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Marginal Fit of 3D Printed Interim Crowns Fabricated with Intraoral Scanners over Conventional and Reverse-Tapered Preparations

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SUMMARY

Background/Aim: *3D printing technology has become increasingly prevalent in the field of dentistry. Research is ongoing regarding the usability of resin-based 3D printed temporary crowns in clinical applications. Marginal fit of 3D printed interim restorations produced from digital impressions obtained with intraoral scanners may vary according to the geometry and inclination of the axial walls of the abutment tooth. The purpose of this in vitro study was to evaluate the marginal fit of 3D printed interim crowns fabricated over conventional and reverse-tapered preparations.* ***Material and Methods:*** *Crown preparations with known total occlusal convergence (TOC) angles (–8°, –4°, 0°, 8°, 12°, 16°, and 22°) were digitally created from a maxillary central incisor and printed in acrylic resin. Then, prepared tooth models (n=7) were scanned 10 times with an intraoral scanner (TRIOS3, 3Shape Inc, Denmark). Each experimental scan was used to design and fabricate a 3D printed interim anatomically contoured crown. Vinyl polyether silicone was used three times to assess the marginal discrepancy of the specimens by measuring five marginal points on digital photographs for each surfaces (buccal, mesial, distal, lingual). Marginal fit measured values did not follow a normal distribution; therefore, the Kruskal-Wallis and the Dunn/Bonferroni multiple comparison tests were applied (p = 0.05).* ***Results:*** *Marginal gap values were found significantly higher (p<0.05) in crowns produced for specimens with -8 and -4 degrees axial wall than other specimens.* ***Conclusions:*** *Negative inclination of the axial walls adversely affects the marginal fit of crowns produced with 3D printing technology.*

Keywords: 3D Printed Crowns, Marginal Fit, Additive Manufacturing

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Introduction

Nowadays CAD/CAM applications have become one of the routine procedures in dental practice with the developments in the digital dentistry. CAD-CAM technologies, along with advancements in restorative materials, offer wide variety of of options for interim prostheses construction. The dental industry has an increasing aim to use additive manufacturing and 3D printing for the production of restorations where the stereolithography and the digital light processing (DLP) are the most used methods of 3D printing. The success of the materials and the technique used to produce interim crowns in fixed prosthetics, is important as it affects the treatment directly[1].

Marginal fit of the restoration is the primary criterion for a fixed prosthesis to be considered as successful because it has a critical importance for preventing secondary decay in teeth and preserving the health of periodontal tissues[2]. Discrepancies in the marginal area can lead to various biological and mechanical problems, such as plaque accumulation, microleakage, and secondary decay[3]. Factors affecting marginal fit in fixed prosthetic restorations have been investigated in many comprehensive studies. The geometry of tooth preparation is one of the factors that directly influence the marginal fit of the restoration. One of the most important concept about tooth geometry is Total Occlusal Convergence (TOC) angle. TOC angle of a tooth preparation is the combined angle made by opposing axial walls when measured against the vertical long axis of the tooth. A lower TOC angle contributed to higher retention and durability of the restorations. However, achieving very low TOC angles can be challenging in a clinical procedures and necessitates a careful balance to provide appropriate restoration while preserving the natural structure of the tooth[4]. (4) Although there are studies demonstrating the precision of intraoral scanners and 3D printers, there is a limited number of studies evaluating marginal fit, which is a direct clinical outcome of precision, in the respective areas[5-7].

The aim of this study was to assess the success of the marginal fit of 3D printed interim crowns produced on conventional and reverse-tapered tooth preparations. The null hypothesis of the study was that there is no significant difference in the success of conventional and reverse-tapered restorations in this regard.

Materıal and Methods

Seven separate maxillary central tooth models designed with axial wall inclinations of 22, 16, 12, 8, 0, -4, and -8 degrees, a cervico-incisal distance of 6.5 mm, and a step width of 2 mm were created using 3D modeling and produced using a 3D printer (Anycubic Photon Mono Ultra; Shenzhen, China) (Figure 1). The models were scanned using a Trios 3 scanner (3shape, Denmark) following the manufacturer's recommendations. Ten scans were performed for each sample, and one crown was produced from each scan, resulting in a total of 70 crowns for each sample, with a cement gap set at 50 microns.

