

Original article

Technical Standards for Full Metal Crown Preparation Performed by Dental Undergraduates during Preclinical Dental EducationNourelhouda Misurati¹ , Noora Berhaim¹ , Siham Omar² , Abeer Mesbah² , Khadija Abu Sittah³ ¹Department of Prosthodontics, Faculty of Dentistry and Oral Surgery, University of Tripoli, Libya²Department of Conservative Dentistry and Endodontics, Faculty of Dentistry, Sirte University, Libya³Department of Prosthodontics, Faculty of Dentistry, Sirte University, LibyaCorresponding email. n.misurati@uot.edu.ly**Abstract**

Preparing teeth for fixed dental prostheses is a fundamental clinical task. While it is a standard part of practice, ensuring the restoration's longevity requires precise preparation, a process that dental students often find difficult to master consistently. This study aimed to assess the technical standards of tooth preparation carried out by dental students in their preclinical training. A total of 132 fourth-year preclinical dental students were randomly allocated into two groups to perform full metal crown preparation in a simulated dental training environment; Group 1 (n = 59) was assigned to conduct the procedure on the maxillary (upper) arch, while Group 2 (n = 73) performed the same procedure on the mandibular (lower) arch. Jaw models were mounted on phantom heads during the tooth preparation procedure. The tooth preparations were evaluated using standardized criteria. Descriptive statistics were employed to categorize the outcomes as (excellent, acceptable, or unacceptable). A Chi-square test was performed to assess the association between dental arch type and the technical quality of the students' tooth preparations. Statistical significance was determined at $P < 0.05$. It shows that the majority of student work is in the (Satisfactory) range, followed closely by (Excellent), with (Unsatisfactory) being the smallest group. Significant differences were observed between arches in two key areas: lingual reduction ($p = 0.016$), where the upper arch had a higher rate of unacceptable results (21%), and preservation of adjacent teeth ($p = 0.034$), where the lower arch showed superior performance (41% excellent). The technical performance of the students was predominantly high, as most preparations either met or surpassed established clinical standards. A significant correlation was found between the dental arch and the quality of lingual preparations and iatrogenic damage to adjacent teeth.

Keywords. Preclinical Dental Students, Technical Standards, Full Metal Crown Preparation.**Introduction**

In general clinical dentistry, tooth preparation for full-veneer crowns is a routine intervention [1]. For posterior teeth with extensive structural damage, complete cast metal crowns remain the preferred restorative choice. The clinical longevity and ultimate success of these prostheses depend heavily on the practitioner's technical precision during the preparation phase [2]. Therefore, dental graduates must attain optimum skills and expertise while practicing under supervision [1, 3]. The tooth preparation must follow specific geometric principles that provide retention and resistance against both vertical and horizontal forces. The most critical factor for retention is the inclusion of two opposing vertical surfaces. These axial walls should feature a slight taper rather than being perfectly parallel; this allows the crown to be properly seated during cementation while maintaining the mechanical friction necessary to keep the restoration in place [2, 4, 5]. Inadequate occlusal clearance remains a frequent error during the preparation of cast metal crowns. Achieving optimal structural durability requires specific geometric features: planar reduction, functional cusp beveling, and the rounding of line angles. This design provides the necessary bulk for the restorative material to effectively resist masticatory loads [6]. Ultimately, while proper occlusal and axial reductions are essential to provide enough space, allowing a good functional morphology and structural durability. Moreover, clinicians must balance this against the need for tooth preservation; no more than necessary dental tissues should be removed in order not to compromise tooth structure and retention of the restoration [2, 5, 7].

Iatrogenic injury to adjacent teeth emerged as a common complication associated with crown preparation procedures [8]. In a study by Long and Smith [9], dentists tasked with preparing extracted teeth in anatomical contact resulted in a 100% incidence of damage to adjacent surfaces. They further concluded that the preparation of teeth with easier access to the contact area was less prone to cause damage to adjacent teeth. Preclinical courses provide an opportunity to assess undergraduate students' abilities before they manage real clinical cases with patients [10, 11]. While preclinical training is essential for developing clinical skills, research suggests that students often struggle with specific aspects of tooth preparation, such as achieving proper marginal integrity and ensuring smooth, even surfaces [12, 13]. Therefore, this study was designed to evaluate the clinical performance of dental students by assessing the technical standards achieved during their preclinical tooth preparation training.

