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Patients' Satisfaction and Aesthetic Outcomes of Single Implant Restorations in Aesthetic Zone Using Superimposition of Intra-Oral Scan and CBCT

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ORIGINAL STUDY

Patients' Satisfaction and Aesthetic Outcomes of Single Implant Restorations in Aesthetic Zone Using Superimposition of Intra-oral Scan and Cone-beam Computed Tomography

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Abstract

Purpose: To assess patients' satisfaction and aesthetic outcomes of single implant restorations in the aesthetic zone using the superimposition of intraoral scanners (IOS) and cone-beam computed tomography (CBCT). **Patients and methods:** A total of 14 patients with a single tooth loss in the upper aesthetic zone indicated for implants, were divided into two equal groups. Group (1): Implant planning without superimposition. Group (2): Implant planning using superimposition. Implant drilling for both groups was performed through a flapless surgical technique. In group (1), the surgical template was fabricated on a diagnostic model and used only during the drilling of the point of entry of the implant. In group (2), IOS and CBCT were imported into RealGUIDE software for superimposition, virtual implant planning, and surgical guide designing. For precisely guided implant surgery, a surgical guide that was three-dimensional printed was utilized. All patients received screw-retained customized zirconia abutments/crowns. Using a subjective outcome questionnaire, patients were asked to score their satisfaction with the overall implant treatment. The Pink Esthetic Score, Implant Crown Esthetic Index, White Esthetic Score, and Peri-Implant and Crown Index were used to assess the soft tissue that surrounds the implant supported crown. **Results:** There was an insignificant difference between the groups in terms of patient satisfaction. Regarding different aesthetic scores, group (2) showed better mean values than group (1) at both intervals, however, the difference was insignificant. The Pink Esthetic Score index revealed a significant increase from T0 to T3 in both groups. **Conclusions:** Superimposition of IOS and CBCT does not significantly affect patients' satisfaction and aesthetic outcomes of single implant restoration in the aesthetic zone.

Keywords: Implant-guided surgery, Intra-oral scanning, Superimposition, Surgical guides, Virtual implant planning

1. Introduction

It may be considered challenging to successfully replace a lost upper anterior tooth with a crown that is supported by implants since success largely depends on various mechanical and aesthetic factors. The restoration's color, shape, surface quality, and peri-implant soft tissues should be aesthetically evaluated [1].

In implant dentistry, using digital planning and treatment are even now relatively new techniques. To ensure an accurate design of the prosthesis, the ideal three-dimensional implant position is critical to the longstanding effectiveness of implant therapy [2].

Applications of cone-beam computed tomography (CBCT) in implant dentistry have significantly increased not only for diagnostic, treatment planning, and postsurgical evaluations, but also for progress in areas where CBCT combines the digital workflow, such as the creation of bio models and surgical guides, as well as surgical guiding support [3].

Digital intraoral scanners (IOS), with computer-aided design/computer-aided manufacturing

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technologies and CBCT have all helped to advance the creation of several computer-aided implant planning systems. Before using any of these platforms in a digital process, the software must be uploaded with the data gathering [4].

Also, surgical techniques can cause many complications. By utilizing a surgical guide for implant location and placement, these complications can be avoided. Implant insertion is aided by the analogue use of surgical guides; however, the position and deviation of the implants might not be ideal for prosthodontic purposes. Under a prosthetics-driven perspective, digital planning of implant surgical guides can lead to a more exact and precise execution of the process without iatrogenic complications [5].

Subjective which is patient-related parameters and objective that is dentist-related are quantitative measures and now are included in aesthetic outcome parameters. These patientreported outcome parameters are designed to contain patient feedback as it provides important supplemental information beyond clinical outcome indicators [6]. The basic subjective descriptions of the patient thoughts of their oral health situation and its influence on their everyday lives includes contentment with oral condition and several nonclinical evaluations, simply referred to as PROMs in dental medicine [7].

The null hypotheses proposed for the present study were that the superimposition of IOS in CBCT does not influence patients' satisfaction and aesthetic outcomes of single implant restorations in the aesthetic zone.

