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Rubric system for evaluation of crown preparation performed by dental students

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Abstract

Objective: This study aimed to investigate the use of an analytic rubric system for the evaluation of all-ceramic crown preparation on the right maxillary central incisor performed by the dental students.

Materials and Methods: Seventy-two-third-year students and 8 faculty members from prosthodontics participated in this double-blind study. The students prepared an ivorine tooth # 11 for all-ceramic crown. The students were given clear instructions regarding the all-ceramic crown preparation and informed about the criteria for the assessment of the preparation. An analytic rubric based on 10-point scale for assessment of various preparation parameters was used by the 8 examiners. Descriptive statistics, ANOVA and post hoc Tukey tests were used for statistical analysis.

Results: One-way analysis of variance indicated significance amongst the examiners for all the parameters except for time management. The overall mean scoring by examiners was 7.60 ± 1.18, with highest and lowest mean scores for Examiner 1 (8.02 ± 1.06) and Examiner 4 (6.82 ± 1.50), respectively. The highest number of inter-examiner variation (difference) in scoring was found for two plane reduction, and the least difference amongst the examiners was observed for finishing of margins and walls of the preparation. Examiner 4 had the highest number of significant difference with the rest of the examiners. The students scored least marks in axial reduction (56.33%) and preservation of adjacent teeth (66.9%).

Conclusions: Criteria-based assessment using analytic rubric for crown preparations in pre-clinical fixed prosthodontics is an effective tool for finding the errors/weak areas of dental students.

KEYWORDS
crown preparation, dental education, dental students, pre-clinical, rubrics, student's assessment

1 | INTRODUCTION

A successful medical/dental education system should enable the faculty to address the students' requirements/needs and understand the various teaching methods, styles and approaches.[1]

Since the mid-1990s, there is a call for change in the way dental education is provided which is evident from a report published in 1995 by the Institute of Medicine, calling attention to the need for change in dental education.[2,3]

Unlike the medical education the assumption in dental education has always been that pre-clinical training is essential to the development of students' psychomotor skills, manual dexterity and comprehension of procedures required for success in the dental clinic. The provision of best possible dental treatment to the patients can

only be achieved with the commencement of preceding pre-clinical courses and their success. The basic foundation of the dental student's skills is developed in these pre-clinical courses, and later, the students continue to build on that foundation during their more advanced clinical training and later in the clinical practice.[4]

Pre-clinical fixed prosthodontics, which involves the teaching of didactic and practical tooth preparations of teeth for crowns and fixed partial dentures, is a very important subject in undergraduate dental curriculum. It is essential for the development of basic knowledge and hand skills required for mastering fixed prosthodontics. However, teaching and most importantly assessing the preparations are challenging for the faculty as they have to start teaching the tooth preparations right from the basics till the students are able to master the required exercises.[5]

Traditionally, the assessment of tooth preparations has been accomplished by visual method subjectively awarding a single grade or objectively by further dividing the single grade into multiple small grades. Researchers have named these two traditional methods as global grading (glance and grade method) and analytical grading (using rubrics).[6] Recently, more advanced methods such as digital grading of tooth preparations using different types of scanners and software programs are also introduced by various computer-assisted design/computer-assisted manufacturing (CAD/CAM) companies and are in practice in some institutes.[7,8] These systems are still not very new and not available in majority of the dental institutes. Majorly, the traditional methods of assessing the pre-clinical work in dental schools are carried out by the faculty.[9]

The traditional analytic assessment of pre-clinical fixed prosthodontics is accomplished by subjective visual assessment of the various parameters involved, such as occlusal reduction, axial reduction, two plane reduction, taper, margin placement, finishing, preservation of adjacent teeth and time management for optimal preparation of the teeth. During the early pre-clinical exercises, it is challenging for the faculty to teach the students to visualise correctly all the parameters together during their practice sessions.[10]

However, the assessment of each individual parameter with the analytic rubrics can be of definite help in finding and highlighting to the students their strength and weaknesses. This study aimed to investigate the use of an analytic rubric system for the evaluation of all-ceramic crown preparation on the right maxillary central incisor performed by the dental students. The study is potentially useful for the development of a reliable system for the pre-clinical tooth preparation course in dental schools.

