COLOR EVALUATION OF LITHIUM DISILICATE CROWNS ON TITANIUM IMPLANT ABUTMENTS IN THE ESTHETIC ZONE AFTER USING TWO MASKING APPROACHES, A RANDOMIZED CLINICAL CONTROLLED TRIAL.

Karim Ahmed Awadallah BDS, MSC 1, Mohamed Labib Zamzam MSC, PhD 2, Reham Said Elbasty MSC, PhD 3

1 Assistant Lecturer, Fixed Prosthodontics department, Faculty of Dentistry, Cairo University, Egypt.
2 Professor, Fixed Prosthodontics department, Faculty of Dentistry, Cairo University, Egypt
3 Associate Professor, Fixed Prosthodontics department, Faculty of Dentistry, Cairo University, Egypt

Corresponding Author: Karim Ahmed Awadallah

Address: Faculty of Dentistry- Cairo University- Cairo- 11 El- Saraya St. Manial, Cairo, Egypt. Postal Code: 11553, Cairo,Egypt

E-mail address: karimawadallah@dentistry.cu.edu.eg

ABSTRACT

Objective: To evaluate of the esthetic outcome of lithium disilicate (e.max) all ceramic crowns on titanium implant abutments in the esthetic zone after different color masking approaches.

Materials & Methods: A total of 27 patients (18 females, 9 males) were selected for the study with an age range between 20 to 62 years old. Each participant received an implant and lithium disilicate (E-max) single crowns over titanium abutments in the esthetic zone. The patients were divided into three groups according to the masking method of the titanium abutments: Group A(control group) patients received E-max crowns over titanium abutments covered by a layer of opaque porcelain (N=9), Group B patients received E-max crowns over titanium abutments covered by a layer of opaque porcelain (N=9), Group C patients received E-max crowns over titanium abutments covered by lithium disilicate (high opacity) coping (N=9).the color measurements were performed using a digital Spectrophotometer (Vita Easyshade V) and CIE L* a* b* color coordinates.
Results: For color difference ΔE values, there was a significant difference among the three groups (P-value < 0.001) where group I showed the highest mean (6.36) while group III showed the lowest (3.71)

Conclusions: Both HO opacity copings and opaquer group revealed acceptable performance in terms color difference. No significant difference was recorded between these two groups regarding the color difference. Therefore, further clinical investigations are recommended.

Keywords: Dental color, color difference, Titanium abutments, Lithium disilicate, Dental implants.

INTRODUCTION

The continuous development in restorative techniques, introduction of new restorative materials and paradigm increase in dental awareness have made it a must to fabricate restorations that simulate the natural teeth, and thereby have created a challenge especially in the anterior region or the esthetic zone. [1]

Highly translucent core ceramics, such as leucite based and lithium disilicate based ceramics, have been introduced in the dental market. Unlike the porcelain fused to metal restorations, these materials are basically composed of moderately transparent small particles of different refractive indices, resulting in more light diffusion in many directions with lowering in the intensity of transmitted light. This inherent property has increased the color value and has given natural tooth-like translucency. [2-4]
However, this excellent translucency has created a new challenge, where the color of the underlying abutment and the luting cement used has influenced the overall esthetic result of the restorations. [4]

Not until recently, esthetic dentists faced several challenges for the reproduction of the precise shade of natural teeth in the direct and indirect restorations. [5] Therefore, the first step towards an excellent shade matching would be understanding the principles of color vision and the methods of their application to clinical dentistry. [6] Various methods have been suggested for quantifying color and expressing color numerically, thereby making it feasible to communicate colors more accurately [7,8]

The L*a*b* color space (also referred to as CIELAB) is presently one of the most reliable spaces for measuring object color and is universally used in virtually all fields. [9,10]

Minute color differences are hard to deal with in industry anywhere that color is used. In the L*a*b* color space, the color difference can be expressed as a single numerical value, ΔE*ab, which explains the size of the color difference rather than what way the colors are different. ΔE*ab is defined by the following equation: ΔE*ab = (∆L² + ∆a² + ∆b²)¹/² [9,10]

There are other color difference formulae in use today; however, the CIELAB ΔE_Lab is still the most prevailing in color research in dentistry. [9,10]