2. Patients and methods

2.1. Sample size calculation

A power analysis was created to have enough strength to use a 2-sided statistical test of the null hypothesis that no difference would be found in patients' satisfaction and aesthetic outcomes of single implants in the aesthetic zone placed using either the conventional method or by the superimposition of an IOS and CBCT. An overall sample size of 14 patients (seven in each group) was anticipated [8].

2.2. Patients' selection was done through the established inclusion and exclusion criteria

(1) This study was conducted on 14 patients with a single missing tooth in the aesthetic region indicated for implants, attending the outpatient clinic of the Crowns and Bridges department, Faculty of Dental Medicine for Girls, Al-Azhar University after obtaining the approval of the Research Ethics Committee (REC), under code REC-CR-23-03. The patients were informed about the purpose of the investigation, the clinical procedures, and the advantages/risks of the materials and techniques used. A written informed consent form was signed by patients before study initiation. The patients were selected based on the pre-established inclusion and exclusion criteria, as follows:

2.3. Inclusion criteria [9]

Patients with at least one tooth that has been missing within 3–4 months in the aesthetic zone or needs to be extracted and the surgical guide can be supported by the remaining teeth, males or females individuals above eighteen years old having the capacity to understand and consent with good treatment compliance, the labial bone plate is complete without any signs of bone dehiscence or fenestration, and there is enough bone tissue to place an implant deprived of the requirement for augmentation (remaining bone height $\geq$10 mm, buccolingual width $\geq$7 mm).

2.4. Exclusion criteria [9]

Existence of infection, or inflammation around the implant sites with uncontrolled systemic diseases, pregnant or lactating females, severe bruxism or clenching, bad oral hygiene practices, psychiatric issues, alcohol, tobacco (>10 cigarettes per day), or drug abuse, and not capable of finishing the follow-up.

2.5. Study design

Selected patients were randomly categorized using a coin toss and divided into two groups ($n = 7$) according to the implant planning and placement technique. Group 1 (the control group): Implant planning without CBCT and IOS superimposition. Group 2 (the tested group): Implant planning using the superimposition of CBCT and IOS.

2.6. Implant planning and surgical guide fabrication

In group (1): Conventional impressions were taken and poured into diagnostic models. Wax-up of the missing tooth was made on the cast concerning the prosthetic and aesthetic demand. A 1.5 mm (0.060 inches) thick clear vacuum-formed material (Easydent Co., Ltd., China) was adapted to the cast to fabricate a surgical template which was used only during the drilling of the point of entry and not the desired angulation of the dental implant. The preoperative CBCT scans (DICOM files) were imported into implant planning Real-GUIDE CoDiagnostiX 9.7 software (Dental Wings Inc., Montreal, Canada).

In group (2): Full arch IOS was taken by a MEDIT intraoral scanner (MEDIT, Seoul, South Korea), and a CBCT of the upper arch was obtained. IOS and the preoperative CBCT scans were superimposed in RealGUIDE software (Dental Wings Inc., Montreal, Canada) for implant planning and surgical guide designing as the following procedures.

2.7. Virtual implant planning

The resulting IOS, STL file and the preoperative CBCT, DICOM file were uploaded into implant planning RealGUIDE CoDiagnostiX 9.7 software. The best image possible for virtual implant planning was obtained by CBCT image segmentation, which involved removing any unneeded areas of the images.

After superimposing DICOM and STL files, implants were virtually located consistent with the bone anatomy, bone height, width (buccolingual and mesiodistal), and the optimum three-dimensional (3D) prosthetic design. In their suggested sites, implants were inserted with a suitable length and diameter. Once the place of the implant was accepted, the virtual surgical guide with a hole built to accommodate a prefabricated metallic sleeve to guide implant placement was designed using the same software (Fig. 1).

2.8. Designing and fabrication of 3D printed surgical guides

Using implant planning software (Dental wings, Montreal, Canada), the surgical guides were designed based on the proposed implant position. To establish proper stability, the surgical guides were tooth-supported with at least two teeth on either side of the surgical site. The following settings were used: a guide thickness of 2 mm, a teeth-to-guide offset of 0.2 mm, and a sleeve-to-template offset of 0.15 mm [10].

