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MAINTENANCE REQUIREMENTS OF PEEK-COMPOSITE VERSUS METAL-CERAMIC TOOTH-IMPLANT SUPPORTED RESTORATIONS: (A RANDOMIZED CONTROLLED CLINICAL TRIAL)

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ABSTRACT

Background: Connecting teeth to implants was always associated with technical complications like veneer fracture and cement bond breakage, especially if rigidly connected, and intrusion with non rigid connection. Different materials were used with the gold standard treatment, porcelain fused to metal (PFM), showing the least technical complications of them. The search for less maintenance requiring material is still demanded.

Aim: The aim of this study is to compare the maintenance requirements of polyetheretherketone (PEEK)-composite versus metal-ceramic tooth-implant supported prostheses (TISP).

Materials and methods: This is a randomized, controlled clinical trial with a split mouth design. The trial included 12 patients (24 subjects). Patients with symmetrical Kennedy class I received one implant in the molar region, followed by a three unit fixed partial denture (FPD) connecting one molar implant to one premolar natural tooth on each side.

In each patient, one side was restored with composite veneered to PEEK FPD, while the other side was restored with PFM FPD. The patients were recalled on 6, 12 and 18 month for inspection. The occurrence of technical complications or lack of was recorded, tabulated and statistically analyzed using Chi square test and Fischer exact test.

Results: The result of the analysis showed that there is no statistical significant difference between the two groups regarding veneering material fracture, loss of cementation, and screw loosening/fracture.

Conclusion: In Kennedy class I cases restored with tooth-implant-supported prosthesis (TISP), both metal-ceramic and PEEK-composite are viable FPD options in short follow-up period of 18 months. Neither of the aforementioned materials showed superiority in reducing prosthetic complications in TISP cases. A protocol of this study has a trial registration number of PACTR201504001079167.

Keywords: Tooth-implant supported prosthesis (TISP), Polyether ether ketone (PEEK), Visiolign, Partial edentulism, Porcelain-fused-to-metal (PFM), Fixed partial denture (FPD)

INTRODUCTION

Kennedy Class I, which represents a significant clinical challenge, has a reported prevalence that ranges from 25.75% to 47.6% in the literature. The loss of posterior teeth not only affects mastication and nutrition but also leads to alveolar bone resorption, complicating future rehabilitation. Additionally, tooth loss has been associated with psychosocial impacts, further emphasizing the need for effective restorative solutions.

Conventional treatment options include removable partial dentures (RPDs), fixed partial dentures (FPDs), and implant-supported prostheses (ISP). While RPDs offer a cost-effective and minimally invasive approach, they are often plagued by issues such as poor retention, instability during function, and aesthetic concerns due to visible clasps. For patients seeking fixed alternatives, either ISPs or TISPs, provide improved function and comfort. On the other hand, the biomechanical disparity between implants and natural teeth introduced complications. Implants, being ankylotic, exhibit minimal mobility; while natural teeth possess periodontal flexibility, leading to uneven stress distribution under occlusal loads. Historically, the Brånemark protocol

discouraged rigid connections between implants and teeth due to concerns about excessive forces on the implant, potentially leading to bone loss, screw loosening, or prosthetic failure. To address this, non-rigid connectors (stress breakers) were proposed, but clinical studies revealed unintended consequences, such as tooth intrusion. Conversely, rigid connections, particularly those using porcelain-fused-to-metal (PFM) frameworks, demonstrated better long-term outcomes with fewer complications, provided that proper prosthetic flexibility was maintained.

The use of TISP arises from both necessity and clinical advantages. Necessity often drives TISP application in cases with insufficient number of natural abutments, unfavorable distribution, or periodontal compromise, where splinting provides stabilization. It also serves as a cost-effective alternative when additional implants or bone grafts are financially prohibitive, or when a failed implant in a multi-implant prosthesis requires immediate stabilization to maintain function without complete replacement. Patient preference to avoid additional surgery may also favor TISP. Beyond necessity, TISP offers distinct benefits, including enhanced tactile sensitivity which means that natural teeth provide 8.8 times greater proprioception than implants, improving chewing comfort and reducing occlusal stress. Additionally, TISP helps preserve esthetic papillae in anterior regions, provides cross-arch stabilization in bruxers for better occlusal guidance, and improves torsional resistance through splinting [1–6].

