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Comparison of the occlusal precision of Polymethylmethacrylate (PMMA) provisional crowns fabricated using CAD/CAM Milling and 3D Printing method

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Abstract

Objectives: The aim of this study was to evaluate and compare the occlusal precision of Polymethylmethacrylate provisional crowns fabricated using CAD/CAM Milling and 3D Printing method.

Materials and methods: In this study, tooth preparation on Mandibular Molar was done on 12 patients, followed by printing and milling of the provisional crowns and thereby, intraoral scanning of pre and post adjustment of the provisional crowns. 24 Provisional crowns were grouped as 12 Milled and 12 Printed provisional crowns. After all the scans are completed, the alignment and superimposition of the STL files was done.[2] The programme calculated the difference in millimetres between the crowns. For continuous data, Mean and Standard Deviation was obtained (SD). For comparison of Milled and Printed Crowns, Independent T Test was applied.

Results: When comparison between Milled and Printed crown (Analysis A) at P1, P2 and P3 was performed, it was observed that at P1 the difference in Mean was .03983, at P2 it was .12183and at P3 it was observed to be .02083respectively and this difference in Mean at P1, P2 and P3 was not statistically significant (p>0.05). When comparison between Milled and Printed crown (Analysis B) at P1, P2 and P3 was performed it was observed that the difference in Mean was --.12958, -.06342 and -.08417respectively and this difference in Mean was statistically significant for P3 (p<0.05) whereas there was no statistically significant difference at P1 and P2 (p>0.05)

Conclusions: Within the limitations of this in vivo study, there was no difference found between the occlusal precision of the Milled vs Printed provisional crowns. Additive and the subtractive methods show varied accuracies depending on the equipment specifications.

Keywords: Intraoral scanner, Provisional crowns, Milled and printed temporary crowns

Introduction: Fixed prosthetic therapies need the use of temporary restorations.[1] Dental abutments must be shielded from the oral environment and their interaction with neighbouring and opposing teeth maintained during the time between tooth preparation and final restoration delivery.[2] Furthermore, provisionals can be thought of as a model that is used to make functional, occlusal, and aesthetic modifications so that the final restoration can be a permanent duplicate of them.[3]

Interim restorations are necessary for the preservation of oral function and aesthetics as well as for the protection of pulpal and periodontal tissues.[4] Fixed prosthetic therapies need the use of temporary restorations. Dental abutments must be shielded from the oral environment and allowed to continue to function as an antagonistic relationship with neighbouring and antagonist teeth during the interim between tooth preparation and final restoration delivery. Furthermore, provisionals can be thought of as a model that is used to make functional, occlusal, and aesthetic modifications so that the final restoration can be a permanent duplicate of them.[5]

There are two types of interim crown fabrication methods: Direct and Indirect. The indirect approach fabricates the interim crown on a stone cast before delivering it to the oral cavity, whereas, the direct method fabricates the interim crown directly on the prepared tooth.[6] The direct approach has drawbacks while being quick and simple. The tooth pulp may sustain thermal stress as a result of the exothermic heat generated during resin polymerization in the direct approach.[7] Furthermore, the leftover resin monomer may damage the oral mucosa, leading to allergic stomatitis or lichenoid reactions. Dimensional differences are brought about by this shrinkage in the occlusal, interproximal, and marginal areas.[4]

Because the polymerization process is carried out on a stone cast in the indirect manner, there are no longer any thermal or chemical dangers to the tooth or mucosa, and the crown's fit to the tooth is enhanced.[4]

Patients find the conventional processes inconvenient and the accuracy of the impressions is an issue. As a result, digital technology developed.[6] It employs both subtractive and additive methods. The three primary stages of the digital workflow are data collecting, data processing, and manufacturing methods. It is imperative to obtain a provisional restoration with precise occlusal surface and contacts in order to minimise the necessity for extensive intraoral modifications, which may jeopardise the material's quality and thickness.[5]