Methods**Study design**

This cross-sectional study was conducted at the Department of Prosthodontics, Faculty of Dentistry and Oral Surgery, University of Tripoli, Libya.

Participants

A total of 132 fourth-year pre-clinical dental students were randomly allocated into two groups to perform full metal crown preparation in a simulated dental training environment; Group 1 (n = 59) was assigned to conduct the procedure on the maxillary (upper) arch, while Group 2 (n = 73) performed the same procedure on the mandibular (lower) arch. Each participant completed the assigned preparation independently under standardized conditions, ensuring consistency in instrumentation, clinical environment, and instructional guidance. The allocation of students into the two groups was also influenced by their personal preference, as each participant selected the arch (maxillary or mandibular) that was most suitable and available for their practice. This ensured that the division respected the students' choices while maintaining the integrity of the study design.

Procedure and evaluation

To facilitate a standardized and objective assessment of the tooth preparations, a reference index was fabricated using heavy-body polyvinyl siloxane (PVS) on an unprepared tooth. This index was subsequently divided into labio-palatal and mesio-distal sections, allowing investigators to perform a direct visual appraisal of the reduction depths relative to the initial tooth morphology. The students received clear instructions on how to prepare the full metal crown and were informed about the evaluation criteria for the preparation. Jaw models were mounted on phantom heads during the tooth preparation procedure. The student's work was collected and given a numerical code. Visual magnification was utilized to verify the accuracy of the tooth preparations and to evaluate the integrity of the adjacent tooth structures for any potential iatrogenic damage. For standardized photographic documentation, each prepared tooth was positioned with its occlusal surface parallel to the horizontal plane. Digital images were captured by a single, qualified investigator using an [iPhone 16 ProMax] positioned at a fixed distance of 25 cm. To ensure an unobstructed view of the preparation and the finish lines, all adjacent teeth were removed from the typodont model prior to photography. The camera was oriented perpendicular to the long axis of the artificial tooth to capture bucco-lingual and mesio-distal views. Following image acquisition, the files were transferred to a computer for digital analysis. Reference lines were traced along the right and left axial wall contours, originating at the finish line and extending coronally. Specifically, these lines were placed at the mid-mesial and mid-distal points for the buccal aspect, and at the mid-buccal and mid-lingual points for the proximal aspects. Both evaluators are faculty members with Master's degrees in Fixed Prosthodontics who have been practicing and teaching the specialty for over ten years. To enhance the reliability of the evaluation process and reduce inter-examiner variability, all participant assessments were conducted jointly through collaborative deliberation between the two faculty members. The tooth preparations were evaluated based on the evaluative criteria. The criteria, in conjunction with magnification, were employed to assess the quality of the tooth preparation and the status of the adjacent teeth. The criteria were systematically developed by four prosthodontics faculty members, each with more than ten years of clinical teaching experience. The initial evaluative criteria were derived from well-established prosthodontic preparation standards and guidelines [2,5], and adapted from previous studies [14,15].

Data analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS; Version 26, IBM Corp, New York, NY, USA). Descriptive statistics, including frequency distributions and cross-tabulations, were employed to categorize the outcomes as (excellent, acceptable, or unacceptable). To explore potential associations, the chi-square test and Fisher's exact tests were employed when indicated in the statistical analysis to evaluate the relationship between the dental arch and the technical quality of tooth preparations performed by dental students. Statistical significance was determined at $P < 0.05$.

