

Retrospective Analysis of Tooth Preparation Done by Postgraduate Trainees for Monolithic Zirconia Restorations

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ABSTRACT

Introduction: Computer-Aided Designing/Computer-Aided Manufacturing (CAD/CAM) technology has revolutionised the practice of restorative dentistry. Zirconia has become a popular choice of restorative material due to the various advantages of metal-free dentistry. Postgraduate prosthodontics trainees undergo rigorous training for fixed prosthodontics. Monitoring the tooth preparations of postgraduate prosthodontic trainees is an important component of auditing a dental school's output and can provide valuable insights into the efficiency of trainees in executing tooth preparations. However, there is a lack of adequate research focusing on tooth preparation by postgraduate prosthodontic trainees.

Aim: The aim of this study was to investigate the quality of tooth preparations performed by postgraduate trainees for monolithic zirconia restorations in order to assess adherence to established tooth preparation guidelines.

Materials and Methods: This retrospective observational study was conducted from 1st May 2022 to 1st June 2024 in the Department of Prosthodontics at Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India. A total of 247 Standard Tessellation Language (STL) files containing 279 tooth preparations for monolithic zirconia

restorations were retrieved. The preparations were assessed by a single evaluator using 3D designing software (Cerec SW 20.0, inLab SW 20.0, Dentsply Sirona) for occlusal clearance, finish line design, finish line width, finish line quality, surface finish, undercuts, and iatrogenic injury to adjacent structures. A 3D software (Geomagic Control X 2024.1.0) was used to create cross-sections of the prepared tooth from the STL files, and measurements were taken for Occluso-Cervical Height (OCH) and Total Occlusal Convergence (TOC). Data were described descriptively. Additionally, the Mann-whitney U test and Pearson Chi-square test were performed using IBM – International Business Machines SPSS – Statistical Package for the Social Sciences, Version 26 software. All statistical analyses were conducted using a 95% confidence interval, and a p-value < 0.05 was considered statistically significant.

Results: A total of 279 preparations were analysed. The mean TOC of all abutments was 19.43±4.86 degrees. The mean OCH and margin width of all abutments were 4.44±1.18 mm and 0.75±0.24 mm, respectively. A total of 148 (53.34%) abutment teeth exhibited adequate preparation.

Conclusion: The adequacy of tooth preparation by postgraduate trainees is predominantly affected by the quality of TOC, especially in the posterior tooth zone and for vital teeth, followed by OCH and finish line geometry.

Keywords: Computer aided designing - computer aided manufacturing, Clinical competence, Fixed partial denture, Prosthodontic tooth preparations

INTRODUCTION

The restoration of a debilitated tooth to adequate function and aesthetics necessitates strict adherence to biomechanical tooth preparation principles. Over the years, meticulous research has developed these principles into guidelines, taking into account long-term clinical evidence of success and failure [1-4]. These principles include occluso-cervical or inciso-cervical height of the abutment, total occlusal convergence (TOC) angle, preparation of finish lines, anatomical or planar reduction of tooth structure, adequate occlusal clearance, the absence of undercuts or sharp line angles, and the preservation of adjacent biological tissues [4,5].

In CAD-CAM dentistry, zirconia has become a popular choice of indirect restorative material, demonstrating similar clinical durability and predictability to metal-ceramic restorations [6]. However, tooth preparation for zirconia restoration must adhere to the same principles as those formulated for metal-ceramic restorations, along with additional considerations such as milling tool diameter and favourable finish lines for optical scanning. An adequate understanding of tooth preparation principles is important for the longevity of restorations [7]. Goodacre CJ recommended that a tooth preparation provides sufficient retention and resistance form when prepared with a TOC

of 10 to 20 degrees, at an abutment height of 4 mm for molars and 3 mm for premolars and incisors, along with a height-to-base ratio of more than 0.4 [3]. Additionally, finish lines with adequate thickness and geometry are of paramount importance while adhering to a conservative tooth preparation protocol. Despite this recommendation, research has shown that the final tooth preparation geometry varies widely among dental students and practitioners with different levels of experience [8-11]. Although undergraduate trainees receive preliminary training in tooth preparation, this training is further enhanced in the postgraduate prosthodontics curriculum.

