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EVALUATION OF MARGINAL AND INTERNAL FIT OF PROVISIONAL RESTORATION FABRICATED BY TWO DIFFERENT SCANNING TECHNIQUES

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ABSTRACT

Background: Provisional restorations in fixed prosthodontic rehabilitation are important treatment procedures. **Purpose:** The purpose of the present study was to evaluate the marginal and internal fit of polymethyl methacrylate (PMMA) restoration fabricated by Cone Beam Computed Tomography versus extra oral scanning techniques.

Methods: Mandibular right first molar on dental model was prepared. Twenty conventional impressions made using a polyvinylsiloxane (PVS) elastomer for the prepared molar. Impressions for the prepared tooth poured using extra hard dental stone. The models divided for two groups. The 1st group scanned with Extra oral scanner(EOS) .The 2nd group scanned with CBCT. Twenty PMMA crowns were designed on virtual casts and milled. The vertical marginal discrepancy (VMD) was measured by U500x Digital Microscope at twelve locations on each abutment. A total of 240 measurements were made at fixed locations in two groups of 20 specimens.

Results: It was found that CBCT group recorded statistically non-significant higher vertical marginal gap mean value ($26.91 \pm 7.11\ \mu m$) than EOS group ($25.47 \pm 6.34\ \mu m$) as proven with two-way ANOVA test ($p = 0.6062 > 0.05$).The internal fit measured using replica technique that revealed CBCT group recorded statistically non-significant higher internal gap mean value ($98.97\pm11.32\mu m$) than EOS group ($90.5\pm12.05\ \mu m$) as proven with two-way ANOVA test ($p = 0.0665 > 0.05$).

Conclusions it was found that CAD-CAM fabricated restorations based on EOS or CBCT scanning provided clinically accepted fit for PMMA crowns.

KEYWORDS: Marginal, Internal Fit, Provisional Restoration, Fabrication, Scanning Techniques

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INTRODUCTION

A crucial step in fixed prosthodontics is the fabrication of provisional restorations [1]. Thus, they have to meet the needs for pulpal protection, occlusal function, positioning stability, cleaning ability, margin precision, wear resistance, strength, and aesthetics. They also fulfill the crucial role of acting as a model for the final restorations after intraoral evaluation [2].

When it comes to fixed prosthodontic rehabilitation, provisional restorations are crucial treatment steps, especially when longer-term functionality is anticipated or extra therapy is needed before the rehabilitation is finished[3].

Treatment involving fixed prosthetic restorations require the use of provisional restoration materials. Their use starting from the tooth preparation until final restoration fitting. [4, 5]

Computer-aided design, Computer-aided manufacturing polymethyl methacrylate (CAD-CAM) (PMMA) based on polymers have varying mechanical qualities, depending on the monomer and chemical structure. [6] They are strongly cross-linked, which may provide benefits over traditionally polymerized interim resins. [7, 8].

Dentistry that provides prosthetics and restorative care now frequently uses CAD-CAM technology. For a variety of prosthetic materials that are offered as prefabricated blocks, obtaining digital data and building 3D virtual models has become standard practice[9]. Using a lab scanner to digitally scan a gypsum cast is one way to create a virtual model[10].

It has been recommended as a dependable approach to superimpose the cone beam computed tomography (CBCT) image files in digital imaging and communications in medicine (DICOM) format and the 3D intraoral surface scan files for stereolithography (STL) format. [11] It has a high patient acceptance rate while being efficient in terms of both time and money. [12].

Soundness of teeth and their periodontal tissue may suffer if fixed dental prosthesis (FDPs) have an excessive marginal mismatch [13]. Although the ideal marginal fit has not yet been established, a 5-year clinical investigation has suggested that the marginal misfit of FDPs should be less than 120 mm [32].

Researchers have attempted to produce crowns using CBCT scan data converted into STL, in addition to intraoral or laboratory scans. CBCT scans are performed using low radiation dosages in accordance with the as low as reasonably attainable (ALARA) concept. [14], mostly for diagnostic purposes, and if they are made, it would be beneficial to use them to fabricate a fixed prosthesis because there would be no need for gingival retraction or the removal of any temporary restorations that may already be in place because the margins might be visible [6, 15].

