALUATION OF IMPLANT RESTORATION IN ESTHETIC ZONE: A LONG-TERM FOLLOW-UP

Harit MUANGMORE[1] and Atiphan PHIMKHAOKHAM[1*]
1 Faculty of Dentistry, Chulalongkorn University, Thailand; atiphan.p@chula.ac.th (Corresponding Author)

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ABSTRACT
The objective of this research was to investigate the correlation between esthetic outcomes of single-tooth implant restorations (STIRs) over an extended follow-up period, utilizing three evaluation tools: the Pink Esthetic Score (PES), White Esthetic Score (WES), and the novel Esthetic Sustainable Criteria (ESC). A retrospective cross-sectional analysis was conducted on 12 patients who received STIRs at the right central incisor. Comprehensive demographic data, clinical protocols, and follow-up outcomes were meticulously recorded. PES and WES assessed esthetic results focusing on soft tissue and prosthetic appearance, while ESC incorporated additional parameters for evaluating gingival health, prosthesis quality, and bone-implant interface stability. Statistical analyses, including ANOVA and K-means cluster analysis, were employed to identify trends and correlations among the variables. The results revealed that PES/WES scores varied from 12 to 18 (mean: 16.16 ± 1.90), while ESC scores ranged from 24 to 36 (mean: 30.08 ± 3.52). Notably, K-means cluster analysis identified three distinct groups: excellent, medium, and divergent. Over the long-term follow-up, outcomes were generally acceptable to excellent. Patients with higher ESC scores, particularly in bone stability, demonstrated more sustainable esthetic results. In contrast, the divergent group exhibited high PES/WES scores but lower ESC scores, particularly in bone parameters, suggesting a disconnect between soft tissue esthetics and underlying bone conditions. These findings underscore the importance of a multifactorial approach when evaluating long-term esthetic success, emphasizing that sustainable outcomes depend not only on immediate visual esthetics but also on the long-term stability of peri-implant bone and soft tissue architecture.
Keywords: Anterior Dental Implant, Esthetic Evaluation, PES, WES, Esthetic Sustainable Criteria

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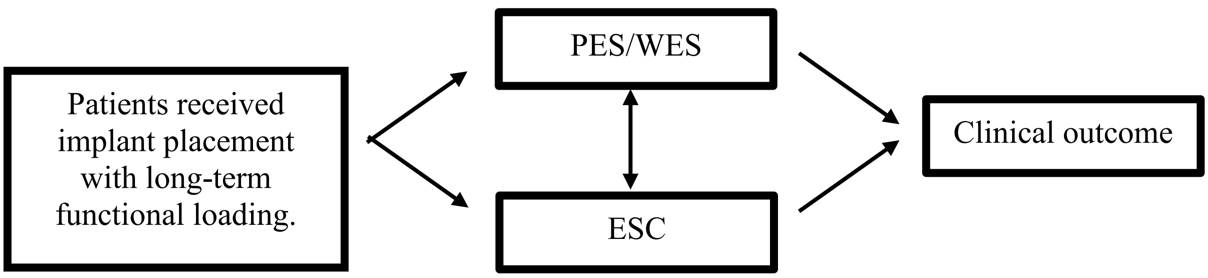
INTRODUCTION

Dental implants have become a cornerstone of modern oral rehabilitation, with single-tooth implant restorations (STIRs) representing a favored treatment option for replacing missing teeth in the anterior maxilla due to their predictable and durable outcomes (Adell et al., 1981; Brånemark et al., 1969). Central to the success of these procedures is the concept of osseointegration, introduced by Brånemark in the late 1960s, which refers to the direct structural and functional connection between the bone and the implant surface (Brånemark et al., 1977). While osseointegration ensures the mechanical stability of the implant, achieving esthetic excellence in anterior restorations involves a more multifaceted approach.

The esthetic zone, which encompasses the anterior maxillary region, presents unique challenges. Esthetically pleasing outcomes in this area require the careful management of both soft and hard tissue profiles, implant positioning, and the integration of prosthetic components (Garcia & Sabrosa, 2018). Traditional evaluation criteria, such as the Pink Esthetic Score (PES) and White Esthetic Score (WES), have long been employed to assess soft tissue esthetics and prosthetic appearance (Fürhauser et al., 2005; Belser et al., 2009). These scores, while effective, may overlook the critical role that underlying bone conditions play in long-term esthetic success (Raes et al., 2019).

