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Comparative Evaluation of the Vertical Marginal Fit of 3 Units Fixed Dental Prosthesis Using Rapid Prototyping, CAD/CAM and Conventional Methods - A Sem Study

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Abstract

Introduction: In digital era of dentistry newer technologies are upgraded in prosthodontics.

Accuracy, quality and prognosis of prosthesis fabricated by new dental martial and Technology became the topic of interest. The One of the biggest challenge is indirect restorations, which are fabricated for replacement and restoration of missing and heavily damaged teeth for prosthodontic rehabilitation. This study was done to assess and compare the marginal fit afforded by the digital and the conventional fabrication method.

Objectives: The main objectives of the study was to compare and evaluate marginal fit of retainers in 3 units Posterior Fixed Dental Prosthesis fabricated using lost wax technique, CAD/CAM and rapid prototyping methods.

Method: One master model was fabricated from Titanium alloy for the reference. A total of 40 prosthesis were fabricated from Titanium alloy material by following techniques: Conventional lost wax techniques direct scanning CAM technique, Extra-oral scanning CAM technique & Rapid prototyping technique.

Result: Significant difference was found among the groups shows conventional method has the highest misfit (55.25µm) among all groups followed by rapid prototyping group (37.19µm), direct scanning computer aided milling (33.05µm) & lab scanning computer aided milling (28.55µm)

Conclusion: Within the limitation of this study, it could be concluded that extra oral scanning followed by computer aided milling shows the minimal marginal discrepancy.

Keywords: Fixed Dental Prosthesis, Vertical Marginal Fit, Rapid Prototyping ,CAD/CAM, Lost Wax Technique

Introduction

Fixed dental prosthesis (FDP) is the treatment plan which is widely used in general dentistry and Prosthodontics. One of the biggest challenges is indirect restorations, which are fabricated for replacement and restoration of missing and heavily damaged teeth for Prosthodontic rehabilitation. If a tooth experiences extensive decay, fracture, or is functionally or aesthetically compromised, a laboratory-fabricated crown is often required. A clinically acceptable crown should accurately fit the prepared tooth. Majority of indirect restoration are fabricated by Conventional lost Wax technique. There are many disadvantages of lost Wax technique such as solidification shrinkage, dimensional inaccuracy, undersized casting and various other processing errors. With the introduction of CAD/CAM (Computer Aided Design /Computer Aided Milling) restoration and recent addition of rapid prototyping automation helped to great extent to eliminate fabrication deficiency. In this digital era CAD/CAM and Rapid Prototyping are technical advancements resulting in better fitting prosthesis and hence marginal fit.

Digital technology has continues to develop as an available means to performing the many steps of crown fabrication. However, what is unknown is the accuracy of crown fit with the digital technology. The longevity of a restoration is determined by its ability to withstand the oral environment, which requires that the margins be closely adapted to the cavo surface finish line[1]. Finish line configuration is determined largely by the requirements of the restorative material and can include the following designs: chamfer, heavy chamfer, shoulder, radial shoulder, shoulder with bevel and the knife-edge finish line. In the case of the all ceramic restoration, the use of a shoulder finishes line with a uniform width of approximately 1mm is used as the gingival finish-line which provides a flat seat that resists forces directed in the axial direction[2]. The marginal integrity can determine longevity and predictability of dental prosthesis and its measurement requires accurate assessment and quantification of marginal parameters so as to differentiate fit from misfit. Holmes et al. defined geometrically the relation of the cavosurface finish line to the prosthesis margin and defined fit for the fixed dental prosthesis in terms of “misfit"& categorized it into eight variables: internal gap, marginal gap, vertical marginal discrepancy, horizontal marginal discrepancy, overextended margin, under-extended margin, absolute marginal discrepancy and seating discrepancy[3]. Fit has been defined in both in vitro and in vivo studies as the marginal discrepancy, either vertically or horizontally[4]. This gap is important because the amount of space will determine the amount of possible cement dissolution. Margin inaccuracy could lead to the accumulation of plaque and bacteria[5], Michael S. Jacobs et al, studies demonstrated that there is minimum rate of cement dissolution for the 25µm[6], the dissolution of luting material, and/or the introduction of unfavourable inflammation of the periodontal tissues[7]. As described by McLean and Von Fraunhofer, clinically acceptable marginal gap are those that are < 120 µm[8]. However, according to the American Dental Association (ADA) Specification No. 8,[9] According to Kenneth B. May et al, the marginal fit of cemented restoration should be in the range of 25-40 µm which allow enough space for lutting cement, This range is seldom achievable [10]. So the aim of this study was to assess and compare the marginal fit afforded by the digital and the conventional fabrication method.