MATERIALS AND METHODS

This experimental laboratory study was conducted after approval from the Ethical Committee Faculty of Dentistry, Tanta University, Tanta, Egypt.

The materials used in this study were listed in table 1

The study consists of two groups: Group I: (control group): dental model that was EOS scanned and Group II: dental model that was CBCT scanned.

TABLE (1) Materials of the study

Material	Composition	Manufacturer
CAD CAM PMMA Blocks	**Powder**: Methyl methacrylate copolymer or monomer, from **Liquid**: methyl methacrylate , dimethacrylate [16]	Yucera zirconia
Dental stone	Calcium sulphate hemihydrate[17].	BMS DENTAL
Impression material	Base paste: Poly(methyl hydrogen siloxane), Other siloxane prepolymers, Fillers accelerator paste: Divnyl polysiloxane,Inert oils & fillers, Platinum salt, Palladium, Retarders, Fillers[18].	3M EPSE Monophase; 3MDeutschland GmbH, Neuss, Germany

Specimen preparation

Silicone index fabrication:

A silicone putty index of the mandibular right first molar that mounted on typodont was done before tooth preparation to check the amount of tooth reduction. Silicone Putty base and catalyst were mixed and applied onto the tooth from all aspects. After complete setting, it was removed from the tooth and the excess was trimmed. The Index was cut carefully starting buccally half way the mesiodistal width and finally end lingually using razor blade number 11 .

Occlusal Reduction

One mm depth orientation grooves were placed on the occlusal surface by tapered round end diamond bur with tip size 10 and medium grits 524 (iso number 806.314.196.524.010) which was held 45° to the occlusal surface to obtain anatomical occlusal reduction then islands between them were removed to obtain proper occlusal clearance. Functional cusp bevel was placed so the amount of reduction was 1 mm on the nonfunctional cusp and 1.5 mm on the functional cusp.

Axial Reduction

Tapered round bur size 20 with medium grits 524 (iso number 806.314.196.524.020) was used for the placement of three depth orientation grooves on the buccal surface ,which was held parallel to the path of insertion of the restoration then islands between them were removed. The 1 mm wide chamfer finish line was created. The lingual surface was prepared as mentioned before for the buccal surface. Mesial and distal contact were broken by a thinner round end diamond bur size 12 with medium grits 524 (iso number 806.314.164.524.012) and enamel lip was done to avoid injury to the adjacent tooth. A fine round tipped tapered diamond bur size 12 with fine grits 514 followed by extra fine grits 504 was used for finishing the preparation. A silicone index was used to check the amount of the occlusal and axial reduction with the aid of graduated periodontal probe to measure the distance between the internal surface of the index and external surface of the prepared tooth.

Two step technique (wash technique)

The procedure required two steps and used two distinct impression materials, one for each stage. Impression materials: a rigid impression material (putty) for the first step and a fluid material(light) for the second step. The combination of putty and fluid silicones can be a good choice [19]. Before the impression making, try in using sectional stainless steel tray was done. In the first stage, the impression was made with a rigid material. After material has been set, the impression became hard and solid. Basically, it formed a tray (or a container) for the fluid material that has been used in the second stage[20]. For the second impression, the cartridge was inserted in a caulking gun–like device, and the base and catalyst were extruded into the mixing tip, in which mixing occured as they progress to the end of the tube. The impression was then repositioned over the dental cast. The running fluid material captured all the fine details of the prepared teeth and surrounding structures [21].

Extra oral scanning for group 1:

The model were placed inside Extra oral scanner (FREEDOM, DOF Inc, Seoul, Republic of Korea). once the power button was pressed, the scanner projecting light onto the scanned model and capturing an image of all surfaces generated a 3D model.

Setting used with EOS: [Camera: 2.0 MP, dimensions: 330mm x 495mm x 430mm (W x H x D), light Source: White light LED, technology: Structured light, output Format: STL , power: 100-240V(AC), 50-60 Hz].

CBCT scanning for group 2:

Before the scanning, Field of View (FOV) was selected, vertical position, horizontal position, image quality, voxel size were selected & standardized for all specimens. Partial image reconstruction with high-resolution was captured as DICOM file.