In response to this gap, more comprehensive indices like the Esthetic Sustainable Criteria (ESC) have been developed. The ESC expands the evaluation framework by considering factors such as gingival health, prosthetic alignment, and the structural integrity of the bone-implant interface (Chan et al., 2014). While promising, the ESC has yet to be fully validated through long-term studies in diverse clinical contexts. This study aims to evaluate the esthetic outcome of STIRs in the anterior maxilla after long-term functional loading, the correlation between the esthetic outcomes of STIRs placed in the anterior maxilla using PES/WES and ESC at long-term follow-up, and to investigate the influence of underlying bone conditions on esthetic outcomes.

CONCEPTUAL FRAMEWORK



MATERIALS AND METHODS

Study population

The study protocol was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2023-043). This cross-sectional study included patients who were treated with a STIR at the right central incisor between January 2009 and December 2024 at the Faculty of Dentistry, Chulalongkorn University. The following patient information was collected: age, sex, date of implant placement and loading, treatment protocol, implant system, type of implant abutment and restoration, any bone augmentation procedure, and post-operative complications. The exclusion criteria were: < 6 months of loading, restored contralateral tooth, ridge-lap restoration on the STIR, and no posterior teeth support. The patients who met these criteria signed an informed consent form before participating in the study.

Data collection

The patients were re-contacted to evaluate the esthetic outcomes of their STIR. A routine maintenance protocol was followed for their assessment. An overall oral examination and a follow-up radiographic examination comprising periapical radiographs and CBCT were performed. A 0.001 ligature wire was wrapped around the restoration contact area, and a digital periapical radiograph (Kodak 2200, Eastman Kodak Company, USA) was taken using the parallel technique with a standard film holder (XCP Film Holder, Densply Rinn, UK). The CBCT (3D Acuitomo, J Morita MFG Corp, Kyoto, Japan) was performed at the lowest field of view (FOV) (4x4 standard) at the STIR area.

To conduct a consistent esthetic evaluation, standardized clinical photographs were taken with a digital camera (Sony A7RIII, Sony). For each patient, a set was arranged including images from three different angles: one picture taken on face, a second focused on the implant site, and a third centered on the contralateral tooth. The soft tissue around the implant and contralateral tooth had to be fully assessable. Upper and lower arch impressions were taken using an irreversible hydrocolloid (Jeltrate, Densply, Australia), and the study models were fabricated with orthodontic stone (Sirius, Ultima, France).

Esthetic assessment

PES/WES analysis

The esthetic evaluation was performed according to the PES/WES criteria (Belser et al., 2009). These criteria comprise 10 parameters: 5 gingiva factors and 5 prosthesis factors. The esthetic score was evaluated by observing the similarity between the STIR of interest and its contralateral tooth via photographs and dental models. Each parameter was scored as 2, 1, or 0, depending on the degree of match or mismatch. Combining each variable, the maximum possible score was 20. A score of < 12 was defined as clinically unacceptable, while a score of ≥ 17 corresponded to an excellent esthetic outcome.

Esthetic Sustainable analysis

The ESC was created by selecting important factors from among many criteria (Belser et al., 2009; Benic et al., 2012; Chang et al., 1999; Dueled et al., 2009; Evans & Chen 2008; Furhauser et al., 2005; Jemt, 1997; Levin et al., 2005; Meijer et al., 2005; Nordland & Tarnow, 1998; Rompen et al., 2007; Schropp & Isidor, 2008; Testori et al., 2005). The ESC consisted of 3 parts comprising 20 parameters: 7 gingival parameters, 6 prosthetic parameters, and 7 bone-implant parameters. Each parameter was scored as 2, 1, or 0, depending on the degree of match or mismatch. The parameter scores were then totaled. The additional bone-implant parameters evaluated by the ESC allow for a maximum possible score of 40. The ESC scores were compared with each patient's PES/WES to define the range of ESC scores as unacceptable, acceptable, or excellent (The acceptable score was set at 24 corresponded to PES/WES acceptability threshold). The seven bone-implant parameters fell into 2 groups: the first group included labial bone thickness, labial bone height, 3D implant position, implant axis, and fenestration. These 4 parameters were evaluated using a dental CBCT imaging program (One Volume Viewer, J Morita MFG Corp, Kyoto, Japan). The other group included 3 parameters: the mesial distance from the base of the contact area to the peak of the bone on the adjacent tooth (DCBM), the distal distance from the base of the contact area to the peak of the bone on the adjacent tooth (DCBD), and the distance from the implant platform to the first visible bone to contact the implant (DIB). These parameters were assessed using a digital periapical radiograph and measurement program (Image-Pro Plus; Media cybernetics, Rockville, USA) that was calibrated using the implant length.

