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MARGINAL FIT OF PMMA CAD/CAM CROWNS FABRICATED BY USING PHOTOGRAMMETRY SCANNING METHOD (AN INVITRO STUDY)

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ABSTRACT

Purpose. The aim of this study was to assess the marginal accuracy of provisional CAD/CAM PMMA crowns fabricated by two-dimensional image-based rendering (IBR) photogrammetry scanning method.

Materials and Methods. 10 epoxy resin dies, duplicated from an anatomically reduced maxillary central incisor. Epoxy dies were distributed into two groups according to the method of die scanning (n=5). Gp I the dies were scanned with extraoral desktop scanner. For Gp II photogrammetry scanning for the dies was done using standardized photos using a professional digital single reflex (DSLR) camera for photo acquisition. Photography technique was standardized using a custom-made device to ensure adequate overlap between acquired photos, further rendering of photos was done using specialized photogrammetry software. Produced standardized tessellation Language (STL) files from both scanning methods were used for fabrication of CAD/CAM Polymethylmethacrylate crowns. Mean vertical marginal gap of crowns fabricated by both scanning methods was measured using stereomicroscope at 20 equidistant points (5 points in each surface), and results were statistically analysed using paired t-test.

Results. Mean marginal gap for Gp I (extraoral scanner) was (106.3 + 12.3 microns), while for Gp II (photogrammetry scanning) mean marginal gap was (99.6 + 28.3 microns). There was no statistically significant difference between marginal gap distances measurement by extraoral scanner and photogrammetry scanning method (p>0.05). produced marginal accuracy results were within the clinically acceptable range below 120 μ.

Conclusion. Photogrammetry scanning image-based rendering can be an affordable and reliable method to fabricate CAD/CAM crowns with proper marginal accuracy.

KEYWORDS: photogrammetry, Marginal accuracy, PMMA, Extraoral scanner

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INTRODUCTION

The marginal accuracy is an essential requirement for success of CAD/CAM fabricated restorations [1]. Studies discussed the consequences of poor marginal fit and its detrimental effects including secondary caries around margins of the restoration and deterioration of the periodontal health [2,3]. Studies have mentioned that acceptable marginal fit should range between 50– 120 microns [4,5], where other studies stressed that successful CAD/CAM restorations should have marginal gap less than 100 microns [6,7].

CAD/CAM systems for dental fixed restorations fabrication has witnessed rapid expansion in the dental market during the past few years, owing to their ability to produce restorations with comparable accuracy to conventional methods [8]. Impression or scanning technique is considered as one of deciding factors for the fitting accuracy of digitally fabricated restorations [9]. Digital Scanners both tabletop and intra-oral, also 3D face scanning for examination and smile analysis are continuously advancing, yet with their prices still remaining quite high restrict many dental practitioners to obtain them and introduce them to their clinics [10]. Search for an economic reliable technique for digital scanning became a demand, this led to introduction of photogrammetry as a viable alternative. Photogrammetry depends on mathematical technique to generate three-dimensional coordinates of specific points generated from multiple two-dimensional images of the same object gained at different angles, which is referred to as image-based rendering (IBR) scanning [11]. Photogrammetry is based on developing precise measurements from photographs by taking a set of overlapping photos, then converting them into a 3D model using a number of computer algorithms, however its precision in the dental scanning and production of accurate CAD/CAM restorations remains unclear [12].

The null hypothesis of this study is that there is no difference in the marginal fit of CAD/CAM fabricated restorations produced by photogrammetry scanning and dedicated dental laboratory scanner.

MATERIALS AND METHODS

Sample size calculation

This power analysis used marginal accuracy as the primary outcome. Based upon the results of a pilot study conducted on three samples, the mean (Standard deviation) values were 0.07 (0.08) and -0.03 (0.1) with scanner and photogram, respectively. The effect size (dz) was 1.091. Using alpha (α) level of (5%), β level of 0.8 (Power = 80%); the minimum estimated sample size was 5 specimens. Sample size calculation was performed using G*Power version 3.1.9.2.

