Application of discipline integration in the practical teaching of endodontic–restorative sequential treatment

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Research Article

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Abstract

**Background:** The cultivation of clinical reasoning and operative skills is the core of the practice course for undergraduates majoring in stomatology. To achieve this goal, a “discipline integration teaching method” is adopted in the practice course for root canal and prosthetic treatments in stomatology.

**Methods:** A total of 893 students of West China School of Stomatology, Sichuan University, participated in this study. Of these students, 443 in the 2016-grade and 2017-grade groups used the traditional teaching method (Group TT) for preclinical practice courses (endodontics and prosthodontics training courses were taught separately), and 450 in the 2018-grade and 2019-grade groups used the discipline integration teaching method (Group DIT) for a preclinical practice course (root canal and prosthetic treatments were integrated into an endodontic—restorative sequential treatment). The scores of the students (clinical skills examination and treatment planning) were compared between the two groups. In addition, students in Group DIT and their teachers were asked to complete a questionnaire on their attitudes and opinions about the DIT method in the preclinical course.

**Results:** The results indicated that the DIT method was more effective than the TT method in enhancing students’ clinical reasoning and operational abilities. The questionnaire results showed that the teachers and students had recognized the DIT method.

**Conclusions:** The DIT method significantly improved students’ learning quality and proved effective in the endodontic—restorative sequential treatment practice course. This teaching method is expected to be further applied to other correlated subjects.

Background

The integration of curricula has become the mainstream recommendation for medical education since the second half of the 20th century [1]. Calls for teaching reforms in dental education were firstly made in the twentieth century, including an overall reduction in class hours and the restructuring or consolidation of some courses [2]. So far, dental colleges in many countries have tried and completed various studies on education reforms with integrated curricula, such as the United States [3], Britain [4], Japan [5], etc. Integrating different disciplines has been effective in the medical training of undergraduate students [6]. A cross-sectional study by Mishra et al. showed that students appreciated and enjoyed the integrated teaching session, with 97% believing the session’s target was achieved and 92.7% believing they had learned new skills [7].

However, the majority of these studies mainly discussed the implementation of integrated teaching strategies such as problem-based learning and case-based learning [8, 9] or emphasized the multidisciplinary curricula consisting of basic science, clinical science [10], biological science [11], pharmacology [12], etc. Differently, this study aimed to describe the process undertaken at West China School of Stomatology, Sichuan University, to design and implement an integrated and interdisciplinary preclinical course in response to strong and direct calls for major reforms in dental education. The
present educational reform integrated disciplines in stomatology rather than medical science. No literature is available on educational reforms in preclinical teaching that integrate the two disciplines of endodontics and prosthodontics.

Stomatology is a highly practical branch of clinical medicine, with particular emphasis on clinical reasoning and practical application, which combines accurate diagnostic and treatment activities [13]. Preclinical education is crucial for developing students’ clinical reasoning and operational skills during the transition from theory to clinical practice [14]. Usually, a crown is associated with improved long-term survival of a root canal-treated tooth. A systematic review by Stavropoulou showed that teeth restored with crowns after RCT exhibited an acceptable long-term survival of 10 years [15]. Therefore, it is frequently a sequence from endodontics to prosthodontics. The principal aim of the practice course and the subject of teaching the transition from endodontics to prosthodontics is how to assist students in developing the right clinical reasoning and basic operational skills quickly. To this end, utilizing the concept of integrating disciplines, we implemented a novel teaching strategy to combine endodontics and prosthodontics teaching contents.

In addition, we used a conventional detachable typodont model with removable resin teeth for dental students to conduct practical dental teaching because students are facing increasing challenges in collecting sufficient quantities of good-quality extracted teeth for different curricula and dental procedures. However, extracted teeth are used to simulate dental procedures and are essential for preclinical education and research studies [16]. Their advantages include natural tissue hardness, morphology, color, texture, and radiodensity [17]. Moreover, Al-Sudani et al. evaluated students’ perceptions of preclinical endodontic training with artificial teeth compared to extracted teeth, reporting that all procedures, except obturation, were more difficult to perform on artificial teeth than on natural teeth, a finding that was attributed to the hardness of the resin [18]. Therefore, to have a more realistic feeling, using extracted teeth has been very important for developing skills in undergraduate students. To simulate the clinical situations as realistically as possible and to make the most of each extracted tooth, in this study, we simultaneously completed all operative procedures on a single tooth so that students could obtain a more actual experience.