CAD/CAM Milling is an example of a subtractive process, while 3D Printing is an example of an additive approach.[5] CAD/CAM milling is a process of obtaining the desired form by grinding block or disc materials. Depending on the cutting device's diameter, this could lead to wastage of material, requires careful maintenance, and have the drawback of having low micro repeatability in concaved regions.[8]

The additive manufacturing system, on the other hand, is a way of producing a product by stacking up powder and liquid ingredients in a sequential order.[7] One of the benefits of 3D printing is that it can produce numerous products at once and can produce models and prostheses that are desired while using the least amount of material.[9] There is a scarcity of studies, comparing the accuracy of CAD/CAM vs. 3D Printed reproduction of the occlusal surface.[5]

The study's purpose was to compare the occlusal precision of CAD/CAM milled against 3D printed temporary crowns based on the same digital CAD design.[10] A secondary goal of the research was to assess occlusal precision by comparing CAD/CAM milled and 3D printed provisional crowns before and after removing occlusal prematurities.[11]

Material and method:

Ethical approval as well as the protection of the rights of the patients was done in this research before starting the study. Prior to starting the research work, **written informed consent** was taken from the patients/subjects.

Sampling technique used was Convenience Sampling Technique and Sample size was 24 samples (12 samples in each group).

GROUP 1: CAD/CAM Milled provisional crowns (n = 12)

GROUP 2: 3D Printed provisional crowns (n = 12)

This study was conducted at the Department of Prosthodontics and Crown and Bridge and Implantology, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y. Patil Vidyapeeth, Pimpri, Pune. Patients were selected from Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y. Patil Vidyapeeth, Pimpri, Pune. Subjects included in the study were 18 years of age or older with no gender distinction, absence of active periodontal disease, good oral hygiene, mandibular molars which are vital or endodontically treated, with no periapical pathology, prosthetically prepared or unprepared. Subjects not included in the study were having primary teeth or teeth lacking an antagonist tooth.

The Mandibular molar was prepared for a full ceramic crown with reduction of 1.5 mm occlusally and axially and 1 mm of shoulder margin was given and retraction was done (Figure 1). Scanning of the prepared tooth and its opposite quadrant with the intraoral scanner (3Shape, Trios 4, Denmark) was done and both the models were printed. Then, the STL file of the tooth preparation was generated and this data was used by the CAD software to design the restoration.

1st STL file was sent to the CAD/CAM Milling machine (CORITEC 150i PRO, Germany) and 2nd STL file was sent to the DLP 3D Printer (SPRINTRAY PRO 95, USA). PMMA blocks were used in the CAD/CAM Milling machine. PMMA resin was used in the 3D Printer. Supporting pins are equivalent to the sprue that is used in the fabrication of metal crowns or framework. To ensure that the measurements are accurate, the supporting pins were not placed on the occlusal surface, but in the vestibular area. Once the Milling and Printing was done, supporting pins were removed and the crowns were finished[12] (Figure 2).

3 points were selected for the correct superimposition of the subsequent STL files. 1 point was on facial surface of the design of provisional crown 2 were on cervical areas of the scan of the neighbouring teeth (Figure 3). The reason for selecting these 3 points is that these will form a triangle and they were used to superimpose the STL file of the original CAD design with the STL file of the scanned crown that was fabricated.

Scanning of the crowns was done extraorally with the Lab Scanner (3Shape, Trios 4, Denmark) and the STL file was obtained. ANALYSIS A: The STL file obtained above, was superimposed with the STL file of the original CAD design in the CAD software, in order to evaluate the occlusal accuracy after fabrication of the crown. This was done for both the CAD/CAM milled and 3D Printed provisional crowns and it was compared. Then, the crowns were cemented intraorally with Try-in paste. Scanning was done before removing the occlusal prematurities and the STL file was obtained. Articulating paper (Maarc, 40µm) was used and the premature contacts were checked and corrected. Scanning was done after removing the occlusal prematurities and the STL file was obtained. ANALYSIS B: STL files of both pre and post adjusment provisional crowns were superimposed in the CAD software and then the extent of adjustment performed was measured. (Figure 4)

For both analysis, 3 points were selected for checking the occlusal precision, they were: P1: Buccal cusp, P2: Lingual cusp, P3: Central fossa. Once the alignment and superimposition of the STL files was done, a 2D cross-section was performed (Figure 5). The blue cursor was slid along the occlusal plane and measurements of discrepancy at points P1, P2, P3 was recorded. The programme calculated the difference in millimetres between the crown before and after removing the occlusal prematurities. This was done for both the

CAD/CAM milled and 3D Printed provisional crowns. Then, the difference between the Pre and Post occlusal prematurities of the Milled with 3D Printed provisional crowns was compared.

