Aesthetic Outcomes of Single-Tooth Implant-Supported Crowns in the Anterior Region: A Retrospective Evaluation Using the Pink and White Esthetic Scores

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Abstract: Background: Aesthetic success in anterior dental implants is critical for patient satisfaction and overall clinical outcomes. The Pink Esthetic Score (PES) and White Esthetic Score (WES) provide standardized methods to evaluate the aesthetic integration of implant-supported crowns, assessing peri-implant soft tissues and visible restorations, respectively. Study Aim: This study aimed to evaluate the aesthetic outcomes of single-tooth implant-supported crowns in the anterior region using the PES/WES scores and to identify clinical factors influencing these outcomes. Methodology: This retrospective study included 49 participants who received maxillary and mandibular single anterior implants between 2017 and 2023. Aesthetic outcomes were assessed using the PES and WES, with the combined total esthetic score (TES) calculated for each implant. Associations between aesthetic scores and clinical variables such as implant type, site, size, bone graft type, and abutment type were analyzed using statistical tests, with significance set at $p < 0.05$. Results: The mean PES was 7.4 ± 2.6. The mean WES was 8.6 ± 1.3. The combined TES was 16.4 ± 2.9. Significant associations were found between PES and implant type ($p=0.010$), implant site ($p=0.000$), bone graft type ($p=0.027$), and abutment type ($p=0.002$). WES was significantly influenced by implant brand ($p=0.018$) and abutment type ($p=0.002$). TES showed significant associations with implant type ($p=0.004$), implant site ($p=0.000$), implant size ($p=0.06$), and bone graft type ($p=0.015$). Clinical parameters such as the modified bleeding index (MBI) and modified plaque index (MPI) also showed significant correlations with aesthetic scores. Conclusion: The study highlights the critical

factors influencing aesthetic outcomes in anterior implant-supported crowns. The PES and WES provide a robust framework for assessing implant aesthetics, with significant influences identified for implant type, site, bone graft material, and abutment type. These findings underscore the importance of meticulous planning and selection of appropriate materials to achieve optimal aesthetic results in dental implantology.

Keywords: Aesthetic outcomes, anterior implants, Pink Esthetic Score, White Esthetic Score, implant-supported crowns, peri-implant tissues, bone grafting, dental implants, abutment types.

1. Introduction

Dental implants have revolutionized the field of restorative dentistry, providing a highly effective solution for replacing missing teeth and restoring oral function and aesthetics [1,2]. Among various types of dental implants, single-tooth implants in the anterior region of the maxilla and mandible are particularly significant due to the aesthetic demands and functional requirements of this area [2,3]. The success of these implants is not solely based on their functional integration but also heavily relies on their aesthetic outcomes, which are crucial for patient satisfaction and quality of life [4,5].

The aesthetic outcome of anterior dental implants is multifactorial, encompassing the appearance of the peri-implant soft tissue and the restoration itself [6,7]. Two widely accepted tools for assessing these outcomes are the Pink Esthetic Score (PES) and the White Esthetic Score (WES). The PES evaluates the soft tissue parameters around the implant, including the presence and form of the papillae, the level and curvature of the facial mucosa, and the color and texture of the soft tissue [8,9]. In contrast, the WES assesses the restorative aspects, such as the form, volume, color, surface texture, and translucency of the crown. These scores together provide a comprehensive assessment of the esthetic success of the implant-supported restorations [8,9].

The introduction of dental implants marked a paradigm shift from traditional fixed partial dentures and removable dentures, offering numerous advantages, including preservation of the adjacent teeth, maintenance of alveolar bone, and improved oral hygiene [1,2]. Osseointegration, a process where the implant fixture becomes directly anchored to the bone, is a critical factor for the long-term stability of dental implants. The pioneering work of Branemark and colleagues in the 1960s laid the foundation for modern implantology by demonstrating the feasibility of osseointegration [10,11]. Since then, numerous advancements in implant design, surface modifications, and surgical techniques have significantly enhanced the success rates of dental implants [10,12].

Aesthetic outcomes in implant dentistry, particularly in the anterior region, have gained increasing attention over the past few decades. This focus is driven by the high visibility of the anterior teeth and the psychological and social impact of their appearance on patients [6,7]. Achieving optimal aesthetic outcomes involves careful planning and execution of both surgical and prosthetic phases. Factors such as implant positioning, the type of prosthetic restoration, and the quality of the peri-implant soft tissue are critical determinants of the final aesthetic result [6,8].

Implant positioning is a key factor influencing the aesthetic outcome. Correct three-dimensional positioning of the implant is essential to ensure that the prosthetic crown emerges naturally from the gingiva, mimicking the appearance of a natural tooth [1,3]. Misplacement of the implant can lead to aesthetic complications, such as gingival recession, black triangles due to the absence of papillae, and asymmetry in the gingival contour. Therefore, precise surgical

planning using tools such as cone-beam computed tomography (CBCT) and surgical guides is crucial [2,13].

Despite the advances in implantology, achieving consistently high aesthetic outcomes remains challenging. Variability in patient anatomy, biological responses, and clinician expertise can affect the final results. Therefore, continuous research and development in this field are necessary to identify factors that contribute to successful aesthetic outcomes and to develop techniques and materials that can enhance the predictability of these outcomes.