Designing and milling of the crowns:

The crown design was chosen in the dentistry program (exocad DentalDB 3.0Galway) at the library. The crown's placement and dimensions were adjusted. The next step was to provide the setting values for the following input variables: cementing space (which was set at 25 μm for the remaining internal space and at zero for the crown edges). Finally, before the crown was fabricated, the size and position of the crown within the Yucera zirconia CAD block were verified using the CAM software. We processed the Yucera zirconia CAD block with an Imes-Icore milling unit.

Measurement of the marginal and internal gap (Replica technique):

A predetermined quantity of low viscosity silicone material (light body, violet color) was applied to the fitting surface of every crown. Using a modified parallelometer, each crown was then gradually seated on the prepared tooth with a defined force of 5 kg in the occlusal direction [22]. After the light body impression material's setup time. The crown was removed from the prepared tooth. The thin coating of light material stuck to the crown's fitting surface. A heavy body silicone impression material of contrasting color (orange) was filled inside the crown to form one piece with the thin layer of the light body impression material to create the silicone replica. This was done in order to stabilize this thin layer of silicone during the sectioning procedure and to prevent its damage. Following sectioning, each replica was marked to enable identification of each surface. Using a cutting blade, each silicone copy was then sectioned first in a bucco-ligual direction(from the centre of the middle buccal surface until the lingual groove) and then in a mesio-distal direction. [23-25]. Each replica had four portions, and two opposite sections were utilized to test internal fit. Each section had six regions measured, so each sample had 12 internal measurements total from the four sections. The light-body silicone thickness, which indicates the separation between the preparation's outside and internal surfaces, was measured for each replica using digital microscopy at ×35 magnification. **Figure 1**

Using a fixed magnification of 35X, the photos were captured at maximum resolution and connected to a suitable personal computer. A resolution of 1280×1024 pixels was used to record each image. Utilizing a computerized image analysis system (Image J 1.43U, National Institute of Health, USA), the replica thickness indicating the internal gap (fit) was measured in (μm)and subjectively assessed. All boundaries, dimensions, frames, and measurable parameters in the Image J software are given in pixels.

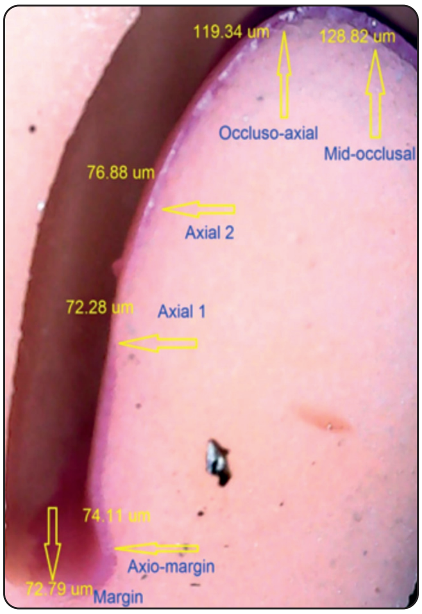

Fig. (1) Marking 6 points for microscopic measuring

Marginal gap distance:

Using a USB digital microscope with an integrated camera, each specimen was captured on camera.

Technique: The following image acquisition system was used to capture the images: A vertically positioned digital camera (U500x Digital Microscope, Guangdong, China) with a resolution of 3 Mega Pixels was put 2.5 cm away from the samples. The angle formed by the lens's axis and the light source is roughly 90 degrees. Eight LED lamps, each with a control wheel for adjustment, were used to create illumination with a color index of over 95%. Using a fixed magnification of 35X, the photos were captured at maximum resolution and connected to a suitable personal computer. A resolution of 1280 × 1024 pixels was used to record each image. [26-28].

A digital image analysis system (National Institute of Health, USA) Image J 1.43U was utilized to assess and measure the gap width. All boundaries, dimensions, frames, and measurable parameters in the Image J software are given in pixels. Consequently, system calibration was carried out in order to translate the pixels into exact real-world units. **Figure 2**