While TISP suffered from complications, prosthesis and implant survival rates in TISP versus ISP demonstrated that TISP showed acceptable short-term results while long-term durability may lag behind ISP, particularly in prosthesis survival, though implant survival remained comparable in rigorously controlled studies [3,7–10]. Among these prosthetic complications is veneer fracture, loss of retention and screw loosening /fracture.

Regarding veneer fracture, Kindberg et al.[11] reported veneer fracture as 9.8% in an observation period ranging from 14 months to 8.9 years. Brägger et al.[12] reported veneer fracture as 9.1% in a follow up period of 10 years. Heinemann et al.[13] reported veneer fracture as 7.7% with TISP in 5 years follow up period. Nickenig et al.[14] with a follow-up period ranging from 2.2–8.3 years, they reported 5.95% of veneer fracture. Noda et al.[15] also reported 16.1% TISP cases had veneering porcelain fracture, they also stated that the major risk factors for veneer fracture were the presence of screw access hole and the limited inter-arch space that is frequently associated with screw-retained superstructure.

Regarding loss of retention, Naert et al.[3] in a fifteen years clinical evaluation cohort study reported 8% cement failure with both rigid and non-rigid connectors. Brägger et al.[12] in a 10-year evaluation time, 16.7% abutment definitive cement failure had occurred which led to caries and eventually loss of TISP, as detection of a loose retainer could be challenging for patient to notice. Palmer et al.[16] in a 3 years prospective study used a temporary cement in 19 cases on both abutments (implant abutment and permanently cemented coping on tooth abutment). Loss of cement occurred in 8/19 cases (42%) with 7/8 of the de-bonded restorations losing cement on both ends which alerted the patients before abutment loss gone unnoticed as in the case of the previous study. Nickenig et al.[14] reported that loss of cementation was observed in 4/35 (11.43%) cemented FPDs.

Regarding screw loosening, a cohort study of 23 patients was published in 4 articles with progression of follow-up period up to 10 years. The authors reported 13% abutment screw loss over the 10 years [8,17–19]. Nickenig et al.[14] reported that screw loosening occurred in 10% of cases. Noda et al.[15] reported 6.8% screw loosening cases. They also stated that, the likelihood of screw loosening is increased with the presence of premature contact irrespective of its intensity.

The evolution of materials for implant supported FPDs has progressed from metal-acrylic and metal-ceramic systems to all-ceramic and veneered polyetheretherketone (PEEK) options. Early designs utilized cobalt-chromium or gold alloys veneered with acrylic or porcelain, with metal-ceramic emerging as the gold standard due to its durability, biocompatibility, and aesthetic adaptability [20,21]. However, they are prone to veneer fractures (20.2% in gold-acrylic vs. 7.8% in metal-ceramic at 5 years), particularly in implant-supported prostheses due to occlusal overload from reduced proprioception [22,23]. Despite its success, PFM prosthetics still require considerable maintenance, prompting the search for alternative materials. All-ceramic alternatives, such as zirconia, offer superior aesthetics and strength (flexural strength: 900–1400 MPa) but exhibit higher chipping rates (50% at 5 years) due to poor adhesion between zirconia and veneering ceramics [24,25]. PEEK, a biocompatible thermoplastic material with bone-like elasticity (elastic modulus: 8.3 GPa), addresses limitations of rigid materials by distributing stresses more evenly and reducing abutment strain [26,27]. Though, PEEK requires composite veneering for aesthetics and surface modifications for adhesion. Its mechanical resilience (fracture at 1383N) and computer- aided design/computer-aided manufacturing (CAD/CAM) compatibility make it a promising alternative, particularly for patients with

high occlusal demands [28,29]. Despite advancements, long-term data on PEEK-based FPDs remain limited compared to metal-ceramic systems.

This study aimed to compare the maintenance requirements and clinical performance of PEEK-composite versus conventional metal-ceramic in TISP cases, evaluating whether PEEK's material properties translate into improved outcomes.