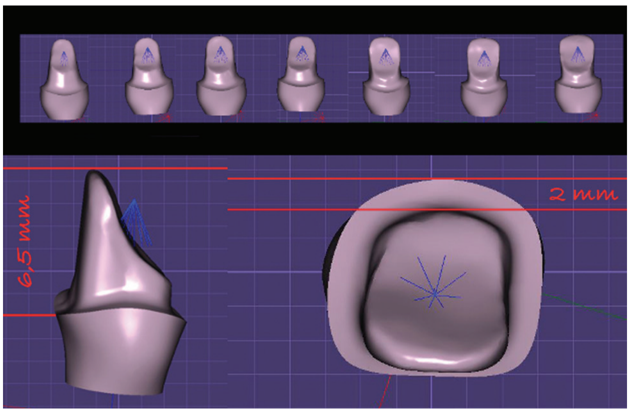

Figure 1. 3D Design of the samples used in the study

Calculation of marginal gap values

VPS-polyvinyl siloxane (3M Express XT Light body Quick, Zhermack) light body was injected into the crowns, placed on the models using finger pressure, and allowed to set for 4 min. Before complete setting, excess silicon was removed with a wet cotton swab. Photographs were taken under a microscope (Carl Zeiss Meditec AG) from four different surfaces (buccal, mesial, distal, lingual) of each model, and measurements were taken from these photographs. The silicone thickness in the marginal area in the photographs was considered the marginal gap. A total of 20 measurements of the marginal gap were taken for each sample from 5 different points on each surface.

Calibration of photographs

The obtained photographs were transferred to the Photoshop CC computer program in "Raw" mode. The data were created by marking the lines with the "Single Row and Single Column Marquee Tool" for each plane to be measured and measuring the distance between the lines with the "Ruler" tool. Calibration was performed to convert the pixel values to millimeters for the measured distances. A digital caliper was used for this calibration, and an orthodontic wire with a known thickness in millimeters was included in the photograph (Figure 2). The marginal gap values were measured in pixels for each photograph, proportionally compared with the pixel value of the same distance in the calibration wire, and converted to microns using Microsoft Excel.

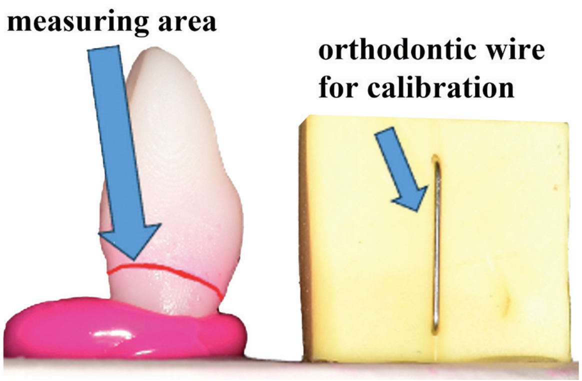

Figure 2. Calculation area of marginal gap values and calibration wire

Statistical anaylses

The sample size of the study was established using an effect size of 0.5, a=0.05, and power=0.8 for the seven groups. The results indicated that a minimum of seven specimens were required. Therefore, the inclusion of 10 specimens per group was considered appropriate.

Because of the non-normal distribution of the marginal fit values ($p = 0.05$), statistical analyses were conducted using the Kruskal-Wallis test to assess overall differences among the groups. (Tables 1, 2) For pairwise comparisons between groups, the Mann–Whitney U test was applied with the Bonferroni correction (Table 3).

Results

Descriptive results, including the median and interquartile range of marginal gaps, are presented for each group in Table 1. In terms of marginal gaps, significant differences were found between Group 6,7 and others. The marginal gaps of group 6,7 was significantly larger than group 1-5 ($p<0.05$). The narrowest marginal gap value was observed in Group 1 samples with a 22-degree inclined axial wall (53.375; IQR 5.38), while the thickest marginal gap value was observed in Group 7 samples with -8-degree axial walls (168.25; IQR 82.94).

Table 1. Median and IQ results of the samples

Sample 1 (22°)	Median	53.375
	Interquartile Range	5.38
Sample 2 (16°)	Median	77.625
	Interquartile Range	17.88
Sample 3 (12°)	Median	70.25
	Interquartile Range	39.38
Sample 4 (8°)	Median	54.75
	Interquartile Range	16.13
Sample 5 (0°)	Median	79.875
	Interquartile Range	22.25
Sample 6 (-4°)	Median	110
	Interquartile Range	53.56
Sample 7 (-8°)	Median	168.25
	Interquartile Range	82.94

