Evaluation of Newly Developed Double-layer Composite Resin Teeth for Crown Preparation Training

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Objective: *To evaluate and compare the crown preparation performance of preclinical dental students training with conventional composite resin teeth and newly developed double-layer composite resin teeth.*

Methods: *The newly developed composite resin teeth consisted of two layers with different colours and hardnesses. Twenty third-year undergraduate dental students (8 men, 12 women) were randomly assigned to the control group (Group 1, using conventional composite resin teeth; n = 10) or the experimental group (Group 2, using double-layer composite resin teeth; n = 10) to prepare metal-ceramic crowns. To practice, each student prepared one tooth per day for 2 days. For the baseline test and final test before and after the practice period, both groups used traditional teeth. The operation time was recorded and the prepared teeth were scored blindly by two experienced instructors. The time and scores were compared within and between groups to determine the difference ($\alpha = 0.05$).*

Results: *Students in both groups spent less time ($P < 0.05$) and achieved better scores ($P < 0.001$) on the final test than the baseline test ($P < 0.01$). In the final test, no significant difference in operating time was found between the two groups ($P > 0.05$), but Group 2 yielded significantly higher scores ($P < 0.05$).*

Conclusion: *Training with the double-layer composite resin teeth enabled students to progress more quickly in terms of operating time and achieve higher scores. Use of this newly-developed tooth in crown preparation teaching practice therefore yields highly promising results.*

Key words: *3D printing, computer simulation, milling, prosthodontics, teaching methods, tooth preparation*

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Prosthodontics is a major discipline that requires theory and practice to be combined closely. As a key skill in restorative dentistry, full crown preparation is a significant part of the preclinical dental curriculum[1]. Tooth preparation principles are fundamental to the success of the resulting crowns and affect the retention and resistance of the restorations[2]; any inadequacies may increase the possibility of prosthesis failure[3,4]. Although students can

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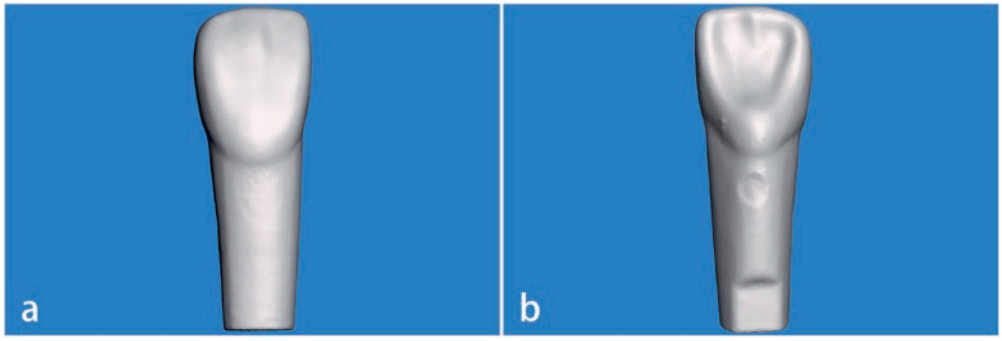

Fig 1 The left maxillary tooth was scanned. **(a)** Labial view and **(b)** lingual view.

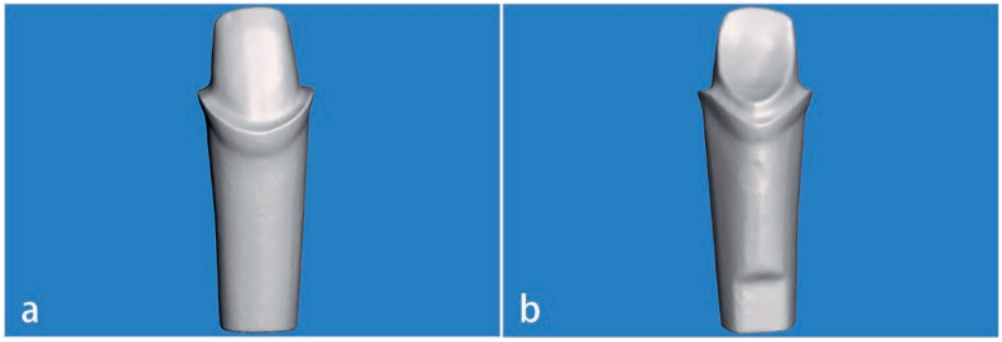

Fig 2 Scanned PFM crown preparation. **(a)** Labial view and **(b)** lingual view.

achieve a good understanding of those principles from theoretical lectures, they usually struggle to achieve an ideal preparation in practice.