MATERIALS AND METHODS

Eligible participants included patients with bilateral symmetrical Kennedy class I, opposing full dentition, at least 10 mm of bone height from the mental foramen or inferior alveolar nerve to the alveolar crest, a minimum of 6 mm keratinized mucosa width, crown height space (CHS) between 9-14 mm, and abutment teeth free of periodontitis signs or symptoms. Exclusion criteria comprised systemic diseases affecting healing, severe bruxism, and heavy smoking. Sample size was calculated using G power software. A chi square test was conducted to estimate the sample size based on prior data of the primary outcome of our study. Pjetursson et al.[30] with 7.3% veneer fracture in TISP and Linkevicius et al.[31] with veneer fracture of 6.7% in ISP with odds ratios of 0.078 and 0.072, respectively. This means that the odds of technical complication are 0.078 /0.072 = 1.08 times greater for TISP than for ISP. The ratio 1.08 is the odds ratio. According to Chinn [32] , odds ratio can be converted to effect size by dividing by 1.81 (1.08 /1.8 = 0.6 effect size). Twenty subjects were needed to be able to reject the null hypothesis with probability (power) 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05. To compensate for drop-outs, 20% was added to reach a total of 24 subjects (12 patients). The randomization process was performed using a random allocation software (Microsoft excel random function) to either control or experimental group with a 1:1 allocation. The study protocol gained approval by the Committee of Ethics and Scientific Research, Faculty of Dentistry, Cairo University. The surgical and prosthetic procedures and observation time were clearly described to all patients. Informed consent was obtained and the patients agreed to participate.

Preoperative patient evaluation involved a detailed medical and dental history. Tooth mobility was evaluated by pressing it gently with the handle of two mouth mirrors. For an intact periodontium with probing depths ≤3 mm, the probing depth around the anterior abutment tooth was recorded with William's graduated periodontal probe. Absence of bleeding on probing was a good sign of periodontal stability.

Eligible patients received a three-unit TISP bilaterally. The prosthesis was retained anteriorly by the terminal natural abutment and posteriorly by an implant placed in the molar region. For each patient, one side was restored with composite veneered to PEEK FPD, while the other side was restored with PFM FPD. Preliminary diagnostic impressions were made using an irreversible hydrocolloid impression material (Tropicalgin, Zhermack, Italy), and were poured using hard dental stone (Gypsano, Egypt). A diagnostic wax up was made, converted into a clear orthodontic resin template, perforated in the exact center of the tooth, and then filled with a gutta percha marker (Meta Biomed, Cheongju-si - South Korea). A Cone Beam Computed Tomography (CBCT) scan was performed with the patient wearing the resin template. The image obtained was imported into a dental implant planning software (Blue Sky Bio LLC, Illinois - USA) to perform a series of measurements and implant positioning based on the availability of bone (Fig. 1). If the position of the implant was verified, the radiographic template would be used to guide the point of entry (pilot guide). Once the case was included, the procedures' details, evaluation time and the frequency of recalls were explained to the patients clearly and the agreement for the treatment was obtained. The surgical procedure was identical for both sides where each side received one implant (Dentis SQ, Daegu, South Korea) in the molar region, in a staged manner with a healing period of 3 months.

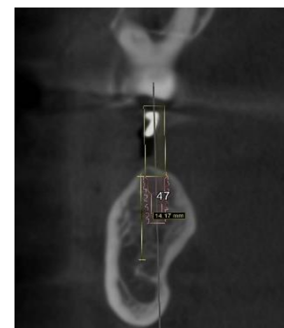

Figure 1. Implant treatment planning,

The areas of implant placement were anaesthetized using Scandonest 2% with infiltration on the buccal, crestal and lingual mucosa. A full thickness flap was raised. The radiographic template was used as a pilot surgical guide to determine the initial penetration point (Fig.2).

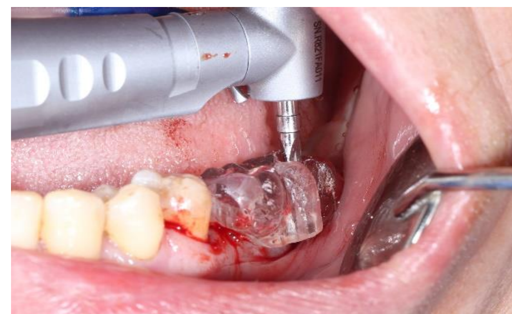

Figure 2. Pilot guide with initial drill

Drilling sequence started by using 2.2 and 2.8 twist drills to establish depth and parallelism. A paralleling pin was inserted (Fig.3), then a periapical radiograph was taken to assess parallelism.