Until now, there has been a large debate regarding the accepted value of CIELAB ΔE_Lab. However, many studies came to a consensus that a color change of ΔE data that is higher than 3.7 units is said to be clinically visible in any site. [11-16]

There are three primary categories of automatic shade selection devices; colorimeters, spectrophotometers, and digital imaging devices. Among which, spectrophotometers are considered the most accurate instrument for color matching in dentistry [17-19]

Spectrophotometers measure the amount of light energy reflected from an object’s surface at 1-25nm intervals within the visual light spectrum (380-780 nm) [18]. They are classified to spectral and imaging. The spectral type depends on the measurement of a small area on the tooth surface (spot measurement (SM)). While the imaging type depends on entire tooth
surface measurements (complete surface), providing a topographical map of the tooth in one image.\[^{[19]}\]

Numerous studies have employed spectrophotometers to measure the color changes developed by the implant-supported restorations in comparison to natural teeth, because of the more sensitive and objective findings they offered.\[^{[20,21]}\]

Ever since they were introduced in dentistry, Dental implants have become successful treatment options for the prosthetic rehabilitations of both total and partial edentulism, solving the dilemma of the critical cases that can’t be restored by conventional prosthodontic methods.\[^{[22]}\]

However, the use of implants to replace missing teeth in the esthetic zone is challenging. Where paying attention to minor esthetic details is of paramount importance to provide naturally looking restorations. Moreover, the amount and the direction of the functional stresses are hazardous and contributing to various mechanical failures in this area.\[^{[22]}\]

Moreover, the metallic color of the implant abutment has adverse influence on the overall appearance of translucent core ceramics by creating a grey hue under the restorations which, indeed, complicated the use of these beautiful restorations in implant supported restorations, especially in the anterior zone.\[^{[22]}\]

This created a need for more opaque ceramic solutions such as zirconia superstructures to mask the unpleasant grey shine of the titanium abutments, which in turn resulted in less value overall restorations.\[^{[23,24]}\]

To solve the disappointing esthetic outcome of titanium, ceramic abutments were introduced. Ceramics like zirconia, lithium disilicate, and hybrid materials have been used recently and several studies have been performed to test their mechanical and esthetic performance as implant abutments.\[^{[25]}\]
The whitish color of zirconia abutments was thought to give a better esthetic outcome. However, their opacity remained an obstacle to the establishment of natural tooth color. Moreover, many studies have found no significant difference in using zirconia instead of titanium on the final color of ceramic restorations or the color of the surrounding soft tissues. In addition to the elevated cost of zirconia abutments compared to titanium. [26]

Many ceramic fractures were associated with using lithium disilicate abutments, despite the notion of their ability to withstand the mechanical loads in the anterior area. [27,28]

Hybrid ceramics have been introduced as an esthetic choice for implant abutments, for their acceptable esthetics and excellent modulus of elasticity that can provide better stress distribution and thereby withstanding occlusal forces. However, a limited number of investigations about them are now available that can confirm the reliability of their use in the anterior region. [29]

Therefore, titanium abutments have remained the most reliable to use, and other solutions have to be established to solve the negative effect of their metallic color. [22]

Various studies have suggested clinical solutions for overcoming the metallic hue of the titanium abutments, including gold and pink anodization, and direct veneering of titanium abutment with composite resins or feldspathic porcelain. [30]

Therefore, the purpose of this study is to investigate the ability to mask the titanium abutments under translucent lithium disilicate crowns, employing two masking methods, where the null hypothesis states that there will be no difference in esthetic results of the lithium disilicate implant-supported restorations in all the tested groups.

MATERIAL & METHODS

1- Study Design
This study was reviewed by the Ethics Committee of Scientific Research, Faculty of Dentistry, Cairo University, Cairo, Egypt and approved in July 2018 (approval no. 18967). Written informed consent was obtained from all patients who participated in the study under the approval of the ethics committee. This study was registered on ClinicalTrials.gov (Identifier: NCT03686267). This study was a triple-blinded randomized controlled clinical trial.

A total of 27 patients (18 females, 9 males) were selected for the study with an age range between 20 to 62 years old. The chief complaint was to enhance their smile. Information was given to each patient regarding the alternative treatment options. The treatment plan was explained for each patient. Then, they agreed to sign the informed consent before proceeding to clinical work. They were all able and willing to maintain good oral hygiene measures. Each participant received an implant and implant prosthesis in the esthetic zone.