2 | MATERIALS AND METHODS

The study was conducted at Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, and approved by the ethical committee of college of dentistry research centre (FR 0395). A total number of 72 third-year dental students and 8 faculty members with minimum qualification of masters in prosthodontics and who had experience of teaching and assessment of tooth preparations in pre-clinical fixed prosthodontics participated in the study.

It was a double-blind study where the participating student's identity was kept confidential from the examiners and the examiners' identity was not disclosed to the participating students. This was to ensure the bias does not influence the results of study as some of the examiners were involved in teaching the same students.

The participating students prepared an ivorine tooth upper right central incisor (Tooth # 11) for all-ceramic crown preparation on an upper jaw dentoform (D85DP-CHO.1, Nissin Dental Products, Inc., Kyoto, Japan) inside the manikin. The students were given clear instructions regarding the all-ceramic crown preparation and informed about the criteria for the assessment of the preparation. Possible exclusion criteria involved students who were found cheating, an alteration of the tooth or dentoform by the students and students who could not finish the exercise within the specified time. The total time allowed for the exercise was two and half hours. After completion of the exercise, the dentoforms were collected and numbered before commencement of the grading by the examiners.

An analytic rubric for assessment of various tooth preparation parameters was used for the assessments by the 8 participating examiners. The examiners who already were familiar with the criteria were further calibrated before the commencement of the assessments. The examiners independently assessed the student's preparations in their own free time. There was no time limit specified for the completion of the grading. However, examiners were requested to do the assessments alone and not in groups.

The rubric used in the study was based on a 10-point scale for assessment of 8 parameters of all-ceramic anterior crown preparation. The scoring of each major parameter such as occlusal reduction, axial reduction, taper and margin placement was further subdivided into a maximum score of 1.5, 1, 0.5 and a minimum score of 0. The rest of the 4 parameters (two plane reduction; finishing of walls and margin; preservation of adjacent teeth and soft tissue; time management) were supposed to get a maximum score of 1, 0.5 and a minimum score of 0. This analytic rubric used resembled a grid in which the parameters were listed in the leftmost column and with levels of scoring (performance) listed across the row using numbers along with the descriptive tags. Each of the criteria (parameter) was scored individually, and the rightmost column was filled with the particular score against each parameter, and then, the sum of all scores for each parameter was taken as the total score of the individual student (Table 1). Individual printed sheets were used for each student's assessment, and the hard copies were numbered according to the blind number assigned to the dentoforms for all the participating students.

2.1 | Statistical analysis

SPSS version 21 (SPSS, Inc., Chicago, IL, USA) was used for the statistical analysis of the obtained data with predetermined significance level at $P < .05$. Descriptive statistics for all the 8 examiners as well as the 8 parameters investigated was carried out. One-way analysis of variance was used for comparison of the scoring for the 8 parameters. Post hoc Tukey test was applied for the comparison of the individual scoring in each parameter by all the 8 evaluators for interexaminer variation.

