Trueness, Precision, fit of FDM printed vs multilayered milled dental restorations– An in vitro study.

Keywords

Fused Deposition Modelling, subtractive manufacturing, Fixed Partial dentures, Standard Tessellation Language

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Abstract:

Zirconia is extensively used for fixed dental prostheses (FDPs) owing to its high strength, biocompatibility, and favorable esthetics. Conventionally, zirconia FDPs are fabricated using subtractive manufacturing (SM) through CAD/CAM milling. Recently, additive manufacturing (AM), particularly fused deposition modelling (FDM), has gained attention as a potential alternative due to reduced material wastage, cost efficiency, and simplified fabrication. However, evidence regarding the accuracy of FDMfabricated zirconia FDPs remains limited.This in vitro comparative study evaluated the marginal fit, internal adaptation, trueness, and precision of zirconia fixed partial dentures fabricated using FDM and SM techniques. Twenty threeunit zirconia FDPs were fabricated from a single STL dataset, with ten specimens produced by FDM printing and ten by 5axis milling. All specimens were sintered under standardized conditions. Threedimensional deviation analysis was performed using Geomagic Control X software, and root mean square values were calculated. Statistical analysis was conducted using ttests and oneway ANOVA.Both groups demonstrated clinically acceptable marginal fit. FDM-fabricated FDPs showed superior precision, while milled FDPs exhibited higher intaglio surface trueness. These findings suggest that FDM is a viable alternative for zirconia FDP fabrication, warranting further clinical evaluation.

Background of the study: According to earlier researchers, printed zirconia crowns are reported as clinically acceptable, but milled crowns are more accurate. This study compares zirconia fixed partial denture (FPD) created using (FDM) fused deposition modeling technique, with traditionally milled FPDs.

Aim: To compare the internal fit, trueness, and precision of zirconia fixed FPDs manufactured by using FDM (Fused Deposition Modelling) and the milling technique.

Study Design: An in vitro comparative study evaluating twenty zirconia FPDs created using FDM (Fused Deposition Modelling) and Subtractive Manufacturing (SM) techniques.

Received: 11.11.2025
Accepted: 19.12.2025
Doi: 10.1922/EJPRD_2865Rengasamy14

Language) file was saved for designing threeunit zirconia FPDs. From that STL file, 10 threeunit zirconia FPDs were FDMprinted with a filament, and 10 were milled using a 5axis machine. All FPDs were sintered and scanned with the 3D MAKERPRO scanner. The (Geomagic Control X - Version) software is used to evaluate fit, trueness, and Precision. Results: Regarding internal adaptation, the findings showed a significant difference ($p < 0.05$) between FDM and SM FPDs, with marginal area (p 0.005*). In terms of trueness, no significant differences were observed between the two test groups ($p = 0.008$). Precision, expressed as RMS ± SD (μm), revealed statistically significant differences between subtractive and additive manufacturing fixed dental prostheses ($p = 0.0005$).
Conclusion: FDMprinted FPDs exhibited better overall precision and cameo surface trueness, while milled FPDs showed higher trueness in the intaglio surface.
Clinical relevance to interdisciplinary Dentistry: The outcome of this study emphasizes on the cost effectiveness and limited time duration of FDMprinted zirconia FPDs compared to milled zirconia FPDs

Introduction:

Monolithic zirconia has become an increasingly favoured material in dentistry for fabricating single crowns, short- and longspan fixed dental prosthesis, and completearch restorations. [1–3] Its outstanding aesthetic appeal and mechanical strength make it a dependable choice for singletooth restorations. Traditionally, zirconia restorations are produced through subtractive manufacturing (SM), where a blank is milled using computeraided design and computeraided manufacturing (CAD/CAM). [[4] This automated system enhances precision, reduces human error, and mitigates many drawbacks associated with the conventional lostwax technique. Aestheticdriven applications such as anterior crowns and fullmouth reconstructions, implantology using extremely biocompatible and aesthetically pleasing zirconia implants, and orthodontics using personalized aligners and retainers are just a few of the multidisciplinary uses of additively fabricated zirconia oral restorations. Across several dental specialties, the combination of CAD/CAM and additive fabrication enables the efficient, highly precise, and customized production of a variety of zirconia restorations, improving patient satisfaction and clinical results.[50]