Results

Of the 132 dental students who participated in the study, the demographic distribution revealed that the majority of participants were female (77%), while males accounted for (23%), no statistical comparison between genders was undertaken. This decision was based on the unequal distribution of participants across the two groups, which limited the validity of any meaningful comparative analysis. A total of 59 preparations were done on mandibular teeth (45%) and 73 on maxillary teeth (55%). (Table 1): displays the technical quality of tooth preparation by dental students. The findings indicate that the majority of students achieved satisfactory outcomes across most parameters, with a notable proportion attaining excellent standards, particularly in buccal (61%) and lingual reduction (55%). However, proximal reduction and functional cusp bevel emerged as areas requiring improvement, given their relatively higher rates of unsatisfactory performance (18% and 25%, respectively) (Figure 1, 2). (Table 2) presents the comparison of crown preparation quality between the lower and upper arches. Overall, most parameters demonstrated comparable distributions between arches, with no statistically significant differences observed. Occlusal reduction, buccal reduction, functional cusp bevel, proximal reduction, axial taper reduction, presence of undercuts, and rounded line angles all showed similar ratings across arches, with satisfactory or excellent outcomes predominating.

A notable finding emerged in lingual reduction, where unacceptable ratings were more frequent in the upper arch (21% vs. 7%), resulting in a statistically significant difference ($p = 0.016$). Proximal reduction, axial taper reduction, and the presence of undercuts demonstrated comparable distributions between arches, with no significant differences observed ($p = 0.590$,

$p = 0.351$, and $p = 0.861$, respectively). Rounded line angles were largely satisfactory in both arches (68% lower, 65% upper), again without significant variation ($p = 0.983$). Although the location of the chamfer finish line showed a higher proportion of excellent ratings in the upper arch (37% vs. 22%), this difference did not reach statistical significance ($p = 0.150$). In contrast, preservation of adjacent teeth revealed a significant difference ($p = 0.034$), with unacceptable ratings more frequent in the upper arch (19% vs. 12%). Overall, the analysis demonstrated that while most aspects of crown preparation quality were comparable between arches, lingual reduction and preservation of adjacent teeth were significantly less favorable in the upper arch, highlighting areas that may require greater clinical attention.

Table 1. Descriptive Statistics of the Technical Quality of Tooth Preparation by Dental Students (n=132)

Characteristic	Frequency	%
<i>Gender</i>		
Male	30	23%
Female	122	77%
<i>Arch</i>		
Lower arch	59	45%
Upper arch	73	55%
<i>Occlusal reduction</i>		
Unsatisfactory	14	11%
Satisfactory	89	67%
Excellent	29	22%
<i>Buccal reduction</i>		
Unsatisfactory	22	17%
Satisfactory	29	22%
Excellent	81	61%
<i>Functional cusp bevel</i>		
Unsatisfactory	24	18%
Satisfactory	70	53%
Excellent	38	29%
<i>Lingual reduction</i>		
Unsatisfactory	19	15%
Satisfactory	40	30%
Excellent	73	55%
<i>Proximal reduction</i>		
Unsatisfactory	33	25%
Satisfactory	47	36%
Excellent	52	39%
<i>Axial taper reduction</i>		
Unsatisfactory	16	12%
Satisfactory	63	48%
Excellent	53	40%
<i>Presence of undercuts</i>		
Unsatisfactory	16	12%
Satisfactory	57	43%
Excellent	59	40%
<i>Rounded line angles</i>		
Unsatisfactory	13	10%
Satisfactory	88	67%
Excellent	31	23%
<i>Location of chamfer FL</i>		
Unsatisfactory	14	11%
Satisfactory	78	59%
Excellent	40	30%
<i>Preservation of adjacent teeth</i>		
Unsatisfactory	21	16%
Satisfactory	72	54%
Excellent	39	30%