TABLE 1 Parameters followed in all-ceramic crown preparation

Parameter	GRADES				Score
	1.5 points	1 point	0.5 point	No points	
Occlusal Reduction	Optimal reduction Supporting areas or porcelain = 1.5 -2.0 mm Non-supporting areas or metal = 1.0-1.5 mm	Moderately under-reduced Supporting areas or porcelain <1.5 mm Non-supporting areas or metal <1.0 mm	Moderately over-reduced Supporting areas or porcelain ≥2.5 mm Non-supporting areas or metal = ≥2 mm	Severely over-reduced or under-reduced Supporting areas or porcelain >3.0 or <1.0 mm Non-supporting areas or metal >2.5 mm or <0.5 mm	
Axial reduction	Optimal reduction (1.0-1.5 mm for metal, 1.5-2.0 mm for porcelain) and Rounded line and point angles	Moderately under-reduced (<1.0 mm for metal, <1.5 mm) or Lack of rounded line or point angles	Moderately over-reduced (2 mm for metal, 2.5 mm for porcelain)	Severely over-reduced or under-reduced (>2 mm for metal, >2.5 mm for porcelain)	
Taper	Optimal taper Retentive walls have 6 degrees of taper	Under- or Over-taper Taper present, but near parallel orOver-tapered on mesial or distal (>8° <16°)	Moderately Under- or Over-taper - Undercuts visually present or - Over-tapered on buccal or lingual (>8° <16°)	Severe Under- or Over-taper - Severe undercuts present or - Severe over-tapered on any axial surface (>16°)	
Margin placement	Optimal margin placement Margins extended to specified target; (even with free gingival margin or 0.5 mm supragingival)	Over- or Under-extended Over-extended (not more than 0.5 mm subgingival) or moderately under-extended (not more than 1 mm supragingival)	Moderately Under- or Over-extended Significantly over-extended (not more than 1.0 mm subgingival) pr significantly under-extended (not more than 1.5 mm supragingival)	Severely Under- or Over-extended Severely over-extended (more than 1.0 mm subgingival) or severely under-extended (more than 1.5 mm supragingival)	
Two plane reduction		Proper planes Providing adequate material bulk for strength/aesthetics.	Moderately improper planes over-reduced or under-reduced	Significantly improper planes over-reduced or under-reduced	
Finish, margins and walls		Optimal finish - Margins and walls are smooth - Margins are continuous, well defined	Moderate roughness - Moderate roughness of margins and walls - Margins are moderately non-continuous, moderate lack of definition	Significant roughness - Significant roughness of margins and walls - Margins are non-continuous - Lack of definition of finish line	
Preservation of adjacent teeth		Adjacent teeth are unaffected	Adjacent teeth are minimally touched.	Adjacent teeth are abraded and flattened	
Time management		Student ends the examination on time	Student ends the examination 10-15 min late	Student ends the examination more than 15 min late	

Total score of 10.

TABLE 2 Mean (Standard Deviation) of parameters for crown preparation by the examiners. (N = 608)

Parameter	[a]E 1	E 2	E 3	E 4	E 5	E 6	E 7	E 8	Overall mean	ANOVA P value
Occlusal reduction	1.342 (.296)	1.289 (.274)	1.296 (.307)	1.033 (.485)	1.283 (.385)	1.178 (.254)	1.289 (.274)	1.099 (.439)	1.226 (.362)	.000
Axial reduction	0.947 (.5)	0.908 (.333)	0.895 (.442)	0.5 (.529)	0.961 (.452)	0.882 (.381)	0.914 (.464)	0.757 (.525)	0.845 (.477)	.000
Taper	1.342 (.384)	1.039 (.267)	1.164 (.34)	0.987 (.418)	1.171 (.428)	1.132 (.349)	1.217 (.377)	1.086 (.419)	1.143 (.384)	.000
Margin placement	1.204 (.441)	1.428 (.177)	1.164 (.33)	1.138 (.405)	1.125 (.455)	1.362 (.239)	1.243 (.404)	1.127 (.403)	1.224 (.382)	.000
Two plane reduction	0.908 (.291)	0.737 (.443)	0.829 (.379)	0.934 (.249)	0.921 (.271)	0.664 (.485)	0.711 (.456)	0.993 (.057)	0.837 (.37)	.000
Finish margin and walls	0.803 (.259)	0.651 (.245)	0.737 (.276)	0.704 (.296)	0.697 (.306)	0.757 (.264)	0.829 (.265)	0.77 (.299)	0.743 (.281)	.002
Preservation of adjacent teeth	0.559 (.215)	0.553 (.154)	0.776 (.25)	0.618 (.325)	0.73 (.263)	0.678 (.254)	0.763 (.276)	0.678 (.302)	0.669 (.27)	.000
Time management	.921 (.183)	.921 (.183)	.921 (.183)	.921 (.183)	.921 (.183)	.921 (.183)	.921 (.183)	.921 (.183)	.921 (.183)	1.000
Total of 10	8.02 (1.06)	7.52 (.743)	7.78 (1.04)	6.82 (1.50)	7.80 (1.17)	7.57 (.885)	7.88 (1.17)	7.41 (1.32)	7.60 (1.18)	.000