Zirconia blocks suitable for milling are available in two primary forms: entirely sintered for hard milling and semisintered for presintered milling. Each method presents distinct challenges. Hard milling can result in crack formation, excessive wear on milling tools, prolonged processing times, and surface imperfections. Conversely, presintered milling necessitates an increase in the design dimensions to account for the shrinkage that occurs during the sintering process. Both approaches lead to substantial material waste, and the quality of the final restoration's surface and structure depends on the size of the milling tools and the number of axes in the milling machine.[4–7]

Additive manufacturing, represents a notable progression in the field of dental restoration technology. This method involves the construction of objects in sequential layers, which is subsequently followed by postprocessing and final finishing stages. There are several additive layered manufacturing methods available, such as thermoplastic extrusion, stereolithography apparatus (SLA), inkjet powder printing, selective laser melting, and thermojet printing. In dentistry, Additive manufacturing is increasingly utilized for producing temporary restorations, dentures, dental models, and metal prosthesis, with rising interest in its application for zirconiabased restorations.[7–9]

Additive manufacturing provides multiple advantages, including minimised material misuse, the capacity to create complex geometries, largescale production potential, and the removal of tool wear issues. Additionally, Additive manufacturing reduces residual stresses that often arise with traditional subtractive techniques. However, it is not without limitations, including dimensional inaccuracies, extended printing durations, inconsistencies in postprocessing methods across different technologies, layer shrinkage, and variations in the final product's physical and surface characteristics.[10,11] A systematic review conducted by Valenti et al[12] compared the mechanical properties of additive and subtractivemanufactured restorations, concluding that while both techniques achieved comparable results, milled restorations demonstrated superior flexural strength, even after aging.[12]

The overall success of additive manufacturing and subtractive manufacturing restorations depends significantly on their marginal fit and internal adaptation. Ensuring minimal marginal discrepancy is essential for maintaining periodontal and pulpal health, preventing cement degradation, and minimizing the risk of secondary caries and periodontal inflammation. In clinical practice, an acceptable marginal gap for indirectly fabricated restorations typically ranges between 50–120 μm, though a gap of under 25 μm is considered optimal.[13–15]

Several methods exist for assessing marginal fit and internal adaptation, including direct microscopic analysis, silicone replica techniques, laser videography, profilometry, Xray microtomography, and optical coherence tomography. However, there is currently no universally established standard for measuring these attributes. Most research on trueness and precision has primarily focused on milled restorations, while fewer studies have examined these factors in 3Dprinted restorations. [4245] Consequently, it remains unclear whether additive manufacturing zirconia fixed dental prosthesis can achieve the same level of accuracy as their milled counterparts.

Conversely, precision relates to the repeatability of measurement, whereas trueness refers to the variations or approximations of the measured values from the intended or planned values.[47] The research on the fit, precision, and trueness of additively manufacturing zirconia fixed dental prosthesis is limited due to the fact that the application of layered manufacturing for ceramic dental crowns is still in its early phases. [4146] This study evaluates and compares the properties of FDM printed zirconia fixed partial dentures with thoseof milled zirconia fixed partial dentures. Hence, the null hypothesis was There is no significant difference in marginal fit, trueness, and precision between zirconia FPDs fabricated by FDM printing and milling.

of milled zirconia fixed partial dentures. Hence, the null hypothesis was There is no significant difference in marginal fit, trueness, and precision between zirconia FPDs fabricated by FDM printing and milling.

Materials and Methods
Study design

A total of 20 zirconia fixed dental prosthesis were fabricated by using FDM (Fused Deposition Modelling) and the milling technique, with 10 FPDs produced through FDM and another 10zirconia FPDs through milling. A total sample size of 20 (10 per group) was **chosen based on pilot data. Using the pilot effect size (Cohen's d ≈ 1.10), this sample provides an estimated power of 64% to detect the observed effect at α = 0.05 (twosided). To achieve conventional 80% power for the same effect size would require ~14 specimens per group (total ~28). Therefore, the chosen N = 20 favours detection of large effects and may have limited power to detect smaller differences.[16,21,41,44] The experimental setup involved a Nissin dentate typodont (Kyoto, Japan), where the 35 and 37 were prepared, with 36 missing, for an allceramic zirconia fixed dental prosthesis (Fig. 1).**