Study Aim

The aim of this study is to evaluate the aesthetic outcomes of single-tooth implant-supported crowns in the anterior region using the Pink Esthetic Score (PES) and White Esthetic Score (WES).

Study Objectives:

1. Assess the PES and WES scores of anterior single-tooth implants.
2. Investigate the factors influencing these scores, including implant type, brand, size, site, loading protocol, and bone grafting.
3. Compare the aesthetic outcomes of different types of restorations and abutments.
4. Determine the correlation between PES, WES, and clinical variables to identify predictors of aesthetic success.

2. Methodology

Study Design and Setting

This cross-sectional retrospective study was conducted at the Prince Abdulrahman Advanced Dental Institute for Postgraduate Studies. The study aimed to evaluate the aesthetic outcomes of single-tooth implant-supported crowns in the anterior region using the Pink Esthetic Score (PES) and White Esthetic Score (WES). The study included patients treated between 2017 and 2023, ensuring a comprehensive evaluation of implants placed over a six-year period.

Participant Selection

A total of 49 participants who had received single anterior implants in the maxillary or mandibular regions were included in the study. The inclusion criteria were as follows: patients aged 18 years or older; patients who had received a single-tooth implant-supported crown in the anterior region (from canine to canine) of the maxilla or mandible; and implants placed between 2017 and 2023. Patients with complete clinical records and follow-up data were also included. Exclusion criteria included patients with multiple missing teeth in the anterior region, implants with peri-implantitis or other complications, and incomplete clinical records or lack of follow-up data.

Data Collection

Data were collected through a comprehensive review of clinical records and radiographs. The clinical examination was conducted following a standardized protocol. The examination included intraoral periapical radiographs using the paralleling technique with a film holder, probing depth measurements using a periodontal probe, and assessments of the Modified Sulcular Bleeding Index (MBI) and Modified Plaque Index (MPI). Aesthetic evaluations were conducted using the PES and WES.

Pink Esthetic Score (PES) and White Esthetic Score (WES) Assessment

The PES and WES were used to evaluate the peri-implant soft tissue and the restoration, respectively. Each score comprises five variables, each rated on a scale of 0 to 2, with a maximum score of 10 for PES, 10 for WES, and a combined maximum score of 20 for TES (Total Esthetic Score). The PES variables include mesial papilla, distal papilla, curvature of the facial mucosa, level of the facial mucosa, and root convexity/soft tissue color and texture. The WES variables include general tooth form, outline and volume of the clinical crown, color (hue and value), surface texture, and translucency and characterization. Four trained examiners,

including one restorative and implantology consultant and three AEGD residents, independently evaluated the PES and WES scores to ensure reliability and consistency. Discrepancies were resolved through discussion and consensus.

Clinical Variables

The following clinical variables were recorded and analyzed for their association with the PES, WES, and TES: type of implant (cantilever, multiple, single); implant brand (Astra Tech, Biomet 3i, Straumann); implant size (≤10mm, ≥11mm); implant site (mandible, maxilla); implant loading protocol (delayed, immediate); bone grafting (yes, no); type of bone graft (allograft, xenograft); restoration type (cement-retained, screw-retained); and abutment type (ceramic, porcelain-fused-to-metal [PFM]).

Statistical Analysis

Statistical analysis was performed using SPSS software (version 25.0). Descriptive statistics were used to summarize the data. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were presented as frequencies and percentages. Associations between PES, WES, and TES scores and clinical variables were analyzed using various statistical tests. One-way ANOVA was used to compare means among multiple groups, while independent t-tests were used to compare means between two groups. Spearman's rank correlation coefficient was used to assess correlations between PES, WES, and other clinical parameters. A p-value of <0.05 was considered statistically significant.

Data Management and Confidentiality

All patient data were anonymized to maintain confidentiality. Each patient was assigned a unique identifier, and all data were stored in a secure, password-protected database. Only the research team had access to the data, ensuring privacy and confidentiality throughout the study.

Ethical Considerations

Ethical approval for this study was obtained from the institutional review board of the Prince Abdulrahman Advanced Dental Institute. All procedures were conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

3. Results

Descriptive Analysis of Clinical Variables

Table 1 provides a descriptive analysis of the clinical variables among the 49 participants included in the study. The distribution of the types of implants shows that the majority were single implants (53.1%), followed by multiple implants (34.7%) and cantilever implants (12.2%). Regarding the implant brands used, Straumann was the most common, accounting for 53.1% of the implants, followed by Biomet 3i (26.5%) and Astra Tech (20.4%). The size of the implants was almost evenly distributed, with 51% being ≤10mm and 49% being ≥11mm.

In terms of implant sites, a significant majority were located in the maxilla (79.6%), with only 20.4% in the mandible. Delayed implant loading was the predominant approach, used in 87.8% of the cases, while immediate loading was used in 12.2%. Bone grafting was performed in 65.3% of the cases, with allograft being the more common type of bone graft (71.9%) compared to xenograft (28.1%).

The type of restoration was predominantly screw-retained (79.6%), with the remaining 20.4% being cement-retained. Regarding abutment types, ceramic abutments were slightly more common (55.1%) compared to PFM (porcelain-fused-to-metal) abutments, which accounted for 44.9%.