All participants were recruited during the time from July 2019 to December 2019 from the outpatient clinic of Fixed Prosthodontics Department, Faculty of Dentistry, Cairo University, Cairo, Egypt. Screenings of patients were carried out until the target number was reached. This study was completed by September 2020. Complete medical and dental history were obtained from all participants.

An anonymous colleague allocated participants into three groups with 1:1 allocation ratio using computerized sequence generation (www.randomizer.org). allocation concealment, randomization and the triple blinding were performed.

The candidate under supervision was responsible for all procedures, patient selection, preparation, shade selection, try in, and bonding.

**2- Sample Grouping:**

The 27 patients were divided into 3 groups: Group (A) (Control) included patients who received lithium disilicate crowns over uncovered titanium abutments (n=9), Group (B) (Intervention I1) included patients who received lithium disilicate crowns over titanium abutments covered by a layer of opaque porcelain (n=9), and Group (C) (Intervention I2)
included patients who received lithium disilicate crowns over titanium abutments covered by lithium disilicate (high opacity) coping (n=9). (Figure 1)

![Figure 1: The 3 groups of the study with Lithium disilicate crowns over: A- uncovered titanium abutments. B- titanium abutments covered by a layer of opaque porcelain. C- titanium abutments covered by lithium disilicate (high opacity) coping.](image)

3-Clinical procedure:

A- Diagnosis and impression

Preoperative photography using a Nikon D3500 DSLR camera with a Nikon macro lens and a ring flash. Primary impressions using alginate impression material(Tropicalgin. Zhermack Elite, Italy) in a suitable size stock tray. The impression was poured using dental stone type iv (GC Fuji Rock, GC Corporation, Japan). The cast was scanned to form a digital study model using an extra oral scanner (Medit T300, Korea). (Figure 2)
Preoperative CBCT radiographs were taken to analyze the bone available for implant selection (Scanora CBCT machine and On Demand Implant Software)

The candidate analyzed the study cast and reviewed the radiographs to decide on the suitable implant length and diameter.

B- Implant insertion:

A surgical flap was incised and elevated followed by sequential drilling, (according to manufacturer’s instructions, Neobiotech IS II Active, South Korea) until the diameter and length of the implant previously decided was reached. The implant (Neobiotech IS II Active, South Korea) was inserted then rotated to the required length using a hand driver. No further rotation should be obtainable.

A trial abutment (Neobiotech IS II Active, South Korea) was installed to check implant position and angulation and periapical radiographs were taken. Finally, closure of the flap using CollaPlug (Collatape, Zimmer USA) and suturing was done. Post-operative instructions and medications were prescribed to the patients. (figure 3)
C- Abutment placement and temporization:

Three months following implant insertion, the implant site was checked for adequate healing (figure 21), then surgical exposure of the implant and placement of a healing collar (Neobiotech IS II Active, South Korea) was done. Soft tissue management was performed by application of customized temporary abutment (Neobiotech IS II Active, South Korea) to improve the emergence profile of the prospective restoration (figure 4)
D- Secondary impressions:

Two weeks following temporization the temporary restoration was removed and emergence profile was evaluated (figure 5). Afterwards an indirect secondary impression (open tray technique) was taken using a transfer coping and analogue. Double mix-one step technique was employed using addition silicone impression material (Zhermack Elite, Italy) in a suitable stock tray. Pouring of the impression was done using extra hard stone. (GC Fuji Rock, GC Corporation, Japan) and the soft tissue mimic (Zhermack Oranwash VL, Italy) was placed over the abutment to adjust the emergence profile of the restorations.