Figure 1. Nissin Typodont with Mandibular Prepared teeth

The procedure involved using a typodont model, and a silicone impression was made before preparation to control volumetric reduction, manually performing the tooth preparation. A 2 mm occlusal reduction, 14 degrees overall Taper for premolars ,22 degrees overall Taper for Molars, 1.5 mm buccal and lingual reduction were carried out, ensuring a rounded shoulder finish line. After each step, the depth was verified using the putty index. All practical work steps were executed by the same operator (G.K.), with a supervisor overseeing each stage of the process. [49]

After preparation, elastomeric impressions were made and scanned by utilizing a 3Shape Scanner E1 (Niels Juels Gade 13,1059 Copenhagen, Denmark) to capture digital impressions of both the prepared teeth and the full arches. The resulting STL file (Standard Tessellation Language) was then converted into a resin die model with Hey Gears Model V2 Resin (Guangzhou, Guangdong, China). Additionally, a threeunit fixed dental prothesis was designed utilizing the Sirona inlab SW CAD software (Dentsply Sirona, North Carolina, [9,17,18]USA). and subsequently milled from a Multilayered Upcera Zirconia Blank12mm (Shenzen Upcera Dental Technology Co., Ltd, Liaoning, China) in a 5axis milling machine Sirona Inlab MCX5 (Dentsply Sirona, Erlangen, Germany) (Fig. 4) and sintered following the manufacturer's instructions (Fig 2).

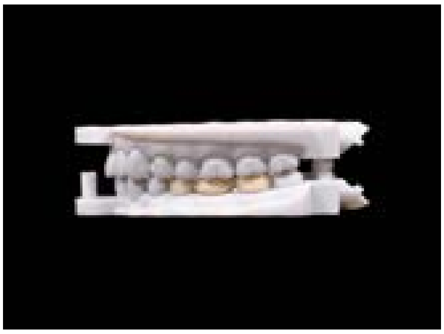


Figure 2. Hey Gears Resin Die Model with a Milled Sample

The CAD parametres of proximal contact, occlusal contact, dynamic contact are 25 microns, overall thickness - 1.5mm,Margin thickness 60 microns, width of ramp- 150 microns, angle of ramp60 degrees, cement spacer- 80 microns. For the FDM process, Zircopax (Zirconium Silicate filament, The Virtual Foundry, Inc.,Stoughton, WI, USA) was utilized in a Bambu Lab X1C printer (Tuozhu Technology Ltd, Shenzhen, China) to fabricate 10 fixed dental prosthesis). Despite not being dentalgrade zirconia, Zircopax is biocompatible, insoluble in water, acids, and alkali, and has a high Mohs hardness (7.5). Moreover, Zirconium silicate has two end uses: enamels and ceramic glazes.[51]

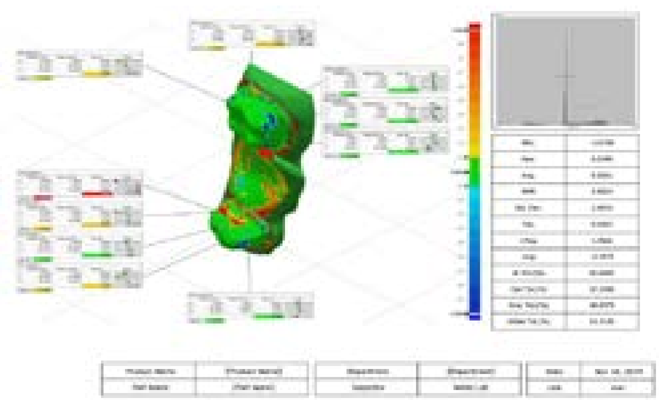
During printing cycle, the contours must be printed alternating clockwise and counterclockwise, heating and cooling speed should be reduced in all stages and the bridge must be less than 5cms in all directions and mustnot contain thin walls. The printing temperature - 220ºc, plate temperature - 50ºc, layer thickness- 0.08mm, infill- 100%. The printed bridge was first packed in fine refractory blast (aluminium oxide) powder in a refractory crucible following which it was heated to 482ºc and held at this temperature for 4 hours. This is called the debinding stage or process and then it is heated up to 1450ºc and then cooled slowly to room temperature. The second heating up to 1450ºc is called the sintering stage or phase.