**Methods**

Considering the characteristics of stomatology and the requirements of clinical practice, we concluded that the practice courses of root canal treatment and prosthetic treatment could be integrated into an endodontic—restorative sequential treatment, hoping that students could improve their ability of clinical reasoning and would be better able to think critically when they encountered practical clinical problems. Meanwhile, the common clinical procedures should be incorporated into the teaching series as much as possible. The practice course is divided into eight sections, all of which are carried out on a maxillary central incisor: access cavity preparation, root canal preparation, root canal obturation, veneer preparation, full-crown preparation, post-and-core preparation, the impression of the post-and-core, and cementing a fiber post (Fig. 1). There are 5 lessons totaling 20 hours throughout the course. All the
procedures are carried out on extracted teeth collected by students and molded into plaster models (examples are shown in Fig. 2, a, b, and c) and then set on simulation head models (Clinisim Clinical Simulation System), which closely resembles the actual oral surgery situation and helps students become highly skilled.

**Root Canal Treatment (Lesson 1–2)**

In our practice course, indication for root canal treatment is given through a small lecture before operation. In this course, irreversible pulpitis is simulated and the procedure consists of three steps: access preparation, root canal preparation and obturation, which required students to complete the relevant operations within 8 hours of 2 sections.

**Access Preparation And Root Canal Preparation (Lesson 1)**

**(1) Access Preparation**

To access the pulp, a small opening was created in the lingual fossa close to the cingulum of the tooth using a drill needle that is perpendicular to the fossa [19]. Adjusted the direction of the drill needle to be parallel to the long axis of the tooth after a sense of disappointment, and uncover the roof of pulp chamber. To the greatest extent, the tooth tissue should be preserved as much as possible during the preparation of the opening cavity and the roof of pulp chamber should be completely removed to allow endodontic files to unimpededly enter the root canal in a straight line. The tooth can be directly prepared for root canal after creating straight-line access.

**(2) Root Canal Preparation**

According to the instruments they already own, students can select one of the preparation techniques from the list, which includes standardized technique, step-back technique and step-down technique. To remove the nerves, blood vessels and tissues inside the tooth, hand files were prepared during our course. In general, root canal obturation can be performed right away following preparation for healthy root canals. However, in order to prevent root canal reinfection, sodium hypochlorite, the most widely used irrigant, must be used before filling infect root canals. In our practice course, in order to enable students to have a good command of a complete treatment program, we required that the treatment based on infected root canal. At last, temporary obturative material was placed to seal the endodontically treated tooth to provide protection until the next lesson.

**Root Canal Obturation (Lesson 2)**
Both the lateral condensation technique and the vertical condensation technique were used for root canal obturation, in either case, the entire root canal system must be firmly sealed in the process (Fig. 2d). The end of the obturation should reach the level of cemento-dentinal junction [20]. Temporary filling material was placed to seal the tooth after endodontic treatments. Finally, teachers gathered the models with the signatures of the students. Postoperative radiographs were essential for determining the adequacy of canal obturation.

**Restorative Treatments (Lesson 3–5)**

Types of fixed denture prosthetic based on tooth locations and the defect after root canal treatment that demanded students to consult pertinent information independently with the indications of different restorations and then to provide a lecture prior to restorative procedures. Five parts made up the practice course of restorative treatments: the preparation of veneer, full crown, post-core, the impression of post-core and the cementing of fiber post. The course is divided into 3 sections for 12 hours in total.