[a]Examiner (N = 76).

3 | RESULTS

The parameters essential for the preparation of teeth for a crown were analysed in this study. Eight examiners evaluated the parameters with analytic rubrics for 76 third-year dental students in a pre-clinical fixed prosthodontic set-up. Descriptive statistics on students score awarded by the 8 examiners are presented in Table 2. One-way analysis of variance indicated significance amongst the examiners for all the parameters except for time management, which was awarded automatically without involving the examiners. The overall mean scoring for all the examiners was 7.60 ± 1.18, with highest and lowest mean scores were found for Examiner 1 (8.02 ± 1.06) and Examiner 4 (6.82 ± 1.50), respectively (Table 2).

Tables 3 and 4 present the results of post hoc Tukey's test, which was applied for the multiple comparisons of the examiners within each parameter. The highest number of interexaminer variation (difference) in scoring was found for two plane reduction, and the least difference amongst the examiners was observed for finishing of margins and walls of the preparation. Amongst the examiners, Examiner 4 had the highest number of significant difference with the rest of the examiners for all the parameters evaluated except for the finishing of margins and walls of the preparation (Tables 3 and 4).

In line with the purpose of this study which was to determine the parameters of tooth preparation for the crown in which the students were having difficulties, it was observed that students scored least marks in axial reduction (56.33%) and preservation of adjacent teeth (66.9%). This is evident from the graphical presentation, comparing the various parameters in Figures 1 and 2.

Therefore, it can be concluded that students' needs to improve their preparation skills within these parameters where they are scoring less according to the examiners. In regard to performance in the other parameters of preparation, the students were above average of 70% and found satisfactory.

4 | DISCUSSION

In this research study, the different parameters/criteria followed during the tooth preparation for all-ceramic anterior crowns by third-year dental students in a pre-clinical fixed prosthodontic set-up were evaluated with an analytic rubric (criteria-oriented grading) by eight instructors. In dentistry, the use of criterion-oriented grading system is in place for more than four decades. Dhuru et al[11] in 1978 highlighted the importance and suggested the use of criteria-oriented grading for pre-clinical dentistry courses. The usefulness of this criteria-based evaluation has been highlighted by many researchers in the following years.[12] Due to the limited access and resources for the more advanced digitalised assessment tools in the majority of the dental schools worldwide, the usefulness of the analytic rubric in the pre-clinical dentistry courses cannot be overemphasised.

The advantages of using analytic rubrics in pre-clinical courses over the subjective global (glance and grade) method are many. It

TABLE 3 Results of post hoc Tukey test* comparing the score of 8 examiners within each major parameter