Zircopax	**Dental zirconia**
Zirconium Silicate – 60% by weight	**Zirconium dioxide (ZrO_2)**
Quartz 1.02.0% by weight	**Yttrium oxide(Y_2O_3)**
Aluminium silicate 1.5% by weight	**Tracesother oxides**
Binding additive and polymer - trace	
Polylactic acid- < 20% by weight	

Courtesy Safety Data sheet of Zirconium silicate filament by Virtual Foundry

Opensource software, Orca Slicer, was used to slice the design before being transmitted via the cloud to the printer. Once printed, the zirconia fixed dental prosthesis was sintered following the manufacturer's recommendations (ISO 12836:2015). In general, the 10 milled fixed dental prosthesis were considered as the control group and the 10 from printing are taken as the test group. Scanning of the resin model as well as the milled and printed fixed partial dentures was done by using a 3D MAKERPRO (Table 1) scanner to evaluate the fit, precision, and trueness.

The internal fit of the zirconia bridges was quantitatively evaluated using a digital inspection protocol implemented in Geomagic Control X (Version 2022.1.0, 3D Systems Inc., Rock Hill, SC, USA). The procedure commenced with an initial alignment, in which the CAD model of the designed FPD was aligned with the CAD representation of the sample zirconia FPD using a global reference coordinate system. This step facilitated a standardized orientation of both datasets prior to fit analysis. Subsequently, a bestfit alignment was performed to refine the superimposition. This alignment utilized a leastsquares algorithm to minimize the overall deviation between the reference and the target models. The bestfit alignment ensured that the observed deviations were reflective of actual discrepancies in internal adaptation, rather than positional errors introduced during model registration. Following alignment, the internal fit was assessed using both threedimensional (3D) and twodimensional (2D) comparison analyses. Each method employed colorimetric deviation mapping to illustrate and quantify areas of fit discrepancy. The 3D comparison analysis was conducted across the regions—including the occlusal, axial, marginal, intaglio and internal overall surfaces—to evaluate spatial conformity between the bridge and die interfaces. Quantitative deviation metrics were derived to assess fit distribution across these zones [Figure 3].



In addition, 2D crosssectional analysis was performed by sectioning the models along the buccolingual plane. Marginal adaptation was assessed by calculating the linear discrepancies at the FPD margins, defined as theperpendicular distances between the outermost surfaces of the reference and target STL datasets at the section boundaries.

To evaluate trueness, the "measured data" scan of each fixed dental prosthesis was superimposed onto its corresponding CAD design. This process was conducted to identify deviations across various regions, including occlusal, axial, marginal, and intaglio surfaces, in addition to assessing overall accuracy. The root mean square (RMS) value was calculated following the procedure reported in the study.[19] RMS was displayed on a scale of values and showed the "measured data's"departure from the original design. where elevated RMS values suggest decreased trueness.

Precision evaluation was conducted by superimposing the "measured data" scan of the initial FPD from each experimental group onto the "measured data" scans of the other FPD within the same group. RMS values quantified deviations between FPD's, with greater RMS values signifying lower precision.[19]

Table 1 3D MAKERPRO Specifications

Credits – Shenzhen Jimuyida Technology co., Ltd (Shenzhen,China)

Measurements	SEAL
Resolution	0.05mm
Accuracy	0.01mm
Weight	200g
Ideal Object size	Small
Working distance	100200µm
Frame rate	10fps
Multiple scanning mode	Handheld+turntable
Single capturing range	56º1009mm

Statistical analyses

Statistical analysis was performed utilising GraphPad Prism version 8. The ttest was conducted to evaluate the mean differences between the FDM printed and milled groups in terms of marginal fit, internal adaptation, precision, and trueness. Comparisons between more than two groups were assessed using oneway analysis of variance (ANOVA) followed by appropriate post hoc tests to determine pairwise differences. A pvalue < 0.05 was considered statistically significant.

Results

Among the assessed regions for marginal fit and internal adaptation, the findings showed a significant difference (p 0.05*) between additive Manufacturing and Subtractive Manufacturing fixed dental prosthesis (Table 2), with the exception of the marginal area. For both groups, the largest gap was found in the axial region **(milled: 46.3±14.8µm, 3D printed: 63.58±14. 8µm). The ANOVA results** show a statistically significant difference (p = 0.05) in overall RMS values between subtractive and additive manufacturing, with an Fratio of 5.23.