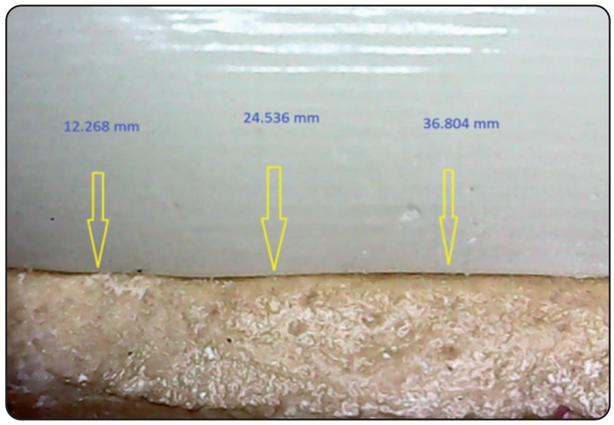

Fig. (2) Measuring 3 points for each surface

Calibration: It was created by contrasting a scale produced by the Image J program with an object of known size—a ruler in this case. For every specimen, shots of the edges were obtained. Following that, morphometric measurements [three equally spaced landmarks around the perimeter for each surface] were made for every image. Every measurement was made three times at each location. After that, the information was gathered, collated, and statistical analysis was performed.

Statistical analysis

The standard deviation and mean of the data were displayed. Following the confirmation of homogeneity of variance and normal distribution of errors, a student t-test was conducted comparing the two groups at each surface. Tukey's post-hoc test was run if the results of the one-way analysis of variance indicated significance. The effects of each factor (scan type and surface) were examined using a two-way ANOVA. The sample size (n=10) was sufficient to detect high effect sizes for pairwise comparisons and main effects, with a 95% confidence level and 80% satisfactory level of power. The Windows program Graph Pad Instat (Graph Pad, Inc.) was used to analyze the data. $P<0.05$ was the threshold for statistical significance.

RESULTS

At marginal and axial site, total effect of scan type on internal gap, mesial, lingual and distal surface were insignificantly higher in CBCT group than EOS group. At axio-marginal site was significantly higher in CBCT group than EOS group. At occluso-axial, mid-occlusal site and buccal surface were insignificantly higher in EOS group than CBCT group. Measurement surface in vertical marginal gap, there was insignificantly higher in CBCT group than EOS group. Table 2

In CBCT group, the highest internal gap mean value recorded with mid-occlusal site followed by occluso-axial surface mean value then axio-margin and margin site mean values while the lowest internal gap mean value recorded with axial site with significantly different (P=0.0016). Pair-wise Tukey's post-hoc test showed insignificant difference between (margin, axio-margin, axial and occluso-axial) and (mid-occlusal and occluso-axial) sites. In EOS group, it was found that the highest internal gap mean values were recorded with mid-occlusal site followed by occluso-axial surface mean value ,then axial and axio-margin site mean values while the lowest internal gap mean value recorded with margin site with significantly different (P=<0.0001). Within CBCT group, it was found that the highest marginal gap recorded with mesial surface ,followed by lingual surface, then distal surface .While the lowest marginal gap recorded were with buccal surface, and this was statistically significant different (P=0.0481). Pair-wise Tukey's post-hoc test showed insignificant different between

TABLE (2) Comparison of internal gap and marginal gap results at different measurement sites and total internal gap results between both groups

		Scan type						P
		CBCT group			EOS group			
			95% CI			95% CI		
			Low	High		Low	High	
Internal gap results								
Measurement site	**Margin**	92.18±18.42	80.76	103.6	72.8±17.69	61.84	83.76	0.0703
	Axio-margin	95.91±11.81	88.6	103.23	74.11±14.87	64.9	83.33	0.0195*
	Axial	88.35±17.19	77.7	99.001	74.58±18	63.42	85.74	0.1941
	Occluso- axial	105.1±16.26	95.03	115.19	119.3±10.31	113	125.7	0.095
	Mid occlusal	123.9±9.352	118.2	129.74	128.8±9.142	123.2	134.5	0.3796
Scan method		98.97±11.32	91.96	105.99	90.57±12.05	83.11	98.04	0.0665
Marginal gap results								
Measurement surface	**Buccal**	18.71±6.28	14.82	22.6	24.27±7.85	19.4	29.13	0.1968
	Mesial	36.49±10.9	29.72	43.25	31.2±13.9	22.61	39.79	0.4821
	Lingual	28.32±11.2	21.38	35.26	22.43±3.8	20.08	24.78	0.3257
	Distal	24.14±11.1	17.28	31.01	23.96±5.03	20.85	27.08	0.9677
Scan method		26.91±7.11	22.51	31.32	25.47±6.34	21.53	29.39	0.6062

Data are presented as mean ± SD or frequency (%). * Significant p value <0.05. CI: confident interval, EOS: Extraoral scanners, CBCT: cone beam computed tomography.