Parameter	Examiner	1	2	3	4	5	6	7	8
Occlusal reduction	2	.983	-	1.00	.000	1.00	.500	1.00	.018
	3	.992	1.00	-	.000	1.00	.422	1.00	.012
	4	.000	.000	.000	-	.000	.175	.000	.942
	5	.967	1.00	1.00	.000	-	.580	1.00	.026
	6	.074	.500	.422	.175	.580	-	.500	.860
	7	.983	1.00	1.00	.000	1.00	.500	-	.018
	8	.001	.018	.012	.942	.026	.860	.018	-
Axial reduction	2	.999	-	1.00	.000	.997	1.00	1.00	.459
	3	.997	1.00	-	.000	.987	1.00	1.00	.580
	4	.000	.000	.000	-	.000	.000	.000	.014
	5	1.00	.997	.987	.000	-	.964	.999	.112
	6	.987	1.00	1.00	.000	.964	-	1.00	.700
	7	1.00	1.00	1.00	.000	.999	1.00	-	.401
	8	.171	.459	.580	.014	.112	.700	.401	-
Taper	2	.000	-	.436	.988	.366	.794	.066	.995
	3	.066	.436	-	.068	1.00	.999	.988	.896
	4	.000	.988	.068	-	.050	.247	.004	.731
	5	.089	.366	1.00	.050	-	.998	.995	.850
	6	.012	.794	.999	.247	.998	-	.850	.995
	7	.436	.066	.988	.004	.995	.850	-	.366
	8	.001	.995	.896	.731	.850	.995	.366	-
Margin placement	2	.005	-	.000	.000	.000	.957	.045	.000
	3	.998	.000	-	1.00	.998	.023	.892	.998
	4	.957	.000	1.00	-	1.00	.005	.649	1.00
	5	.892	.000	.998	1.00	-	.002	.498	1.00
	6	.145	.957	.023	.002	.003	-	.498	.003
	7	.998	.045	.892	.649	.498	.498	-	.521
	8	.904	.000	.998	1.00	1.00	.003	.521	-

*P value was significant at $P < .05$.

provides useful feedback on areas of strength and weaknesses of each parameter, and criterion can be weighted to reflect the relative importance of each dimension. Using analytic rubrics by the junior faculty members for evaluation of the undergraduate student's pre-clinical work to overcome the faculty shortage in dental schools is another useful advantage. In a study by Al Amri et al[6] it was reported that the level of expertise (junior vs senior faculty) did not affect the pre-clinical evaluation using rubrics. It is logical to conclude that junior faculty will do more accurate evaluations using analytic rubrics than global method of grading compared to senior faculty who can overcome the inaccuracies/disadvantages of global grading with their experience and expertise. However, using rubrics consumes more time compared to the global method of grading and unless each criterion for individual parameter in rubrics is well defined the chances of interexaminer variation in the scoring are high.

We hypothesised that the use of analytic rubrics could increase the consistency of grades amongst the different examiners. The results of this study showed an average score of 7.6 of 10 (76%) by the eight examiners for the participating students. For most of the examiners (6 of 8), their average score was well in line with the overall score. Exception was for examiner 1 (average score 8.02 ± 1.06) and examiner 4 (average score 6.82 ± 1.50) who tended to grade higher and lower than the rest of the examiners, respectively. The grades awarded by the examiner 1 were on the higher side but still within reasonable limits. The mean difference between the grades of Examiner 1 (8.02) and the Examiner 8 (7.41) whose grades were the lowest other than Examiner 4 was 0.61, whilst the mean difference between the grades of Examiner 4 (6.82) and the Examiner 7 (7.88) whose grades were the highest other than Examiner 1 was 1.06. With these results, it was evident that the Examiner 4 was not well trained/calibrated in using the rubric. However, it was evident that majority of the examiners had some agreement/consistency amongst their awarded grades. This finding of the current study is in line with the findings of Satheesh et al[2] who reported increased reliability of 90.2% with the use of analytic rubrics in their research study.

