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A comparative evaluation in marginal accuracy of implant supported metal-free FPDS fabricated using two different cad-cam systems - An in-vitro study.

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Abstract

This study aims to evaluate the marginal accuracy of implant supported metal free prosthesis of a newly available commercial CAD-CAM material (PEEK) fabricated using combination of one intraoral scanner with two milling machines. An implant analogue integrated master model was fabricated. Ten digital impressions of scan bodies were taken using Trios 3Shape Intra-oral Scanner. A three-unit metal free full contoured FPD was designed using 3Shape CAD software and milled using two five-axis milling machines: ROLAND DGSHAPE DWX-52D (dry milling) and ARUM 5X-450 (wet milling). A total of 20 samples (10 for each group) were fabricated and marginal gap was measured between the restoration margin and the abutment finish line using a

stereomicroscope (Nikon SMZ745T) under 50X magnification. Mean marginal gap was calculated by measuring marginal gap at six predetermined points on abutment finish line (mid-buccal, mid-lingual and all four-line angles). Shapiro-Wilk test was done to show that the data were normally distributed (P>0.05). Com parison of mean marginal gaps between the two study groups was done using independent t-test (P < 0.0 5).

The mean marginal gap in Group A was found to be 54.51µm, whereas the mean marginal gap in Group B was found to be 83.45µm respectively. A statistically significant difference in overall mean marginal gaps (P=0.002) between Group A and Group B was found. The marginal accuracy of both the CAD-CAM systems studied were within the clinically acceptable range, with dry milling found more accurate than wet milling.

Keywords: Implant supported FPD, Marginal accuracy, CAD-CAM, PEEK.

Introduction

The main criteria for successful dental implant treatment are function and esthetics. For that, interim restorations are selected for the time period between the loading of implant and the definitive prosthesis insertion[1] which can either be pre-fabricated or custom made. Poly methyl methacry late (PMMA) resins and bis-acryl composite resins are most commonly used materials for custom-made prostheses.[2] The CAD-CAM technology uses pre-fabricated blanks of high-density composite or PMMA polymer.[3] Polyetheretherketone (PEEK) is also used for CAD-CAM restorations which is a poly aromatic semi crystalline thermoplastic polymer. Modified version of PEEK known as Bio HPP has been used in dentistry lately.[4] It exhibits elasticity similar to human bone, relieving stress from the abutment-prosthesis interface.[5]

Success of a fixed prosthesis depends upon many factors and the marginal accuracy is one of them[6]. Theoretically, marginal fit can range from 25 to 50 m, however in some research, deviations more than 120 m are considered acceptable.[7,8,9] A tight fit amid the abutment and the restoration is closely related to the long-term clinical success of implant-supported prostheses.

An unacceptable marginal gap leads to bacterial growth in the peri-implant area leading in the loss of bone support.[10] The probable cause for marginal discrepancy are impression making and prosthesis fabrication.[11] Better vertical marginal fit is obtained with full digital manufacture of a whole crown using intraoral scanners and milling machines than with crowns made using traditional methods.[12]

Commercially available scanners include optical scanners and mechanical scanners. Optical scanners use triangulation principle to record the 3D structures.

Mechanical scanners measure the 3D structure mechanic ally by using a contact sensor around the object. The use of scanner has also extended to implants with indirect or direct work flow. Making a traditional implant impression and digitising it in the lab make up the indirect workflow. In the direct process, intraoral scan body and an intraoral scanner (IOS) are used to produce digital scan intraorally.[13] Both the extraoral and intraoral scanners employ various approaches, such as wavefront sampling, confocal microscopy, triangulation, interferometry, structured light, video and laser, so that the raw data can be collected in form of point clouds. The characteristics of the surface or surfaces to be scanned can affect digital implant impression accuracy, even though the particular IOS system can affect the overall quality of the data to be digitised.

A method of repair fabrication known as milling or machining makes use of subtraction manufacturing from huge solid blocks. Milling machines are divided based on the number of axes in the machine[14] as 3-axis machine, 4-axis machine and 5-axis machine.[15]

The compatibility and efficiency of intra-oral scanner with other milling machines is questionable.

Hence, the present in-vitro study was aimed to evaluate the marginal accuracy of implant supported metal free prosthesis of a newly available commercial CAD-CAM material (PEEK) fabricated by one intraoral scanner and two milling machines using CAD-CAM systems.

Materials and methods

This study was carried out in Department of Prosthodontics, Crown and Bridge and Implantology, Himachal Institute of Dental Sciences, Paonta Sahib.

The equipment used in the study are: Intra oral scanner (TRIOS 3Shape, Copenhagen, Denmark), Computer aided Five-axis Milling machines: A - DGSHAPE DWX - 52D (ROLAND, USA) and B - ARUM 5X-450 (ARUM Dentistry, Korea), Stereo-microscope (SMZ 745T, Nikon, USA), 50 x magnification.