Materials and Methods

Step 1: Master Model and Crown Fabrication

Two stainless steels metal dies (Figure 1) were designed to simulate clinical conditions with a 1-mm-wide circumferential shoulder finish line, and a 6° taper with 12° angle of convergence of the axial walls and resembling mandibular left 1st molar (10mm in cervico-occlusal length) & mandibular left third molar by laser sintering with fixed base.

- The dimensions of base were 4 cm × 2 cm × 1 cm height.

Figure 1 : Master Model Fabricated by using stainless steel dies.

A total of 40 samples were prepared from Titanium alloy. The samples were then divided into 4 groups with 10 samples in each groups, the details of which are as follow:

Groups	Methods
Group I (n=10)	Conventional FDP Fabrication
Group II (n=10)	FDP fabrication with intra-oral scanning and CAM
Group III (n=10)	FDP fabrication using Lab scanner with CAM
Group IV (n=10)	FDP fabrication using Lab scanning and Rapid-prototyping

(FPD= Fixed Dental Prosthesis, (CAD/CAM= Computer Aided Design/Computer Aided Milling)

Group I: Conventional FDP Fabrication

Mandibular custom trays were fabricated using an autopolymerized polymethylmethacrylate. Then custom tray mold is fabricated using Addition silicon material. Then the custom acrylic resins trays were then duplicated by a silicone mold by pouring the autopolymerized polymethylmethacrylate resin in the mold. The mold is left in 37^{0} C (at room temperature) for 24 hours for complete polymerization of custom tray. 10 sets of acrylic resin trays in exact made, accordance to Ecker's process.[11,12] Each tray was stored for a period of 7 days for the accommodation of polymerization shrinkage before impression making.

Polyvinyl siloxane adhesive was applied to each tray and allowed to dry for a period of 30 minutes to Achieve maximum tensile bonding strength.[13] Polyvinyl siloxane impression material was loaded, using equivalent volume of base and catalyst delivered by 50/75 Imprint Dispensing dual dispensing holder into the custom tray. The loaded tray was seated firmly and allowed to set for 5 minutes, according to manufacturer's recommendation. Ten such impressions were secured.

10 casts then were fabricated (GC Fuji Rock type IV) and allowed to set according to manufacturer's instructions.

Group II: FDP fabrication with intra-oral scanning and CAM

To make digital impression CEREC AC Intraoral scanner was used, which is dental office scanner equipped with CEREC AC XL computer aided milling machine. Reference model was placed on the platform which mimics the intra orally prepared teeth. As it was the stainless steel die, CEREC optispray (Figure 2) was used to cover the shiny surface of the die.

After coating with the spray, digital impression was made (Figure 3) beginning from the mandibular left third molar to mandibular left first molar by the operator. 10 impressions were made reapeatedly by the same operator. All impressions were stored in computer in STL file format. Sirona CEREC AC is a dental office scanner which comes with the office milling machine Because of availability of the machine at the same dental office, transfer of STL files is not required. Ten such 3 unit FDPs were fabricated by this process.

