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THE ASSESSMENT OF THE PRECISION (MARGINAL AND INTERNAL) OF 3D PRINTING AND MILLED INTERIM CROWNS.

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ABSTRACT

Objective: This study aims to assess the precision (marginal and internal) of 3D printing and milled interim crowns. **Methods:** a study model of all ceramic preparation for the maxillary first molar was fabricated. Interim crowns were fabricated using milling systems (imes-icore 250i, n = 10) and 3D printing (Rapidshape D30, n = 10).The marginal misfit and Internal gap were assesed using the replica technique. All the achieved data was analyzed with Shapiro-wilk's test which was followed by independent t-test. **Results:** The smallest discrepancy of 63.30±13.27 μm was observed in marginal misfit of the Printing group followed by milled group with the gap of 121.94±1.53 μm. The marginal misfit and internal gap showed a significant difference between the two groups, it has been observed that the 3D Printing technology has the capability to fabricate an interim crown with better precision fit than milling one. **Conclusions:** Interim crowns that is constructed by 3D printing technology have better precision (marginal and internal) compared to milled one.

KEY WORDS: 3D printing, Milling, Interim, crown, marginal, internal gap

INTRODUCTION

Interim restoration precision and trueness depend mostly on the fabrication techniques, material used and form of prepared teeth. Interim restorations can be fabricated using subtractive or additive technology. The benefit of these two methods is that the biological harmful risks to the tooth and supporting structure are eliminated and prosthesis adaptation is improved with marginal gap range from 30–140 um with and axial gap was 35–150 um and at occlusal part was 40 –210 um [1–7].

In fixed prosthodontics the step of the Interim restorations are very important from the tooth preparation to the crown cementation [2]. They are very important not only for tooth and the supporting structure protection but also for the

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correction, evaluation and rehabilitation of oral structure, aesthetics, and phonetics[3,4]. The success of the interim's restorations dependent mainly on its inteprecision and trueness. In the milling technology, we use a highly performance resin blocks offering an adequate degree of mechanical properties and accuracy [5,7] but with limited designs due to the limitation of the milling machine tools, the material mechanical and physical properties. On the other hand; The additive manufacturing technology offers a freedom of designing due to the way of manufacturing by using printing layering technique to produce definitive shape [6,8]. Adding on, the amount of printing material is less compared to the milling one [9] and practically no material loss even though wasted material can be used in the future. Also, multiple shapes with different designs can be printed at the same time with very precise reproduction detail [10].

A limited studies [11–20] were found regarding the precision of the interim crowns fabricated by additive manufacturing technology. Thus, this study aim to eassess the marginal misfit and internal gap of interim crowns fabricated by 3D printing technology and comparing it with the milling methods using a scanning electron microscope (SEM). The null hypothesis assumed that there will be no difference between the 3D printing technology and milling one regarding the precision of fit .

The study aims to evaluate and compare the precision (internal gap and marginal misfit) of interim crowns constructed by 3D printing and milling technology,

The objective was to calculate and corelate the precision of 3D printing and milling interim crowns.

MATERIAL AND METHODS

Tooth preparation was done for upper first molar tooth of the dental model (NISSIN DENTAL PRODUCTS INC., 8 Karahashi Hiragakichō, Minami-ku, Kyoto 601-8469 JAPAN) with the help of diamond stones having a 1.5 mm reduction for the occlusal surface, 1 mm for the axial reduction having a 1 mm chamfer finish line . An Express addition silicone based impression (3M Australia Building A, 1 Rivett Road NORTH RYDE NSW 2113) material was taken for the model to produce a master cast . The upper right first molar of a standard dental gypsum model (Nissen dental products incorporation –Nakagyoku, Japan) was sectioned to get a removable die.

The Sample size calculation was done using R statistical package (version 3.3.1 (21-06-2016)). An equal allocation to two arms (8 restorations in each group). Group I: CAD / CAM milling group 8 crowns. Group II: 3D printing group (Digital Light Processing) 8 crowns.

The master cast with the removable die was scanned with the help of the 3 shape D 850 dental model scanner (3 Shape, Niels Juels Gade 13, 1059 Copenhagen K Denmark) and saved in STL format. The CAD design was done with 60 um cement space . The virtual design of the interim crown was designated using the 3 shape software (Niels Juels Gade 13, 1059 Copenhagen K Denmark) . The STL file of CAD design having all specifications was sent to CAM system ; the milling and 3D printing machine Figure (1).