Fabrication of master die

For the study, an implant analogue integrated master die was fabricated. Modelling wax was poured in a metal mold (38 mm x 27mm x 36mm). A dental surveyor was used to place two regular analogs (Osstem) in the wax filled metal mould with implant analogs and Osstem regular impression copings (open tray) and positioned 1mm subcrestally in their respective locations. One analog was placed vertically and the other analog was placed at 15° respectively. Wax was melted and poured in the space around the implants to secure its position. Upon cooling of wax, impression coping was released from the surveyor. The prepared die was then invested in plaster of Paris. Dewaxing and acrylization was done in conventional manner.

Fabrication of samples

For the fabrication of the experimental samples, 2 short TS scan bodies were tightened over the analogs by hex driver and digital impression of the scan bodies were taken using Trios 3Shape Intra-oral Scanner (Fig.1). A total of ten scans of the master model was taken by an experienced dentist.

A three-unit metal free full contoured FPD involving teeth number 45, 46 and 47 was then designed using 3Shape CAD software (Fig.2 and Fig.3). Two transfer abutments, one straight and one Type A helix was selected in the CAD software for designing of the samples accordingly (Fig.4).

The STL (standard tessellation language) data was transferred to two computer-aided milling machines (DG SHAPE DWX-52D and ARUM 5X-450).

- Group 1: milling machine A (DG SHAPE DWX-52D) (Fig.5).
- Group 2: milling machine B (ARUM 5X-450) (Fig.6).

Ten experimental models were milled for both groups. All the samples were fabricated in PEEK material. (Fig.7)

Testing of samples

Marginal gap was measured in micro-meter (µm) for all the samples of both the experimental groups by measu ring the vertical space between the restoration margin and the abutment finish line (Fig.8) at 6 pre-determined points: mid-buccal, mid-lingual and all four-line angles using a stereomicroscope (Nikon SMZ745T) under 50X magnification. The sample contact was kept parallel to the microscope's optical axis. The collected data was tabulated and was statistically analysed.

Statistical analysis

Using SPSS, the statistical analysis was carried out. Normality was done using Shapiro-Wilk test which exhibited a normal distribution of the data. Comparison of mean marginal gaps (in µm) between the two study groups was done using independent t-test. The P value for the current study's level of significance was chosen at less than 0.05.

Results and discussion

Marginal gap values of Group A ranged from 0.00µm to 338.31µm, while marginal gap values of Group B ranged from 0.00µm to 291.49µm respectively. Graph 1 shows mean marginal gap in Group A, while Graph 2 shows mean marginal gap in Group B. Table 1 and Graph 3 shows the comparison of overall mean marginal gaps (in µm) between the study groups. There was a statistically significant difference in overall mean marginal gaps (P=0.002) between Group A and Group B.

The mean marginal gap was significantly higher in Group B (83.45µm) than that observed in Group A (54.51µm).

The marginal fit of the prosthetic components has a significant impact on how long implant-supported restorations last. A poor fit of the interim prosthesis can lead to mechanical problems, fracture, ceramic chipping, loss of retention, and other problems. For fixed dental prostheses, clinically acceptable misfit levels have been established around 50–120 µm.[16] A marginal gap of under 200 µm is said to be clinically acceptable for computer-based restorations.[17]

Manufacturing methods and materials can influence the fit and adaptation of implant-supported frameworks. Studies have shown better marginal fit using computer-aided design and computer-aided manufacturing (CAD/ CAM) technology when compared with conventional manufacturing techniques. In spite of the growth of CAD/ CAM technology, digital workflow flaws still exist[18] because it is subject to various device types and manufacturing variables.

According to a study conducted by Jemt T[19] and Book K[20], marginal misfit of implant supported prosthesis less than 150µm has been considered clinically acceptable. The maximum clinically acceptable marginal fit value of dental restorations created using CAD-CAM technology, according to McLean and von Fraunhofer[21], was 120 m. The comparison between five-axis milling machines using same scanner and same design is not yet studied. In this study we compared marginal accuracy of PEEK three-unit implant supported provisional prosthesis fabricated using one intra-oral scanner and two five-axis milling machines. The study was carried out in two groups in which one group included milling machine A (with dry milling condition) and other group included milling machine B (with wet milling condition).