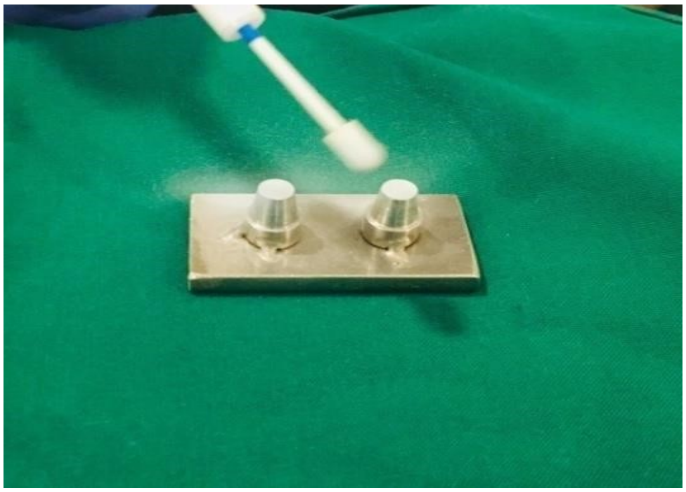


Figure 2: Application of optispray

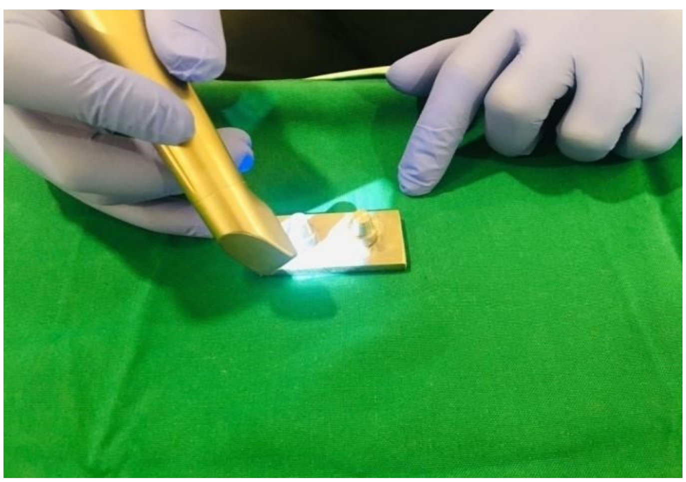


Figure 3: Scanning of master model with CEREC AC scanner

Group III : FDP fabrication using Lab scanner with CAM

To fabricate the prosthesis with lab scanner, master model was cleaned before scanning and coated with silver oxide spray evenly on entire surface of dies. The model was then mounted on the Identica blue labscanner (Figure 4). 10 Digital impressions were made and saved as STL files in the computer (Figure 5). This was followed by fabrication of 10 virtual wax patterns on the digital impressions which were processed for the milling in Yenadent D30 milling machine (Figure 6).

Group IV. FDP fabrication using Lab scanning and Rapid-prototyping

10 fixed dental prosthesis were also fabricated using rapid prototyping method at the same time in the dental lab. All the samples were stored in the containers and are carefully transferred to the laboratory for the measurement of vertical fit.

Figure 4: Identica Blue lab scanner

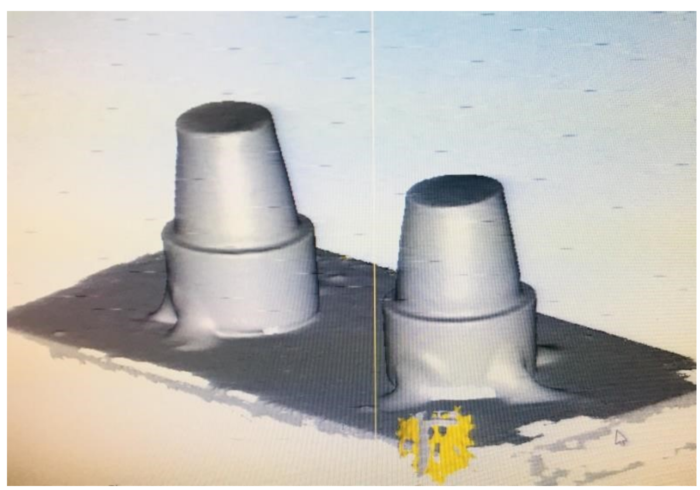


Figure 5: Digital form of impression

Figure 6: Yenadent D30 milling device

Measurement technique

All the samples were measured for vertical fit/misfit in Scanning electron microscope. 40 samples as discussed were measured at randomly selected areas in die. The bias was eliminated by blinding the microscope operator by the main investigator. Die was cleaned with air spay before the measurement and inserted in the chamber of microscope. The measurements done by measuring the distance between cervical area of retainer (3 unit fixed dental prosthesis) and prepared margins/finish lines of stainless steel die. Four random surfaces were chosen from the prosthesis and mean value was considered as the score for respective samples. The obtained data was tabulated. Only prosthesis was changed during the measurements. The obtained data was tabulated all the measurements were converted in to micrometer from nanometer (1 µm = 1000 nanometer).

The Statistical Package for Social Sciences (SPSS) was used to analyze the results obtained in this study. The results of the measurements were analyzed using One-way analysis of variance (ANOVA) followed by Post hoc test used to analyze difference between means of groups. All the results were included in the analysis.

