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Improving the quality of preclinical simulation training for dental students using a new digital real-time evaluation system

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Abstract

Background: With the rapid development of technology, traditional dental education has undergone a transition with the active incorporation of digital technology into curricula. DCARER is a recently developed digital real-time evaluation system for the digital assessment of student preclinical simulation practice performance. The system provides supplementary feedback on process analysis in addition to an objective final result. This study evaluated the grading validity of the DCARER system and its effect on dental preclinical practice skills training.

Methods: Seventy-three residents of Grade 2018, all of whom had completed their 3-year term residencies in standardised and systematic training, were recruited into this study to examine the system's grading validity. All performed crown preparations with the adoption of the DCARER system, which generated both process and final scores. Three experts gave their own grade anonymously according to the final work. The differences between the digital system and the expert scores were analysed. In addition, 60 dental students in Grade 4 and 10 dental faculty members were randomly divided into traditional and digital groups. The students in the traditional group prepared the tooth with the guidance of supervisors, whilst the digital group used the DCARER system. After the class, the students' tooth preparations were scored by the same three experts in a blinded manner. The students and faculty members completed two different sets of questionnaires to evaluate the effects of teaching, acceptance, satisfaction, and evaluation accuracy of the digital system and the traditional method.

Results: The grading validity assessment showed no significant difference between the tooth preparation scores given by the DCARER system and the experts ($P > .05$). The unique process scores given by the DCARER system were weakly correlated with the final scores given by both the digital system and the experts. The main characteristics of the 60 students and 10 faculty members were homogeneous at baseline ($P > .05$). The tooth preparations of the traditional group scored significantly lower than those of the digital group ($P < .01$).

Abbreviations: DG, digital group; ICC, inter-class correlation; PFM, porcelain fused metal; TG, traditional group.

More students in the digital group (93.3%) believed the judgement to be objective than in the traditional group (73.3%). All students guided by the DCARER system (100%) and 80% of students taught in a traditional manner felt that the assessment reinforced the learning process. Faculty members reported that use of the digital system did not significantly increase their workload and reinforced the learning process for the internship.

Conclusion: The results presented here indicate the validity of grading using the digital real-time evaluation system. Students and faculty could benefit from application of the system in tooth preparation practice, which may provide effective clinical interaction training for dental education.

KEYWORDS

dental education, digital real-time evaluation system, preclinical training, tooth preparation

1 | INTRODUCTION

Dentistry is a practical discipline that requires the acquisition of psychomotor skills. Dental students require a great deal of laboratory practice during preclinical simulation training to achieve good performance in subsequent direct patient care. Oral fixed prosthodontics is an essential component of prosthodontics, which introduces the fundamental biomechanical principles, materials and techniques required to rehabilitate oral function.[1] Velayo et al[2] reported that the preliminary preclinical operative skills of dental students were positively correlated with their operating skills as dentists.

In traditional simulation laboratories, one experienced tutor usually supervises several students at the same time. Generally, the instructors first demonstrate theoretical knowledge using presentations or informative diagrams, pictures and models of the practical procedures to be performed. It is not easy to communicate accurately or present clearly explanations of the complex three-dimensional geometry of the work.[3]

Moreover, there are issues regarding the inability to provide objective assessment, with incompleteness and irreproducibility of faculty members' subjective responses to the final preparations. In addition, the instructors require extra time to score each student's work after class.[4] Traditionally, grades are given based on visual inspections, which are not always consistent between different times by the same evaluator, let alone between different evaluators.[5] Although several digital standardised grading criteria have been suggested, it is necessary to assess many detailed indexes and their use is time-consuming for evaluators.[6]