The data was obtained and entered in Microsoft Excel Version 13. The data was subjected to statistical analysis using IBM Statistical Package for Social Science version 21. For continuous data, Mean and Standard Deviation was obtained (SD). For comparison of Cad design versus extraoral scanning between Milled and Printed Crowns Independent T Test was applied and for comparison of Milled and Printed Crown for pre adjustment and post adjustment) at P1, P2 and P3 Independent T test was applied. All the statistical tests were applied keeping confidence interval at 95% and ($p<0.05$) was considered to be statistically significant.

Figure 1 – Retraction

Figure 2 – Milled and Printed Provisional Crown

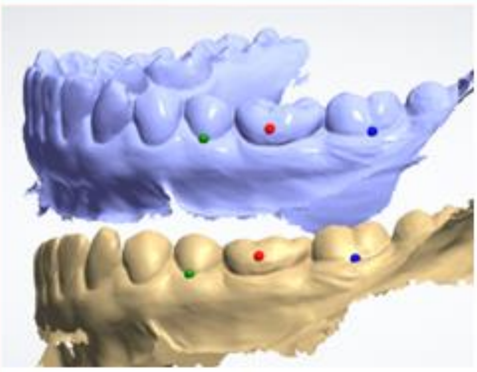


Figure 3 – 3 points for superimposition

Figure 4 – Superimposition of pre and post adjustment of Crown

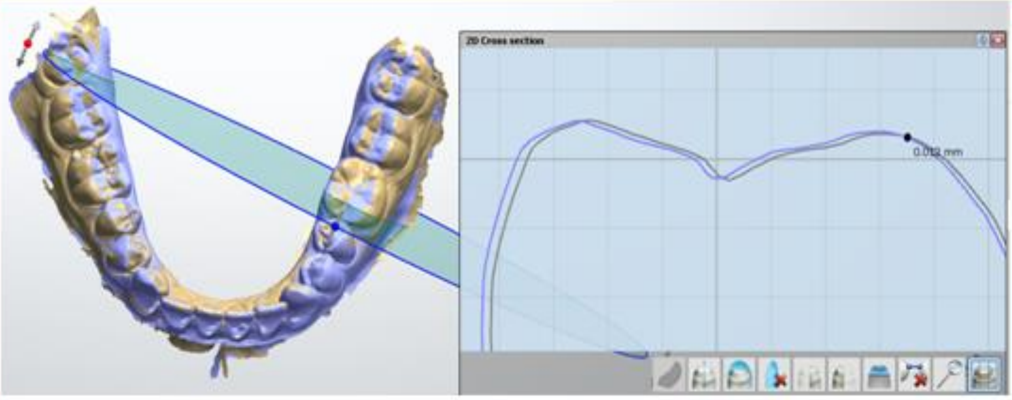
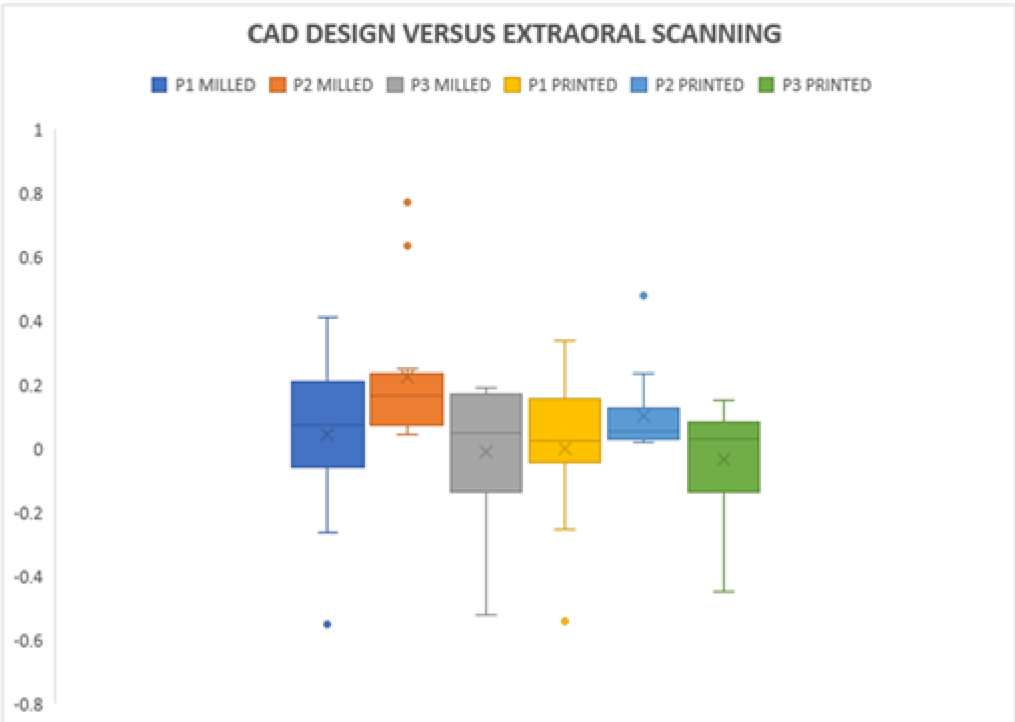