Descriptive Analysis of WES, PES, and TES Scores

Table 2 presents the descriptive analysis of the White Esthetic Score (WES), Pink Esthetic Score (PES), and Total Esthetic Score (TES). The mean probing depth on the facial aspect was

3.9 ± 1.4 mm, while on the palatal aspect it was 3.6 ± 2.1 mm. The Modified Bleeding Index (MBI) had a mean value of 1.3 ± 0.8, and the Modified Plaque Index (MPI) had a mean value of 1.2 ± 0.8.

For the PES components, the mean scores were as follows: mesial papilla (1.3 ± 0.9), distal papilla (1.4 ± 0.7), curvature of the facial mucosa (1.6 ± 0.6), level of the facial mucosa (1.6 ± 0.6), and root convexity/soft tissue color and texture (1.6 ± 0.5). The total PES score was 7.4 ± 2.6.

For the WES components, the mean scores were: tooth form (2.1 ± 1.2), tooth volume/outline (1.9 ± 0.3), color (hue/value) (1.7 ± 0.6), surface texture (1.8 ± 0.4), and translucency and characterization (1.6 ± 0.5). The total WES score was 8.6 ± 1.3. The combined PES and WES score (TES) was 16.4 ± 2.9.

Association between PES Score and Clinical Variables

Table 3 explores the association between PES scores and various clinical variables. The type of implant showed a significant association with PES scores (F = 5.1, P = 0.010), with single implants having the highest mean PES score (8.4 ± 1.9) compared to multiple (6.4 ± 3) and cantilever implants (6 ± 2.1).

The implant brand did not show a significant association with PES scores (F = 0.1, P = 0.912). Similarly, implant size also showed no significant association (t = -1.1, P = 0.261), with ≤10mm implants having a mean PES score of 7 ± 2.6 and ≥11mm implants having a mean PES score of 7.8 ± 2.5.

Implant site was significantly associated with PES scores (t = -4.2, P = 0.000), with maxillary implants having a higher mean PES score (8.1 ± 2) compared to mandibular implants (4.8 ± 3.1). Implant loading type did not show a significant association (t = 0.4, P = 0.683).

Bone grafting also did not show a significant association with PES scores (t = 1.2, P = 0.245), although those without bone grafting had a slightly higher mean PES score (8 ± 2.9) compared to those with bone grafting (7.1 ± 2.4). Among the types of bone grafts, xenografts were associated with higher PES scores (8.6 ± 1.1) compared to allografts (6.5 ± 2.5) (t = -2.3, P = 0.027).

The type of restoration did not significantly affect PES scores (t = 0.7, P = 0.504), nor did the abutment type, with ceramic abutments showing significantly higher PES scores (8.4 ± 1.8) compared to PFM abutments (6.2 ± 2.9) (t = 3.3, P = 0.002).

Association between WES Score and Clinical Variables

Table 4 details the association between the White Esthetic Score (WES) and various clinical variables among the 49 participants. The type of implant did not significantly affect the WES (F = 0.7, P = 0.498), with mean scores for cantilever, multiple, and single implants being 8.3 ± 1.4, 8.4 ± 1.8, and 8.8 ± 0.9, respectively. However, the implant brand was significantly associated with WES (F = 4.4, P = 0.018). Astra Tech implants had the highest mean WES score of 9.6 ± 0.5, compared to Biomet 3i (8.7 ± 0.8) and Straumann (8.2 ± 1.6).

Implant size showed a trend towards significance (t = -1.7, P = 0.094), with implants ≥11mm having a higher mean WES (9 ± 0.9) than those ≤10mm (8.3 ± 1.6). The implant site (mandible vs. maxilla) did not show a significant association with WES (t = -0.1, P = 0.932), nor did implant loading type (delayed vs. immediate) (t = -0.7, P = 0.477).

Bone grafting status showed no significant effect on WES (t = 1.2, P = 0.242), with those not receiving grafts having a slightly higher mean WES (8.9 ± 1) compared to those who did (8.5 ± 1.5). The type of bone graft, however, showed a non-significant trend (t = -1.6, P = 0.127), with xenografts having a higher mean WES (9.1 ± 0.9) compared to allografts (8.2 ± 1.6). The type of restoration (cement-retained vs. screw-retained) and abutment type (ceramic vs. PFM) did not significantly affect WES scores (P = 0.254 and P = 0.819, respectively).

Association between TES Score and Clinical Variables

Table 5 shows the association between the Total Esthetic Score (TES) and clinical variables. The type of implant was significantly associated with TES (F = 6.3, P = 0.004), with single

implants having the highest mean TES (17.7 ± 1.8), compared to multiple (15.2 ± 3.6) and cantilever implants (14.3 ± 2.7). Although the implant brand showed no significant association (F = 2.2, P = 0.122), Astra Tech implants had a notably higher mean TES (18.1 ± 1.4) compared to Biomet 3i (16 ± 3.4) and Straumann (16 ± 3).