**Preparation Of Veneer And Full Crown (Lesson 3)**

(1) Veneer Preparation

The preparation was limited to enamel and the reduction of tooth tissue as less as possible. In our lesson, students chose one of the three types of preparation including window type, butt-to-butt type and overlap type (Fig. 3a-f).

(2) Preparation of Full Crown

According to the different composition, full crown can be divided into full cast metal crown, porcelain fused to metal crown, call ceramic crown, resin fused to metal crown, etc. Technique of full crown preparation is same for all except for the type of margins and amount of reductions needed. In this practice course, students were required to prepare all ceramic crowns as an example (Fig. 3g-h), and they are required to master the preparation methods of full crowns of other materials. It should be noted that, the extracted teeth have already been prepared for veneers, the amount of teeth tissue should be taken into consideration during the completion of full crown.

**Post And Core Preparation And Impression (Lesson 4)**

An artificial defect in the crown of the extracted tooth was needed to form an inadequate tooth structure for the preparation of a post-and-core crown (Fig. 4a). Nowadays, we have an ever-increasing assortment of post materials to pick from, such as metal, fiber, and all-ceramic [21]. Different post-and-core takes various preparation and procedure. Students were expected to perform a root canal treatment for a fiber post-core tooth as part of this curriculum. The post-and-core system can be divided into metal post, fiber post and all-ceramic post according to the various material compositions. Tooth preparation and
treatment procedures vary across post-and-core systems. In order to facilitate the bonding of fiber post, students were required to take the fiber post as an example for root canal preparation and to be familiar with the indications and operations of other post-and-core systems and to master the indications and procedures of other post-and-core systems (Fig. 4b). We also required students to practice the impression of post space for post-and-core fabrication (Fig. 4c).

**Cementing The Post (Lesson 5)**

Offering the advantage of aesthetics, and with the continuous improvement of mechanical properties, fiber dental post has become the most common post material at present [22]. Therefore, in the practical course, students were required to work with fiber post to have a good command of post cement procedures (Fig. 4d, e and f). According to the standard of the all-ceramic crown preparation, to consolidate the preparation of full crown once again after a complete light curing.

**Results**

To assess the effect of teaching on students in grades 2016 and 2017, the study used a retrospective comparison method. Root canal treatment and restorative treatments were taught independently to 443 students of grades 2016 and 2017 (group TT) at the West China School of Stomatology using traditional teaching techniques. Veneer, full-crown, and post-and-core preparation procedures were all accomplished individually throughout the restorative procedures on various plastic teeth. A total of 450 students in grades 2018 and 2019 were taught using the discipline integration teaching method (group DIT). The skill evaluation score was given by the same two teachers, and the two teaching techniques were conducted in the same laboratory, with the same hours and assessment criteria. The kappa value was 0.74, which had a good degree of consistency. The identical instances completed as exams were the cases utilized for analysis. The case analysis was conducted independently by the students; therefore, the results were comparable. The t-test and chi-squared test were used to compare the two groups. Statistical analysis of the data was performed using SPSS 22.0 software.

Results showed that students of 2018 and 2019 grades demonstrated exceptional operational capabilities in the evaluations carried out following the conclusion of the practice course, according to Table 1 (p < 0.05). In the same case, a higher percentage of students properly formulated a treatment plan (p < 0.05). According to these objective results, an integrated teaching approach could significantly enhance students’ clinical reasoning and operational abilities.
After the course, a questionnaire survey was administered to the students of the two grades simultaneously. The majority of the questionnaire questions were closed-ended and employed a Likert scale with response categories on a 1-to-5 scale. The numbers 1, 2, 3, 4, and 5, in order, indicated very little, less, moderately, very much, and extremely significant. Recognition was defined as scoring between 4 and 5. The material was based on pertinent research, incorporating this experiment’s features. It had 7 components, with an overall score of 35. Table 2 shows that most students in the 2018 and 2019 grades believed this teaching approach could improve their ability in many aspects. The questionnaire’s reliability using SPSS 20.0 was 0.79, and its validity was 0.86, indicating that it had a high level of reliability and could accurately assess students’ abilities. Briefly, 99.5% of the students stated that DIT enhanced their clinical reasoning ability and operational skills, which would be applicable in future practice. The majority of students (97.9%) believed that DIT enhanced the capability of indication analysis; 94.4% of the students believed the session was entertaining, increasing their ability to study independently. Approximately 86.7% of students reported that DIT had sparked their interest in learning, contributing to some of the teaching processes (Table 2).