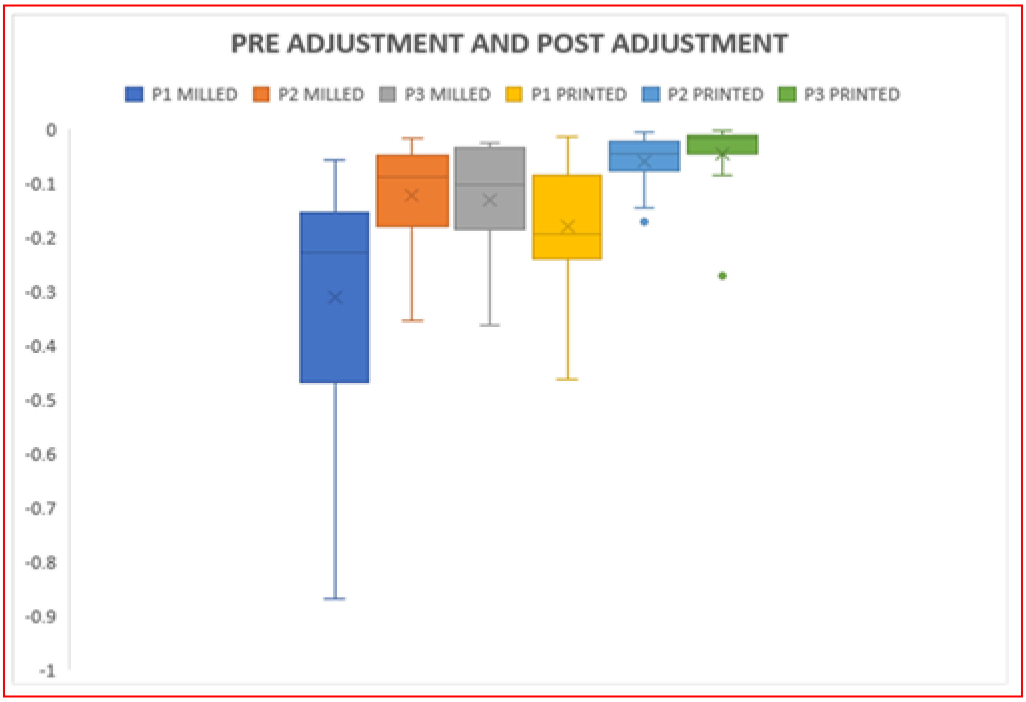
Figure 5 – 2D cross section at Mesiobuccal cusp (Point P1) of Printed crown