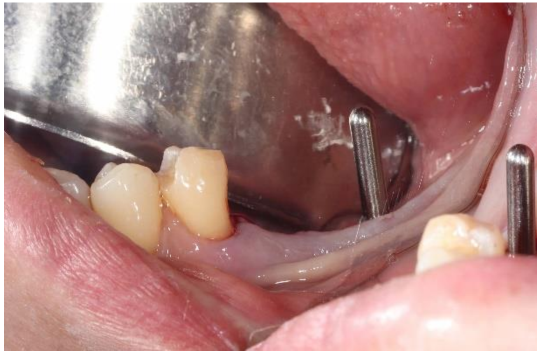

Figure 3. Parallel pin in place (lateral view)

Pilot drills were used to increase the diameter of the osteotomy site. The osteotomy expansion was done by using drills of incremental sizes, 3.7 and 4.1 mm. Countersink drills were used to remove the cortical bone for smoother insertion and to allow for subcrestal implant placement. An implant of 4.1×10 mm was placed then torqued to 40 Ncm. Implant cover screw was fastened in place and the flap was sutured via interrupted stitches using Vicryl 4-0 suture (Assut Medical Sàrl, Switzerland). Complete aseptic conditions were necessary during all surgical procedures to control infection. Postoperative medications included oral antibiotic (Augmentin 1 gm, GSK, United Kingdom) for 5 days & non-steroidal anti-inflammatory drug (Brufen 400 mg, Abbott, Illinois - United States) with a starting dose 30 minutes before the surgery, then 1 tablet 6 hours after surgery, followed by 1 tablet every 12 hours if needed during the following days. Antiseptic mouth rinse, 0.2% Chlorhexidine oral rinse (Hexitol, ADCO, Egypt) was prescribed for 1 minute, three times daily for 7 days. Patients were instructed to consume soft diet during the initial period to enhance the healing process. Sutures were removed 8 to 10 days after the surgery.

Patients were instructed to perform meticulous oral hygiene. Mechanical cleaning using regular and inter dental tooth brush was advised. The definitive prosthetic phase was initiated 3 months later. It started off by preparation of the anterior abutment (natural tooth) as well as fastening a closed tray impression coping over the placed implant for impression making. A periapical radiograph was taken to confirm the seating of the impression coping. A special tray -previously constructed on the primary models to accommodate the impression material and the height of the impression coping- was used for definitive impression making. A double phase, single-step definitive impression using a combination of heavy body and light body polyvinyl siloxane impression material was made.

The impression material was allowed to set then removed leaving the impression coping inside the patient's mouth. The impression coping was unfastened from the fixture then screwed to the appropriate implant analogue. The impression coping/analogue assembly was manually fitted back inside the impression with the help of the flat geometry surfaces. The impression was rinsed, disinfected, and then a layer of petroleum jelly (Evasiline, Eva Cosmetics, Egypt) was applied to prepare the fitting surface for receiving a layer of addition silicone gingival mask material (Hydrorise, Zhermack, Italy). Finally, the impression was poured using extra hard dental stone to produce a model over which a stock abutment was screwed and prepared parallel to the anterior abutment if needed.

A three-unit PFM bridge was constructed on one side of the cast using the lost wax technique, while the other side was digitally scanned. The master model was scanned via a lab scanner and a three-dimensional (3D) image of the abutment teeth was generated in a standard tessellation language (STL) file format. The STL file was imported into dental CAD software to design a three-unit substructure that was later milled from PEEK via a dental computer numerically controlled (CNC) milling machine. The milled PEEK framework was tried in the patient's mouth (Fig. 4) and a jaw relationship was registered and sent back to the laboratory for veneering. The PEEK substructure was conditioned by sand blasting using 110 µm aluminum oxide powder at a pressure of 2-3 bar at a distance of 10mm. Visio.link primer was then applied and light-cured for 90 seconds. The veneering layer was constructed in accordance with the manufacturer's instructions, consisting of three layers: an opaque layer, a body and neck (dentin) layer, and an incisal edge layer. Each layer was then light-cured for a period of 180 seconds using a dedicated polymerization device (Brelux, Bredent, United Kingdom). PEEK veneering started with, a first layer of combo.lign opaque, and then was polymerized for 180 seconds. The body of the substructure was then built with crea.lign dentin followed by enamel at cusp tips and proximal contacts. The bridge was then finished and polished using Acrypol polishing paste and Visio.lign polishing Kit and was ready for cementation. The substructure of the PFM prosthesis was waxed to the desired shape using inlay wax and cast from Cobalt-Chromium-Molybdenum (Co-Cr-Mo) alloy using the lost wax technique. The cast metal copings were sandblasted, checked inside the patient's mouth (Fig. 4) and then resent to the laboratory for porcelain build-up. The finished TISPs were cemented using zinc phosphate cement and seated under finger