Over the last several decades, the development of digital dental simulation training tools has provided new opportunities for improving dental education. With early tools utilising a mouse or keyboard to complete virtual dental tasks as in software racing games, it was difficult for dental learners to master basic sensorimotor skills. There has been a great deal of subsequent development in virtual reality, haptic (tactile) and robotic technologies.[7] The two most commonly used technologies in dental education are virtual simulation systems and digital timely evaluation systems.[5] There is no need to prepare a phantom head and burs with the application of a virtual simulation system, thus creating an image processing setting and making it more environmentally friendly. However, such systems have a number of deficiencies in comparison to real healthcare conditions, and they do not provide sufficient feedback although they allow more self-directed education and standardisation for grading. Digital real-time evaluation systems can provide more realistic practice conditions and facilitate the transition from laboratory work to clinical practice. Such systems facilitate teaching and evaluation by supervisors or education specialists. Three-dimensional scanning systems allow

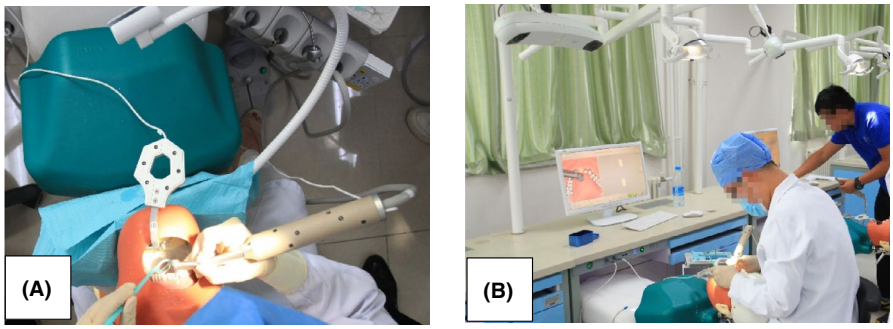

FIGURE 1 Dental digital real-time evaluation system. A, The mannequin, student's handpiece, typodont tooth of DCARER system. B, The computer and infrared camera of DCARER system

TABLE 1 Assessment criteria modified from an analytic rubric[6]

	Grades			
Parameters	**5-6 points**	**3-4 points**	**1-2 points**	**0 points**
Incisal reduction	2.0 mm	2.0-2.5 mm or 1.5-2.0 mm	0.5-1.5 mm or 2.5-3.0 mm	<0.5 or > 3.0m
Labial reduction	1.2-1.4 mm	1.5-2.0 mm or 1.0-1.2mm	0.5-1.0 mm or 2.0-2.5 mm	<0.5 or > 2.5 mm
Proximal reduction	1.0 mm	0. mm or 1.0-1.2mm	0.5-1.0 mm or 1.2-1.5 mm	<0.5 or > 1.5 mm
Axial palatal reduction	0.5 mm	0.8-1.0 mm or 0.5-1.0 mm	1.0-2.0 mm	>2.0 mm
Palatal fossa reduction	0.7-1.0 mm	0.5-0.7 mm or 1.0-1.5 mm	1.5-2.0 mm	<0.5 or > 2.0 mm
Labial margin placement	With free gingival margin	<0.5 mm sub- or supra-gingival	>0.5 and < 1.0 mm sub- or supra-gingival	>1.0 mm sub- or supra-gingival
Labial margin morphology	Shoulder, 1.0 mm width, continuous, rounded line and point angles	Shoulder, 0.5-1.0 or 1.0-1.5 mm width, continuous, rounded line and point angles	Shoulder, <0.5 or 1.5-2.0 mm width moderately un-continuous, unrounded line and point angles	No margin or > 2.0 mm width or significantly un-continuous, unrounded line and point angles
Palatal margin placement	With free gingival margin	<0.5 mm sub- or supra-gingival	>0.5 and < 1.0 mm sub- or supra-gingival	>1.0 mm sub- or supra-gingival
Palatal margin morphology	Chamfer, 0.5 mm width, continuous, rounded line and point angles	Chamfer, 0.1-0.5 or 0.5-1.0 mm width, continuous, rounded line and point angles	Chamfer, 1.0-2.0 mm width moderately un-continuous, unrounded line and point angles	No margin, or > 2.0 mm or significantly un-continuous, unrounded line and point angles
Parameters	**Grades**			
	8 points	**6-4 points**	**3-1 points**	**0 point**
Undercuts	none	< 0.3mm	>0.3 and < 1.0 mm	>1.0 mm
Taper	6°- 10°	11°- 20°	21°- 25°	> 25°
Finish	Optimal finish	Slight roughness	Moderate roughness	Significant roughness
Parameters	**Grades**			
	12 points	**8-10 points**	**2-6 points**	**0 point**
Preservation of adjacent teeth	Unaffected	Minimally touched < 0.5 mm	Moderately touched > 0.5 and < 1.0 mm	Abraded and flattened > 1.5 mm
Parameters	**Grades**			
	10 points	**6-8 points**	**1-4 points**	**0 point**
Preservation of gingival	Unaffected	Minimally touched < 0.5 mm	Moderately touched > 0.5 and < 1.0 mm	Abraded and flattened > 1.5 mm