Die construction

First a master die was prepared; an acrylic typodont maxillary central incisor was selected and reduced manually reduced to receive an all-ceramic restoration; a deep chamfer finish line and anatomical preparation to simulate the clinical conditions.

The master die was duplicated (n=10) by taking individual two step polyvinyl siloxane impressions (Elite HD, Zhermach, Italy). The impressions were poured using chemically activated epoxy resin (Kemapoxy 150, CMB, Egypt). The Epoxy resin was mixed and left to set for 24 hours according to the manufacturer instructions. The produced epoxy dies were checked to be free of voids and defects (fig. 1).

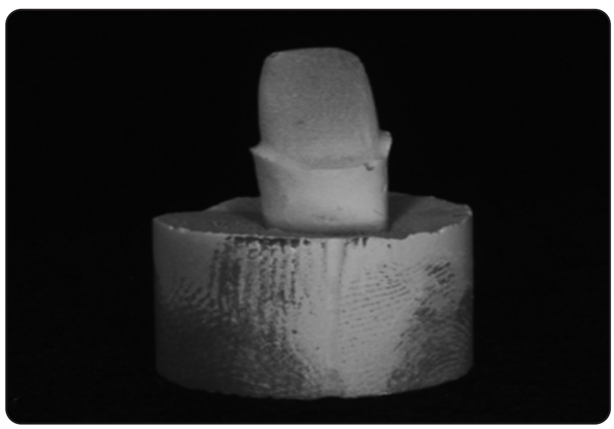

Fig. (1) Epoxy die duplicated from the original preparation.

Sample grouping

The epoxy resin dies (n=10) were divided into two groups according to the digital scanning method; (control group) group I (n=5) dies were scanned with professional desktop laboratory dental scanner Up300+ (Up3d Shenzhen, China) (table 1). While samples for Group II (n=5) were scanned based on photogrammetry concept. Scanning produced Standard Tessellation Language (STL) file:

TABLE (1): Sample grouping.

Method Of scanning	Extraoral scanning (Group I)	Photogrammetry scanning (Group II)
Number of samples	n= 5	n= 5

Before scanning with both methods samples were sprayed with anti-reflection scanning spray for CAD CAM (IP scan spray, IPdent , Germany) in order to eliminate reflective surfaces that may lead to deformations in reconstruction.

Scanning: desktop lab scanner

For this group the epoxy dies were scanned using a structured light extraoral laboratory dental scanner Up300+ (up3d, Shenzhen, China) with blue structured light technology.

Scanning: Image acquisition using photogrammetry

Digital single reflex camera (DSLR) camera (Nikon D3200, Nikon, Japan)setup used, fixed the camera on a tripod to acquire photos of the dies placed on a customized mobile platform to standardize image acquisition

For image acquisition the (DSLR) camera, macro photography employed using a 40 mm macro lens (Nikkor, Nikkon Japan were used). The camera settings were adjusted to shutter speed 1/160 sec, f 22 and iso 100. Camera was stabilized on a tripod and set at a distance of 20 cm from the object to avoid image blurring during shooting. Adequate even lighting was ensured using a ring flash (Godox, Shenzen, China) to avoid shadowing of the image and ensure proper light distribution. A product photography box (General, Egypt) with a dark background was used to standardize the photography outcome.

To standardize the image capturing for photogrammetry and angles of images accuired, an Audrino controlled (Audrino, Uno, USA) mobile turnable platform was customized (figure 2) and built on two motor axes system. It consists of an acrylic circular part with diameter of 10 cm fixed on a stepper motor used for precise positioning and controlling the rotation step angle between different image positions, micro stepping feature for this motor was used for smooth operation and vibration reduction during image capturing. Another stepper motor was fixed with an acrylic arm to the side of the circular part, allowing for tilting of the circular part to capture images from a different angle. An infrared remote transmitter was used to send trigger signal to the camera for capture an image after each movement of the platform. A graphical user interface (GUI) (figure 3) based on Python programming language was used to control the device motors stepping angle and tilting angle as well as the speed of rotation.