According to a study conducted by Pasali et al[22] the mean marginal gap of implant-supported metal copings fabricated by a five-axis milling machine was 81µm, which is similar to Group B in our study. Park JY et al[23] conducted a study to evaluate marginal discrepancy in interim implant restoration fabricated by CAD-CAM system using a four-axis milling machine and found the mean marginal discrepancy to be 58.02µm, which is similar to Group A in our study. Seker et al[24] reported a mean marginal discrepancy of 57.08µm for milled PMMA crowns using a lab scanner, 3Shape CAD soft ware and a five-axis milling machine, which correlated with the result in our study. Four steps are involved in the milling process: rough outside surface milling, fine outside surface milling, rough inside milling after 180° rotation of the workpiece; and fine inside milling.[25] Guo C et al[26] conducted a study to verify that dry milling PEEK using a five-axis milling machine with suitable parameters can significantly improve the surface finish quality and decrease surface defects. They discovered that the cutting tool's force and wear were minimal during dry milling because the milling of PEEK only required a very small amount of cutting force and wear of the tool's material, tungsten carbide, in comparison to milling metals. Beleidy M and Ziada A[27] evaluated marginal accuracy on PEEK crown fabricated using CAD/CAM technique and a five-axis dry milling machine. They found the mean marginal accuracy to be 59µm, which correlates with Group A in our study.

The quick fabrication time of CAD-CAM has been mentioned as a benefit over the traditional approach.[28] Unfortunately, it is expensive, and the accompanying machining, designing, and scanning operations have a negative impact on the precision of the final pro stheses.[29] The benefit of subtractive manufacturing is that it enables the mass manufacture of extremely accurate restorations.[30]

Moreover, the colour stability and slight adaptability acquired through milling PMMA blocks are superior than those obtained using the traditional method.[31] However, the milling process has some draw backs, such as low accuracy brought on by positive and negative bur diameter errors, excessive material consumption, and bur usage when milling.[32] The possible limitation of this study is that thermo cycling was not performed on the samples before measuring the marginal gap.

Fig 1: Trios 3Shape Intra-oral Scanner.

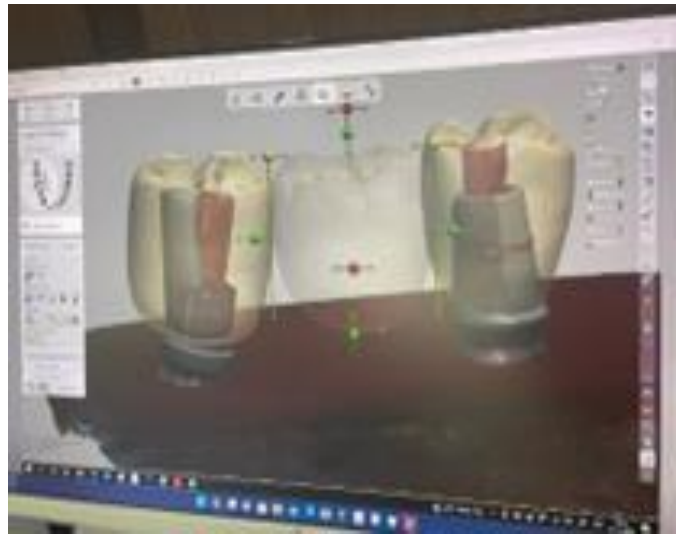


Fig 2: Designing of sample.

Fig 3: Three-unit full contoured metal free FPD.

Fig 4: Master die with transfer abutments.

Fig 5: Milling machine A (DG SHAPE DWX-52D).

Fig 6: Milling machine B (ARUM 5X-450).

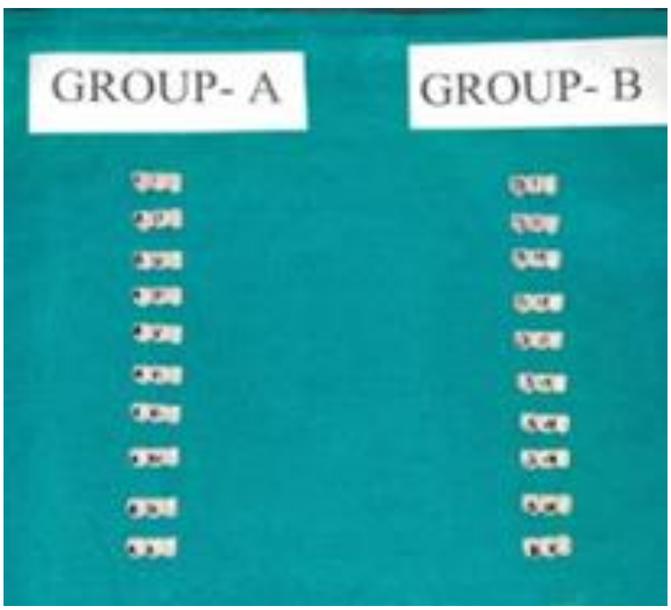


Fig 7: Experimental samples.