Each patient's CBCT image greyscale was adjusted to give the clearest. The sagittal and coronal images were rotated so that the implants were perpendicular to the horizontal plane. Next, the horizontal plane was moved to the implant platform level. The sagittal-plane and coronal-plane lines were then moved in the coronal and sagittal images, respectively, until the lines bisected the implant. The cross-sectional image was rotated until a symmetrical arch form appeared. Finally, the two reference lines were created at a 90° angle. The parameter definitions were:

1) Labial bone thickness: the distance from the outermost surface of the implant platform perpendicular to the outermost surface of the labial cortical wall on the reference line. This parameter was scored as: > 2 mm (2), 1-2 mm (1), or < 1 mm (0).

2) Labial bone height: the distance from the uppermost surface of the implant platform to the peak of the labial wall. A positive value indicated that the peak of the bone was lower than the implant platform, whereas a negative value indicated that the peak of the bone was higher than the implant platform. This parameter was scored as: > 0 mm (2), 0-2 mm (1), or < 2 mm (0).

3) 3D position: the implant must have been located correctly in the following dimensions:

3.1) Mesio-distal: ≥ 1.5 mm at the shortest distance between the outermost surface of the implant platform to the outermost surface of the adjacent root. Both the mesial and distal distances must be ≥ 1.5 mm.

3.2) Labio-lingual: 2-3 mm from the outermost surface of the implant platform perpendicular to an imaginary curve connecting 4 points of the adjacent teeth.

3.3) Apico-coronal: 3-4 mm between the implant platform level to the lowest and outermost surfaces of the implant crown.

This parameter was scored as: all positions correct (2), 2 positions correct (1), or 1 or no positions correct (0)

4) Implant axis and fenestration: the area at which the coronal plane passed through the implant crown, defined as the cingulum, incisal, or labial position. This parameter was scored as: the cingulum position with no fenestration (2), the incisal position with no fenestration (1), or fenestration present (0).

The periapical radiograph with a ligature wire was subsequently evaluated. The DCBM, DCBD, and DIB were assessed as follows:

1) DCBM and DCBD: the distance from the most apical point of the wire to the reference plane. This parameter was scored as: < 5 mm (2), 5-7 mm (1), or > 7 mm (0).

2) DIB: the average distance from the implant platform to the first visible bone to contact the implant on the mesial and distal sides. This parameter was scored as: < 0.6 mm (2), 0.6-2.5 mm (1), or > 2.5 mm (0).

Two examiners were trained in evaluating both criteria by an expert. Both evaluations were performed under the expert's supervision. An intra-rater agreement analysis was performed by randomly selecting 6 subjects to be re-evaluated. Each evaluation was carried out two weeks apart. If any parameter was scored differently between the first assessment and the second assessment, this parameter was re-evaluated again. For this evaluation, a third examiner participated, and a consensus agreement between the two examiners was sought. If a consensus was not achieved, the lower score would be used to avoid bias towards overly favorable results. In addition, the examiner re-evaluated the STIRs in a different order. The examiner evaluated outcomes based on both the PES/WES and the ESC. Each re-evaluation was performed within 3 days of the first evaluation. The interval between the first and second assessments was 2 weeks. After that, the examiner evaluated the STIRs again. This time, all recruited STIR patients were assessed in a different order for the agreement test. The examiner evaluated outcomes based on both the PES/WES and the ESC. Each evaluation was conducted within 3 days. The interval between the PES/WES evaluation and the ESC evaluation was 2 weeks with all STIRs evaluated in a different order.