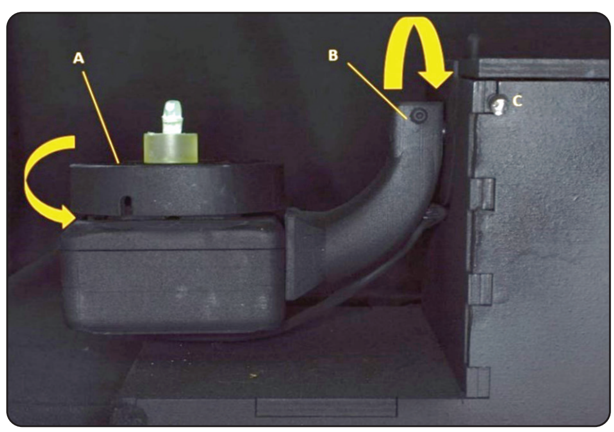

Fig. (2) custom- made device for photogrammetry. A: Circular turnable part, B: stepper tilting motor C: infrared sensor for camera triggering

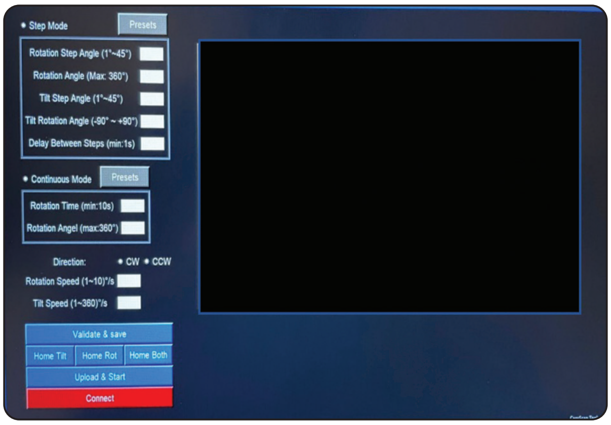

Fig. (3): Graphical user interface (GUI) to control the custom-made device

The dies were placed in the center of the turnable part of the platform, and the rotation angle was set to 10 degrees to ensure maximum overlap between the images for optimum photogrammetric construction. Images were captured from three angle: Horizontal, 30 and 60 degrees (fig. 4 a & b).

Before photography, the epoxy dies were sprayed with anti-reflection scanning spray for CAD CAM to eliminate reflective surfaces that may lead to deformations in photogrammetry reconstruction.

Photogrammetric construction

A dedicated photogrammetry software (Zephyr 3d , 3d flow, Italy) was used for reconstruction of the three dimensional model in aim of creating a Standard Tessellation Language (STL) file .

The software works in different steps. After uploading of images, the software selects common points between them to construct a sparse point cloud (fig. 5a) to identify the relation between common points of the overlapping images, followed by densification of these points to make a dense point cloud (fig. 5b) and finally creating a mesh for the three dimensional model with detailed surface texture (figure 5 c&d).

Fabrication of PMMA crowns

Following scanning of epoxy dies, exocad software (exocad, Darmstadt, Germany) was used for designing PMMA crowns. 5 axis milling machine (K5+, Vhf, Ammerbuch, Germany) was used for milling and production of the crowns.

Measurement of Vertical Marginal Gap

The vertical marginal gap distance for each crown was measured by stereomicroscope (Olympus SZ-PT, Olympus, Japan). Each crown was seated on its corresponding epoxy die, and a specially designed jig was used to stabilize the crown in its position during marginal gap measurement. Images for the margins were taken using special camera in the microscope (Olympus DP-10, Olympus, Japan). Five equidistant points were recorded at each surface (fig. 6) with a total of twenty points for each crown with magnification of 8X. Measurements were recorded in microns and mean of the twenty points was recorded for analysis.