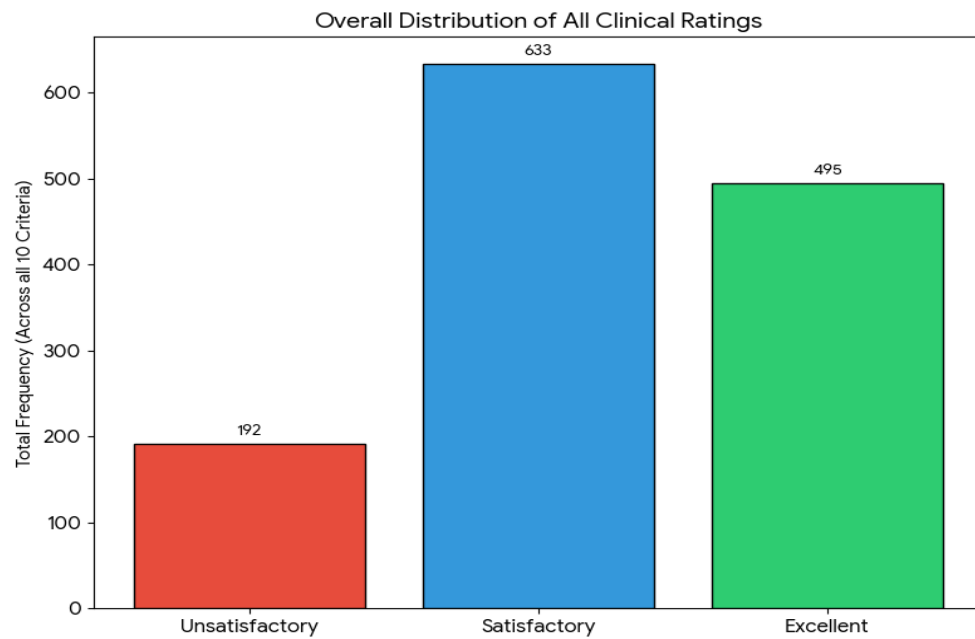


Figure 1. Overall Distribution of All Clinical Ratings

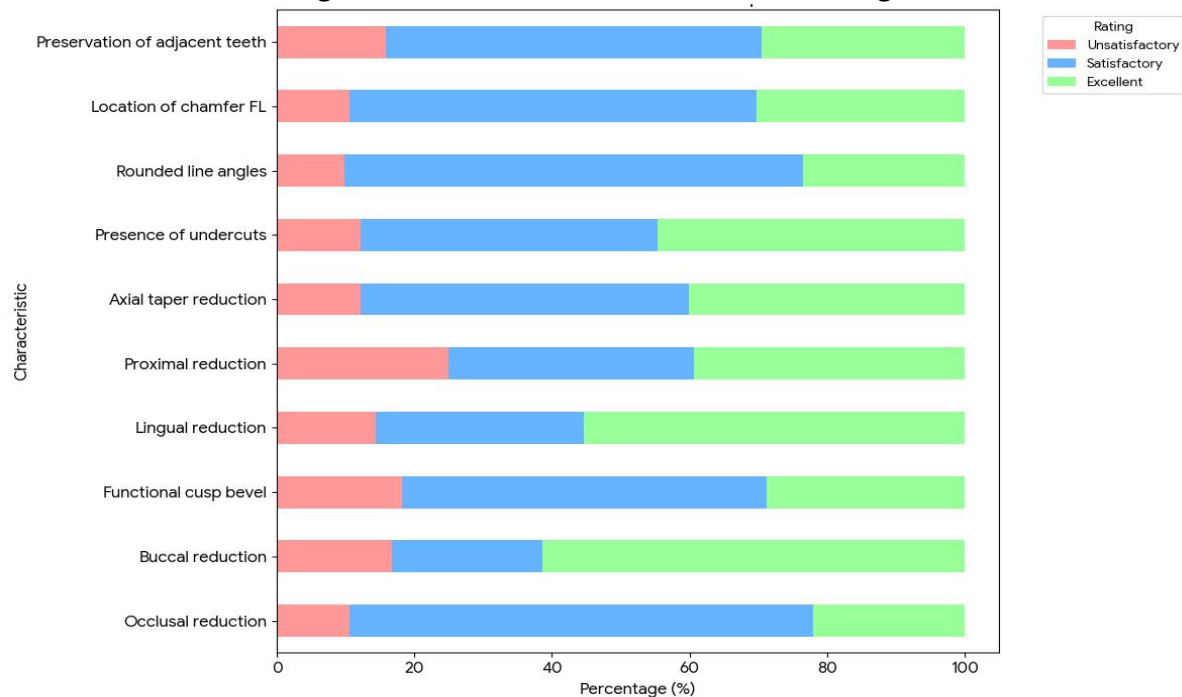


Figure 2. Evaluation of Dental Students' Tooth Preparation Standards

Table 2. Comparison of the Technical Quality of Crown Preparations Between Arches