Implant size showed a trend towards significance (t = -1.9, P = 0.06), with larger implants (≥11mm) having a higher mean TES (17.2 ± 2.7) than smaller ones (≤10mm) (15.6 ± 3). The implant site was significantly associated with TES (t = -4.2, P < 0.001), with maxillary implants having a higher mean TES (17.2 ± 2.1) than mandibular ones (13.4 ± 3.8). Implant loading type did not show a significant association (t = 0.4, P = 0.72).

Bone grafting was significantly associated with TES (t = 2.0, P = 0.05), with non-grafted sites having a higher mean TES (17.5 ± 3) compared to grafted sites (15.8 ± 2.8). Within graft types, xenografts were associated with a significantly higher TES (17.7 ± 1.4) than allografts (15.1 ± 2.9) (t = -2.6, P = 0.015). Restoration type and abutment type showed significant associations with TES. Ceramic abutments had a higher mean TES (17.3 ± 2.3) than PFM abutments (15.3 ± 3.3) (t = 2.6, P = 0.013), while the type of restoration did not show a significant difference (t = -0.2, P = 0.804).

Association between Modified Bleeding Index (MBI) and Clinical Variables

Table 6 examines the association between the Modified Bleeding Index (MBI) and clinical variables. The type of implant was not significantly associated with MBI (F = 2.2, P = 0.127), with mean scores for cantilever, multiple, and single implants being 1 ± 0, 1 ± 1.1, and 1.5 ± 0.6, respectively. However, the implant brand showed a significant association with MBI (F = 8.0, P = 0.001). Astra Tech implants had the lowest mean MBI (0.7 ± 0.5), compared to Biomet 3i (1.8 ± 0.7) and Straumann (1.1 ± 0.7).

Implant size did not show a significant association with MBI (t = -0.4, P = 0.703). The implant site also showed no significant association (t = 0.2, P = 0.821), nor did the type of implant loading (t = -2.0, P = 0.048). However, bone grafting status was significantly associated with MBI (t = 3.4, P = 0.001), with non-grafted sites having a higher mean MBI (1.7 ± 0.8) compared to grafted sites (1 ± 0.6).

The type of bone graft did not show a significant association with MBI (t = -0.867, P = 0.394). Restoration type was significantly associated with MBI (t = 2.2, P = 0.037), with cement-retained restorations having a higher mean MBI (1.7 ± 0.9) compared to screw-retained restorations (1.1 ± 0.7). Abutment type did not show a significant association with MBI (t = -1.2, P = 0.25).

Association between Modified Plaque Index (MPI) and Clinical Variables

Table 7 analyzes the association between the Modified Plaque Index (MPI) and clinical variables. The type of implant was not significantly associated with MPI (F = 1.3, P = 0.277), with mean scores for cantilever, multiple, and single implants being 1.2 ± 0.8, 1.4 ± 1.1, and 1 ± 0.4, respectively. The implant brand showed a trend towards significance (F = 2.7, P = 0.078), with Astra Tech implants having the lowest mean MPI (0.6 ± 0.5), compared to Biomet 3i (1.4 ± 0.8) and Straumann (1.2 ± 0.8).

Implant size did not significantly affect MPI (t = 1.4, P = 0.178), though implants ≤10mm had a higher mean MPI (1.3 ± 0.7) compared to those ≥11mm (1 ± 0.8). The implant site was significantly associated with MPI (t = 3.1, P = 0.004), with mandibular implants having a higher mean MPI (1.8 ± 1.2) compared to maxillary implants (1 ± 0.5). Implant loading type showed no significant association with MPI (t = -1.7, P = 0.105).

Bone grafting status was not significantly associated with MPI (t = 0.4, P = 0.694), nor was the type of bone graft (t = 0.5, P = 0.639). The type of restoration did not significantly affect MPI (t = 1.0, P = 0.316), nor did the abutment type (t = -1.6, P = 0.124).

Spearman's Rank Correlation Coefficients between WES, PES, and Individual Aesthetic Parameters

Table 8 explores the correlations between the White Esthetic Score (WES), Pink Esthetic Score (PES), and individual aesthetic parameters among the 49 participants. The total WES showed significant positive correlations with several parameters. The distal papilla had a correlation of 0.323 (P = 0.024), the level of facial mucosa was correlated at 0.284 (P = 0.048), tooth form at 0.317 (P = 0.026), color (hue/value) at 0.474 (P = 0.001), surface texture at 0.557 (P = 0.000), and translucency and characterization at 0.398 (P = 0.005). The total WES had no significant correlation with mesial papilla (0.152, P = 0.296), curvature of the facial mucosa (0.195, P = 0.180), root convexity, soft tissue color, and texture (-0.014, P = 0.924), or tooth volume outline (0.176, P = 0.225).

The total PES displayed significant positive correlations with nearly all parameters except for tooth form (-0.255, P = 0.077) and tooth volume outline (-0.035, P = 0.809). Specifically, the mesial papilla had a high correlation of 0.727 (P = 0.000), distal papilla was at 0.614 (P = 0.000), curvature of the facial mucosa at 0.695 (P = 0.000), level of facial mucosa at 0.590 (P = 0.000), and root convexity, soft tissue color, and texture at 0.488 (P = 0.000). Additionally, the total PES was correlated with color (hue/value) at 0.125 (P = 0.392), surface texture at 0.193 (P = 0.183), and translucency and characterization at 0.149 (P = 0.308).