Result

The vertical fit of all 40 prosthesis retainers was measured. The results are summarized in

Table 1: Marginal discrepancy of 3 unit fixed dental prosthesis

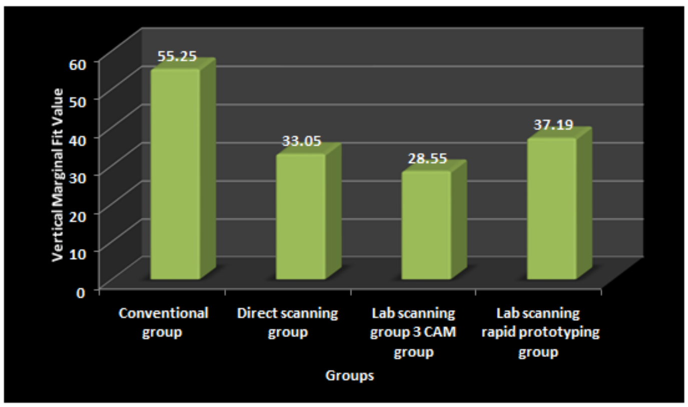
Sn.	Group I Conventional Method	Group II Intra oral scanner CAM	Group III Lab-scanning CAM	Group IV Lab Scanning Rapid Prototyping
1	45.4	34.2	24.2	38.3
2	48.3	37.5	27.4	36.3
3	56.2	30.7	30.7	35.7
4	62.6	31.8	31.4	31.9
5	46.2	32.2	32.2	31.5
6	52.3	39.1	29.6	39.3
7	50.4	28.7	28.3	37.2
8	54.4	29.2	29.8	42.8
9	59.8	32.5	25.8	40.1
10	56.9	34.6	26.1	38.8

All the measurement is in µm

Table 2: Vertical marginal fit wise distribution among all the groups (One Way ANOVA)

Time	Number	Vertical marginal fit		P Value
		Mean	SD	
Group I Conventional Method	10	55.25	6.46	0.000 S
Group II Intra oral scanner CAM	10	33.05	3.36	
Group III Lab-scanning CAM	10	28.55	2.63	
Group IV Lab Scanning Rapid Prototyping	10	37.19	3.52	

Vertical marginal discrepancy was high in Conventional group (55.25 ± 6.46) followed by Lab scanning rapid prototyping group, Direct scanning group and Lab scanning CAM group. Statistically, significant difference was present in Vertical Marginal Fit value among all the Groups. ($P \leq 0.05$)



Graph 1: Vertical marginal fit values in µm

Graphical illustration shows that (Graph 1) shows Group I conventional method has the highest misfit (55.25µm) among all groups followed by Group IV rapid prototyping group (37.19µm), Group II direct scanning computer aided milling (33.05µm) & Group III lab scanning computer aided milling (28.55µm).

The vertical marginal discrepancy can be listed as under:

Group I > Group IV > Group II > Group III

Hence, Group III: lab scanning computer aided milling gives the best result in terms of marginal fit.

Table 3: Vertical marginal fit wise distribution between various Groups (Post Hoc Test)

Groups		P Value
Group I: Conventional method	Group II: Intra oral scanner CAM	0.000 S
	Group III: Lab-scanning CAM	0.000 S
	Group IV: Lab Scanning Rapid Prototyping	0.000 S
Group II: Intra oral scanner CAM	Group III: Lab-scanning CAM	0.103 NS
	Group IV: Lab Scanning Rapid Prototyping	0.150 NS
Group III: Lab scanning group CAM	Group IV: Lab Scanning Rapid Prototyping	0.000 S

Statistically, significant difference was recorded in Vertical marginal fit Value between Group I Conventional Method and Group II Intra oral scanner CAM. ($P \leq 0.05$)

Similarly, statistical significant difference was seen in Vertical marginal fit Value between Group I Conventional Method and Group III Lab-scanning CAM .($P \leq 0.05$)

Statistically, significant difference was present in Vertical marginal fit Value between Group I Conventional Method and Group IV Lab Scanning Rapid Prototyping. ($P \leq 0.05$)

However, the results were not statistically significant when vertical marginal fit Value of Group II Intra oral scanner CAM was compared with Group III Labscanning CAM and Group IV Lab Scanning Rapid Prototyping. ($P > 0.05$)

Statistically, significant difference was present in Vertical marginal fit Value between Lab scanning group III Computer Aided Milling group and Group IV Lab Scanning Rapid Prototyping. ($P \leq 0.05$)

Discussion

This study aimed to comparatively evaluate the vertical marginal fit of retainers in 3 units fixed dental prosthesis, fabricated using lost wax technique, CAD/CAM and rapid prototyping methods. The purpose of using vertical marginal fits is due to its clinical relevance as stated in the study by Holmes et al.[3] As crown marginal fit is critical for success of the restoration; Crown with poor fit (marginal gap) are prone to failure due to several reasons such as micro-leakage, cement dissolution, and dental caries. In this study, the fit of the crowns was assessed based on the vertical gap measurement which was selected as the most critical factor of marginal gap while being the least susceptible to manipulate postfabrication, as indicated. Vertical marginal gap has the most clinical relevance and should be regarded as the most critical in crown margin evaluation as it can be closed only with luting cement, which is prone to dissolution.