| Parameter	Examiner	1	2	3	4	5	6	7	8
Two plane reduction	2	.061	-	.751	.015	.031	.914	1.00	.000
	3	.870	.751	-	.601	.751	.084	.445	.084
	4	1.00	.015	.601	-	1.00	.000	.003	.970
	5	1.00	.031	.751	1.00	-	.000	.007	.914
	6	.001	.914	.084	.000	.000	-	.993	.000
	7	.015	1.00	.445	.003	.007	.993	-	.000
	8	.815	.000	.084	.970	.94	.000	.000	-
Finishing of margins and walls	2	.019	-	.551	.940	.971	.274	.002	.147
	3	.827	.551	-	.996	.988	1.00	.451	.996
	4	.357	.940	.996	-	1.00	.940	.102	.827
	5	.274	.971	.988	1.00	-	.893	.070	.745
	6	.971	.274	1.00	.940	.893	-	.745	1.00
	7	.999	.002	.451	.102	.070	.745	-	.893
	8	.996	.147	.996	.827	.745	1.00	.893	-
Preservation of adjacent tissues	2	1.00	-	.000	.774	.001	.062	.000	.062
	3	.000	.000	-	.005	.958	.274	1.00	.274
	4	.856	.774	.005	-	.140	.856	.015	.856
	5	.001	.001	.958	.140	-	.917	.994	.917
	6	.095	.062	.274	.856	.917	-	.464	1.00
	7	.000	.000	1.00	.015	.994	.464	-	.464
	8	.095	.062	.274	.856	.917	1.00	.464	-

*P value was significant at $P < .05$.
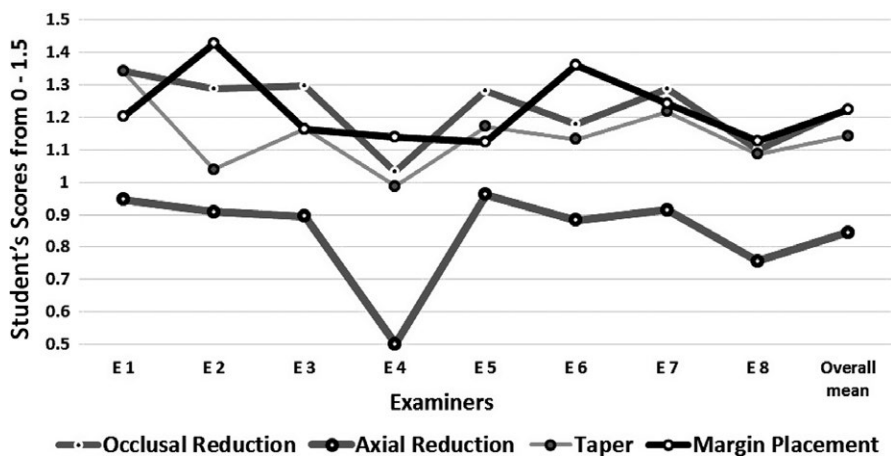
FIGURE 1 Graphical comparison of assessments by 8 examiners for major paramaters

Analytical rubric system helps in providing the students with a detailed feedback making it easier for them to receive much information from their marks about each of the criteria. They can find the exact areas of their strengths and weaknesses with the provision of detailed result, without the need for specific comments from their instructors.[13] Within the individual preparation parameters investigated in the current study, the parameter/criteria in which the students scored the least were axial reduction. The mean score for the axial reduction was 0.845 of 1.5 (56.33%).

Proper axial reduction is essential to provide enough space for allowing good functional morphology and structural durability. Vertical depth grooves are performed in the vestibular surface with a tapered diamond bur followed by removing the tooth structure in between the grooves. The placement of depth grooves helps to control the amount of reduction. Rosella et al[14] reported these criteria to be the most demanding challenge for prosthodontists, that is to control the depth and direction of tooth tissue removal.
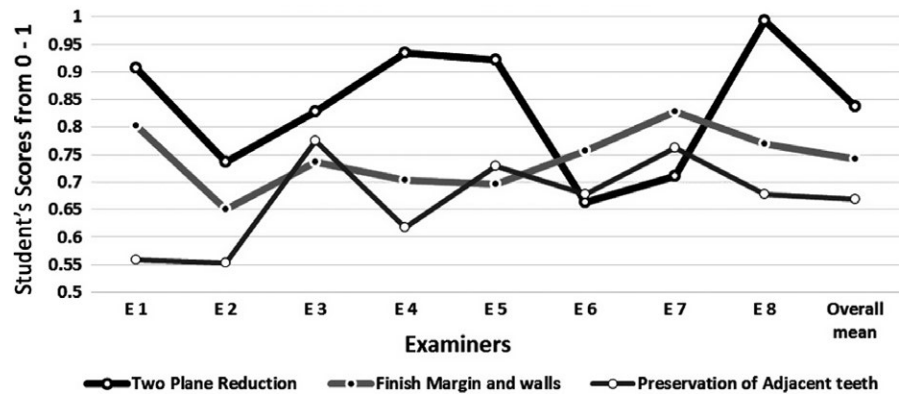
FIGURE 2 Graphical comparison of assessments by 8 examiners for minor paramaters