Comparison of PES, WES, and TES Scores across MBI and MPI Categories

Table 9 compares the Pink Esthetic Score (PES), White Esthetic Score (WES), and Total Esthetic Score (TES) across different categories of the Modified Bleeding Index (MBI) and Modified Plaque Index (MPI). For the MBI categories, the PES showed a significant difference (F = 3.6, P = 0.021), with mean scores ranging from 7.9 ± 2.7 in category 0 to 2 ± 0 in category 3. The WES did not show a significant difference across MBI categories (F = 1.1, P = 0.375), with scores ranging from 7.9 ± 2.7 to 8.9 ± 0.6. The TES, however, did show a significant difference (F = 3.9, P = 0.015), with scores ranging from 16.9 ± 3.4 to 10 ± 0.

Regarding the MPI categories, the PES showed a highly significant difference (F = 12.8, P = 0.000), with scores ranging from 8.4 ± 1.1 in category 0 to 2 ± 0 in category 3. The WES did not show a significant difference across MPI categories (F = 1.9, P = 0.140), with scores ranging from 7.9 ± 2.8 to 8.9 ± 0.9. The TES showed a highly significant difference across MPI categories (F = 17.7, P = 0.000), with scores ranging from 17.6 ± 1.7 in category 0 to 10.3 ± 0.5 in category 3.

Spearman's Rank Correlation Coefficients between Probing Depths and Esthetic Scores/Indices

Table 10 examines the correlations between probing depths (facial and palatal) and esthetic scores/indices. The total PES did not show significant correlations with probing depth facial (0.010, P = 0.944) or probing depth palatal (-0.205, P = 0.157). The total WES showed a significant negative correlation with probing depth facial (-0.285, P = 0.047), but not with probing depth palatal (-0.233, P = 0.107). The TES did not show significant correlations with either probing depth facial (-0.112, P = 0.445) or probing depth palatal (-0.264, P = 0.067).

The Modified Bleeding Index (MBI) showed significant positive correlations with both probing depth facial (0.513, P = 0.000) and probing depth palatal (0.317, P = 0.036). The Modified Plaque Index (MPI) did not show significant correlations with either probing depth facial (0.076, P = 0.616) or probing depth palatal (0.076, P = 0.617).

Table 1: Descriptive analysis of the clinical variables among the included subjects (n=49).

Parameter		No (%)
Type of implant	Cantilever	6 (12.2%)
	Multiple	17 (34.7%)
	Single	26 (53.1%)
Implant brand	Astra tech	10 (20.4%)
	Biomet 3i	13 (26.5%)
	Straumann	26 (53.1%)
Implant size	≤10mm	25 (51%)
	≥11mm	24 (49%)
Implant site	Mandible	10 (20.4%)

	Maxilla	39 (79.6%)
Implant loading	Delayed	43 (87.8%)
	Immediate	6 (12.2%)
Bone grafting	No	17 (34.7%)
	Yes	32 (65.3%)
Type of bone graft (n=32)	Allograft	23 (71.9%)
	Xenograft	9 (28.1%)
Restoration type	Cement retained	10 (20.4%)
	Screw retained	39 (79.6%)
Abutment type	Ceramic	27 (55.1%)
	PFM	22 (44.9%)

Table 2: Descriptive analysis of the WES, PES, and TES scores (n=49).

Parameter		Mean ± SD
Probing depth Facial		3.9 ± 1.4
Probing depth palatal		3.6 ± 2.1
Modified Bleeding Index (MBI)		1.3 ± 0.8
Modified Plaque Index (MPI)		1.2 ± 0.8
PES	Mesial papilla	1.3 ± 0.9
	Distal papilla	1.4 ± 0.7
	Curvature of facial mucosa	1.6 ± 0.6
	level of facial mucosa	1.6 ± 0.6
	Root convexity soft tissue color and texture	1.6 ± 0.5
	Total PES	7.4 ± 2.6
WES	Tooth form	2.1 ± 1.2
	Tooth volume \outline	1.9 ± 0.3
	Color (hue\value)	1.7 ± 0.6
	Surface texture	1.8 ± 0.4
	Translucency and characterization	1.6 ± 0.5
	Total WES	8.6 ± 1.3
Total PES + WES		16.4 ± 2.9

Table 3: Association between PES score and clinical variables (n=49).

Parameter		PES	Statistic, P-value
Type of implant	Cantilever	6 ± 2.1	F = 5.1, P = 0.010
	Multiple	6.4 ± 3	
	Single	8.4 ± 1.9	
Implant brand	Astra tech	7.7 ± 2.3	F = 0.1, P = 0.912
	Biomet 3i	7.2 ± 2.8	
	Straumann	7.4 ± 2.7	
Implant size	≤10mm	7 ± 2.6	t = -1.1, P = 0.261
	≥11mm	7.8 ± 2.5	
Implant site	Mandible	4.8 ± 3.1	t = -4.2, P = 0.000
	Maxilla	8.1 ± 2	
Implant loading	Delayed	7.5 ± 2.4	t = 0.4, P = 0.683
	Immediate	7 ± 3.9	
Bone grafting	No	8 ± 2.9	t = 1.2, P = 0.245
	Yes	7.1 ± 2.4	
Type of bone graft (n=32)	Allograft	6.5 ± 2.5	t = -2.3, P = 0.027
	Xenograft	8.6 ± 1.1	
Restoration type	Cement retained	7.9 ± 3.1	t = 0.7, P = 0.504
	Screw retained	7.3 ± 2.4	
Abutment type	Ceramic	8.4 ± 1.8	t = 3.3, P = 0.002
	PFM	6.2 ± 2.9	

Table 4: Association between WES score and clinical variables (n=49).