Results

Graph 1: Intergroup comparison between Milled and Printed crown (Cad design versus extraoral scanning) at P1, P2 and P3



Graph 2: Intergroup comparison between Milled and Printed crown (pre adjustment and post adjustment) at P1, P2 and P3



Discussion: Interim restorations are necessary for the preservation of oral function and aesthetics as well as for the protection of pulpal and periodontal tissues.[4] There are two types of interim crown fabrication methods: Direct and Indirect.[4] Digital technology was developed for temporization which was fast and convenient. It employs both subtractive and additive methods.[13]

Making temporary crowns and bridges is arguably one of the operations that stands to gain the most from the most recent advancements in digital technologies.[14] In contrast to the large-scale, intricate full-arch structures that need 3D printing and milling, such as orthodontic appliances, surgical guides, and dental casts, single unit crowns can be printed and milled in as little as 20 minutes.[15]

There is a scarcity of studies, comparing the accuracy of CAD/CAM vs. 3D Printed reproduction of the occlusal surface. The study's purpose was to compare the occlusal precision of CAD/CAM milled against 3D printed temporary crowns.[16]

In the present study, tooth preparation for all-ceramic crown on Mandibular Molar was done, followed by intraoral scanning of the prepared tooth and its opposite quadrant. Models were printed and then, the designing of the crown was done, followed by printing and milling of the provisional crowns. Then, the crowns were placed on the model and scanned with the lab scanner and the STL file was obtained, which was compared with the STL of the designed crown. Then, the crowns were placed intraorally and the scanning was done. High points were adjusted and again the scanning was done. After all the scans were completed, the alignment and superimposition of the STL files was done, and a 2D cross-section was examined. The blue cursor in the software was slid along the occlusal plane and the measurements of discrepancy were recorded. The programme calculated the difference in millimetres. Then, the difference between the Pre and Post occlusal prematurities of the Milled with 3D Printed provisional crowns were compared.

When the occlusal surface of the original CAD design was compared with the occlusal surface of the extraorally scanned Milled and Printed crown, the difference in Mean was found to be not statistically significant (p>0.05). In other words, there was no difference found between the occlusal precision of the original CAD design and the occlusal precision of the extraorally scanned Milled vs Printed provisional crowns.

When the occlusal surface of the pre and post adjusted Milled and Printed crowns were compared, the difference in Mean was found to be not statistically significant (p>0.05). In other words, there was no difference found between the occlusal precision of the pre and post adjusted Milled vs Printed crowns. But, the mean values obtained for the occlusal precision of the printed crowns were less than the milled crowns which means that printed crowns needed less adjustments than milled crowns.

It may have been difficult to precisely design rugged surfaces or sharp edges, like margins, due to the limitations of the available cutting tool diameters and range of motion, as noted in the study by Achsah Ann Thomas et al in 2023, necessitating more adjustments in the milled crown. Modifications such as changing the object's shape, modifying the spacer parameter, or eliminating interferences while fitting the restoration can be done to address such milling problems. But, these methods widen the internal gaps.[17]

The efficiency of printing as compared to milling is demonstrated by the fact that a single blank may mill about 20 crowns at a time, while a single print can create up to 100 crowns. One major disadvantage of milling is that it requires programming tool paths, which adds time to the machining process. Errors may also occur during certain software operations, such as alignment. The accuracy of the occlusal surface may be impacted by data conversion, processing, and structuring of an STL file, among other factors.[17]