pressure. Excess cement was removed and necessary occlusal adjustments were performed (Fig. 5).

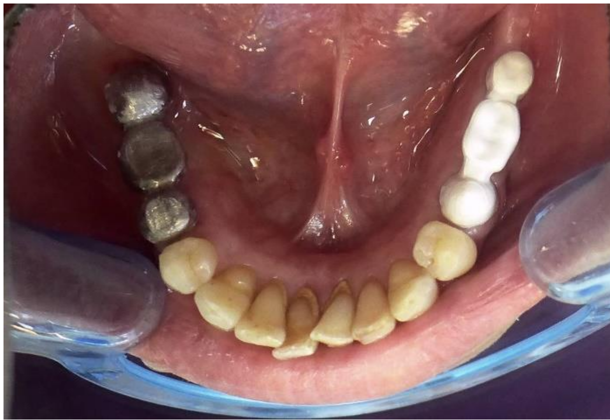

Figure 4. Frameworks try in (occlusal view)

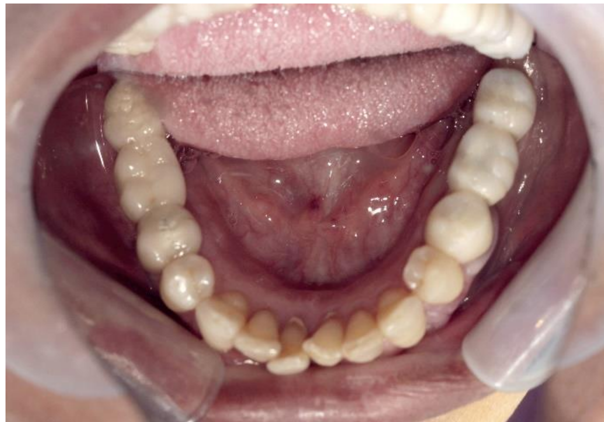

Figure 5. Final restoration cemented (occlusal view)

Patients were given instructions regarding brushing and flossing and were informed about recall appointments every 6 months. Patients were recalled at 6, 12 and 18 month for inspection. Observations regarding the occurrence of technical complications were recorded, tabulated and statistically analyzed.

RESULTS

1. Study Population Characteristics

This randomized controlled split-mouth trial evaluated 24 cases (12 patients with bilateral symmetrical free-end saddles) from the Prosthodontics Department outpatient clinic. The trial comprised 16 females (66.7%) and 8 males (33.3%), with an age range of 38-57 years (mean 47.25±5.55). All participants met inclusion criteria and completed the study without dropout. The patients were allocated with 1:1 ratio with 12 subjects (mouth quarters) receiving the control treatment while the other 12 received the new treatment in a split mouth configuration.

2. Statistical Analysis

Statistical analysis was performed using SPSS v23 with chi-square and Fisher's exact tests for categorical data. No outcome measures showed statistically significant differences between treatment groups ($p > 0.05$), supporting that there is no association between the restoration material and the maintenance requirement in TISP cases.

3. Outcome Measures: The cases were visually inspected for the occurrence of one or more of the technical complications mentioned in this study.

3.1 Veneer Fracture: There was one incidence (1/12) of veneer fracture in the PFM group and 2/12 in the PEEK group. Despite showing numerically higher fracture rate (16.7% vs 8.3%), statistical analysis revealed no significant difference between groups with Exact Significance (p-value) > 0.05 (Table 1).