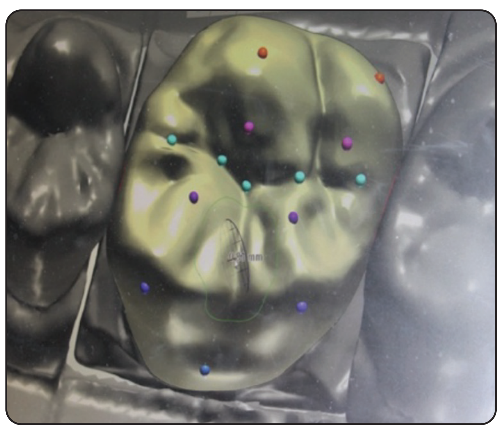

Fig. (1) Designing of interim crown

For construction of 8 crowns CAD/CAM temporary crowns, imes-icore 250 i (imes-icore GmbH, Im Leibolzgraben 1636132 Eiterfeld Hessen, Germany) a five axis milling machine was used in milling using DC PMMA A1 Disc (Whitepeaks dental solutions, Gmbh & co., Germany), The two supporing structures were removed and crown was finished and polished with jota Arkansas stone 649 (Jota – Ruthi, Switzerland) to get perfect smooth surface, All interim crowns were initially evaluated with a dental explorer and 3.5 x magnifying lopes. Figure (2), Table (1).

For construction of 8 3D printed interim restoration, The other STL file for 3D printing was sent to Rapidshape D30 -3D printer (NextDent - Soesterberg, Neitherland). A Next Dent C&B resin liquid especially for interims crown was used (NextDent - Soesterberg, Neitherland). After printing the 3d printed crown was attached to upper compartment with 10 supports, After complete printing, the resultant restorations were cured using Next Dent LC-3D Print Box (NextDent - Soesterberg, Neitherland),

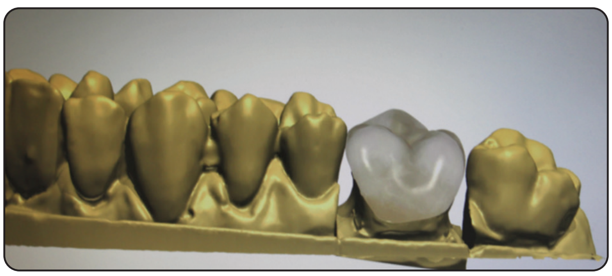

Fig. (2) 3D printing crown design

Post- processing Ultra-violet light heat treatment was done to ensure that all the crowns are fully polymerized obtaining a high mechanical property. The post processing heat treatment cycle last for 30 minutes with blue Ultra-violet light with wavelength from 315-400 nm with total light output 72 watt . This is a necessary procedure to ensure produceing a biocompatible end-product. All supporing structures were removed and crown was finished and polished with jota Arkansas stone 649 (Jota – Ruthi, Switzerland – Patch number 649104001506) to get perfect smooth surface. Ethanol solution was used for cleaning and disinfection of the restoration. It was then placed on the master die to be checked. Figure (3)

Fig. (3) Designing of interim crown

Internal gap was measured by the help of replica technique. The interim crown was filled with ultra light body silicone (Express, 3M Australia

TABLE (1) Material composition and description

Commercial name	Type	Chemical composition/ properties	Manufacturer's name	Patch number
Next Dent C&B	3D printer liquid resin.	Monomer based on acrylic ester.	NextDent, Soesterberg, Neitherland.	XL134N01
DC block	PMMA CAD/CAM block	99.5 wt.% Poly Methyl Methacrylate <1 wt. % Pigments	Whitepeaks dental solutions, Gmbh & co., Germany	70050120
Express™	Addition silicon impression material	vinyl polysiloxane	3M Australia Building A, 1 Rivett Road NORTH RYDE NSW 2113	R13401

Building A, 1 Rivett Road NORTH RYDE NSW 2113). All samples were mounted on a controlled modified parallel-meter (Model 3345; Instron Industrial Products, 825 University Ave Norwood, MA, 02062-2643, USA) of 750gm load cell for 10min until material sets; samples were secured to the lower fixed compartment of modified parallel meter machine. Compressive load was applied in the occlusal direction by a spherical tip of a metallic rod (1cm diameter). The crown was removed after setting the light body. Since it was impossible to remove the light-body from the intaglio surface of the crown without tearing it, so a heavy-body silicone (Express, 3M Australia Building A, 1 Rivett Road NORTH RYDE NSW 2113) was applied for stabilizing the light-body silicone. the replicas were sectioned carefully Using a razor blade (n°. 15) (Jiangsu huida Medical Inst. Co., LTD, 12F south Building, Julong center, Feng Huang, Jiangsu, China .) into four equal segments. Each segment was labeled and marked as follow distopalatal(DP), mesiopalatal (MP), distobuccal (DB), and mesiobuccal (MB). Figure (4)