(mesial, lingual and distal) surfaces. Within EOS group, it was found that the highest marginal gap mean value recorded with mesial surface followed by buccal surface then distal surface while the lowest marginal gap mean value recorded with lingual surface and this was insignificantly different (P=0.2968). **Table 3**

Irrespective of scan method, totally it was found that the highest internal gap mean value recorded with mid-occlusal site, followed by occluso-axial surface mean value, then axio-margin and margin site mean values .While the lowest internal gap mean value recorded with axial site with significantly different (P<0.0001). Pair-wise Tukey's post-hoc test showed insignificant (p>0.05) difference between (margin, axio-margin and axial), (mid-occlusal and occluso-axial) sites and between (mesial, lingual and distal) surfaces. Irrespective of scan method, totally it was found that the highest marginal gap mean value recorded with mesial surface followed by lingual surface then distal surface while the lowest marginal gap mean value recorded with buccal surface and this was statistically significant as indicated by two-way ANOVA test (P=0.016). **Table 4**

TABLE (3) Internal and marginal gap results for both groups at different measurement sites

		Scan type					
		CBCT group			**EOS group**		
			95% CI			**95% CI**	
			Low	**High**		**Low**	**High**
Internal gap results							
Measurement site	**Margin**	92.18±18.42	80.76	103.6	72.8±17.69	61.84	83.76
	Axio-margin	95.91±11.81	88.6	103.23	74.11±14.87	64.9	83.33
	Axial	88.35±17.19	77.7	99.001	74.58±18	63.42	85.74
	Occluso- axial	105.1±16.26	95.03	115.19	119.3±10.31	113	125.7
	Mid occlusal	123.9±9.352	118.2	129.74	128.8±9.142	123.2	134.5
P value		**0.0016***			**<0.0001***		
Marginal gap results							
Measurement surface	**Buccal**	18.71±6.28	14.82	22.6	24.27±7.85	19.4	29.13
	Mesial	36.49±10.9	29.72	43.25	31.2±13.9	22.61	39.79
	Lingual	28.32±11.2	21.38	35.26	22.43±3.8	20.08	24.78
	Distal	24.14±11.1	17.28	31.01	23.96±5.03	20.85	27.08
P value		0.0481*			0.2968		

Data are presented as mean ± SD or frequency (%). * Significant p value <0.05. CI: confident interval, EOS: Extraoral scanners, CBCT: cone beam computed tomography.

TABLE (4) Internal and marginal gap results (Mean values ±SDs) for both groups at different measurement surfaces

			95% CI		P
			Low	**High**	
Internal gap results					
Measurement site	**Margin**	82.49±18.05	71.3	93.68	**<0.0001***
	Axio_margin	85.01±13.34	76.75	93.28	
	Axial	81.46±17.6	70.56	92.37	
	Occluso_axial	112.2±13.29	104	120.5	
	Mid_occlusal	126.4±9.247	120.7	132.1	
Marginal gap results					
Measurement surface	**Buccal**	20.94±6.5	16.91	24.97	**0.016***
	Mesial	33.26±11.8	25.95	40.57	
	Lingual	25.37±7.5	20.73	30.02	
	Distal	24.56±8.21	19.48	29.65	

Data are presented as mean ± SD or frequency (%). * Significant p value <0.05. CI: confident interval, EOS: Extraoral scanners, CBCT: cone beam computed tomography.

TABLE (5) Two-way ANOVA showing effect of each variable on internal gap value

	SS	df	MS	F	P-value	F crit
Internal gap results						
Sample	1284.858	1	1284.858	3.450079	0.066519	3.946876
Columns	33790.68	4	8447.669	22.68353	5.58E-13	2.472927
Interaction	5049.35	4	1262.337	3.389607	0.012471	2.472927
Within	33517.27	90	372.4141			
Marginal gap results						
Sample	41.98453	1	41.98453	0.268166	0.606152	3.973897
Columns	1717.913	3	572.6376	3.657583	0.016311	2.731807
Interaction	425.795	3	141.9317	0.906554	0.442283	2.731807
Within	11272.45	72	156.5618			

DISCUSSION

The technique and level of accuracy utilized in the fabrication of FPDs and provisional crowns have a significant impact on the eventual restoration's quality. To best replicate the clinical setting, a semi-clinical setup with a master model was used[29, 30].