Parameter		WES	Statistic, P-value
Type of implant	Cantilever	8.3 ± 1.4	F = 0.7, P = 0.498

	Multiple	8.4 ± 1.8	
	Single	8.8 ± 0.9	
Implant brand	Astra tech	9.6 ± 0.5	F = 4.4, P = 0.018
	Biomet 3i	8.7 ± 0.8	
	Straumann	8.2 ± 1.6	
Implant size	≤10mm	8.3 ± 1.6	t = -1.7, P = 0.094
	≥11mm	9 ± 0.9	
Implant site	Mandible	8.6 ± 0.8	t = -0.1, P = 0.932
	Maxilla	8.6 ± 1.4	
Implant loading	Delayed	8.6 ± 1.4	t = -0.7, P = 0.477
	Immediate	9 ± 0.9	
Bone grafting	No	8.9 ± 1	t = 1.2, P = 0.242
	Yes	8.5 ± 1.5	
Type of bone graft (n=32)	Allograft	8.2 ± 1.6	t = -1.6, P = 0.127
	Xenograft	9.1 ± 0.9	
Restoration type	Cement retained	8.2 ± 0.6	t = -1.2, P = 0.254
	Screw retained	8.7 ± 1.4	
Abutment type	Ceramic	8.6 ± 1.6	t = -0.2, P = 0.819
	PFM	8.7 ± 1	

Table 5: Association between TES score and clinical variables (n=49).

Parameter		TES	Statistic, P-value
Type of implant	Cantilever	14.3 ± 2.7	F = 6.3, P = 0.004
	Multiple	15.2 ± 3.6	
	Single	17.7 ± 1.8	
Implant brand	Astra tech	18.1 ± 1.4	F = 2.2, P = 0.122
	Biomet 3i	16 ± 3.4	
	Straumann	16 ± 3	
Implant size	≤10mm	15.6 ± 3	t = -1.9, P = 0.06
	≥11mm	17.2 ± 2.7	
Implant site	Mandible	13.4 ± 3.8	t = -4.2, P = 0
	Maxilla	17.2 ± 2.1	
Implant loading	Delayed	16.5 ± 2.7	t = 0.4, P = 0.72
	Immediate	16 ± 4.6	
Bone grafting	No	17.5 ± 3	t = 2.0, P = 0.05
	Yes	15.8 ± 2.8	
Type of bone graft (n=32)	Allograft	15.1 ± 2.9	t = -2.6, P = 0.015
	Xenograft	17.7 ± 1.4	
Restoration type	Cement retained	16.2 ± 3.3	t = -0.2, P = 0.804
	Screw retained	16.5 ± 2.9	
Abutment type	Ceramic	17.3 ± 2.3	t = 2.6, P = 0.013
	PFM	15.3 ± 3.3	

Table 6: Association between modified bleeding index (MBI) and clinical variables (n=49).

Parameter		MBI	Statistic, P-value
Type of implant	Cantilever	1 ± 0	F = 2.2, P = 0.127
	Multiple	1 ± 1.1	
	Single	1.5 ± 0.6	
Implant brand	Astra tech	0.7 ± 0.5	F = 8.0, P = 0.001
	Biomet 3i	1.8 ± 0.7	
	Straumann	1.1 ± 0.7	
Implant size	≤10mm	1.2 ± 0.7	t = -0.4, P = 0.703
	≥11mm	1.3 ± 0.9	
Implant site	Mandible	1.3 ± 1.3	t = 0.2, P = 0.821
	Maxilla	1.2 ± 0.6	
Implant loading	Delayed	1.2 ± 0.7	t = -2.0, P = 0.048
	Immediate	1.8 ± 1.2	
Bone grafting	No	1.7 ± 0.8	t = 3.4, P = 0.001

	Yes	1 ± 0.6	
Type of bone graft (n=32)	Allograft	0.9 ± 0.7	t = -0.867, P = 0.394
	Xenograft	1.2 ± 0.4	
Restoration type	Cement retained	1.7 ± 0.9	t = 2.2, P = 0.037
	Screw retained	1.1 ± 0.7	
Abutment type	Ceramic	1.1 ± 0.8	t = -1.2, P = 0.25
	PFM	1.4 ± 0.8	

Table 7: Association between modified plaque index (MPI) and clinical variables (n=49).