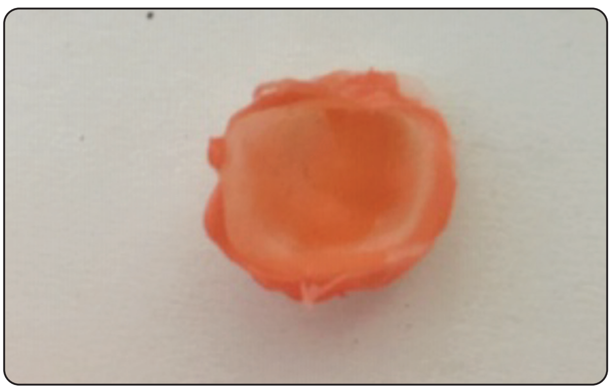

Fig. (4) Light body covering the fitting surface of interim crown

From each replica, two opposite sections were used to measure internal misfit, measuring a three point in each section (marginal point, axial wall point and occlusal point), giving a 12 internal measurements for each coping. The light body thickness was measured using USB digital microscope (U500 X Digital Microscope, Guangdong, China) with magnification 25x having a built-in camera for data saving. the measured data represent the distance between the internal of and the external surface of the coping. Figure (5) A Digital analysis software (Image J 1.43U, National Institute of Health, USA) was used to quantitively and qualitatively measure the gap width. Within the limitation of Image J software; frames, gap sizes, and measured parameters were expressed in pixels. Therefore, the pixels were convert to universal unite (μm) using system calibration Figure (6).

Fig. (5) The light body with putty supporting layer ;A: Putty layer, B : light body layer

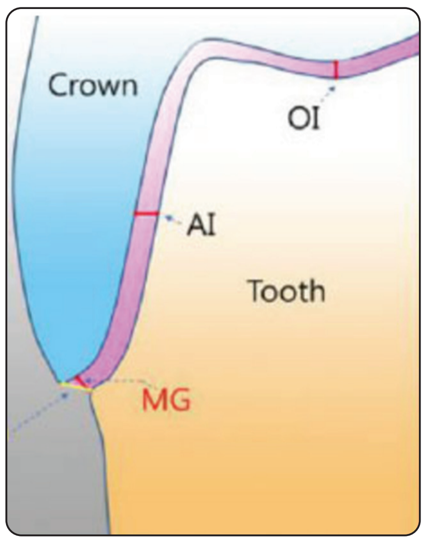

Fig. (6) Point of checking the marginal misfit and internal gap

MG: Marginal gap distance, AI : Axial gap distance, OI: Occlusal gap distance

RESULTS

Numerical data were presented as mean and standard deviation (SD) values. Shapiro-Wilk's test was used to test for normality. Data were normally distributed and were analyzed using independent t-test. The significance level was set at p<0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows (R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.).

Results of intragroup comparisons presented in table (2) and figure (7) showed that for different measurements, 3D printed samples had significantly better fit than milled samples (p<0.001).

TABLE (2) Intergroup and Intragroup comparisons of 3d Printing and milling interim crown

Measurement	*Internal fit (µm) (Mean±SD)*		*t-value*	*p-value*
	Milling	*3D printing*		
Marginal	121.94±1.53	63.30±13.27	**19.63**	**<0.001***
Axial	152.85±1.58	72.74±11.47	**30.93**	**<0.001***
Occlusal	306.54±2.46	151.89±2.46	**198.49**	**<0.001***
Overall	193.78±81.43	95.98±41.30	**8.30**	**<0.001***

****significant (p<0.05)***

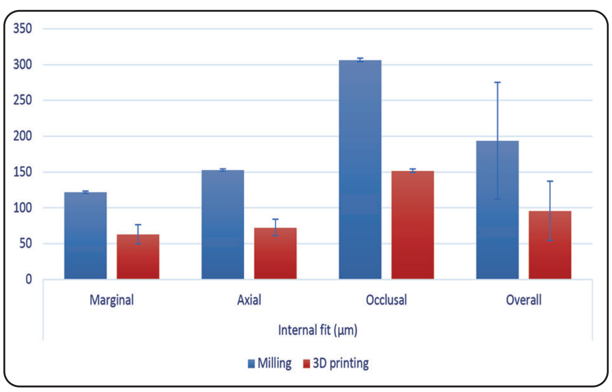

Fig. (7) Bar chart showing mean and standard deviation values for internal gap (µm) in different groups

DISCUSSION

Interim prostheses are very important for the fixed prosthesis protocol form tooth protection, final prosthesis cementation to even full mouth rehabilitation [1]. The precision and trueness of the restoration regardless its mechanical and physical properties have never been evaluated although it is one of the critical factors for long term success of the fixed prosthesis [2-5].