The surgical guide was seated without interruption from soft or hard tissue because of the 4 mm-high guide sleeves. The diameter of the metal sleeves was 5 mm. To facilitate precise and accurate fitting of the surgical guides to the underlying supporting structure intraorally, the surgical guides were constructed with several inspection windows. Once the digital planning was completed, this plan was stored as an STL file, exported, and uploaded into a 3D printer machine (Envision Inc, Dearborn, Michigan, U.S.A).

The model was postcured under intense UV light (Bre. Lux Power Unit 2, Bredent, Germany) when manufacturing was accomplished to complete the curing process. Metal guide sleeves were positioned into predetermined locations after printing, and it was snugly inserted in their place within the guide. One local dental laboratory conducted all the laboratory work and 3D printing.

2.9. Surgical protocol

In group (1): After disinfection of the teeth-supported surgical template, to ensure its accuracy and

Fig. 1. Superimposition of cone-beam computed tomography and intraoral scan and virtual planning of implant and crown.

correct position; it was tried in the patient's mouth. A dental implant with the proper diameter and length was reassessed for each case according to bone anatomy, height, and width. Implant drilling for both groups was performed through a flapless surgical technique. The first pilot drill (Oxy Implant dental system, Italy) was guided through the surgical template to locate the starting point. The remaining sequential drilling was done freehand according to the manufacturer's instructions. A bone-level, conical threaded, internal connection titanium implant (Oxy Implant dental system, Italy) with self-tapping design, and platform switching was placed freehand without using the surgical template. A proper healing abutment was selected and placed at the time of the surgery.

In group (2): The 3D-printed surgical guide was disinfected and placed in the patient's mouth to check its stability and fitness by visual and tactile inspection and by using an explorer through the inspection window. Osteotomy with sequential drilling was commanded by Oxy implant computer-guided surgical kit (Oxy Implant dental system, Italy), and the guided surgical protocol of the implant system was done to be in line with the surgical plan created by the implant planning software (Dental Wings Inc., Montreal, Canada). A bone-level, conical threaded, internal connection titanium implant with self-tapping design, and platform switching was placed through a surgical guide. The immediate attachment of a healing abutment to the implant was done after its insertion.

Implant positions, diameter, and length in both groups are illustrated in Table 1.

2.10. Prosthodontic protocol

After three months, patients went back for the second stage of the procedure for taking master impressions using the open tray technique at the implant level. The Vita 3D Master Guide (VITA, Säckingen, Germany) was used to select the proper shade, and the design of the abutments was carried out using Exocad software (Exocad Dental CAD, Darmstadt, Germany), in the same dental lab. All patients received monolithic screw-retained zirconia crowns on customized abutments (Katana STML Zirconia, Kurary Noritake Dental Inc. Japan), cemented on a Ti-base.

2.11. Assessment of patients' satisfaction

To create the questionnaire for this study, questionnaires from previous studies [7,11] on the future of implants, implant treatment motivation, and implant satisfaction were used. Six visual analogue scale (VAS) for investigating patients' subjective perceptions of the implant restoration, questions were VAS-1: view of the overall success of the treatment, VAS-2: patient comfort from the procedure and restoration, VAS-3 and 4: patient contentment from an aesthetic perspective, VAS-5: patient satisfaction from a functional perspective, and VAS-6: Ease of using self-care oral hygiene procedures.

2.12. Assessment of aesthetic outcomes

Soft tissue assessment was recorded at the facial aspect of each implant and reference teeth at (T0); on the day of the final crown delivery, and (T3); 3 months after the final crown delivery. Clinical photographs were assessed by 3 blind examiners (prosthodontist, oral surgeon, and periodontist) who did not participate in the patients' treatment. Aesthetic assessment of crowns and soft tissues was performed according to the parameters illustrated in Table 2.