Parameter		MPI	Statistic, P-value
Type of implant	Cantilever	1.2 ± 0.8	F = 1.3, P = 0.277
	Multiple	1.4 ± 1.1	
	Single	1 ± 0.4	
Implant brand	Astra tech	0.6 ± 0.5	F = 2.7, P = 0.078
	Biomet 3i	1.4 ± 0.8	
	Straumann	1.2 ± 0.8	
Implant size	≤10mm	1.3 ± 0.7	t = 1.4, P = 0.178
	≥11mm	1 ± 0.8	
Implant site	Mandible	1.8 ± 1.2	t = 3.1, P = 0.004
	Maxilla	1 ± 0.5	
Implant loading	Delayed	1.1 ± 0.7	t =-1.7, P = 0.105
	Immediate	1.7 ± 1	
Bone grafting	No	1.2 ± 0.8	t = 0.4, P = 0.694
	Yes	1.1 ± 0.8	
Type of bone graft (n=32)	Allograft	1.2 ± 0.9	t = 0.5, P = 0.639
	Xenograft	1 ± 0	
Restoration type	Cement retained	1.4 ± 0.8	t = 1.0, P = 0.316
	Screw retained	1.1 ± 0.8	
Abutment type	Ceramic	1 ± 0.5	t = -1.6, P = 0.124
	PFM	1.4 ± 1	

Table 8: Spearman's Rank Correlation Coefficients between White Esthetic Score (WES) and Pink Esthetic Score (PES) and Individual Aesthetic Parameters (n=49).

Parameter	Total WES	Total PES
Mesial papilla	0.152 (P = 0.296)	0.727** (P = 0.000)
Distal papilla	0.323* (P = 0.024)	0.614** (P = 0.000)
Curvature of facial mucosa	0.195 (P = 0.180)	0.695** (P = 0.000)
Level of facial mucosa	0.284* (P = 0.048)	0.590** (P = 0.000)
Root convexity soft tissue color and texture	-0.014 (P = 0.924)	0.488** (P = 0.000)
Tooth form	0.317* (P = 0.026)	-0.255 (P = 0.077)
Tooth volume outline	0.176 (P = 0.225)	-0.035 (P = 0.809)
Color (hue/value)	0.474** (P = 0.001)	0.125 (P = 0.392)
Surface texture	0.557** (P = 0.000)	0.193 (P = 0.183)
Translucency and characterization	0.398** (P = 0.005)	0.149 (P = 0.308)

Table 9: Comparing PES, WES, and TES scores across the MBI and MPI categories (n=49).

Parameter		PES	Statistic, P-value	WES	Statistic, P-value	TES	Statistic, P-value
MBI categories	0	7.9 ± 2.7	F = 3.6, P = 0.021	7.9 ± 2.7	F = 1.1, P = 0.375	16.9 ± 3.4	F = 3.9, P = 0.015
	1	7.2 ± 2.2		8.6 ± 1.1		16.2 ± 2.2	
	2	8.1 ± 2.9		8.9 ± 0.6		17.1 ± 3.2	
	3	2 ± 0		8 ± 0		10 ± 0	
MPI categories	0	8.4 ± 1.1	F = 12.8, P = 0.000	7.9 ± 2.8	F = 1.9, P = 0.140	17.6 ± 1.7	F = 17.7, P = 0.000
	1	8.1 ± 2		8.9 ± 0.9		17.4 ± 1.8	
	2	6.1 ± 2.7		8 ± 0.8		14.1 ± 3.3	
	3	2 ± 0		8.3 ± 0.5		10.3 ± 0.5	

Table 10: Spearman's Rank Correlation Coefficients between Probing Depths and Esthetic Scores/Indices (n=49).

Parameter	Probing Depth Facial	Probing Depth Palatal
Total PES	0.010 (P = 0.944)	-0.205 (P = 0.157)
Total WES	-0.285* (P = 0.047)	-0.233 (P = 0.107)
TES	-0.112 (P = 0.445)	-0.264 (P = 0.067)
MBI	0.513** (P = 0.000)	0.317* (P = 0.036)
MPI	0.076 (P = 0.616)	0.076 (P = 0.617)

Figure 1. Clinical photo and radiograph of a single anterior tooth implant at upper right lateral region with high PES/WES.

4. Discussion

The aesthetic outcome of dental implants in the anterior region is a critical concern for both patients and clinicians. The Pink Esthetic Score (PES) and White Esthetic Score (WES) have emerged as standardized methods to evaluate the aesthetic success of implant-supported crowns. These indices provide a comprehensive assessment of both peri-implant soft tissues (PES) and the visible restoration (WES), making them invaluable tools in implantology [1,14]. This study aimed to evaluate the aesthetic outcomes of single-tooth implant-supported crowns in the anterior region using the PES/WES scores, providing insights into factors influencing these outcomes and comparing our findings with existing literature.

Our retrospective study included 49 participants who had received maxillary and mandibular single anterior implants between 2017 and 2023. The mean PES was 7.4 ± 2.6, and the mean WES was 8.6 ± 1.3, resulting in a combined total esthetic score (TES) of 16.4 ± 2.9. The analysis revealed significant associations between PES and several clinical variables. Notably, the type of implant (p=0.010), implant site (p=0.000), type of bone graft (p=0.027), and abutment type (p=0.002) significantly influenced PES. For WES, significant associations were found with the implant brand (p=0.018) and abutment type (p=0.002). The total esthetic score (TES) was significantly associated with implant type (p=0.004), implant site (p=0.000), implant size (p=0.06), and type of bone graft (p=0.015). Modified Bleeding Index (MBI) and modified Plaque Index (MPI) also demonstrated significant correlations with aesthetic scores.