With the rapid evolution of the digital technology and more efficient method for fabricating a interim restoration is now possible by virtual designing and manufacturing the restoration with either subtractive or additive technology [11]. Despite of being the subtractive technology the gold slandered of the digital era, it shows many limitations regarding the milling process of the intaglio surface of the restorations and the complex structure due to the restriction in the milling tools, angle, and directions [14,16]. On the other hand, additive manufacturing technology shows efficient material utilization and complex structure production than subtractive one. Much research has concluded that subtractive interim restorations possess a higher internal and marginal fit than conventionally produced interim prosthesis [3].

Additive manufacturing technology has different techniques according to the materials used in which Stereolithography (SLA) and Digital Light Processing (DLP) were used for polymer polymerization. Both techniques are under the umbrella of VAT photopolymerization where the polymer is polymerized by light source passing through its particles layer by layer [20,21]. Although DLP and SLA technology have the same printing principle, they are different in the basis of light, way of hardening the layer of the polymer and even printing capability leading to a significant change in the end product results. In the DLP, the whole resin layer is polymerized in the same time rather than the STL which polymerize point by point [13]. So, DLP systems were chosen in the study.

There are many methods to evaluate the precision of the restorations as profile projection, microcomputed tomography, replica technique, cross-sectioning method, and laser videography.

The replica technique has the advantage of being nondestructive methods as it shows low risk of restoration damage through the testing procedure[1,2,9]. Many researchers believe that the replica technique show verifiable and reliable result when compared by other testing methods [1,2, 9,22,23]. So in the present study, the marginal misfit and the internal gap was evaluated by the help of the replica technique. The silicon replicas were cut in all the samples in one clear plane, a customized template jig guide was fabricated for the two groups, then the replica was cut into four parts. After that all the parts were checked under a stereomicroscope with the magnification of 10x[1,2].

In the present study, the obtained results show a significant difference (table 2) between the 3D printing and the milled group in which the null hypothesis of the research was rejected. These results were in accordance with Wan-sun Lee et al.2017 (table 2) [1]. In which they assessed the precision of the interim fixed partial denture manufactured by two 3D printing (149.1, 91.1 μm) and one milling method (171.6 μm). Also, there are some different studies which showed similar result; Rajtukova V et al. [34] and Park JY et al. [35] assessed the marginal and internal gap of different technology (3D printing, subtractive and conventional) with a superior fit to the 3D printing technology. Mai Hang-Nga et al. 2016 compared the precision of 3D printings material jetting of interim crown with the milling one showing high precision to the material jetting than the milling group [2]. Earar K et al. [37] tested the trueness of PMMA crown. They concluded that the 3D printed crowns showed low misfit than milling group. Also, other research has concluded that the additive manufacturing technology show better precision than subtractive technique [21,38,39, 40].

The results of the present study (Table 2) showed an ideal range of precision despite of the discrepancies between the measured points of the two groups. The milled group showed high overall discrepancy (193.78±81.43 μm). This result is due to the different in the manufacturing methods; the milling method use a cutting tool for subtractive purpose [41]. As a result, the direction of milling ,the size of bur and the precision of cutting are a limitation factors in the milling process giving a difficulty in milling sharp edge, right angles preparations and small precise restorations [2]. As the milling is mostly depended on the tools smallest diameter (1mm) which can't mill smaller than its own diameter. This limitation gives a precision and trueness errors which appears significantly on the marginal and internal misfit [1,42,35].

Finally the difference in the marginal misfit and internal gap between the milling and 3D printing technology (193.78, 95.98 μm) (table 2) may be summarized to the following reasons a) milling bur Diameter, b) High speed cutting, c) high vibrations, d) thermal changes, f) Excessive pressure . whereas the 3D printing technology overcome these limitations by building the restorations layer by layer giving the possibility for fine details, stress free and complex structure production [17]. And for this reasons the 3D Printing methods show low marginal misfit and internal gap (figure 7) [43].

CONCLUSION

The marginal misfit and internal gap values showed a significant differences between the two groups and the 3D Printing technology has the capability to manufacture an interim crowns with better precision than subtractive group.

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