Table 2 Marginal fit and internal adaptation mean ± standard deviations (SD) at four different measurement areas (µm)

Evaluated Surface	*Axial*	*Occlusal*	*Marginal*	*Intaglio*	*Over all*	*pvalue*	*Anova (f ratio)*	*95% CI*
Subtractive Manufacturing RMS ± SD	**46.3±14.8**	**21.7±7.6**	**27.9±10.6**	**31.4±7.3**	**44.3±2.9**	**0.05***	**5.23**	**42.98 (28.1357.83)**
Additive Manufacturing RMS ± SD	**63.58±14.8**	**42.68±21.8**	**31.41±17.1**	**48.87±18.0**	**46.4±1.1**			**61.10 (44.8877.32)**

*Significant at p < .05.

Table 3 provides a summary of descriptive statistics pertaining to trueness assessment. The two test groups differed significantly in all areas: axial, intaglio, occlusal, and marginal. (p 0.008).This ANOVA analysis demonstrates a statistically significant difference (p = 0.008, Fratio = 3.96) in overall RMS values between subtractive and additive manufacturing techniques.

Table 3 Trueness means RMS ± SD (µm) and significance values between the subtractive and additive manufacturing fixed dental prosthesis

Evaluated Surface	**Axial**	**Occlusal**	**Marginal**	**Intaglio**	**Over all**	**pvalue**	**Anova (f ratio)**	**95% CI**
Subtractive Manu-facturing RMS ± SD	**16.4±0.9**	**22.7±1.7**	**18.5±1.3**	**21.8±0.9**	**18.0±2.2**	**0.008**	**3.96**	**20.88**
Additive Manufacturing RMS ± SD	**9.2±0.4**	**15.6±0.7**	**17.2±0.2**	**18.2±0.3**	**17.2±3.3**			**16.46**

*Significant at $p < 0.05$.

Table 4 provides a summary of descriptive data for accuracy evaluation. All regions (occlusal, axial, marginal, intaglio, and overall) exhibited a significant difference in precision across test groups (p 0.0005*). The results reveal a highly significant difference (Fratio = 31.01) in overall RMS values between subtractive and additive manufacturing methods.

Table 4 Precision means RMS ± SD (μm), and significance values between the subtractive and additive manufacturing fixed dental prosthesis

Evaluated Surface	Axial	Occlusal	Marginal	Intaglio	Over all	pvalue	Anova (f ratio)	95% CI
Subtractive Manu-facturing RMS ± SD	14.5±0.6	23.1±1.6	18.01±1	17.1±0.7	17.6±1.6	0.0005*	31.01	18.96
Additive Manufacturing RMS ± SD	8.3±0.3	9.8±0.2	10±0.1	11.3±0.5	9.3±0.3			9.86

*Significant at $p < 0.05$

Discussion

This research examined the marginal fit and internal adaptation of milled multilayered zirconia and FDMprinted monolithic zirconia fixed dental prosthesis.

Zircopax (Zirconium Silicate) is generally known for its high opacity and Greyish white colour, however this study examined its fixed partial denture-fabricating potential and its marginal fit. Furthermore, it assessed the precision and trueness of the fabricated fixed dental prosthesis in comparison to both the initial design and another. The results demonstrate a partial acceptance of the null hypothesis related to adaptation, while it was rejected in the context of precision and trueness. The null hypothesis was rejected due to the trueness and precision values were beyond the acceptable range of the certified reference material (CRM).

The present investigation employed two different manufacturing methods—3D printing and milling — utilizing the same STL file to ensure consistency in the constructed fixed partial denture. The digital 3D superimposition technique facilitates a thorough evaluation of fit and adaptation by offering an entire visualization of the fitting surface. This method allows for the calculation of a vast number of points across the entire surface, more than the capabilities of conventional point-based measurement techniques.