Table 1-Chi-Square Tests veneer fracture

	Value	df	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.381 [a]	1	1.000	.500
Fisher's Exact Test			1.000	.500
N of Valid Cases	24			

df: degree of freedom

3.2 Decementation: Both groups exhibited identical 1/12 (8.3%) decementation rates. The results showed no statistical significance of the outcomes between the two groups regarding decementation with p-value > 0.05

3.3 Screw Loosening: Equivalent 1/12 (8.3%) complication rates were observed in both groups The results showed no statistical significance of the outcomes between the two groups regarding screw loosening with p-value > 0.05

DISCUSSION

This study investigated the maintenance requirements of metal-ceramic versus PEEK-composite TISP in bilateral distal extension cases, addressing both mechanical challenges and material limitations. The rationale for the usage of TISP included cost reduction, utilization of natural tooth proprioception, and avoidance of complex bone grafts which is particularly relevant in atrophic posterior mandibles where standard-length implants (≥10 mm) and adequate bone width (≥5 mm) were prioritized to mitigate failure risks [33,34]. Patient selection criteria excluded systemic diseases, heavy smokers, and bruxers to minimize confounding variables [35,36], while surgical precision was ensured

through CBCT-guided planning and flapped approaches with 4 mm-diameter implants placed under copious irrigation [37].

The results demonstrated comparable performance between materials, with veneer fracture rates of 8.3% for metal-ceramic and 16.7% for PEEK-composite prostheses. These findings align with existing literature where veneer fracture remains the most frequent complication [30,38]. The slightly higher incidence in PEEK group likely reflects the technical sensitivity of bonding composite to PEEK frameworks despite meticulous surface treatments. In the literature, achieving bond strengths of 23-26 MPa [39,40] is possible which when compared to metal-ceramic bond strengths of 26-63 MPa [41,42], they both exceed the ISO 9693 standard of 25 MPa.

Regarding loss of retention, both groups showed identical 8.3% rates of decementation, consistent with reported ranges of 6.2 %-7.3 % for TISP cases after 5 years [30,38]. The use of permanent cementation in this study design appears justified, as systematic reviews demonstrated fivefold higher failure rates with temporary cements [43]. The use of rigid connection protocol with flexible PEEK material can enhance stress distribution while preventing tooth intrusion which is a known complication of non-rigid designs [3,44]. Regarding screw loosening, both groups showed identical 8.3% rates of screw loosening, lying within the known rate in the literature of 6.9%-15% for TISP [30,45].

Methodologically, our randomized controlled trial design with 1:1 allocation and computer-generated randomization minimized selection bias [46]. The patient demographics (mean age 47 years, 66.7% female) reflect typical Kennedy Class I populations [47]. Prosthetic fabrication adhered to gold standards: metal-ceramic via lost-wax technique [48] and PEEK-composite through multilayer polymerization [49].The closed-tray impression technique proved appropriate for posterior mandibular cases with parallel implants [50].

While metal-ceramic remains the gold standard for TISP due to its durability and biocompatibility [21], the results of this study suggest PEEK-composite as a viable alternative, particularly given its bone-like elasticity (modulus: 8.3 GPa) that demonstrated superior stress distribution in finite element analyses [27]. The material's fracture resistance (1383N) comfortably exceeds average masticatory forces (400N) [26], though long-term clinical data remain limited compared to metal-ceramic systems.

The study's limitations include its sample size and the inherent trade-off between retrievability and intrusion prevention through permanent cementation. Future research should explore PEEK's performance in broader cohorts and longer follow-ups, particularly comparing different surface treatment protocols to optimize composite bonding. Nevertheless, these findings contribute valuable clinical evidence for material selection in TISP cases, demonstrating that while metal-ceramic maintains certain advantages, PEEK-composite presents a promising alternative with comparable overall maintenance requirements.

CONCLUSION

Both metal-ceramic and PEEK-composite are viable FPD options in Kennedy class I cases restored with TISP in short follow-up period of 18 months. Neither of the aforementioned materials showed superiority in reducing prosthetic complications in TISP cases.

DECLARATIONS

Funding

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Competing and conflicting Interests

The authors declare that they have no competing interests.

Ethical approval

The study protocol gained approval by the Committee of Ethics and Scientific Research, Faculty of Dentistry, Cairo University.

Informed consent

Informed consent was obtained from all participants.

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