teachers to grade student tooth preparations more rapidly, reliably and reproducibly compared with traditional visual inspection.[5]

The DCARER digital real-time evaluation system (Aizhixing, DCARER, Jiangsu, China) includes a mannequin with typodont teeth (Figure 1A), a student's handpiece and a computer with an infrared navigation system (Figure 1B). Infrared LEDs on the handpiece connected to the in-mouth model help the infrared navigation system detect and track the operator's movements once the operation begins (the system can calculate relative position changes in less than 1 s).[8] The digital unit with spatial positioning and instantaneous grading of all preparation details can be used for students and faculty to facilitate dental clinical training, providing digital real-time guidance and professional assessment to enhance the operator's practical ability.

This main research question of this study was to evaluate whether undergraduate students' tooth preparation performance was no different between traditional teaching methods and with DCARER real-time evaluation system guidance, and feedback of students and teachers in preclinical dental training of oral fixed prosthodontics was also focused. Before this, the secondary research question to the validity of the grading of the digital real-time evaluation DCARER system was clarified.

2 | MATERIALS AND METHODS

Research approval was obtained from Peking University School and Hospital of Stomatology.

2.1 | Validity of the digital real-time evaluation system in tooth preparation

Seventy-three residents (aged 25.8 ± 3.3 years; 32 males and 41 females) who had completed their 3-year term residencies in standardised and systematic training were enrolled in this research project. As part of the final examination of their normative training, all were required to complete right maxillary central incisor tooth preparation for a porcelain fused metal (PFM) crown with the DCARER system. Three deputy chief physicians (experts) scored the quality of all preparations anonymously in a blinded manner based entirely on visual observations. The inter-rater correlation coefficient (ICC) was determined before rating. The average score given by the experts was calculated for each resident. Both the expert and system scores were numerical and ranged from 0 to 100 according to the same assessment criteria modified from an analytic rubric[6] (Table 1).

2.2 | Comparison of student performance with the DCARER digital system versus traditional teaching

The 60 students that participated in this study were randomly divided into two groups, one receiving traditional training (traditional group, TG), and the other receiving guidance with the DCARER digital system (digital group, DG). All students were given clear instructions regarding PFM crown preparation, and they understood the criteria for assessment of the preparation. After receiving instruction on PFM crown preparation, the students in the TG and DG were required to prepare a PFM crown using an artificial resin upper right central incisor mounted on a dental model in a simulated phantom head (KaVo Sybron Dental, Shanghai Co., Ltd., Shanghai, China) within the stipulated time. Grading of the practical examination was performed as described above by three individual experts who were responsible for evaluating each preparation from the students in the TG.

2.3 | Student and faculty opinions on digital versus traditional training

Questionnaires comprised of five items were distributed to the students and faculty members to determine their attitudes towards the teaching methods in which they participated (Tables 2 and 3). The items were related to the teaching effectiveness, acceptance, satisfaction and objectivity of the evaluation. Responses were elicited to each statement below using a 3-point Likert scale: 1, "I disagree"; 2, "I agree"; or 3, "I strongly agree."

TABLE 2 Questionnaire for students

	Questionnaire items
1	You are very interested in the practice of oral prosthodontics.
2	The internship judgment is objective.
3	The assessment reinforced the learning process.
4	The internship has increased your burden.
5	Overall, the oral prosthodontics internship is satisfying.