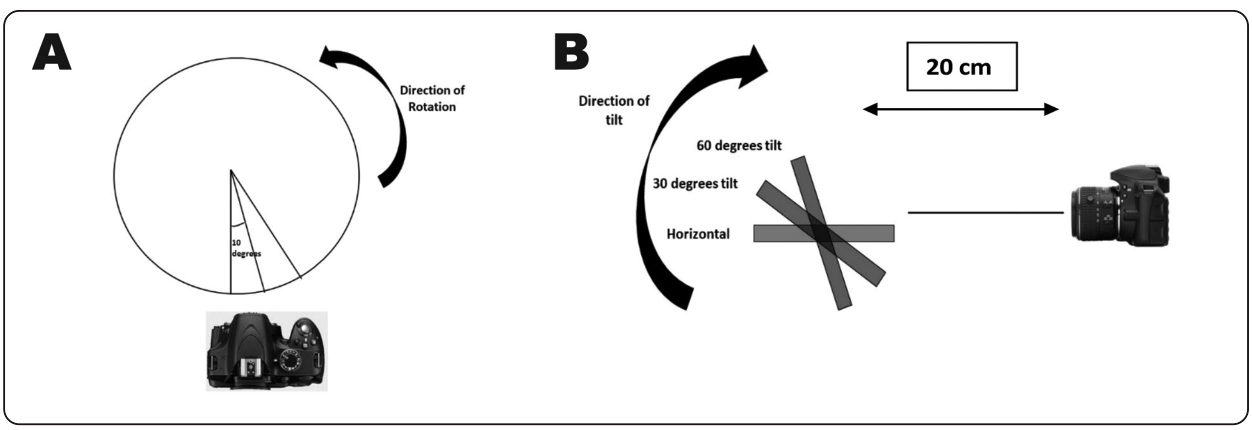

Fig. (3): a): Rotation step angle for image capturing b) Tilting angle for image capturing

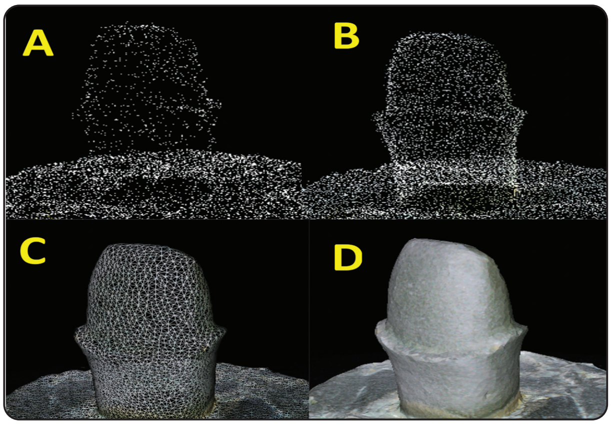

Fig. (5): Stages of production of 3d model inside photogrammetry software (Zephyr 3D) A: sparse point cloud, B: Dense point cloud, C: Mesh construction D: Adding surface texture

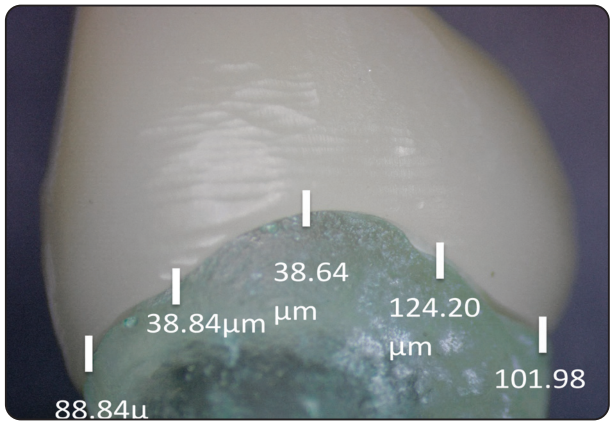

Fig. (6): Measurement of marginal gap at five equidistant points in each surface.

Statistical analysis

Numerical data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Marginal gap distances data showed normal (parametric) distribution. Data were presented as mean, standard deviation (SD), median and range values. For parametric data; paired t-test was used to compare between scanner and photogram. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. (Armonk, NY: IBM Corp).

RESULTS

Marginal gap distance

The mean marginal gap for Gp. I crowns fabricated with extraoral scanner was 106.3 ± 12.3 microns, while Gp. II fabricated with photogrammetry scanning showed mean marginal gap of 99.6±28.3 microns (fig.7 and table 2)

There was no statistically significant difference between marginal gap distances measurement by scanner and photogram.