Statistical analysis

The data were analysed using statistical software (SPSS 20.0; SPSS, Chicago, IL, USA). Descriptive statistics, including means and standard deviations, were calculated. Weighted Cohen's kappa was used to measure the intra- and inter-observer agreements. The ESC scores were categorized using K-mean cluster analysis. ANOVA was used to evaluate the differences in the mean scores for each factor between the clusters, with the significance level set at $p < 0.05$. Then, the score characteristic of each cluster was compared to the outcome obtained using the PES/WES.

RESULTS

A total of 12 patients met the inclusion criteria, comprising 5 males and 7 females, with ages ranging from 26 to 66 years (mean age: 46 ± 12.49 years). The follow-up period for the evaluated implants ranged from 101 to 162 months, averaging 126.67 ± 23.46 months. The implant systems utilized included 5 Astratech (Densply Sirona, Mölndal, Sweden) and 7 Straumann (Institute Straumann, Basel, Switzerland) (*Table 1).*

Table 1 Demographic data of the 12 patients.

Variables	**Subjects (n = 12)**
Age (years)	46 ± 12.496 (range: 26-66)
Sex	
Male	5
Female	7
Implant system	
Astratech	5
Straumann	7
Observation period (months)	126.67 ± 23.46 (range: 101-162)

The intra-rater and inter-rater reliability analyses demonstrated robust agreement, with Cohen's kappa scores ranging from 0.685 to 0.764, indicating moderate to almost perfect reliability. PES/WES scores for the evaluated implants ranged from 12 to 18, with a median and mode of 16, resulting in a mean PES/WES score of 16.16 ± 1.90. ESC scores exhibited a broader range, spanning from 24 to 36, with a median of 29.5 and unidentified mode, yielding an average ESC score of 30.08 ± 3.52 *(Table 2).*

Table 2 Summary of the PES/WES and ESC scores.

		Min	**Max**	**Median**	**Mode**	**Mean**	**Sd**
PES		3	9	7.5	9	7.25	1.78
WES		7	10	9	9	8.83	0.89
	PES/WES	12	18	16.5	18	16.16	1.90
Gingiva		8	13	11.5	12	10.75	1.69
Prosthesis		9	12	11	11,12	10.91	0.95
Bone		3	13	8.5	-	8.41	2.63
	ESC	24	36	29.5	-	30.08	3.52

K-mean cluster analysis revealed three distinct clusters based on the gingiva and bone criteria: excellent, medium, and divergent *(Table 3).* The prosthesis part of the criteria was not included in the analysis due to these criteria was significantly separated the patients only when a 6-cluster analysis were performed. The excellent cluster displayed superior scores, with average gingival and bone parameters of 12.25 and 11, respectively, and total ESC scores ranging from 33 to 36. The medium cluster's average gingival and bone scores were 9.2 and 6.8, with total ESC scores between 25 and 29. Notably, the divergent cluster demonstrated high PES/WES scores with average gingival and bone scores of 10.66 and 7.66, respectively. Alongside lower bone-related ESC scores with total score ranged from 28-31 points.

Table 3 PES/WES and ESC scores for each subject in each cluster.

Subject	PES/WES		Total	ESC			Total	cluster
	PES	WES	(20)	Gingiva	Prosthesis	Bone	(40)	
4	8	10	18	12	12	9	33	1
5	9	9	18	12	11	13	36	1
9	9	8	17	13	10	11	34	1
11	9	9	18	12	11	11	34	1
6	6	10	16	8	12	5	25	2
8	5	8	13	8	10	10	28	2
12	3	9	12	9	12	3	24	2
1	7	8	16	9	11	9	29	2
2	8	7	15	12	10	7	29	2
3	7	9	16	11	11	8	30	3
7	7	10	17	12	12	7	31	3
10	9	9	18	11	9	8	28	3

DISCUSSION

The results of this study provide important insights into the esthetic evaluation of anterior single-tooth implant restorations. The significant variation in PES, WES, and ESC scores across the patient cohort underscores the need for a comprehensive, multifactorial assessment framework. PES and WES, widely used for evaluating soft tissue and prosthetic appearance, focus on elements like tissue contour, color, and alignment with adjacent natural teeth (Fürhauser et al., 2005; Belser et al., 2009). Although these tools are reliable for short-term assessments, they do not fully address the complex interaction between soft tissue, prosthetics, and underlying bone health, which significantly impacts long-term esthetic success (Roccuzzo et al., 2014).