TABLE 3 Questionnaire for teachers

	Questionnaire items
1	The preparation work for the internship is heavy.
2	The internship judgment is objective.
3	The assessment reinforced the learning process.
4	The workload for the student scoring process is very heavy.
5	Overall, the oral prosthodontics internship is satisfying.

The questionnaire for students included five items as shown in Table 2.

The questionnaire for teachers included five items as shown in Table 3.

The questionnaire items were subjected to statistical analysis.

2.4 | Statistical analysis

IBM SPSS Statistics, version 21 (IBM Corp., Armonk, NY), was used for statistical analysis of the data with $P < .05$ taken to indicate statistical significance. Using SPSS reliability analysis (two-way mixed effects model and consistency type) to generate average measures inter-class correlation coefficient (ICC). Descriptive statistics were calculated for characteristics of both residents and

TABLE 4 Main characteristics of the 73 residents

Characteristics	Number(n)
Total(n)	73
Gender	
Female(n)	41
Male(n)	32
Age(Y)	25.8 ± 3.3
Qualification	
Doctor degree(n)	26
Master degree(n)	37
Specialty Background	
General Dentistry(n)	30
Oral Medicine(n)	14
Oral Surgery(n)	9
Oral Prosthodontics(n)	20

undergraduates. Student's t test was applied to compare the final scores given by the experts and the digital system for the 73 residents. T test was also used to compare the preparations scores of the two groups of undergraduates with different teaching method application.

3 | RESULTS

3.1 | Digital real-time evaluation system validity for the assessment of tooth preparations

A total of 73 residents (Table 4) participated in tooth preparation training. As shown in Figure 2, there were no statistically significant differences between the grades generated by the experts and the digital system ($P > .05$). The inter-class correlation coefficient (average measures) amongst the three examiners was 0.71. Additionally, a process score for each tooth preparation was reported (79.1 ± 6.5) by the digital system.

3.2 | Comparison of the examination scores for tooth preparations guided by traditional teaching versus the digital system

The main characteristics of the 60 students and 10 faculty members were homogeneous at baseline (Tables 5 and 6). There were no statistically significant differences between the two groups.

The examination scores of the DG were significantly higher than those of the TG (80.4 ± 3.1 *vs.* 76.7 ± 4.5, respectively, $P < .01$) (Figure 3).

TABLE 5 Main characteristics of the 60 students

Characteristics	Groups	
	Traditional group	Digital group
Number(n)	30	30
Gender		
Female(n)	21	18
Male(n)	9	12
Age(Y)	22.67 ± 0.76	22.73 ± 0.79
Qualification		
Dental degree(n)	30	30
Specialty		
General dentistry	30	30

TABLE 6 Main characteristics of the 10 teachers

Characteristics	Groups	
	Traditional group	Digital group
Number(n)	5	5
Gender		
Female(n)	2	2
Male(n)	3	3
Age(Y)	39.20 ± 4.32	38.00 ± 5.15
Qualification		
Doctoral degree(n)	5	5
Specialty		
Prosthodontics	5	5
Teaching experience(years)	12.60 ± 3.64	11.80 ± 4.15

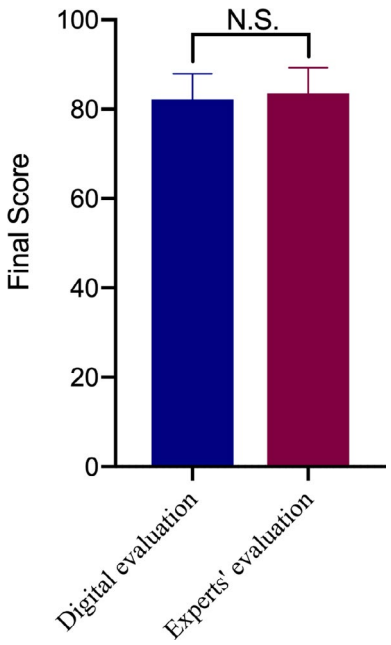

FIGURE 2 Final score given by different evaluation method (mean ± standard deviation) [Colour figure can be viewed at wileyonlinelibrary.com]