Another important criterion, where the students underperformed, was preservation of adjacent teeth and tissues. The mean score for this criterion was 0.669 ± .27 of 1 (66.9%). Even though this score was above the minimum 60% passing score but was considered unacceptable because of its irreversible damage. Unlike other human tissues, dental tissues do not have regenerative capacity.[15] Therefore, the removal of dental biological material should be planned and executed with maximum attention and care.

Based on the results of the study, variations were observed within the various parameters for the examiners. According to the rubric for the majority of the parameters, there was consistency in grades awarded by the examiners except for the two plane reduction. Mays et al[10] described the total occlusal convergence or taper to be the most challenging parameter for the examiners. In the current study, variability amongst the examiners was also observed for the taper; however, it was the two plane reduction where major differences were noted. The reason could be the geometrical similarity between the taper and the two plane reduction. With visual inspection, the estimation of these angles is fairly challenging for the examiners and chances of underestimation and overestimation of these parameters are high.[16]

One of the challenging aspects of managing a pre-clinical fixed prosthodontic course is finding enough time to meet with students during and outside of scheduled laboratory timings sessions to provide feedback. The dental students these days have competing academic responsibilities, and it is difficult to find time for meeting with them.[8] However, the use of analytic rubrics for the assessment of tooth preparation can provide students with instant and objective feedback. They leave the examination with identified areas of weaknesses and can inquire via email or whenever convenient for the faculty to get information on how to address those weaknesses.

A possible limitation of this research as well as generally with analytical systems is that often the aggregate of the whole is less than its parts or vice versa and examiners may find that the marks awarded from analytical system do not "feel" right. An example might come from applying an analytical marking scheme within this pre-clinical research study, which awards zero marks to a very important component but overall the student gets benefit from the sum of total components and is able to successfully get the passing

mark for the course. Even though from the examiners' point of view, the students deserve to be failed for the irreversible damage caused by the student within that individual parameter.

The ultimate objective of pre-clinical dental education is to prepare students for delivering the best possible dental care to their patients in the clinics. The students then build on the foundation created in the pre-clinical courses and the learning persists during their more advanced clinical courses. In a study by Velayo et al[4] the pre-clinical performance was positively correlated with clinical success. Students who are found weak in practical domain can continue to do extra practice to improve their psychomotor skills.[17]

Limitation of the current study is that it was conducted at one dental school and the results cannot be generalised as well as it should be interpreted with caution. The time management parameter can be omitted, and its value can be added to the parameters two plane reduction and preservation of adjacent teeth. The author suggests revision of the analytic rubric used in the study whilst keeping in consideration the irreversible procedure of tooth preparation. Continuous revision of the rubric is mandatory to ensure its efficacy for measuring intended criteria.

5 | CONCLUSIONS

The results of this study suggest that criteria-based assessment using analytic rubric for crown preparations in pre-clinical fixed prosthodontics set-up is an effective tool for finding the errors/weak areas of the dental students. Amongst the tooth preparation parameters investigated in this study, axial reduction followed by the damage to the adjacent teeth was the areas of weaknesses found for the participating students. For majority of the examiners, a consistency in the evaluations was observed whilst using rubrics used in this study.

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