Teachers provide many methods and tools to bridge the gap between theory and practice. Among these, tooth preparing demonstrations and prototype preparation models are most commonly used in preclinical courses[5]; images, videos and models of tooth preparations are usually incorporated into practical teaching[6]. However, using only conventional two-dimensional (2D) images and illustrations tends to make visual recognition and skill acquisition difficult for dental students in simulation clinic exercises. These 2D images and illustrations cannot provide students with a sense of depth or a view of the angles and walls of crown preparations[7]. 3D models enable students to observe the shape of ideal preparations more directly, but they cannot guide the amount of tooth reduction. A study found that a support system with a parallel link mechanism aided dental students in achieving greater competency[8]. Practical demonstration is also an effective measure; however, when the teacher demonstrates using real teeth, students' field of vision is limited, making it difficult for them to visualise every detail of the operation[9]. Moreover, it is not always possible for a teacher to provide a good explanation of how every step is carried out, even if they have mastered the skills themselves[10]. Learners' performance is related to the arrangement of the training course; a step-by-step approach has shown better results than the all-in-one protocol[11].

When practising on composite resin teeth, students usually determine the depth of tooth reduction with the help of the diameter of burs and tooth reduction guides. A typical reduction guide is fabricated as follows: the dental practitioner makes a replica of the original tooth with polyvinyl siloxane (PVS) putty impression material, then cuts it facial-lingually and positions it on the prepared tooth[12]; thus, it can only show one section of the preparation. Another kind of guide is made from a transparent thermoplastic sheet, which allows visual evaluation and measurement of the distance underneath by probing through holes or slots in the matrix[13]; however, the guidance is also limited to the specific holes, not every surface or margin of the preparation. Nowadays, digital training systems are also used to guide and evaluate tooth preparation and have proven to be a good alternative to the traditional training method, but one that requires substantial economic input[14].

Artificial composite resin teeth are indispensable in preclinical training. Compared with natural human teeth, artificial teeth are more accessible and do not pose the risk of cross-infection[15]. Their use became commonplace in the late 20th century when dental education was developing rapidly and the supply of real teeth was limited[16]. Except for teeth with artificial root canals, most composite resin teeth for tooth preparation

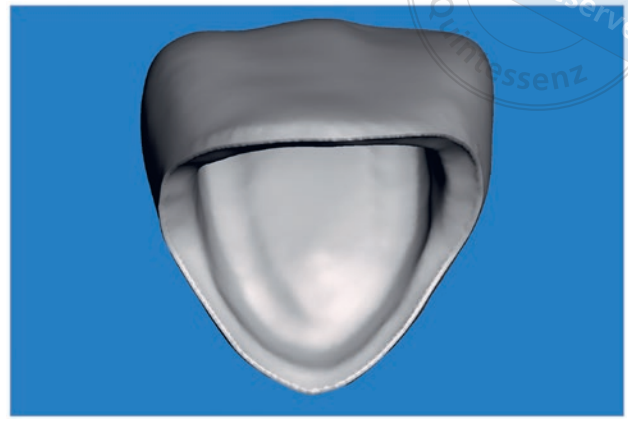

Fig 3 Digitally designed crown.