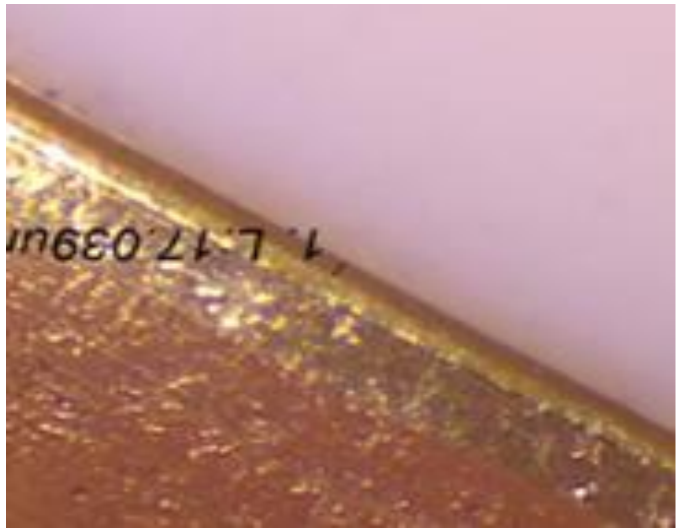


Fig 8: Marginal gap between crown margin and abutment finish line.

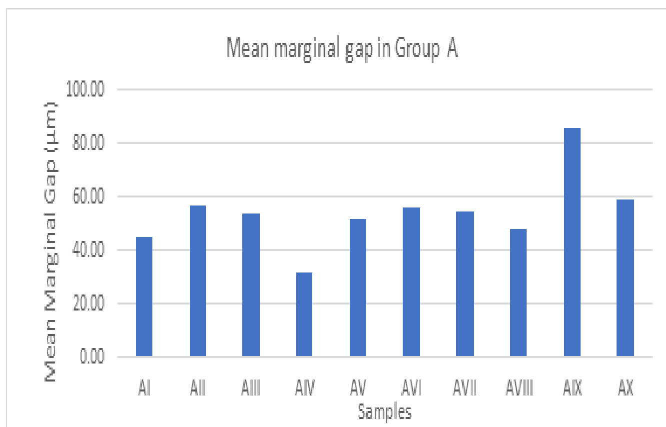
Tables

Table 1: Comparison of overall mean marginal gaps.

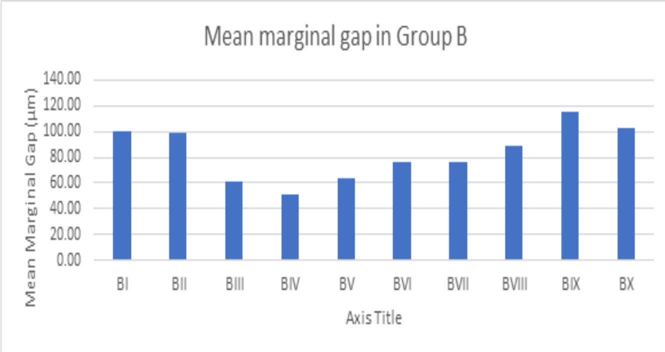
	Group	N	Mean (µm)	Std. Deviation	P value
Overall	Group A	10	54.5150	13.53952	0.002*
Marginal Gap	Group B	10	83.4500	21.13155	

*Statistically significant (P<0.05, Independent t-test)

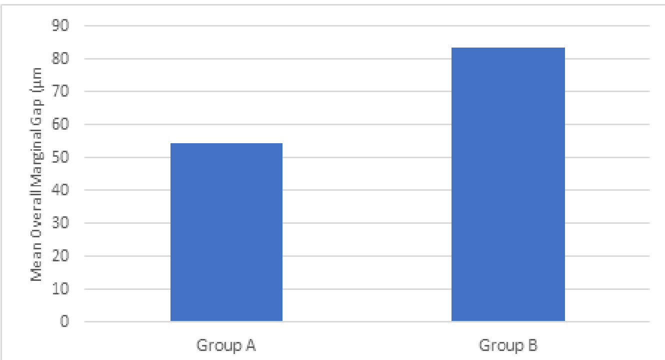
Graph 1: Showing mean marginal gap of all samples in Group A.



Graph 2: Showing mean marginal gap of all samples in Group B.



Graph 3: Showing mean marginal gaps (µm) between the study groups



Conclusion

Within the limitations of this study, following conclusions were drawn.

The marginal accuracy of both the CAD-CAM systems studied were within the clinically acceptable range. The CAD-CAM system with milling machine DGSHAPE DWX-52D was found to be more accurate as compared to the CAD-CAM system with milling machine ARUM 5X-450 in terms of marginal accuracy. The dry milling condition was found to be better than wet milling condition for fabrication of PEEK CAD-CAM implant supported prosthesis.

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