Monitoring the tooth preparations of postgraduate prosthodontic trainees is an important component of auditing a dental school's output and can provide crucial insights into the efficiency of trainees in executing tooth preparations for various types of restorations, including monolithic zirconia restorations. However, there is a lack of adequate research focusing on tooth preparation by postgraduate prosthodontic trainees. Therefore, this retrospective analysis aims to investigate the quality of tooth preparations performed by postgraduate trainees for monolithic zirconia restorations, assess adherence to established tooth preparation guidelines, evaluate the accuracy of tooth preparation, and identify common preparation errors.

MATERIALS AND METHODS

This retrospective observational study was conducted in the Department of Prosthodontics at Guru Nanak Institute of Dental Sciences and Research, Kolkata, West Bengal, India, focusing on all preparations for monolithic zirconia restorations, from 1st May 2022 to 1st June 2024, and received exemption from the Institutional Review Board (GNIDSR/IEC/2025/52).

Inclusion and Exclusion criteria: A total of 247 STL files containing 279 tooth preparations were retrieved, which included single crowns, fixed partial dentures, and vital and non vital teeth. Preparations carried out for metal-ceramic restorations, layered zirconia restorations, and other types of all-ceramic restorations were excluded from the study.

Study Procedure

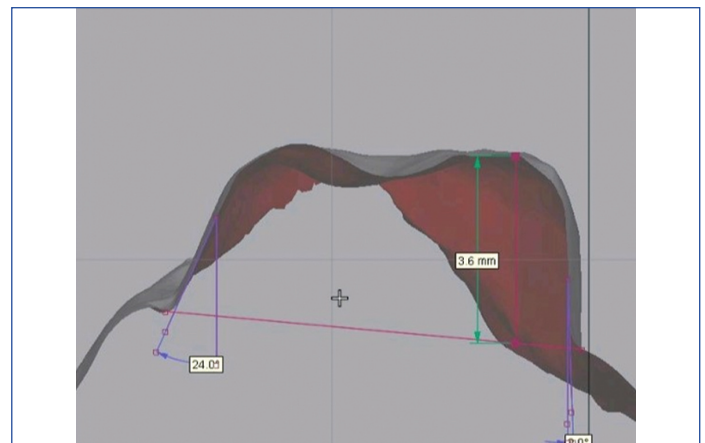
The preparations were assessed by a single evaluator in the following three parts, followed by an analysis of the adequacy of tooth preparation.

Part A- Analysis of occlusal clearance, surface finish, undercuts and iatrogenic injury: Cerec SW 20.0 software (Dentsply Sirona), a chairside designing software, was utilised for this purpose. The "Prepcheck" tool, part of the preparation analysis section of the software, allowed for the measurement of occlusal clearance in functional and non functional cusps by placing the computer cursor on the most prominent point of the cusp. Information on the quality of surface finish and the presence of undercuts was also provided by the preparation analysis section through different colour contrasts. The presence of iatrogenic injury was assessed by observing the gingival margin area and the contact area of the adjacent tooth.

Part B- Analysis of finish line width, design and quality: inLab SW 20.0 software (Dentsply Sirona), a laboratory designing software, was used for this analysis. Finish line width was measured at eight regions: mid-buccal, mid-lingual, mid-mesial, mid-distal, mesio-buccal, disto-buccal, mesio-lingual, and disto-lingual line angles, using a digital ruler integrated into the software to connect two points—one at the junction of the axial surface and finish line and the other at the endpoint of the finish line. The average of the eight values was taken for further analysis [10]. Finish line design was assessed and classified as follows: knife-edge, bevel, slight chamfer, deep chamfer, sharp shoulder, rounded shoulder, and indefinable preparation. A deep chamfer was defined as one that measured at least 0.4 mm in width [11].