The marginal fit and internal adaptation of fixed dental prosthesis are influenced by various factors, such as the fabricating technique and system, operating parameters, substance composition, preparation design, sintering shrinkage, and type of cement used. In this study, both milled and FDM-printed fixed partial dentures demonstrated comparable adaptation across different measurement areas.[9,20]

The recorded marginal (**milled: 46.3±14.8μm, 3D printed: 63.58±14.8μm**) fit values for both fixed partial dentures remained within the acceptable literature range of 50–120 **μm**.[21,22] The smallest gaps were found in the marginal region, extending from the finish line to 1 mm medially, emphasising the significance of the minimal cement spacer utilised in that area. Additionally, the similar values between the two groups may suggest comparable shrinkage during sintering. However, these findings contrast with several previous studies that reported marginal, axial, and occlusal discrepancies ranging from 42 to 159 **μm**. Notably, those studies employed the silicone replica technique, which captures isolated point measurements at the occlusal surface or along the margin.[23,24]

The results of this study aligned with existing literature, despite differences in materials, measurement techniques, locations, and timing. A systematic review of CAD/CAM-fabricated non-metal restorations, encompassing materials beyond zirconia, evaluated 54 in vivo and in vitro studies.[23] The analysis revealed a mean borderline gap of 120 **μm**, with a reported range of 3.7 to 174 **μm**. The significant variability observed in these values can be attributed to the various systems and materials employed, along with variations in measurement techniques utilized across different studies. Freire et al25 documented marginal gaps ranging from 31.0 to 47.4 **μm**, based upon the utilization of intraoral or extraoral scanning methods.[25] A separate investigation assessing marginal discrepancies at eight circumferential points around monolithic zirconia crown fabricated from partially pre-sintered blocks revealed values between 38 and 60 **μm**, with variations dependent on the measurement stage (post-sintering, after firingglazing, or after-cementation).[26] Furthermore, investigations into production parameters, such as finish line design, crown thickness, and sintering protocols, indicated the presence of marginal gaps ranging from 11 to 52 **μm** across various groups. All findings were specifically related to milled zirconia crowns.[27]

Studies assessing the margin discrepancy of additively created monolithic zirconia crowns are among the few available on 3D-printed zirconia in dentistry as compared to milled zirconia.[11,16,21,28–30]
Compared to this investigation, Li et al31 revealed greater occlusal (63 µm), axial (135 µm), and marginal (169 µm) gap values.[31] The median gaps were also greater in internal (79 µm) and marginal (146 µm) regions, according to Revilla-León et al.[9] These disparities might result from variations in the materials or techniques used for measurement. Li et al study did not specify the brand of zirconia paste; instead, they utilised a different 3D printer (CSL 150, Porimy, Kunshan, China) and intraoral scanner (CEREC Omnicam, Dentsply Sirona, Charlotte, NC, USA).[31] The latter study employed the same zirconia paste (3DMix ZrO2, 3DCeram) and printer (CERAMAKER C900, 3DCeram), and for the measurement method used a silicon replica.[32,33]
In addition to ensuring a proper fixed dental prosthesis fit on the prepared tooth, high trueness and accuracy of the finished fixed dental prosthesis in relation to the intended restoration also contribute to minimising chairside corrections and restoration modifications..[34] The accuracy of an object measured points match the planned design is known as trueness. In this study, milled fixed partial denture showed greater trueness on the intaglio surface, whereas additive layer-manufactured fixed dental prosthesis showed superior trueness on the cameo surface, closely mimicking the original design. The marginal trueness of the two manufacturing techniques was similar. The overall trueness of both crown types was comparable, even though there were differences in trueness between various measurement locations.[46] The number of milling burs, the axis used, or the bur's geometric and dimension limitations might all be responsible for the larger variations seen on the occlusal surface of a milled fixed partial denture.[35] The study's trueness findings, however, were different from those of other studies. [7,9,31,36–39]
For optimal biological response and accurate fit, dental restorations require a high degree of precision. The accuracy of an additive layered manufactured object is influenced by many factors, including the AM technique employed, the configuration, number, and dimensions of supports, as well as the scanning system and the digitization process utilized.[36] This study aimed to evaluate the precision of fixed dental prosthesis fabricated utilizing various approaches by comparing the measured data of one FPD with that of others within the same group.
Findings revealed that, in all examined areas, fixed dental prosthesis created using FDM demonstrated greater precision than those produced via milling. This difference might stem from the production method—while FDM fixed dental prosthesis were manufactured concurrently utilizing identical zirconia paste, printers, and processing steps, milled fixed dental prosthesis were made one after another from a single zirconia disc. Since the subtractive milling process begins to wear down the burs from the first use, both trueness and precision may be affected.[48] Furthermore, inconsistencies in the positioning of zirconia fixed dental prosthesis within the disc relative to the milling bur and spindle may introduce deviations from the CAD design.[47] FDM FPDs showed higher precision but lower intaglio trueness due to Shrinkage.[55]
Although some research has found similar precision levels between subtractive and additive techniques, those assessments primarily relied on calibrated prosthodontists evaluating marginal fit and proximal contact instead of digital measurement methods.[16]
Usage of only one typodont and scanner limits generalizability and this limitation are marginally mitigated by both continuous scanning with the scanner head mostly held horizontally and the segmental technique, which scans the region of interest first, are suitable full-arch scanning procedures. Nonetheless, intraoral scanners should rotate vertically as little as possible and two teeth premolar and molar preparation with different degree of taper are used in this study. [53,54]
The use of non-standard materials, the lack of fatigue testing, only the vitro study, and the absence of an aesthetic or optical evaluations are the study's limitations. Customizability, low-cost, high-volume production, and decreased material waste are all impacted by FDM printing of zirconia dental restorations.[52] Inconsistencies in the literature on the distribution and number of calculated areas (occlusal, axial, marginal, internal, exterior, etc.) also made it difficult to compare results with those of earlier research. Furthermore, the specimens were evaluated without being exposed to cyclic fatigue, which may have shown various forms of marginal fit, and in their sintered state.[40]
Further testing with a variety of additive manufactured zirconia fixed dental prosthesis and other additive manufacturing methods is recommended by the authors. Standardised measurement area distributions should be established, and the effect of bur wear on crown accuracy and trueness should be examined.
Additionally, it is recommended that minor variations in aged fixed dental prosthesis be evaluated. The clinical relevance of this study emphasizes the cost-effectiveness and limited time duration of printing zirconia fixed dental prosthesis compared to milled ones.