Beom-Il Lee et al. conducted a comparison in 2021 between the postcuring time and accuracy (trueness and precision) of interim crowns made with digital light processing (DLP). There was a statistically significant difference in the exterior and intaglio surface accuracy in the ten-minute post-curing interim crown (10-MPCI), twenty-minute post-curing interim crown (20-MPCI), and thirty-minute post-curing interim crown (30-MPCI) groups. In the 10-MPCI group, the trueness and precision were the highest. The most accurate interim crowns were those with a 10-minute post-curing period. The current investigation adhered to a 12-minute post-curing duration. Optical diffraction, which happens during the irradiation of the interim crown in post-curing, is probably the source of statistical inaccuracies in the precision of the exterior and intaglio surfaces. Furthermore, as the post-curing period grew, UV-induced bending got worse, which had an impact on the accuracy of the exterior and intaglio surfaces' analyses.[11]

Duygu Karasan et al in 2021, investigated the accuracy of additive manufacturing (AM) in terms of internal fit of fixed dental prostheses (FDPs) fabricated with two AM technologies using different resins and printing modes (open system vs closed system) compared to milling and direct manual methods. Regarding their accuracy findings, the AM interim FDPs that were evaluated offered better substitutes for the milled ones. The manufacturing accuracy of interim FPDs was greatly influenced by the resin, printing mode, and AM technology employed. A digital light projector with varying resolutions is used by DLP 3D printers, and this directly affects the printer's accuracy. The laser beam used in 3D printers travels through each layer, and the diameter of the laser spot determines the printer's accuracy. Continuous photopolymerization of the resin produces a superior surface quality and renders the layers undetectable under a scanning electron microscope as stated and performed in the study by Duygu Karasan et al.[18]

In 2022, Giannetti L et al. conducted a comparison of the occlusal accuracy between 3D printed and CAD/CAM polymethylmethacrylate temporary crowns. When compared to milled crowns, the study revealed that the 3D printed provisional crowns had superior occlusal surface dimensional accuracy. The faithful replication of the specific prosthetic surfaces may be affected by the milling machine's bur diameter and the range of motion. On the other hand, the occlusal table's intricate geometries appeared to be accurately replicated by the 3D printer. A 5-axis milling machine with burs ranging in diameter from 1 to 1.5 mm was used in this current study. One could argue that more detail and precision would be possible with smaller bur sizes. Smaller burs, on the other hand, were not recommended when using PMMA as they could lead to material overheating, bur adhesion, and bur breakage. It should also be taken into account that the CAD design has a digital surface that is difficult to completely replicate. However, 3D printers operate through the deposition of material, yielding an output that closely resembles the CAD design. The printing technology itself is another factor that contributes to the high level of precision; the data from the 3D computer models are divided into cross sections and converted into numerical files in the form of virtual trajectories that direct the printer during manufacturing. This makes it easier to create prosthetic components with exact occlusal geometry than with the subtractive method.[5]

The fit of temporary crowns made with 3D printing was assessed and compared with that of milling and conventional techniques in the research by Hang-Nga Mai. The results from the milling and 3D printing processes were more accurate than those from the conventional method. When compared to other methods, the 3D printing process proved to be the most precise in the occlusal region. Cutting burs are used in the milling procedure to produce an object in a subtractive manner. As a result, in fabrication, the bur size and cutting motion range are constraints. When an object has rough surfaces or sharp edges, the milling procedure cannot replicate the object. In some cases, the object image's shape should be changed to make the milling process easier. The automatic relief function of dental CAD software, which is used to create restorations, uses a particular algorithm to convert the point clouds of the image into one that can be milled. While this function is necessary for practical use, the procedure could cause a significant deviation in the occlusal region and worsen the restoration's fit. Whereas, layer by layer, materials are applied in an additive manner using the 3D printing technique. As a result, this technique makes it possible to create items with intricate structures without the need for deliberate design adjustment.[4]

A further review should be done, taking into consideration, not only single crowns, as in this study, but long-span FPDs as well.

Conclusion: Within the limitations of this in vivo study, the following conclusions were drawn:

1. There was no difference found between the occlusal precision of the original CAD design and the occlusal precision of the extraorally scanned Milled vs Printed provisional crowns.
2. There was no difference found between the occlusal precision of the pre and post adjusted Milled vs Printed crowns
3. Additive and the subtractive methods show varied accuracies depending on the equipment specifications.

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