TABLE (2): Descriptive statistics and results of paired t-test for comparison between marginal gap distances (µm) measurements by scanner and photogrammetry

Scanner		Photogram		P-value
Mean	SD	Mean	SD	
106.3	12.3	99.6	28.3	0.633

: Significant at P ≤ 0.05

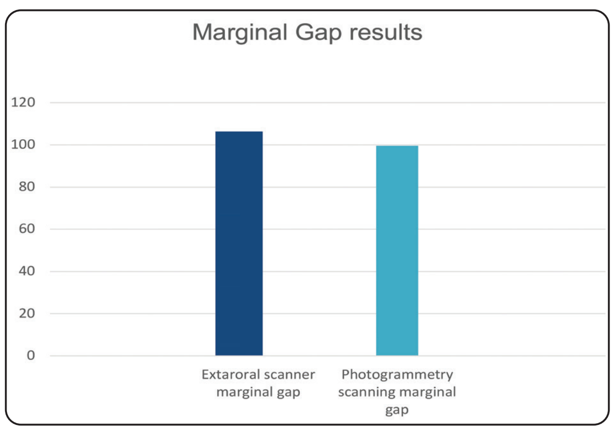

Fig. (7): Bar chart representing marginal gap of PMMA crowns produced by scanning methods

DISCUSSION

The purpose of this invitro study was to evaluate the marginal fit of PMMA CAD CAM manufactured by photogrammetry digital scanning method. Marginal accuracy is one of the perquisites for long term success of intraoral restorations [2,3]. Photogrammetry method was developed as an affordable and simplified image based rendering method (IBR) using overlapping two-dimensional images to produce three dimensional model with high accuracy.

The utilization of DSLR camera offers the advantages of superior image quality, which facilitates image rendering process in photogrammetric software, together with increased degree of edges in images [11]. Ring light with diffuser was used to provide even light distribution and to avoid shadowing as much as possible, as shadowing can cause loss of the entire shadowed area [13, 14]. The standardization of the ambient light scanning conditions inside the product photography box helps in improving the mesh quality of the obtained three-dimensional model [15].

The custom-made turntable two motor system device used in this study was constructed to ensure accurate and consistent positions of photographs, as these image positions are required to ensure image overlap of 60 to 80 % needed for successful image correlation and processing as indicated by the 3D Zephyr software manufacturer company. Another advantage of this automated system for image acquisition is providing a stable imaging environment, preventing camera shakes and blurring of images by stable movement of stepper motors and infrared remote connection with camera that was held on a tripod.

Spraying of epoxy resin model with scanning spray, aimed to eliminate refraction and scattering of ambient light used for photographing the object, which may result in a deficient determination of the depth of the scanned object [16]. Another reason of using scanning spray is that teeth are quite uniform objects with minimal photometrical landmarks. Using a small amount of powder was intended to create a random-texture surface to aid in the image correlation process inside photogrammetry software[17].

Restorations were fabricated using CAD CAM PMMA crowns in this study, as they showed high marginal accuracy and require no further processing steps (neither sintering nor crystallization). From clinical aspect PMMA crowns can be used as intermediate restorations for longer periods of time in some cases for esthetic or functional reasons in addition to having high biocompatibility advantage[18-20].

Multiple factors can affect the marginal accuracy of CAD CAM crowns as die spacer thickness, finish line design and accuracy of digital scanning method used [21].

Results of this study revealed mean vertical marginal gap of (91.5 microns) and (82.44 microns) for PMMA crowns fabricated from photogrammetry scanning and laboratory desktop scanner methods respectively, these results were within the clinical acceptable range of 120 microns mentioned for marginal accuracy mentioned in multiple studies [22,23,24]. Furthermore, there was no statically significant difference in mean of vertical marginal gap of crowns produced by photogrammetry scanning and those produced by laboratory desktop scanner.

The null hypothesis of this study was accepted as no statistically significant difference in marginal was displayed for PMMA crowns fabricated by either scanning methods.

CONCLUSION

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

1. Photogrammetry image-based rendering method is an affordable and reliable method for extraoral dental scanning.

2. PMMA crowns produced using photogrammetry scanning method showed mean marginal gap within the clinical acceptable range (below 120 microns).

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