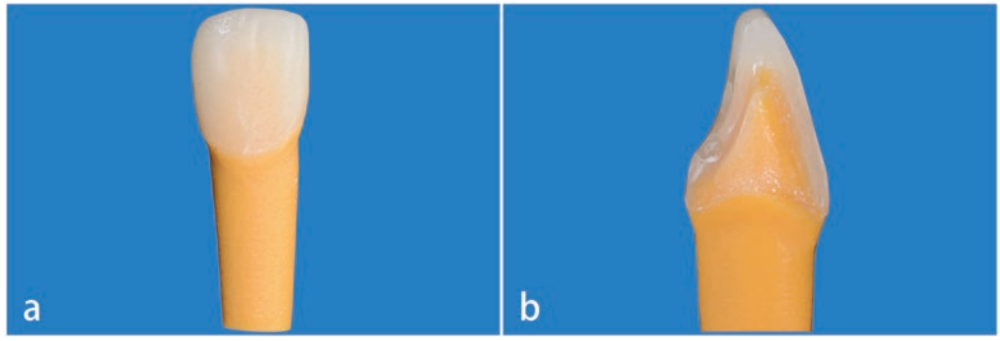

Fig 4 **(a)** Labial view and **(b)** cross-section view of the newly developed double-layer composite resin tooth. The shape of the abutment and thickness of the crown can be seen in the cross-section view.

training are single-layer and homogeneous. In recent years, CAD/CAM, including digital scanning, design, rapid prototyping and numerical control processing, has been used in different fields of dentistry[17,18]. The application of computer-assisted learning in dental education is also growing[19-21]. With the help of 3D printing, teaching models with composite structures that are designed to help students to visualise the anatomical structures or cavity preparations have been produced[9]. To the present authors' knowledge, however, little evidence has shown that students may perform better if modified composite resin teeth are used in the training course.

This study aimed to evaluate and compare the tooth preparation performance of preclinical dental students trained with conventional and newly developed double-layer composite resin teeth. The null hypothesis was that the students in both groups would spend the same time on tooth preparation and obtain similar scores in the final test after training.

Materials and methods

This study was granted exemption by the Peking University School of Stomatology Institutional Review Board (no PKUSSIRB-202056002).

Fabrication of the double-layer composite resin teeth

First, a conventional composite resin tooth (A5A-200, Nissin, Kyoto, Japan) of the maxillary left central incisor was scanned with an optical lab scanner (D2000, 3Shape, Copenhagen, Denmark) and exported as a standard tessellation language (STL) file named File A (Fig 1). Second, the tooth was prepared according to porcelain-fused-to-metal (PFM) crown criteria by an experienced prosthodontist (LC). After preparation, the tooth was scanned with the same scanner and saved as File B (Fig 2). Then, File A and File B were imported into digital dental software (Trios Design Studio, 3Shape) and a crown was designed (Fig 3) by copying the shape of File A. The thickness of the crown was double-checked thoroughly and adjusted if necessary.

The STL file of the crown was exported and fabricated with A2 colour polymethylmethacrylate (PMMA) disc (Upcera, Shenzhen, China) with a 5-axis milling machine (UPmill X5, Upcera). File B was printed using a digital light processing (DLP) printer (Varseo, Bego, Bremen, Germany) with a yellow-brown resin (VarseoWax Model, Bego, Bremen, Germany). Most of the milled crowns were completely seated on the printed abutments with perfect marginal adaptation. Several of

Table 1 Comparison of operating time for each group (n = 20). The data are presented as mean ± SD.

Group	Time (minutes)			
	Baseline test	Day 1	Day 2	Final test
Control	43.60 ± 10.02^{Aa}	39.30 ± 13.34^{Aa}	35.30 ± 13.82^{Aa}	32.10 ± 9.77^{Ab}
Experimental	42.00 ± 12.75^{Aa}	29.40 ± 12.29^{Bb}	26.30 ± 9.50^{Bb}	30.70 ± 7.07^{Ab}
Significance	0.759	0.185	0.109	0.718

Different uppercase letters in the same column indicate significant differences between groups, and different lowercase letters in the same row indicate significant differences among the different tests ($P < 0.05$).

them needed minor adjustment to be inserted fully. A double-layer tooth (Fig 4a) was produced by cementing the crown and abutment with self-cured methyl methacrylate resin (UNIFAST Trad, GC, Tokyo, Japan). Since the crown and abutment had different hardnesses and colours, students could be aware when they achieved proper reduction around all the axial and incisal surfaces (Fig 4b).