Part C- Analysis of OCH and Total angle of convergence: A 3D software (Geomagic Control X 2024.1.0) was used for this analysis. Cross-sections of the prepared tooth from the STL files were prepared following the protocol established in an earlier study for the standardisation of measurement [11]. The sections were defined by the cusps or the incisal edges of the prepared tooth. This resulted in four cross-sections (two mesio-distal, two bucco-lingual) for molar teeth, three cross-sections (two mesio-distal, one bucco-lingual) for premolar teeth, and two cross-sections (one mesio-distal, one bucco-lingual) for anterior teeth. The total angle of convergence was assessed by adding the opposing preparation angles of each cross-section, and to determine the abutment height, a baseline was generated for each cross-section, followed by measuring the maximum distance from the baseline to the cusp [Table/Fig-1]. Four, three, and two values were generated for molar, premolar, and anterior tooth preparations, respectively, which were then averaged to yield a single value for further analysis.

Analysis of Adequacy of tooth preparation: Tooth preparations were further analysed for the quality of occluso-cervical height, total occlusal clearance, finish lines, surface finish, and restorative clearance by comparing them with established tooth preparation



[Table/Fig-1]: Evaluation of Occluso Cervical Height (OCH) and Total Occlusal Convergence (TOC) from cross-section of STL file of molar tooth, through mesio-buccal and mesio-lingual cusp tips.

guidelines for monolithic zirconia restorations. The parameters were considered clinically acceptable if: a) TOC was between 6 and 20 degrees; b) minimal abutment height was 4 mm for molars and 3 mm for anterior teeth (including canines) and premolars; c) margin was regular with a deep chamfer and rounded shoulder design, without rough, irregular, or stepped finish lines or unsupported enamel lip; d) occlusal reduction was between 1 and 1.5 mm; e) there was planar tooth reduction, with smooth surfaces without undercuts and sharp internal line angles, and the absence of iatrogenic injury to adjacent teeth. Finally, the tooth preparations were deemed adequate if all six parameters were found to be acceptable.

STATISTICAL ANALYSIS

The data gathered from this study were described descriptively. Additionally, comparisons of the assessed parameters were conducted for tooth preparations of vital teeth and non vital teeth, as well as for the tooth preparations of fixed partial dentures and single crowns, using the non-parametric Mann-whitney U test. Comparisons of the quality parameters across various tooth categories were performed using the Pearson Chi-square test to assess the strength of association. All statistical analyses were conducted with a 95% confidence interval, considering a p-value < 0.05 for statistical significance. IBM SPSS Statistics for Windows, Version 26.0 (Armonk, NY: IBM Corp) was used for the statistical analysis.

RESULTS

A total of 279 preparations were analysed from 247 STL files. Of these, 52 (18.6%) were part of fixed partial dentures, while 227 (81.4%) were preparations for single crown restorations. Specifically, 258 (92.5%) tooth preparations were performed on endodontically treated teeth, and 21 (7.5%) were for vital teeth.

[Table/Fig-2] displays the mean and standard deviation of occluso-cervical height (OCH), total occlusal convergence (TOC), margin width, functional cusp clearance, and non functional cusp clearance for all assessed abutments across various tooth categories. [Table/Fig-3] illustrates the comparison of different preparation quality parameters across various tooth categories. The quality of TOC was found to have a significant association with the different tooth categories ($p=0.042$). [Table/Fig-4] shows the comparison of various parameters between preparations done on vital and non vital teeth. Non vital teeth exhibited significantly greater TOC than vital teeth ($p=0.033$), while vital teeth demonstrated significantly greater margin width ($p=0.003$) and functional cusp clearance ($p=0.003$). [Table/Fig-5] compares the various parameters between tooth preparations for fixed partial dentures and those for single crowns, indicating that tooth preparations for single crowns had significantly higher TOC ($p=0.006$).