Criteria	Lower	Upper	P value*
1. Occlusal reduction			
Unacceptable	7%	14%	0.143
Satisfactory	64%	70%	
Excellent	29%	16%	
2. Buccal reduction			
Unacceptable	15%	18%	0.811
Satisfactory	20%	23%	
Excellent	65%	59%	
3. Functional cusp bevel			
Unacceptable	17%	19%	0.400
Satisfactory	59%	78%	
Excellent	24%	33%	
4. Lingual reduction			

Unacceptable	7%	21%	0.016*
Satisfactory	41%	22%	
Excellent	52%	57%	
5. Proximal reduction			
Unacceptable	22%	27%	0.590
Satisfactory	34%	37%	
Excellent	44%	36%	
6. Axial taper reduction			
Unacceptable	8%	15%	0.351
Satisfactory	46%	49%	
Excellent	46%	36%	
7. Presence of undercuts			
Unacceptable	12%	12%	0.861
Satisfactory	46%	41%	
Excellent	42%	47%	
8. Rounded line angles			
Unacceptable	10%	10%	0.983
Satisfactory	68%	65 %	
Excellent	22%	25%	
9. Location of chamfer FL			
Unacceptable	10%	11%	0.150
Satisfactory	68%	52%	
Excellent	22%	37%	
10. Preservation of the adjacent teeth			
Unacceptable	12%	19%	0.034*
Satisfactory	47%	60%	
Excellent	41%	21%	

Discussion

Tooth preparation represents a critical component of both pre-clinical training and clinical practice, serving as a foundational element of dental procedures [13]. According to standard prosthodontics literature, detailed and precise preparation is a prerequisite for the fabrication of a clinically successful full-coverage crown [2,4,5]. This process must adhere to principles of tooth preparation, including appropriate retention and resistance, structural durability, marginal integrity, and the preservation of both the tooth structure and the periodontium [2,7]. Our study assessed the technical standards of tooth preparations performed by preclinical dental students. Results in (Table 1) demonstrate that most students performed competently across the majority of criteria, with more than half reaching an excellent standard in buccal (61%) and lingual (55%) reductions. These findings align with the research of Al-Omari and Al-Wahadni [16], who observed that axial reduction is typically the most successfully executed component of crown preparation among dental students. Furthermore, the data support the observations of Alqifari and Sadan. [17], who noted that students frequently achieve, and often exceed, the minimum recommended requirements for axial and occlusal clearance. This shows that students tend to focus more on buccal and lingual reduction, because these areas are easier to see and measure while they work.

Conversely, proximal reduction and functional cusp beveling were identified as the most challenging tasks, evidenced by unsatisfactory rates of 18% and 25%, respectively. Such deficiencies are clinically critical, as without a proper functional cusp bevel, the final crown lacks sufficient thickness, results in a deflective occlusal contact, and has reduced structural durability [2,7]. These findings are consistent with AL-Moaleem et al. [8] and Poon and Smales. [18], and Waligóra et al. [19], who noted that dental student preparations were often clinically insufficient to ensure structural integrity. This stands in contrast to research by Syed et al. [1], who reported that fresh graduates performed well in this area, with 60.71% adequately preparing the functional cusps bevel. The data indicate that while most students can prepare a tooth that is clinically functional (Satisfactory), nearly one-third are capable of producing work that is technically ideal (Excellent). The relatively low failure rate suggests that the current curriculum is successful in teaching the 'big picture' of tooth preparation. However, the results also highlight a need for increased focus on refined details, specifically functional cusp beveling and proximal clearance, to further reduce the unsatisfactory count. Ultimately, although these specific areas remain challenging (with failure rates of 25% and 18%, respectively), the overall technical proficiency of the students is predominantly positive. This finding contrasts with the study by Almohefer et al. [14], which reported that a majority of students achieved unsatisfactory results in their crown preparations. The taper angle is defined as the degree of convergence between the opposing axial walls. It plays a critical role in the retention of the restoration, as the retention of dental castings is inversely related to the degree of taper; as the angle increases, the retention significantly diminishes [20,21]. while the ideal total convergence