Evaluation of the effect of double-layer composite resin teeth on crown preparation training

A total of 20 third-year undergraduate dental students (8 men, 12 women; mean age 21 years) from Peking University School of Stomatology with no training experience in fixed prosthodontics participated in the evaluation and training programme. They were equally balanced in terms of age and both groups contained the same number of women and the same number of men, and were then randomly divided into the control group (Group 1, n = 10) and experimental group (Group 2, n = 10). The teeth were fixed in a maxillary typodont model (Prosthetic Restoration Jaw Model, Nissin) and later attached into the dental simulator (NISSIM Type 2, Nissin). Every time, tooth preparation was carried out on the simulator within 60 minutes.

On the first day, after a 20-minute didactic lecture on tooth preparation for PFM crowns and a 10-minute operation video that provided instructions and outlined the skills and criteria required for preparation, students from both groups prepared a traditional composite resin tooth (A5A-200, Nissin) as the baseline test. The following 2 days, Group 1 practised with double-layer composite resin teeth and Group 2 used traditional composite resin teeth. Each student prepared one tooth each day. On the fourth day, the final test was performed, in which both groups used the traditional teeth. The operating time for the two tests and 2-day practice were recorded. The teeth prepared at baseline and in the final test were numbered randomly and scored blindly by two experienced instructors, whose mean was determined as the score.

Prior to grading, a lecture was given to the two instructors to calibrate the grading against the 'gold standard' of preparation, which was based on visual inspection of preparation aspects such as taper, reduction and quality of finish line. After the lecture, the instructors evaluated a sample of different preparations to ensure that they agreed independently as to what constituted scores of 60, 70, 80, 90 and 100. In addition, preparation guides were gained by facial-lingually sectioning the impressions of the original teeth, which were made of PVS material (Silagum Putty, DMG, Hamburg, Germany). The instructors could then use a periodontal probe (CP-15/CP-11.5B, Hu-Friedy, Illinois, USA) to measure the distance between the abutment and the preparation guide.

Differences in operation time within each group were determined using a repeated-measures one-way analysis of variance and least significant difference post-hoc test and the preparation time between groups was compared for each day using an independent Student *t* test. The difference in scores between baseline and the final test for each group was compared with a paired Student *t* test. The difference between groups for baseline and the final test was determined using an independent Student *t* test. Statistical software (SPSS Statistics, Version 25.0, IBM, Armonk, NY, USA) was used for all statistical analyses ($\alpha = 0.05$).

Results

Comparing the operating time within the groups, we found that no matter what type of teeth students used, the more they practised, the less time they took. There was no significant difference between groups at the baseline and final tests. However, the operating time for Group 1 decreased constantly, while the time for Group 2 dropped significantly during the training days and increased in the final test. For Group 1, no statistically significant differences were found at baseline and the two practices, but the steady progress accumulated to a significant difference in the final test. Group 2 achieved a significant drop in operating time as soon as they used the newly-

Table 2 Comparison of scores for each group (n = 20). The data are presented as mean ± SD.

Group	Score	
	Baseline test	Final test
Control	77.84 ± 1.72^{Aa}	81.98 ± 1.41^{Ab}
Experimental	77.02 ± 0.83^{Aa}	84.42 ± 1.69^{Bb}

Different uppercase letters in the same column indicate significant differences between groups, and different lowercase letters in the same row indicate significant differences between the two tests ($P < 0.05$).

developed teeth for practice. The time increased in the final test where they shifted back to the traditional teeth, but was not statistically different to the time for the two practices (Table 1). The two groups achieved similar results at baseline, and both recorded better scores after training; however, in the final test, Group 2 performed better and yielded significantly higher scores (Table 2).