Tooth category	Frequency	Occluso Cervical Height (OCH) (mm)	Total Occlusal Convergence (TOC) (degree)	Margin width (mm)	Functional cusp clearance (mm)	Non Functional cusp clearance (mm)
Mandibular molar	99 (35.48%)	4.26±0.4	19.85±4.68	0.78±0.24	1.34±0.24	1.16±0.18
Maxillary molar	93 (33.33%)	4.28±0.4	20.73±5.08	0.70±0.24	1.37±0.2	1.14±0.22
Maxillary premolar	40 (14.34%)	3.69±0.44	18.4±4.61	0.67±0.21	1.5±0.18	1.18±0.23
Mandibular premolar	23 (8.24%)	3.7±0.44	16.14±4.52	0.74±0.22	1.57±0.78	1.33±0.22
Maxillary anterior	20 (7.16%)	8.13±0.94	17.3±2.89	0.92±0.18	1.44±0.13	-
Mandibular anterior	4 (1.43%)	6.28±0.17	18.63±3.96	0.88±0.06	1.48±0.09	-
All preparation	279	4.44±1.18	19.43± 4.86	0.75±0.24	1.4±0.22	1.18±0.22

[Table/Fig-2]: Mean and standard deviation of Occluso Cervical Height (OCH), Total Occlusal Convergence (TOC), margin width, functional cusp clearance and non Functional cusp clearance of all abutments assessed and across various tooth category.
Table descriptively summarising all measurements of preparation geometry parameters across all tooth categories

Tooth category	Accepted quality of Occluso Cervical Height (OCH)	Accepted quality of Total Occlusal Convergence (TOC)	Accepted quality of restorative clearance	Accepted quality of finish lines	Accepted quality of surface finish	Accepted quality of iatrogenic injury
Maxillary molar (n=93)	77 (82.8%)	51 (54.8%)	84 (90.3%)	65 (69.9%)	76 (81.7%)	89 (95.7%)
Mandibular molar (n=99)	81 (81.8%)	64 (64.6%)	84 (84.8%)	77 (77.8%)	84 (84.8%)	97 (98%)
Maxillary premolar (n=40)	37 (92.5%)	28 (70%)	37 (92.5%)	28 (70%)	31 (77.5%)	38 (95%)
Mandibular premolar (n=23)	21 (91.3%)	19 (82.6%)	21 (91.3%)	17 (73.9%)	19 (82.6%)	22 (95.6%)
Maxillary anterior (n=20)	20 (100%)	17 (85%)	19 (95%)	18 (90%)	17 (85%)	20 (100%)
Mandibular anterior (n=4)	4 (100%)	3 (75%)	3 (75%)	4 (100%)	4 (100%)	4 (100%)
Total (n=279)	240 (86%)	182 (65.2%)	248 (88.9%)	209 (74.9%)	231 (82.8%)	270 (96.8)
Pearson Chi-square	8.089	11.522	4.031	5.967	2.056	2.101
p-value	0.151	0.042*	0.545	0.309	0.841	0.835

[Table/Fig-3]: Comparison of different quality parameters across various tooth categories along with Pearson Chi-square Value and p-value.
Result of Pearson Chi-square test to assess strength of association of different preparation quality parameters across various tooth category, using 95% confidence interval and p-value <0.05 for statistical significance

Parameters	Vital teeth (N=21) (7.5%)			Non vital teeth (N=258) (92.5%)			p-value
	Median	IQR	Mean rank	Median	IQR	Mean rank	
Occluso Cervical Height (OCH) (mm)	4.5	4.7	171.38	4.2	0.7	137.45	0.64
Total Occlusal Convergence (TOC) (degree)	16.7	3.3	103.79	18.4	6.9	142.95	0.033*
Margin Width (mm)	0.87	0.09	191.17	0.83	0.24	135.84	0.003*
Functional Cusp Clearance (mm)	1.53	0.3	190.45	1.36	0.3	135.89	0.003*
Non Functional Cusp Clearance (mm)	1.25	0.24	142.96	1.16	0.27	127.93	0.434