Table 2. Independent Samples Kruskal-Wallis Test Results of the study

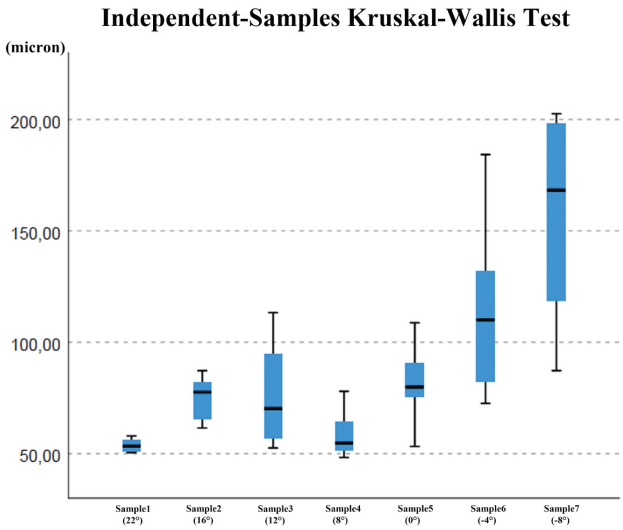

Table 3. Pairwise comparisons of the samples

	Test Statistic	Std.Error	Std. Test Statistic	Sig.	Adj.Sig.a
Sample 1 – Sample 4	-5.5	9.1	-0.604	0.546	1
Sample 1 – Sample 3	-22.75	9.1	-2.5	0.012	0.261
Sample 1 – Sample 2	-24.2	9.1	-2.659	0.008	0.164
Sample 1 – Sample 5	-27.95	9.1	-3.071	0.002	0.045
Sample 1 – Sample 6	-39.85	9.1	-4.379	<0.001	0
Sample 1 – Sample 7	-51.6	9.1	-5.67	<0.001	0
Sample 4 – Sample 3	17.25	9.1	1.896	0.058	1
Sample 4 – Sample 2	18.7	9.1	2.055	0.04	0.838
Sample 4 – Sample 5	-22.45	9.1	-2.467	0.014	0.286
Sample 4 – Sample 6	-34.35	9.1	-3.775	<0.001	0.003
Sample 4 – Sample 7	-46.1	9.1	-5.066	<0.001	0
Sample 3 – Sample 2	1.45	9.1	0.159	0.873	1
Sample 3 – Sample 5	-5.2	9.1	-0.571	0.568	1
Sample 3 – Sample 6	-17.1	9.1	-1.879	0.06	1
Sample 3 – Sample 7	-28.85	9.1	-3.17	0.002	0.032
Sample 2 – Sample 5	-3.75	9.1	-0.412	0.68	1
Sample 2 – Sample 6	-15.65	9.1	-1.72	0.085	1
Sample 2 – Sample 7	-27.4	9.1	-3.011	0.003	0.055
Sample 5 – Sample 6	-11.9	9.1	-1.308	0.191	1
Sample 5 – Sample 7	-23.65	9.1	-2.599	0.009	0.196
Sample 6 – Sample 7	-11.75	9.1	-1.291	0.197	1

Discussion

The null hypothesis of the study "there is no significant difference in the marginal fit of conventional and reverse-tapered restorations produced with 3D printed interim crowns" was rejected.

Inclination of the axial walls is one of the factor affecting the fit of restorations in dental preparations. It is important to consider that regions with undercut depth during image capture may hinder a successful scan, and the amount of undercut can impact the fit of the produced material. This study is significant in investigating the relationship between the axial angles in the preparation and the fit of resin restorations produced with 3D printers.

In this context, a study by Mej *et al*. has shown that the amount of undercut left in axial walls during dental preparation affects the internal and marginal fit of the produced zirconia restorations[4]. Previous research has also indicated that the production method and the superstructure material used are factors that affect the fit of restorations. Refaie *et al*.[8] investigated the marginal and internal fits of monolithic zirconia crowns produced using both 3D printing and milling methods; they found the crowns produced by milling to exhibit better fit. Nonetheless, they noted that the fits of the 3D printed zirconia crowns they examined were clinically acceptable.

Studies involving 3D printed acrylic interim crowns also demonstrate controversial results. In their study, Chaturvedi *et al.*[1] found that the marginal fits of 3D printed interim crowns to be more successful compared to the milling method. In contrast, in the study by Igret *et al.*[9], the fits of milled interim crowns were demonstrated to be better than 3D printed ones.

In this study, the marginal gap values of the samples varied between 53.375 and 168.25 microns depending on the axial angle in the preparation. There have been extensive debates regarding the acceptable marginal fit value for full crowns, and there is a general consensus in clinical practice that a marginal discrepancy of ≤120 µm is acceptable[10]. In this context, it can be observed that the marginal fit of 3D-printed restorations on abutments with walls inclined at -8 degrees in dental preparations is not within acceptable limits. Furthermore, even though the average marginal gap values of some 3D-printed samples on abutments with walls inclined at -4 degrees fall below this threshold, it is evident that in some cases, the limit has been overlooked.

Research in this field has predominantly focused on assessing the accuracy and precision of intraoral scanners."Trueness" denotes the deviation of the impression geometry from its original form, while "precision" encompasses the agreement between measured quantities derived from replicate measurements on the same objects under specified conditions, highlighting the proximity of deviations in test results[11]. These terms are indeed significant, but their clinical outcomes are observed in the marginal gap values. This study is important in terms of demonstrating the outcomes of current materials due to the intraoral scanning being done with digital technology and production being carried out using the 3D printing method.

Conclusions

According to the results of this study, reverse tapered preparations decrease the marginal fit of 3D printed interim crowns produced using digital measurements obtained with intraoral scanners.

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