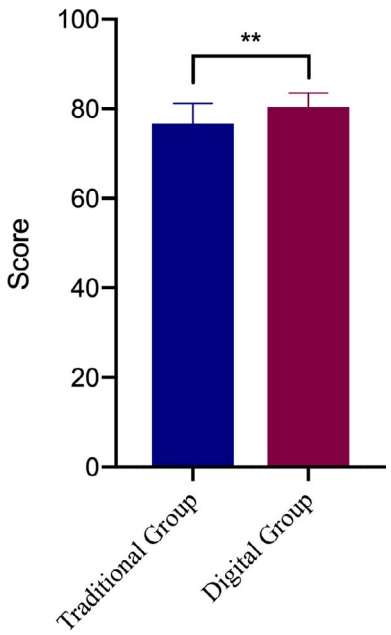

FIGURE 3 Assessment of students guided in different method (mean ± standard deviation), $^{**}P < .01$ [Colour figure can be viewed at wileyonlinelibrary.com]

3.3 | Feedback from students and faculty regarding digital and traditional training teaching, acceptance, satisfaction and evaluation objectivity

In total, 70 valid questionnaires (60 from students and 10 from faculty members) were analysed; the response rate was 100.0%.

More DG students (96.7%) than TG students (90%) reported an active interest in preclinical practice of oral fixed prosthodontics. The judgement was classified as objective by 93.3% of students in the DG compared to 73.3% in the TG. All (100%) of the students in the DG and 80% of the students in the TG considered that the assessment reinforced the learning process. Most of students (90%) in the DG and TG felt that the internship had not increased their burden. In the DG, 96.7% of respondents stated that they had an active interest in the preclinical practice of oral fixed prosthodontics, compared to 90% in the TG (Table 7). All of the faculty members who participated in digital real-time training reported that the workload associated with preparing for the internship was not heavy. More faculty in the DG considered the process to be objective, and they felt that it reinforced the learning process, compared to the faculty in the TG. None of the teachers considered digital real-time training to place a greater burden on students than traditional teaching. More faculty in the DG expressed satisfaction with the internship compared to faculty in the TG (Table 8).

4 | DISCUSSION

4.1 | Grading validity of the DCARER digital real-time evaluation system

DCARER is an interactive clinical simulation training system that can track and present the whole process in real time. Our results show that objective assessment by the digital real-time evaluation system was comparable to expert evaluation for the 73 residents, indicating that the system evaluation was valid and could be used to evaluate tooth preparations.

The residents recruited in the present study had completed their residencies in standardised and systematic training in which PFM crown preparation was a compulsory course. We found a weak correlation between the residents' process performance scores and the grades given regardless of whether grading was done by the software or experts, suggesting bias in the scores that were calculated directly according to the contour of the students' final tooth preparations. Standardised preclinical dentistry practice training is important. In addition, the simulation featured an ergonomic design and expanded the students' clinical experience. Prompt process feedback corrected any perceived problems encountered by the students during the procedure, rendering the training more effective. It also helped students to appreciate their practice and further their scientific development. This system is useful not only for dental practical training, but also for the standardised evaluation of various competition events and quality control of different teaching methods.

4.2 | Comparison of the DCARER digital system with traditional teaching

The mean score was higher for students in the DG than in the TG in the present study. Using traditional teaching methods, although the application of videos helps students to better grasp three-dimensional concepts, different students may experience varying problems at different stages of the practical process. Instructors are often spread too thin to deal simultaneously with large numbers of questions; this has an adverse effect on classroom order. Students who do not receive timely visual feedback may suffer some anxiety, which may have an adverse effect on their interest in clinical practice.[9] With DCARE, it was easy to track the preparation details and consistently achieve instant feedback. In addition, the feedback helped the students to correct any misunderstandings they had, which was not possible in the traditional teaching classroom. The digital system provided a reproducible, reliable and objective assessment of the process based on an evaluation of quantifiable parameters, providing the students with continued feedback whenever needed.