Compared to teeth prepared with a shoulder finish line, the teeth prepared with a deep chamfer finish line displayed lower mean marginal gap values. The reason for this could be because the deep chamfer finish line design allows for a more precise seat for the crown restoration ,since it has a rounder angle between the gingival and axial seats. Additionally, during the crown seating, the stress that is focused around the finish line is spread more evenly. This completely aligns with what Rosenstiel et al. have [31] declared: that "the gingival margin geometry should be replicated in the occluso-axial line angle of the tooth preparation.".

Pre-polymerized blocks are machined out of the restorations during the CAD/CAM process of making temporary restorations. Polymerization shrinkage doesn't happen as a result. The accuracy of temporary restorations can be influenced by the design of the restoration preparation, the type of software, the accuracy of the scanning, the restoration materials, and the repeatability of the milling. It should be highlighted, nonetheless, that all restorations in both the current trial and the other investigations had dimensional accuracy that fell within the range that is considered clinically acceptable. It is reported that a marginal gap of 20 to 120μm is clinically appropriate for restorations [32]. Peng et al. [33] demonstrated that the internal fit and marginal discrepancy of provisional crowns made digitally were better.

Using a two-way ANOVA test, it was determined that the CBCT group recorded a statistically non-significantly greater (VMD) Vertical Marginal Discrepancy than the EOS group, regardless of the measurement surface. And using a two-way ANOVA test, it was discovered that the CBCT group had a statistically non-significantly greater internal gap mean value than the EOS group. This is a result of the CBCT's poor contrast to noise ratio and the intricacies in the grooves being less visible. [34].

Regardless of the scanning technique, it was discovered that the axial site had the lowest internal gap mean value, which was 81.46 μm, and that the mid-occlusal site had the highest internal gap mean value (126.4 μm), which was followed by the occluso-axial surface mean value (112.2 μm), axio-margin, and margin site mean values (85.01 μm, 82.49 μm, respectively). This was statistically significant, as shown by the one-way ANOVA test. The incapacity of the milling bur to precisely cut the small details at the occlusal surfaces may be the reason for the non-significant ($p>0.05$) difference between the margin, axio-margin, and axial, and the mid-occlusal and occluso-axial, sites, as revealed by the pairwise Tukey's post-hoc test.

For the VMD it was found that the highest marginal gap mean value recorded with mesial surface (33.26 μm) followed by lingual surface mean value (25.37 μm) then distal surface mean value (24.56 μm) while the lowest marginal gap mean value recorded with buccal surface (20.94 μm) and this was statistically significant as indicated by two-way ANOVA test.

Noh et al. [35] revealed that the buccal and lingual surfaces group or the lingual surface only group had smaller registration errors than the other two. Sun et al. [36] exhibited that the registration error of the buccal and labial surfaces only group was higher than other groups.

At the end, the results of the current study accepted the null hypothesis. As the PMMA crowns fabricated from CBCT had non significant higher VMD and internal gap values than those fabricated from EOS data.

The following suggestions can be made in light of the study's limitations and the findings: the use of CBCT to scan only impressions or gypsum casts; otherwise, artifacts may be seen in the images, making it impossible to use the data for creating restorations. Additionally to the patients' exposure to radiation. A few in vitro investigations have been created to lessen the radiation exposure during a CBCT scan[37]. Using different brands of PMMA materials. Using CBCT scanning for definitive restorations. Using superimposition technique (CBCT with IOS or EOS) for more accurate restorations.

CONCLUSIONS:

A clinically acceptable fit for PMMA crowns was made possible by CAD-CAM manufacturing based on EOS or CBCT scanning. The CBCT data-driven workflows (adapted processes) made it possible to fabricate PMMA crowns with vertical margin discrepancies of less than 120 mm. Nonetheless, appropriate occlusal and interproximal contacts depend on the incorporation of CBCT scans into 3D surface scans. The present technique's viability should be further investigated for fabricating FDPs following the incorporation of 3D surface scans.

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Conflict of Interest: Nil

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