Acknowledgement: I express my sincere gratitude to my research guide, Dr. R. Venkat, for valuable guidance, constant encouragement, and critical insights throughout the course of this research. Their scholarly expertise and supervision were instrumental in shaping the study.
I am thankful to the Head of the Department of Prosthodontics, Dr Muthu Kumar and all faculty members for their academic support, constructive suggestions, and access to necessary facilities during the study period. I acknowledge the support extended by the Department of Dental Materials / CAD-CAM Laboratory, and the technical staff for their assistance in specimen fabrication, scanning procedures, and data acquisition. I also extend my appreciation to the institutional research committee and ethical review board for granting approval and providing valuable recommendations. Finally, I express my heartfelt thanks to my family for their unwavering support, patience, and encouragement, which made the successful completion of this research possible.

Conclusion :

The preliminary findings of both FDM and milled manufacturing methods demonstrated comparable marginal fit and internal adaptation for zirconia fixed partial denture. FDM manufactured fixed partial denture exhibited enhanced occlusal and axial trueness, whereas subtractive manufactured fixed partial denture excelled in intaglio trueness. It is possible to obtain precise FDM fabricated fixed partial dentures. Further studies, both in vitro and in vivo, are required to evaluate additional characteristics of FDM manufactured zirconia fixed partial dentures, including their mechanical and opticalproperties, despite the current preliminary findings for direct clinical applications. Future research has been underway with white Zirconia (ZrO_{2}. Y_2O_3) material with an additional parameter of flexural strength evaluation.

Conflict of interest :- The authors declare no conflict of Interest

Funding:- This research received no external funding. Data Availability Statement:- The data can be provided by the corresponding author upon reasonable request

Abbreviations:

FPD	Fixed Partial Denture
FDM	Fused Deposition Modeling
SM	Subtractive Manufacturing
STL	Standard Tessellation Language
CADCAM	Computeraided design and Computeraided manufacturing
SLA	stereolithography apparatus
G.K	Ganesh kumar
3D	3 Dimensional
2D	2 Dimensional
RMS	Root mean square
ANOVA	Analysis of Variance
SD	Standard Deviation
AM	Additive Manufacturing

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