In current it was found that the vertical marginal fit value was high in conventional group (55.25 + 6.46) followed by lab scanning rapid prototyping group (37.19+3.52), direct scanning group (33.05+3.36) and lab scanning CAM (28.55+2.63). There is statistical significant difference in the vertical marginal fit value among the groups ($p<0.05$).Similar

Results were found in several studies Philip L. Tan et al.[13] , Francisco Martínez-Rus et al.[14], Júnio S et al.[15] ,Yolanda Freire et al.[16]

Jonathan N et al.[17] (2013) conducted study to determine and compare the marginal fit of crowns fabricated with digital and conventional methods and he observed that the overall mean SD vertical gap measurement for the digitally made crowns was 48- 25 mm, which was significantly smaller than that for the conventionally fabricated crowns (74 -47 mm).It was also found that there was no significant statistical difference among direct scanning group, lab scanning CAM, lab scanning rapid prototyping group and conventional lost wax technique. which contradict the study of Tamer Abdel-Azim et al.[18], Paul Seelbach et al.[19] Panos Papaspyridakos et al.[20] In which they compared the accuracy of digital and conventional impression techniques for completely edentulous patients and to determine the effect of different variables on the accuracy outcomes. No significant differences were found between Groups I (splinted, implant level), III (digital, implant level), IV (splinted, abutment level), and V (non-splinted, abutment level) compared with the control.

In this study, attempts were made to control and standardize the steps involved. Each impression was accompanied by an identical and standardized written prescription that carefully outlined the specifications of materials and material handling for the fabrication of crowns. The author observed the fabrication of the crowns at the commercial laboratory to ensure that the prescription was followed. However, the impossibility of controlling all the variables, combined with propensity for human error, can result in poor marginal fit and even misfit. The use of digital methodology decreases the chances for error and should produce better fitting crowns at improved cost efficiency. The results of this in vitro study determined that the digital method produced crowns that had acceptable margins, and surpassed the fit of conventional fabricated crowns. The use of the digital technique of impression and crown fabrication has numerous advantages over the technique of securing a conventional impression and crown fabrication such as the elimination of the need for consideration of impression materials, tray type selection, use of adhesives, disinfection, transportation temperature changes time elapsed before pouring, pouring temperature and gypsum choice, notwithstanding the numerous steps involved in post-impression prosthesis fabrication. Digital impressions offer added value in time savings, cost savings, space saving, and reproducibility, nevertheless, these benefits are only realized if accuracy is comparable to or greater than that of the conventional technique.[21] Based on the results obtained, the digital methodology seems to be a legitimate alternative for the traditional methodology.

However, as the clinical acceptance of a crown requires more than simply an acceptable vertical MG, Further studies are required to assess digital crown fabrication and to evaluate the accuracy of the technology in terms of capturing, designing and manufacturing.

Although the study conducted under precautions but there are several limitations in the study. Apart from marginal fit of the prosthesis other factors like crown height ration. Anatomy of tooth patient's oral hygiene status, remaining tooth structure, periodontal condition of tooth, underlying bone condition should also be evaluated for better prognosis of the Fixed Dental Prosthesis.

Conclusion

Within the limitation of the study the following conclusion can be made:

- Mean marginal gap of cobalt chromium fixed dental prosthesis made by conventional lost wax method is 55.25 µm.
- Mean marginal gap in all cobalt chromium crowns fixed dental prosthesis fabricated by Direct Scanning Computer Aided Milling is 33.05 µm and FDPs fabricated by Lab Scanning Computer Aided milling is 28.55 µm.
- Mean marginal gap in cobalt chromium crowns fixed dental prosthesis made by Rapid Prototyping Method is 37.19 µm.
- All four groups has Marginal Discrepancies are within the clinical parameter which is 140 µm.
- Vertical marginal fit value was high in Conventional Lost Wax Method (55.25 ± 6.46) followed by Lab Scanning Rapid Prototyping Group, Direct Scanning Group And Lab Scanning Group. Statistically, significant difference was present in Vertical marginal fit value among all the Groups.

Further studies comparing these materials stimulatory oral condition are requiring.

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