TABLE 7 Feedback of students involved in this study

	Groups					
	Traditional group			Digital group		
Items	1	2	3	1	2	3
You are very interested in the practice of oral prosthodontics.	3	10	17	1	9	20
The internship judgment is objective.	8	15	7	2	5	23
The assessment reinforced the learning process.	6	15	9	0	8	22
The internship has increased your burden.	27	0	3	27	2	1
Overall, the oral prosthodontics internship is satisfying.	3	11	16	1	7	22

TABLE 8 Feedback of teachers involved in this study

	Groups					
	Traditional group			Digital group		
Items	1	2	3	1	2	3
The preparation work for the internship is heavy.	2	2	1	5	0	0
The internship judgment is objective.	1	3	1	0	1	4
The assessment reinforced the learning process.	1	3	1	0	0	5
The workload for the student scoring process is very heavy.	0	1	4	5	0	0
Overall, the oral prosthodontics internship is satisfying.	2	1	2	1	1	3

4.3 | Opinions of the students and faculty on the teaching effectiveness, acceptance, satisfaction and evaluation accuracy of the digital and traditional training methods

The digital real-time training system is student-centred, and students are more actively involved in the learning process making the learning process more enjoyable.[10] Our study showed a greater degree of interest amongst students in the DG than the TG. The immediate feedback provided by the system effectively enhanced students' independent learning ability. They also developed a good understanding of complex concepts, including undercuts, path placement and convergence angles, and the system enhanced students' self-fulfilment.[11] Students also gave high marks regarding the system's practicality, feasibility and availability.[12]

The regular application of a digital real-time evaluation system in teaching could further improve students' proficiency with the system, which, in turn, would optimise the class and promote teaching efficiency.[12] With the wide acceptance and integration of these technologies into the dental curricula, students could achieve a higher level of competency and potentially decrease their learning curve in the early clinical environment prior to clinical patient care. Students were able to expand their skill set and receive fair clinical feedback during their preclinical training.

With the aid of the digital real-time evaluation system, the educators changed their role from traditional teacher-centred teaching to student-centred teaching. The instructor, instead of acting as the classroom's controller, became a supervisor and coordinator. Faculty feedback in this study suggested that the digital system helped reduce the preparation tasks and classroom organisation burden. Teachers personalised their directions and explained the procedure in detail to students who did not understand the system via recordings. We also found that there were differences in the process rates of the 73 residents with expert or system scores, which also explained the shortcomings of this traditional teaching approach. Even if a preparation seemingly fulfilling the stipulated requirements was handed in, it did not mean that the students had thoroughly mastered the standardised tooth preparation process. A real-time system could report practical weaknesses in the preparation period, facilitating teaching in a more individualised manner.

4.4 | Deficiencies in and educational improvements offered by the digital system

The DCARER advanced simulation system showed some potential to improve the quality of dental education. However, the financial costs required to achieve a student/system ratio of 1:1 would be a major consideration. It was challenging and time-consuming during the early stages of adopting the system to train the teachers, especially senior instructors with a great deal of experience in traditional teaching methods.[11] The sacrifice of some laboratory practice time was unavoidable to allow the students to receive instruction in using the system before practice. Students may have been negatively affected by the introduction of an unfamiliar system at the initial stage of the study. In addition, the training data package was originally installed on the system and may differ from actual practice, thus necessitating further optimisation and testing.

Compared with traditional teaching, the DCARER digital real-time evaluation system is still in the development stage, and it differs markedly from traditional teaching by teachers who have accumulated a great deal of experience and could flexibly deal with various situations as they arise. With the assistance of a digital real-time evaluation system, teachers should still play a major role in the classroom, optimising the experience for students and making the class more effective.

5 | CONCLUSION

Within the limitations of this study, the digital real-time evaluation system was shown to be useful for objectively and effectively grading students' work. Adoption of the system would improve the tooth preparation performance of dental students.

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