![Figure 5: Emergence profile](image)

E- Abutments’ modifications:

In Group (A), the final crowns were constructed directly with no modification of the titanium abutments. While in Group (B), titanium abutments were covered by a layer of opaque porcelain before the fabrication of the final crowns according to the following steps: Metal preparation using standard SHP burs (SHOFU DENTAL GmbH, Germany) for titanium at maximum speed 15,000 RPM, followed by sandblasting (Basic eco. Renfert, Germany) with aluminum oxide particles of grit size (125-150 µm), 2.5 bars or 30 psi of pressure, and a
blasting angle of 45°. Then substructures were steam cleaned for 30 minutes and let dry on a tissue for 5 minutes to naturally oxidize. A thin coating of titanium bonder (GC titanium bonder, GC America) was applied and properly fired under manufacturer instructions. Finally, the titanium opaquer (GC Initial Ti Shoulder Opaque SO-38, GC America) was applied and fired according to established firing parameters. In Group(C), before the fabrication of the final crowns, titanium abutments were covered by lithium disilicate copings (IPS e.max pressable ingots HO, Ivoclar Vivadent, Germany) that were manufactured according to the following steps: PMMA patterns of thin anatomical copings with an equi-gingival finish line were constructed in a minimum thickness as recommended by the manufacturer (the same manufacturing steps of the superstructures). The patterns were finished, sprued, invested and pressed by the conventional pressing technique. After divesting, the copings were finished and polished according to the manufacturer recommendations.

F- Superstructure manufacturing:

lithium disilicate crowns (IPS e.max pressable ingots HO, Ivoclar Vivadent, Germany) were constructed as follows: The master casts were scanned by an extra oral scanner (I3DSCAN ECO, imes-icore® GmbH, Germany) and PMMA patterns (Bloomden Bioceramics Co., Ltd, China) were designed by a CAD software (EXOCAD CAD SOFTWARE, imes-icore® GmbH, Germany), and milled by a CAD/CAM milling machine (CORITEC 250I SERIES, imes-icore® GmbH, Germany)

The PMMA patterns were sprued and invested by the conventional lost wax & pressing technique. After cooling, divesting process was performed using polishing beads (Ivoclar Vivadent, Germany), where the rough divestment was done at 4 bars (58 psi) pressure and the fine divestment at 2 bar (29 psi) pressure, the reaction layer formed during the press procedure was removed using IPS e.max Press Invex Liquid (Ivoclar Vivadent, Germany) followed by sandblasting using Al2O3 at 1–2 bar (15–30 psi) pressure.

Finishing of the restorations was done using a suitable separating disc and grinding burs (KOMET Dental, Brasseler, Germany). Brief sandblasting with type 100 Al2O3 at 1 bar (15 psi) pressure and steam cleaning (Steaman II Steam Cleaner. Bar Instruments LLC) were
performed, then stains and fluorescent glazing material were applied consecutively and fired according to the manufacturer recommendations.

G- Surface Treatment and Bonding protocol:

After removal of the provisionals, the final restorations were placed for checking and verification step and further adjustments were performed insitu if needed (figure 6). The superstructures and the abutments were then removed and cleaned prior the surface treatment and bonding step as follows: 1- sandblasting of the titanium abutments were performed (in groups A & C) using aluminum oxide (Al2O3) of 50 µm particle size at 1.5 bar pressure until a matt surface was confirmed. 2- the lithium disilicate HO copings (group (C)): were subjected to internal and external surface treatment using hydrofluoric acid 9% (Ultradent, USA) for 20 seconds followed by thorough water rinsing and air cleaning, that resulted in a frosty white color. Then a silane coupling agent (Ultradent, USA) was applied on both surfaces for 60 seconds. Then air thinning to remove the excess. Finally, cementation of the copings with their alternative superstructures extra orally to facilitate the removal of the excess cement. 3- The internal surface treatment of the final restorations (lithium disilicate LT) was carried out using hydrofluoric acid 5% for 20 seconds followed by silane application for 60 seconds. Then the restorations were bonded in place using a dual cure self-adhesive resin cement. (Breeze™ Resin Cement, Pentron, USA). Tack curing for 2 to 5 seconds was applied for easy removal of the excess cement. Then further light curing for 40 seconds on each surface was applied (figure 7)

Figure (6): abutments placed in-situ
H- Follow up and Recording of Color:

The patient was recalled after 1 month to check the healing of the peri-implant soft tissue and to record the color measurements.