The introduction of the ESC into the assessment framework represents an important evolution in how esthetic outcomes are evaluated. While the PES/WES system is valuable, it is limited by its focus on the superficial appearance of soft tissue and prosthetics, without considering deeper biological factors. The ESC fills this gap by incorporating a more holistic evaluation of gingival health, prosthetic alignment, and bone conditions. This aligns with the findings of Chan and colleagues, who emphasized the need for a comprehensive evaluation system to ensure long-term esthetic success (Chan et al., 2014).

The overall mean PES/WES and ESC scores of 16.16 and 30.08, respectively, indicate long-term success, with esthetic outcomes ranging from acceptable to excellent. Multiple studies have emphasized the importance of peri-implant bone stability in achieving sustainable esthetic success. In the esthetic zone, implants must maintain not only the soft tissue architecture but also underlying bone health to prevent complications like midfacial recession and implant exposure, both of which severely compromise esthetic outcomes (Cosyn et al., 2019). Preservation of peri-implant bone, especially the buccal bone plate, is essential for maintaining soft tissue contours and reducing gingival recession over time (Thoma et al., 2018).

The observation that cases with high PES/WES scores were sometimes accompanied by low ESC scores, particularly in bone parameters falling below acceptable thresholds, highlights the potential limitations of relying solely on soft tissue and prosthetic esthetics to assess overall implant success. The divergent cluster, where patients achieved high PES/WES scores but relatively low ESC, points to a critical issue in esthetic implantology: the possibility of achieving an immediate visually pleasing result even in cases of underlying bone compromise. This observation raises important questions about the long-term sustainability of these outcomes, as bone health is known to play a pivotal role in maintaining gingival architecture and overall implant stability (Zucchelli et al., 2012; Ramaglia et al., 2015). Research by (Raes et al., 2019) further supports the notion that bone loss or poor bone quality can negatively impact esthetic outcomes over time, even when initial soft tissue results are favorable.

Moreover, the result points out that compensatory mechanisms, such as advanced prosthetic designs or patient-specific biological factors, may contribute to favorable soft tissue esthetics in cases where bone integrity is compromised (Misch et al., 2015). These results are consistent with the findings of Cristalli et al. (2015), who observed that in certain cases, optimal implant positioning and the use of high-quality prosthetic components could mitigate the effects of marginal bone loss on the esthetic outcome.

Another critical observation is the disparity between the excellent and medium clusters, result demonstrates different in bone score. Lower in either bone volume or thickness can reduce overall esthetic pleasing. This reinforces the idea that maintaining sufficient bone volume, particularly in the anterior maxilla, is essential not only for functional stability but also for achieving and sustaining esthetic outcomes (Sanz et al., 2020; Buser et al., 2017).

The limitations of this study include the relatively small sample size and the cross-sectional nature of the evaluation, which restrict the ability to draw definitive conclusions about long-term esthetic sustainability. Future studies with larger patient cohorts and extended follow-up periods are needed to validate these findings. Additionally, the use of subjective visual assessments, even with standardized photographic and radiographic protocols, introduces potential bias (Roccuzzo et al., 2014). Incorporating more objective metrics, such as digital intraoral scanning and automated image analysis, could enhance precision and reproducibility in future esthetic evaluations (Lin et al., 2019).

CONCLUSION

In conclusion, while PES and WES remain valuable for assessing the immediate esthetic results of anterior single-tooth implants, the inclusion of long-term indicators such as bone health, tissue stability, and prosthetic material performance is essential for predicting lasting success. The ESC framework enhances this by offering a more comprehensive evaluation, integrating the key biological and mechanical factors that influence esthetic longevity. Future research should focus on validating these findings over longer timeframes and across diverse patient populations to refine the predictive accuracy of esthetic evaluation tools.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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