2.13. Statistical analysis

The chi-square test was used to analyze categorical data, which were given as frequencies and percentages. The Shapiro-Wilk test was used to determine if the numerical data were normal and were given as mean and standard deviation values. Independent t-tests were used to analyze age-related parametric data. All other numerical data were nonparametric and were compared using the Mann–Whitney U test for comparisons between groups and the signed-rank test for comparisons within groups. Using Spearman's rank-order correlation coefficient, correlations were analyzed. Reliability analyses were done using Kendall's

Table 1. Implant positions, diameter, and length in groups 1 and 2.

	Group 1							Group 2						
Implant position	UR4	UL5	UL4	UR1	UR3	UR4	UR4	UR1	UL2	UR1	UR4	UR4	UL5	UL3
Implant diameter	4.5	4.5	4.5	3	4	4.5	4.5	3.5	3	3	4.5	4.5	4.5	4
Implant length	13	10	15	13	15	15	13	13	10	13	15	13	8.5	15

Table 2. Parameters and scores of indices for the esthetic evaluation [6,12,13].

	Pink esthetic score (PES)	Implant crown aesthetic index (ICAI)	White esthetic score (WES)	Peri-implant and crown index (PICI)
Peri-implant soft tissue and implant crown parameters	Mesial papilla, distal papilla, facial curvature, level of facial mucosa, root convexity and color	Labial margin, papillae, contour of the labial surface, color and surface, mesiodistal dimension, position of the incisal edge, labial convexity, color, translucency, surface	Tooth form, tooth outline, color, surface texture, and translucency	Papillae, zenith, root Convexity, Shape, color, and characterization.
Reference teeth	Contralateral tooth	Adjacent and contralateral teeth	Contralateral tooth	Contralateral tooth
Scores for each parameter	2 (No deviation) 1 (Small deviation) 0 (Large deviation)	(No deviation) (Small deviation) 5 (Large deviation)	2 (No deviation) 1 (Small deviation) 0 (Large deviation)	100 mm visual analogue scale
Overall Scores	0–14	0–45	0–10	0–600

coefficient of concordance (W). For all tests, the significance level was set at *P* 0.05. R statistical software for Windows, version 4.1.3, was used for statistical analysis.

3. Results

A total of 14 cases, with 7 cases each, were randomly and evenly allocated to one of the study groups for the study. Two (28.6%) of the cases in group (1) were males and five (71.4%) were females, while three (42.95%) of the cases in group (2) were males and four (57.1%) were females and both groups showed insignificant difference ($P = 1$). The mean age of the participants in group (1) was (44.91 ± 4.81) years, and in group (2), it was (40.82 ± 3.09) years and there was an insignificant difference between both groups ($P = 0.083$).

3.1. Statistical analysis of patients' satisfaction

12 out of the 14 patients who answered the questionnaire were wholly satisfied with the treatment, according to the question on overall satisfaction. Two patients in group 1 expressed a desire to replace their crowns (one; due to shade selection, and one; fracture, patient reported that he chewed hard food a few days after loading). The two patients who wanted new crowns represent 14.2% of the total patients number. There was no discernible difference between the two groups for any of the questions ($P > 0.05$).

3.2. Statistical analysis of aesthetic outcomes

For different aesthetic indices, group (2) showed better mean values than group (1) at both intervals, however, there was insignificant difference between both groups ($P > 0.05$). By the time, in both groups, there was a significant increase in Pink Esthetic Score (PES) index values from T0 to T3 ($P < 0.05$). No discernible difference existed between values recorded at various intervals ($P > 0.05$) for other indices as illustrated in Table 3.

3.3. Correlations between different indices

There was a moderate negative correlation between PES and ICAI (rs = −0.457). There was a moderate positive correlation between PES and PICI (rs = 0.474). There was a strong negative correlation between ICAI and WES (rs = −0.770) and between ICAI and PICI (rs = −0.657). There was a strong positive correlation between WES and PICI (rs = 0.521).

3.4. Reliability analysis

For ICAI, there was no significant agreement between the different examiners (prosthodontist, oral surgeon, and periodontist) ($P = 1$). For other indices, the agreement was strong and statistically significant ($W > 0.7$, $P < 0.001$).