The color of the final restoration was evaluated using an intraoral digital spectrophotometer (Vita easy shade V, Vita Zahnfabrik, Germany) according to Kim et al 2016[^15]. and the color analysis was done by the spectrophotometer according to the CIE L*a*b* color coordinates (figure 8). The color difference (ΔE) was calculated using the following equation: ΔE= ((ΔL*)² + (Δa*)² + (Δb*)²)¹/².
Figure (8): Color analysis according to CIE Lab coordinates using Vita easy shade V

**Statistical Analysis**

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). ΔE, ΔL, Δa and Δb data showed normal (parametric) distribution. Data were presented as mean, standard deviation (SD), median and range values. For parametric data, one-way ANOVA test was used to compare between the three groups. Bonferroni’s post-hoc test was used for pair-wise comparisons when ANOVA test is significant. Qualitative data were presented as frequencies and percentages. Fisher’s Exact test was used to compare between the three groups. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

**RESULTS**

Means and SDs of CIE L*, a*, b* values for each group are presented in Table 1. one-way ANOVA test was used to compare between the three groups. Bonferroni’s post-hoc test was used for pair-wise comparisons when ANOVA test is significant

1. **Color difference (ΔE) & (ΔL) values:** There was a statistically significant difference between mean ΔE & ΔL values in the three groups (P-value <0.001, Effect size = 0.846& 0.766 respectively) with the highest mean in group A, followed by group B, while group C showed the lowest mean.
2. **Red-Green axis (Δa) values:** There was no statistically significant difference between mean Δa values in the three groups (P-value = 0.828, Effect size = 0.016).

3. **Blue-Yellow axis (Δb) values:** There was a statistically significant difference between mean Δb values in the three groups (P-value < 0.001, Effect size = 0.863) with the highest mean in group A, followed by group B, while group C showed the lowest mean.

**Table (1): Descriptive statistics and results of one-way ANOVA test for comparison between ΔE, ΔL, Δa and Δb in the three groups**

<table>
<thead>
<tr>
<th></th>
<th>Group A (n = 9)</th>
<th>Group B (n = 9)</th>
<th>Group C (n = 9)</th>
<th>P-value</th>
<th>Effect size (Eta Squared)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔE</td>
<td>6.36 (0.62)   A</td>
<td>4.46 (0.58)    B</td>
<td>3.71 (0.19)    C</td>
<td>&lt;0.001 *</td>
<td>0.846</td>
</tr>
<tr>
<td>ΔL</td>
<td>4.42 (0.6)    A</td>
<td>3.18 (0.43)    B</td>
<td>2.63 (0.2)     C</td>
<td>&lt;0.001 *</td>
<td>0.766</td>
</tr>
<tr>
<td>Δa</td>
<td>0.79 (0.21)</td>
<td>0.79 (0.24)</td>
<td>0.7 (0.25)</td>
<td>0.828</td>
<td>0.016</td>
</tr>
<tr>
<td>Δb</td>
<td>4.48 (0.34)   A</td>
<td>3.02 (0.47)    B</td>
<td>2.53 (0.16)    C</td>
<td>&lt;0.001 *</td>
<td>0.863</td>
</tr>
</tbody>
</table>

*: Significant at P ≤ 0.05, Different superscripts are statistically significantly different according to Bonferroni’s post-hoc test

**DISCUSSION**

Lithium disilicate based ceramics, are considered the most reliable esthetic materials available, in terms of translucency and natural appearance. [2-4] Unfortunately, the underlying abutments and cement colors have grossly affected the final outcome of these restorations.
This created a technique sensitivity that could result in a total failure of the restorations from the esthetic point of view. [4]

In the present study, we investigated a novel approach (lithium disilicate high opacity copings) for masking the gold standard prefabricated titanium abutments, compared to another masking method (covering titanium abutments with opaque porcelain), in an attempt to improve the esthetic outcome of lithium disilicate final crowns.

Color difference was evaluated in this study using a digital intra oral spectrophotometer and by calculating the CIE Lab equation ($\Delta E = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$).

Researches had proven that digital shade matching was the only objective method for assessment of the color change. And among them, the spectrophotometers were proven to be much more accurate and reliable than the colorimeters or the RGB digital cameras. [17-19]

The CIE Lab color coordinates were used, due to their accuracy in representing the color space and explaining the different color variations. [9,10]

The null hypothesis was rejected where the overall color change $\Delta E$ results revealed a significant difference among the tested groups. These results came to the authors expectations, as it confirmed the success of the masking methods used in the study to improve the color values of the lithium disilicate implant supported superstructures.