The overall mean PES and WES scores in our study (7.4 and 8.6, respectively) are within the range of what is considered satisfactory aesthetic outcomes in implantology literature. These scores are indicative of a generally acceptable level of aesthetic integration for both the peri-implant tissues and the implant-supported crowns themselves. For instance, Belser et al. [15] reported similar PES and WES values, highlighting the reliability of these indices in clinical evaluation.

The type of implant significantly affected the PES, with single implants scoring higher (8.4 ± 1.9) compared to multiple (6.4 ± 3) and cantilever implants (6 ± 2.1). This suggests that single implants might be more favorable for achieving superior aesthetic outcomes in the anterior region, likely due to their minimal disruption of the alveolar bone and adjacent soft tissues [16]. The implant site was another critical factor, with maxillary implants achieving significantly higher PES (8.1 ± 2) compared to mandibular implants (4.8 ± 3.1). This discrepancy can be attributed to the anatomical and aesthetic challenges presented by the mandible, including denser bone quality and less favorable soft tissue conditions. These findings corroborate the work of den Hartog et al. [17], who found that maxillary implants tend to have better aesthetic outcomes due to the more favorable soft tissue and bone conditions in the upper jaw.

Bone grafting, particularly the type of graft used, significantly influenced PES. Implants with xenografts scored higher (8.6 ± 1.1) than those with allografts (6.5 ± 2.5). The superiority of xenografts may be due to their biocompatibility and ability to maintain volume over time, thus providing a more stable foundation for soft tissue aesthetics [18]. This finding is supported by Simion et al. [19], who demonstrated that xenografts provide better long-term stability and aesthetic outcomes compared to allografts.

Restoration and Abutment Type

The type of abutment had a notable impact on both PES and WES scores. Ceramic abutments yielded higher PES (8.4 ± 1.8) and TES (17.3 ± 2.3) compared to PFM abutments (6.2 ± 2.9 for PES and 15.3 ± 3.3 for TES). Ceramic abutments offer superior aesthetic properties due to their ability to mimic the natural translucency and color of teeth, as well as their biocompatibility which promotes better soft tissue response [20]. These results align with those of Jung et al. [21], who found ceramic abutments to significantly enhance the aesthetic outcomes of implant-supported restorations.

Clinical Parameters and Aesthetic Scores

The modified bleeding index (MBI) and modified plaque index (MPI) were significantly correlated with aesthetic scores, highlighting the importance of peri-implant tissue health in achieving optimal aesthetic outcomes. Higher MBI and MPI values were associated with lower PES, WES, and TES scores. This underscores the critical role of meticulous oral hygiene and regular maintenance in ensuring the aesthetic success of implant-supported restorations. Similar correlations were reported by Romeo et al. [22], emphasizing the impact of peri-implant health on the aesthetic and functional longevity of implants.

Comparative Analysis with Literature

Our findings regarding the PES/WES scores are consistent with several studies in the literature. For example, Cosyn et al. [23] reported mean PES and WES values of 7.3 and 8.4, respectively, in their assessment of anterior implant aesthetics, which closely mirror our results. Furthermore, the significant impact of implant site on PES, with maxillary implants outperforming mandibular ones, has been consistently documented. Studies by Buser et al. [24] and Chen et al. [25] support the notion that the maxillary anterior region offers more favorable conditions for achieving superior aesthetic outcomes.

The influence of the type of bone graft on PES aligns with the findings of Schlee et al. [26], who demonstrated that xenografts tend to result in better soft tissue aesthetics compared to allografts. Our study further supports the preference for ceramic abutments in achieving higher aesthetic scores, a conclusion also drawn by Linkevicius et al. [27], who highlighted the aesthetic advantages of ceramic over metal abutments.

Limitations and Future Directions

While our study provides insights into the aesthetic outcomes of anterior implant-supported crowns, it is not without limitations. The retrospective nature of the study may introduce selection bias, and the relatively small sample size limits the generalizability of our findings. Additionally, the subjective nature of PES/WES scoring, despite being performed by trained examiners, may still be prone to inter-examiner variability.

Future studies should aim to include larger, more diverse populations and consider prospective designs to eliminate retrospective biases. Investigating the long-term aesthetic outcomes and stability of different implant types, abutments, and graft materials over extended periods would also provide more comprehensive data. Moreover, incorporating patient-reported outcome measures (PROMs) could offer valuable insights into the subjective satisfaction and aesthetic perceptions of patients, complementing the objective PES/WES assessments.

5. Conclusion

This study highlights the multifaceted nature of achieving aesthetic success in anterior implant-supported crowns. The PES and WES scores provide a robust framework for evaluating both soft tissue and restoration aesthetics, and our findings underscore the importance of implant type, site, bone graft material, and abutment type in influencing these outcomes. Consistent with existing literature, our results affirm that meticulous attention to these variables can significantly enhance the aesthetic results of anterior implantology. Future research should build on these findings to further refine and optimize aesthetic outcomes in dental implantology.

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