Table 3. Inter- and intra- group comparison, mean and standard deviation values for esthetic scores.

Measurement	Time	(Mean ± SD)		*P* value
		Group (1)	Group (2)	
PES	T0	12.00 ± 1.70	12.48 ± 1.54	**0.388ns**
		(Mean ± SD)		
Measurement	Time	Group (1)	Group (2)	*P* value
	T3	12.38 ± 1.43	12.71 ± 1.27	**0.468ns**
	P value	**0.025***	**0.037***	
ICAI	T0	1.24 ± 1.55	1.10 ± 1.22	**1ns**
	T3	1.19 ± 1.50	0.95 ± 1.20	**0.689ns**
	P value	**1ns**	**0.149ns**	
WES	T0	9.19 ± 1.29	9.43 ± 0.75	**0.875ns**
	T3	9.19 ± 1.29	9.43 ± 0.75	**0.875ns**
	P-value	**1ns**	**1ns**	
PICI	T0	512.86 ± 29.69	526.90 ± 24.77	**0.185ns**
	T3	512.86 ± 28.88	527.62 ± 24.27	**0.124ns**
	P value	**1ns**	**0.149ns**	

* Indicates statistically significant results ($P < 0.05$).

4. Discussion

The effectiveness of implant-supported prostheses over the long term and their aesthetic results are thought to be significantly influenced by the accurate prosthetically guided implant fixture location in three dimensions. To visualize bone availability, bone quality, and important anatomical features, data was collected using CBCT which helps in optimal virtual implant placement during the planning phase.

Soft tissue and intraoral characteristics were recorded using an IOS device to produce a digital impression. Those digital STL files can be used with the CBCT DICOM information to produce remarkably precise hard and soft tissue 3D models of patients for implant designing and surgical guide manufacturing [4].

The software utilized in the present study was RealGUIDE software which used the original CBCT data to visualize axial, panoramic, cross-sectional, and three-dimensional images all at the same time in five interactive windows on the computer monitor. The software was used to put virtual implants in accordance with the anatomy of the bone and prosthetic design [8].

The approach followed in the present study was the flapless surgical procedure, which requires less time for surgery, results in less surgical trauma, provides a quick recovery after surgery, and consequently has less postsurgical issues. Additionally, because it decreases pain, edema, and patient inconvenience, it is considered more favorable and hopeful than the open flap approach [14].

In the present study, the tooth-supported surgical guides used in group (2) were designed to fit directly on the teeth. Metallic sleeves were inserted into the preplanned holes in the 3D printed surgical template to ensure the precise location and access of the planned implants guide during the drilling. These sleeves were tightly fitted into their position to avoid their dislodgement during the drilling [8].

In group (1), partially limiting design surgical guides were fabricated by a clear surgical template over the diagnostic model. This surgical template was used only for the pilot drill and the remainder of the osteotomy and implant placement was then finished free hand.

The questionnaire used in the present study was self-developed and the questions were simply phrased and like those used by previous studies [7,11]. It should also be noted that the present data included assessments of patients' satisfaction from a single time point only.

In the results, group (2) showed better patients' satisfaction and aesthetic outcomes than group (1), however, there were insignificant differences between both groups ($P > 0.05$). Therefore, the study hypothesis was accepted. Several factors may be responsible for the insignificant difference between the two groups, including proper case selection, the identical implant planning software used, the flapless surgical technique, and the same prosthetic protocol followed.

Indeed, the present results revealed that the fully guided surgical protocol proved to deliver higher scores in both patient satisfaction and aesthetic indices; however, when comparing to freehand approach with the half-guided technique there was no significant difference. This might have been due to both procedures being carried out as a flapless surgical technique using a soft tissue punch. Flapless surgery is often associated with reduced edema, pain, and discomfort following surgery and with higher patients' satisfaction can explain the insignificant difference between both groups regarding patient satisfaction.