[Table/Fig-4]: Comparison of various parameters between vital teeth and non vital teeth.
Result of Mann-Whitney U Test, using 95% confidence interval and p-value<0.05 for statistical significance. *IQR: Interquartile range

Parameters	Tooth preparation for fixed partial denture (N=52) (18.63%)			Tooth preparation for single crowns (N =227) (81.37%)			p-value
	Median	IQR	Mean Rank	Median	IQR	Mean Rank	
Occluso Cervical Height (OCH) (mm)	4.2	1.9	140.28	4.2	0.7	139.94	0.978
Total Occlusal Convergence (TOC) (degree)	17.35	3.35	112.43	18.4	7	146.31	0.006*
Margin Width (mm)	0.84	0.16	153.35	0.84	0.24	136.94	0.186
Functional Cusp Clearance (mm)	1.44	0.27	157.64	1.36	0.29	135.96	0.081
Non Functional Cusp Clearance (mm)	1.17	0.27	129.71	1.16	0.32	127.69	0.875

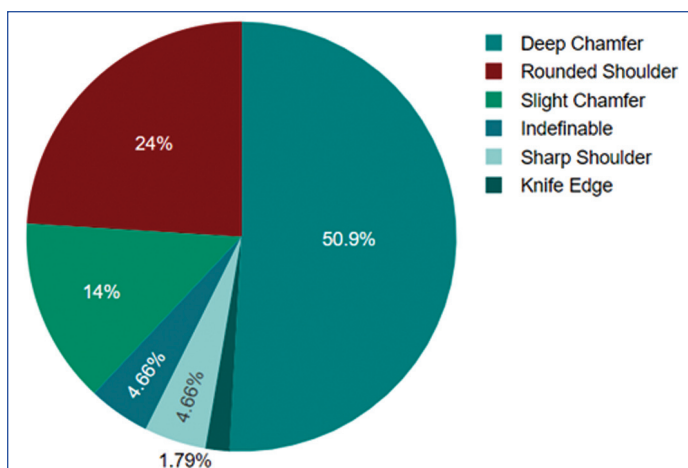
[Table/Fig-5]: Comparison of various parameters between tooth preparation for fixed partial denture and tooth preparation for single crowns.
Result of Mann-Whitney U Test, using 95% confidence interval and p-value < 0.05 for statistical significance. *IQR: Interquartile range

The most common type of finish line was “deep chamfer” at 142 (50.9%), followed by “rounded shoulder” at 67 (24%) and “slight chamfer” at 39 (14%). A total of 70 (25.09%) tooth preparations had inadequate finish lines, and 48 (17.2%) had inadequate surface finish. Additionally, 9 (3.23%) preparations resulted in iatrogenic injury to adjacent teeth. [Table/Fig-6] illustrates a pie chart showing the distribution of finish lines. In total, 148 (53.34%) abutment teeth had adequate preparations, while 131 (46.66%) preparations were

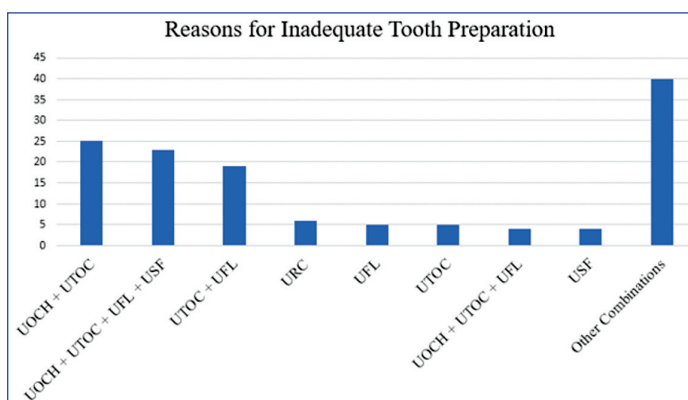
considered inadequate. [Table/Fig-7] features a clustered column chart displaying the reasons for inadequate preparations.