angles (TCA) for opposing axial surfaces remain a subject of discussion among leading prosthodontists. Shillingburg et al. propose a range of (4°–6°) as ideal and a range of (4°–14°) as acceptable [2]; other authorities suggest broader margins. Goodacre et al. and Rosenstiel et al. recommend a range between (10°–20°) [4,5].

In the present study, the majority of students attained a satisfactory level of technical performance, meeting the established clinical criteria. These results contrast with the findings of Okuyama et al. [22], who observed that student preparations exhibited a statistically significant degree of over-reduction compared to established standards. Similarly, El-Mubarak et al. [23] reported that none of the student preparations achieved the recommended optimal range for tooth reduction. This tendency toward over-tapering is further evidenced by Rafeek et al. [3], who reported that the taper achieved by dental students was outside the ideal range of (4° to 40). Regarding differences in tooth preparation between arches presented in (Table 2), variations in the preparations were noted between maxillary and mandibular teeth. A significant disparity was observed in lingual reduction quality between the two arches. The maxillary teeth exhibited a substantially higher rate of unacceptable preparations (21%) compared to the mandibular teeth (7%), a statistically significant difference ($p = 0.016$). This aligns with the findings of Almohefer et al. [12] and Syed et al. [1], who also reported statistical differences in bucco-lingual reduction between maxillary and mandibular teeth performed by recent dental graduates." Ideally, tooth preparation should be performed without causing the slightest damage to adjacent teeth; however, achieving such precision remains clinically elusive.

Existing literature corroborates this difficulty, documenting a high incidence of iatrogenic injury during the crown preparation process [24,25]. Specifically, Abdulwahhab et al. [10] observed that nearly 98% of adjacent teeth sustained proximal injuries, with a significantly higher frequency of damage occurring in the maxillary arch. Our findings align with this trend, as the preservation of adjacent teeth showed a significant difference ($p = 0.034$), with unacceptable ratings being more prevalent in the upper arch compared to the lower arch (19% vs. 12%). In contrast, Badar et al. [26] reported a significant association where the mandibular teeth experienced more severe surface damage than their maxillary counterparts. Despite these conflicting results regarding the most vulnerable arch, the higher failure rates observed in the maxilla in the present study may be attributed to the necessity of using indirect vision. The reliance on a dental mirror for maxillary preparations introduces technical complexities that can significantly contribute to the observed variances in clinical quality.

Limitations

Several limitations of this study should be acknowledged. First, the evaluation relied on visual clinical assessment, which, despite the use of standardized criteria, may be subject to inter-examiner variability. Second, the study was conducted within a single institution, which may limit the generalizability of the results to other dental programs with different curricula. Finally, the focus was exclusively on full metal crown preparations; future research should incorporate digital scanning technologies and a broader range of restorative materials to provide a more comprehensive overview of student technical proficiency.

Conclusions

Within the limitations of this study, several conclusions can be drawn. First, student technical performance was found to be largely successful, with the majority of preparations meeting or exceeding clinical standards. This high prevalence of satisfactory and excellent ratings indicates a predominantly positive technical performance overall. However, targeted instructional focus is still required to improve proficiency in more complex areas, specifically functional cusp beveling and proximal reduction. Finally, a significant correlation was found between the dental arch (maxillary versus mandibular) and both the quality of lingual preparations and the iatrogenic damage to adjacent teeth. This strongly suggests that anatomical location significantly impacts the accuracy of student crown preparations.

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