The significant difference between the two masking methods can be attributed to several factors. First, the variation in the construction techniques used in both groups, where in group B the color outcome can be affected by the human errors related to the application, layer thickness, firing and finishing procedures of the opaquer. While in group C, the use of the CAD/CAM technology resulted in more standardized technique that enabled a more successful masking effect. Second, the variation in the materials, where high opacity lithium disilicate may have a more masking ability than the feldspathic opaque porcelain layer.

Finally, the presence of additional interfaces in group C (titanium abutment/ cement/ coping/ cement/ crown) would have increased the masking effect in comparison to group B (opaqued titanium abutment/cement/crown).
The mean ΔE value of group A was 6.36 (0.62), which is considered a clear color mismatch, as suggested by most of the researches available in the literature.\[^{11-16}\]

In group B, the mean ΔE value was 4.46 (0.58). This value was considered as a moderate color mismatch and clinically accepted by the patient, in consensus with Gáspárík et al 2014\[^{13}\] and Yamanel K et al 2010\[^{14}\]. However, other studies classified the resultant value as an unacceptable color mismatch such as Kim et al 2016\[^{15}\] and Martínez-Rus et al 2017\[^{31}\].

Group C showed a mean ΔE value of 3.71 (0.19). This indicated that using the copings as a masking method yielded an excellent color matching, where the value of ΔE value of 3.7 is considered the gold standard for having unnoticeable naturally appearing restorations.\[^{11-16}\]

Regarding the results of the individual color coordinates (ΔL*, Δa* and Δb*). There was a significant difference among the three groups, where group A had the highest (ΔL*) followed by group B while group C showed the lowest (ΔL*). These results can be attributed to the fact that adding masking interventions in groups B&C resulted in an increase in the overall thickness of the final restorations, which increased the amount of light absorbed and decreased the amount of the reflected light. This means that the thicker the restoration, the lower the (ΔL*) values would be recorded. These findings came in agreement with Shokry et al 2006\[^{32}\] and Ozturk et al 2008\[^{33}\] who investigate the influence of the ceramic thickness on the color difference of the restorations.

The results also came in consensus with Shono et al 2018\[^{34}\] & Vichi et al 2000\[^{35}\] who evaluated the efficiency the masking ability of different ceramic systems.

The results of Δa* came insignificantly different among the three groups, while those of Δb* came similar to the results of ΔL* with the highest and the lowest Δb* scores were recorded by groups A and C respectively. These results can be also related to the difference in the overall ceramic thickness among the three groups, which was supported by the results of Shono et al 2018\[^{34}\]. However, these findings came in contrast to Ajlouni et al 2017\[^{22}\], Shokry et al 2006\[^{32}\], Ozturk et al 2008\[^{33}\] and Dozic et al 2003\[^{36}\] who found an increase in the values of Δa* and Δb* with the increasing the ceramic thickness. This contradiction can be justified by the difference in the methods of ceramic fabrication and the nature of the study design (in-vitro vs clinical studies).
Conclusions

Within the limitations of this study, the following can be concluded:

1- The use of lithium disilicate crowns over uncovered titanium abutments revealed disappointing esthetic results.

2- The attempts to mask the color of titanium abutments underneath the lithium disilicate superstructures improved their esthetic outcome.

3- The use of high opacity copings over titanium abutments was proven to be a promising esthetic solution, for reaching naturally appearing implant supported superstructures.

RECOMMENDATIONS

1- Further studies should be conducted comparing the esthetic outcome of the novel approach for masking the titanium abutments, with the ceramic abutments available.
2- Although the use of opaque porcelain as a masking method seems to be appealing due to its simplicity, however it would be recommended to use an opaque cement in conjunction with this technique.

3- Long term clinical studies are needed to confirm the stability of the esthetic success of the novel approach.

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Conflict of Interest:

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.
Regulatory Statement:

This study was conducted in accordance with all the provisions of the local human subjects’ oversight committee guidelines and policies of: the Ethics Committee of Scientific Research - Faculty of Dentistry – Cairo University. The approval code for this study is: 18967.

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