DISCUSSION

Adequate tooth preparation plays a major role in the success and longevity of fixed prosthodontic restorations, irrespective of the choice of restorative materials or the clinical situation. A total of 46.66% of the tooth preparations performed by postgraduate



[Table/Fig-6]: Pie chart of distribution of finish lines.



[Table/Fig-7]: A clustered column chart showing reasons for inadequate tooth preparation.

UOCH: Unacceptable occluso cervical height; UTOC: Unacceptable total occlusal convergence; UFL: Unacceptable finish line; USF: Unacceptable surface finish; URC: Unacceptable restorative clearance

trainees exhibited significant errors in preparation geometry and finish quality, with the most notable contributions arising from inadequate total occlusal convergence (TOC), inadequate occluso-cervical height (OCH), and inadequate finish lines.

In this study, 14% of preparations did not meet the criteria for acceptable OCH, which is an improvement compared to a previous study on tooth preparations submitted by general dental practitioners, where the figure was 69.64% [10]. In that study, it was reported that 39% of premolar preparations had dimensions less than 3 mm, and 82.7% of molar preparations were below 4 mm. However, no significant differences were found between various tooth preparation categories regarding location, vitality, or prosthesis type in the current study. This result is slightly higher than that reported by Winkelmeyer C et al., where only 7.9% of preparations did not meet the criteria for adequate OCH [11].

TOC is a significant contributor to the retention form of a restoration. Earlier laboratory investigations recommended a TOC ranging from two to six degrees for optimal retention [12,13]. However, achieving this in clinical settings can be challenging due to the potential for complications, such as creating undercuts. Therefore, later recommendations increased this range to a more clinically achievable 10 to 20 degrees [3]. In this study, the mean TOC for all abutments was found to be 19.43 ± 4.86 degrees, which falls well within the reported range of mean TOC angles in the literature for buccolingual dimensions (7.4 degrees to 35.7 degrees) and mesiodistal dimensions (7.1 degrees to 37.2 degrees) [8]. Nevertheless, 34.77% of all teeth had unacceptable TOC. Additionally, there was a significant difference between various tooth categories regarding TOC quality, with maxillary molars (45.16%) and mandibular molars (35.4%) demonstrating the poorest outcomes. This aligns with previous studies, where 44.3%

of preparations did not meet the TOC criteria, and posterior teeth tended to have more conical preparations than anterior teeth [11]. Another study indicated that 89% of all preparations performed by general practitioners had a TOC greater than 20 degrees [10]. In this study, preparations on non vital teeth exhibited significantly higher TOC than those on vital teeth, and preparations for single crowns had significantly greater TOC than those for fixed partial dentures. This is consistent with the findings by Winkelmeyer C et al., where TOC for crowns (19.2 ± 9.6 degrees) was higher than for fixed partial denture preparations (17.5 ± 9.7 degrees), although no statistical significance was found [11].

Margins play an important role in the biological integrity of the dentogingival complex, as marginal inaccuracies can lead to secondary caries, gingival inflammation, and other issues. In this study, 25.09% of preparations lacked an acceptable quality of finish lines, which is significantly better than previous studies on preparations by general practitioners [10,11]. The mean marginal width was 0.75 ± 0.24 mm, with 50.9% of preparations featuring deep chamfer finish lines, followed by rounded shoulder finish lines (24%). The posterior tooth zone had a higher incidence of unacceptable finish lines compared to the anterior tooth zone; however, no statistically significant difference was observed. Vital tooth preparations exhibited significantly greater marginal width than non vital teeth. This can be attributed to the fact that most vital tooth preparations were located in the anterior tooth zone, where there is a general trend of increased marginal width. It is worth noting that wide margin widths do not provide increased fracture strength to monolithic zirconia; therefore, conservative tooth preparations should be encouraged to preserve valuable tooth structure without impairing the final aesthetic outcome [14].