Discussion

The purpose of the present study was to compare the training result of newly developed double-layer and self-guided composite resin teeth with that of traditional single-layer teeth. Statistical analysis indicated that in the final test, the two groups recorded similar operating times, but the experimental group received significantly higher scores. Thus, the null hypothesis was partially rejected, confirming that the new resin teeth performed better.

Unlike traditional single-layer and homogeneous composite resin teeth for dental training, the newly developed composite resin teeth consisted of two layers of material with different colours and hardnesses so that students could see and feel the different layers or position during preparation. Since the inner part of the tooth was a standard abutment prepared by a senior prosthodontist and the outside part was digitally designed with adequate volume, the tooth guided students to prepare adequately and following the approach used by a senior prosthodontist, which made learning more efficient. Although some multilayer resin teeth have artificial root canals or even different layers representing enamel and dentine[22], the imitation of natural structures cannot give students direct understanding of standard abutments. Unlike other tooth reduction guides indicating only specific cross-sections[12,13], double-layer teeth can show the reduction volume and shape of the ideal abutment all around the axial and incisal surfaces. The new design helped learners to master the preparation skills and criteria easily, quickly and directly. As students were preparing the teeth, the ideal preparations gradually appeared, which gave them a good 3D sense of the abutment.

Compared with the baseline test, students in both groups spent less time on the final test, but the double-layer teeth enabled students to progress more quickly; Group 2 made significant progress in the practice on day 1, but Group 1 did not experience significant changes until the last test. Although operating time increased in Group 2 in the final test where they shifted back to traditional teeth, there were no significant differences compared with Group 1. Practice can improve students' operating time, and the improvement is quicker with the help of double-layer teeth.

Students in both groups made progress during the training programme; however, the fact that the experimental group achieved a higher score in the final test confirmed that the new teeth were more effective, which implied that the skills they learnt by preparing the new teeth could be transferred to preparation of regular single-layer teeth. Scores were not awarded to the teeth prepared during the day 1 and day 2 practices, because the students in the experimental group were guided in their preparation, which was significantly better in terms of reduction volume, margin and overall shape upon visual inspection. It was unfair to compare the two groups when one received direct guidance while the other did not.

Another advantage of newly developed composite resin teeth is that they would be cost effective if mass production became possible. Since the shape and size of the new teeth are the same as those of conventional teeth, dental schools do not need to modify the typodont and simulations. Production can be optimised and upgraded using industrial equipment and a multimaterial 3D printer could be used to print the two layers of the tooth simultaneously with two kinds of materials to make the production process simpler and more efficient. In order to help students to form a visual memory of the shape of the ideal preparation efficiently, the most appropriate colour and hardness of the two layers need further improvement. The double-layer design concept of this composite resin tooth can also be applied to the simulation preparation training of veneer, onlay and other restoration types and extend its benefits to more dental students.

Since the present study was carried out in a single dental school with a limited sample size, further studies with larger sample sizes and with more objective scores awarded by digital evaluation are necessary before promoting these newly developed composite resin teeth. The effect of differences in colour and hardness between the two layers on training performance is also unknown. The greater the difference, the easier it is for students to see and feel when the burs cut through the first layer. Further studies should be conducted to determine the most appropriate colour and hardness of the two layers.

Conclusion

Considering the limitations of the present study, the following conclusions can be drawn:

- Both traditional single-layer teeth and newly developed double-layer composite resin teeth can significantly improve students' operating skills and efficiency after 2 days of practice.
- The double-layer composite resin teeth enabled students to progress more quickly in terms of operating time.
- Students who trained with double-layer composite resin teeth achieved higher scores after training.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Xuan QI organised the training and tests and drafted the paper; Dr Xiao Li LI designed the composite resin teeth, provided technical support in the dental laboratory and wrote the paper; Dr Yang YANG performed the statistical analysis and reviewed the paper; Dr Li CHEN provided the experimental protocol, secured the funding, scored the preparations and wrote and reviewed the paper; Dr Jian Guo TAN provided the experimental protocol, scored the preparations and reviewed the paper.

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