Also, the same prosthetic protocol used in both groups could explain the insignificant difference in aesthetic outcomes. It has been reported that by preventing the emergence of a greyish line in patients with a delicate gingival phenotype, ceramic implant abutments improved the PES [15].

From an aesthetic perspective, the selection of ceramic abutment made of zirconia material is the one of the main issues that determine the aesthetic success for implant restorations in anterior zone. Also, the soft tissue quality, color, and contour choices for an aesthetic crown are important factors [16].

Compared to titanium abutments, a perfect color match to the soft tissue of the natural teeth was seen in the soft tissue surrounding implant abutments made from zirconia [17,18]. According to the findings of a recent investigation [19], it was concluded that, to achieve adequate patient satisfaction and desirable aesthetic results, high-translucency multilayered monolithic zirconia in upper aesthetic zones might be a treatment option.

In addition, all patients in both groups in the present study received a delayed loading protocol after three months of implant placement. This is consistent with a previous research investigation [12] demonstrating that the time of the restoration had no influence on the clinical and aesthetic outcomes in the maxillary aesthetic zone.

The results of this study were confirmed by those of other studies [20–22]. In which the flapless surgical technique by using the superimposition of IOS and CBCT has no effect on patients' reported outcomes and esthetic indices measurement in single implant placement in the esthetic regions. Nevertheless, the duration of the surgical procedure done by the aid of computer aided surgery technique significantly decreased.

On the other hand, these findings are in contradiction with the results of previous study [9] that showed that freehand surgery was less accurate in transmitting the implant position from the planning to execution than computer guided surgery. This contradiction may be related to different study methodologies.

Regarding the reliability of aesthetic indices, the findings of this study conform to the reports of previous studies [6,23,24]. These findings are comparable to that of other study utilizing the ICAI, and PES, both showing lower reliability for color and alveolar process assessments and the best intra-rater reliability for papilla scores. It makes sense that aspects like color of the soft tissue and alveolar process insufficiency are more subjective than papilla height and exhibit greater judgmental variability.

One more main fact to highlight is that professional background influenced the evaluation of implant crowns and mucosa esthetics. The findings of the current study demonstrated that oral surgeons gave higher marks than other specialties, indicating that they were more forgiving in their appraisal. Prosthodontists appeared to be more critical in the evaluation, and nearly all of their mean rank values were lower.

These results are in accordance with the results obtained in other studies [12,25] that reported aesthetic outcomes during follow-ups are useful in monitoring the implants in the anterior aesthetic zone.

The present study is not free from limitations. Further research is required in order to generalize the results of this study because the small sample size is considered to be one of its limitations. Also, in order to accurately predict any potential future peri-implant variations, an extended period for monitoring is needed to fully evaluate PES/WES accuracy alterations throughout time.

4.1. Conclusions

Considering the study's limitations, it was possible to conclude the following:

(a) Superimposition of CBCT and IOS does not significantly affect patients' satisfaction and esthetic outcomes of single implant-supported restorations in the esthetic zone.
(b) Subjective patients' opinions (Patient-Reported Outcome Measures, PROMs) of the treatment's overall satisfaction for implant restorations in the esthetic zone that were carried out using fully digital workflows demonstrated equivalent higher levels of satisfaction. The PES index showed a significant change over time.

4.2. Clinical significance

An additional success criterion for implant-supported restorations in the aesthetic zone is the assessment of aesthetic outcomes. The use of computer-guided surgery helps to achieve the optimal prosthetic and aesthetic planned implant position.

4.3. Recommendations

(a) Future studies can follow up on and include more patients that match the study's inclusion criteria to increase the sample size and produce results that can be both statistically and clinically significant.
(b) More comparative clinical trials should be conducted, with differences between the approaches utilized (flapless, nonflapless, immediate loading).
(c) Future research should include superimposition of the facial scan, and IOS in CBCT.
(d) Further investigations about the effect of customized abutments/crowns constructed with different ceramic materials on different aesthetic indices.

Ethics information

This study was approved by the Ethics Committee of Al Azhar University under code P-CR-21-06.

Biographical information

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Conflicts of interest

There are no conflicts of interest.

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