When planning for occlusal restorations, adequate reduction (1-1.5 mm) of the occlusal surface while maintaining planar reduction is crucial, as it ensures the conservation of tooth structure. Recent studies have shown that the absence of a planar reduction leads to significantly larger marginal gaps for CAD-CAM restorations [15,16]. The mean functional and non functional cusp clearance for all abutments was 1.4 ± 0.22 mm and 1.18 ± 0.22 mm, respectively. This is consistent with the occlusal reduction recommended for all-ceramic restorations [6,7]. However, vital tooth preparations had significantly greater functional cusp clearance than non vital teeth. This may be correlated with the greater amount of functional cusp clearance seen in the premolar and anterior tooth regions, potentially indicating over-preparation.

Preparation for milled zirconia restorations requires special consideration of milling tool geometry. Designing software includes special tools to block undercuts, while milling tools can over-prepare areas with sharp line angles, leading to decreased retention, stability, and increased cement space for the restoration [17]. In the present study, 17.2% of teeth had an unacceptable surface finish due to the presence of significant undercuts, sharp internal line angles, and rough surfaces. This figure is an improvement compared to a previous study, where 67% of preparations exhibited significant undercuts [10]. Furthermore, 3.23% of preparations resulted in inadvertent injury to adjacent teeth, which is unacceptable as it increases the risk of secondary caries, complicates the development of proximal contours, and may lead to periodontal issues.

In this study, 53.34% of all preparations were deemed adequate after all preparation geometry parameters were found to be acceptable. This is significantly higher than the result of a study on preparations by general practitioners, where only 4.3% were considered adequate [11]. They reported that 50.8% of preparations had unacceptable finish lines and 37.4% had unacceptable TOC alongside unacceptable finish lines [11]. It is evident in the present study that the quality of tooth preparations was compromised due to a combination of various critical attributes, with the main

contributing factors being unacceptable OCH, TOC, and finish lines. This analysis of tooth preparations submitted by postgraduate students provides important insights into trends, challenges, and areas for improvement in tooth preparation for monolithic zirconia restorations. Recent studies suggest the potential benefits of implementing digital self-assessment tools as a complement to traditional evaluations by faculty [18,19]. Therefore, prospective studies can be planned to evaluate the effectiveness of various assessment methods in enhancing the clinical competency of postgraduate students.

Limitation(s)

- All tooth preparations for monolithic zirconia restorations were retrieved during the assessment period; therefore, no randomisation was performed.
- The number of cases within each tooth category varied, with the majority being maxillary and mandibular molar teeth.
- A single operator assessed all parameters.
- Many parameters were averaged to a single value for further statistical analysis, such as TOC and margin width.
- The sample size was relatively small.

CONCLUSION(S)

Within the limitations of the study, it can be concluded that 53.34% of tooth preparations performed by postgraduate trainees were found to have adequate preparation geometry. The adequacy of tooth preparations is primarily influenced by the quality of TOC, especially in the posterior tooth zone and for vital teeth, followed by OCH and finish line geometry. Further adherence to parameters such as adequate occlusal reduction, surface finish, and the prevention of iatrogenic injury will ensure adequate tooth preparation and increase the success rate of the prosthesis. Computerised preparation analysis could be integrated into the routine assessment of clinical work, allowing for immediate feedback to guide postgraduate trainees towards improved learning.

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- For any images presented appropriate consent has been obtained from the subjects. NA

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Dec 07, 2024
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