### Table 1

Assessments in the two groups with two teaching methods ($\bar{x} \pm s$)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Clinical Skills Examination (score)</th>
<th>Correct Treatment Plans (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIT (n = 450)</strong></td>
<td>90.2 ± 4.16</td>
<td>413 (91.8%)</td>
</tr>
<tr>
<td><strong>TT (n = 443)</strong></td>
<td>86.3 ± 3.57</td>
<td>331 (74.7%)</td>
</tr>
<tr>
<td><strong>P-value</strong></td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

### Table 2

Students’ evaluation of the two teaching methods

<table>
<thead>
<tr>
<th>Items</th>
<th>Mean</th>
<th>Recognition Degree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DIT</td>
<td>TT</td>
</tr>
<tr>
<td>Cultivated Clinical Reasoning</td>
<td>4.85*</td>
<td>4.43</td>
</tr>
<tr>
<td>Improved the Ability of Indication Analysis</td>
<td>4.69*</td>
<td>4.26</td>
</tr>
<tr>
<td>Improved Operational Skills</td>
<td>4.80*</td>
<td>4.58</td>
</tr>
<tr>
<td>Increased Knowledge</td>
<td>4.88</td>
<td>4.84</td>
</tr>
<tr>
<td>Stimulated Enthusiasm for Learning</td>
<td>4.37*</td>
<td>4.12</td>
</tr>
<tr>
<td>Improved Autonomous Learning</td>
<td>4.59*</td>
<td>4.45</td>
</tr>
<tr>
<td>Improved the overall Ability</td>
<td>4.83*</td>
<td>4.68</td>
</tr>
</tbody>
</table>

* means p < 0.05 compared to the Group TT.
Additionally, a survey of the general satisfaction with this method of instruction revealed that 100% of teachers and 98.5% of students in the 2018 and 2019 grades expressed extreme satisfaction with the discipline integration teaching method and showed a high level of willingness to keep using it.

**Discussion**

Generally, schools of stomatology in China have five academic years of undergraduate education, and the third and fourth years include most professional courses [23]. The students begin clinical practice in their fifth year, and there is limited time. The practice course is crucial for developing students’ clinical reasoning and abilities since it serves as a transitional course for stomatology students from theory to clinical practice. The plan of receiving a restorative treatment after the root canal treatment for patient with a dental pulp disease is comprehensive; the decision-making process between various restorative procedures also considers their specific indications. However, in the TT methods, the practice courses in “Endodontics” and “Prosthodontics” are carried out separately, requiring the students to perform operations on various teeth. This frequently leads to students’ lack of a deeper understanding of the entire treatment procedure and their inability to better distinguish the indications of various treatments. Students cannot flexibly apply the knowledge they have gained to think and formulate an overall treatment plan from multiple levels and angles because they have not yet developed correct clinical thinking before starting the clinical practice.

Numerous teaching strategies, including problem-based learning, case-based learning, and online and offline instruction paired with the modular teaching technique, have been used in undergraduate education of stomatology to better develop students’ comprehensive capacities [24–27]. Through case studies and group discussions, these techniques contribute to the development of students’ capacities for independent learning and their capacities to connect theory with practice, with a primary emphasis on preclinical teaching inquiry. Differently, the DIT method helped foster various skills, including clinical reasoning and operational abilities, assisting students in making a smooth transition from the classroom to the clinical practice stage.

In this study, we adopted the DIT method for undergraduates of grades 2018 and 2019. The DIT method improved students’ operational skills and clinical reasoning as they achieved better results in the final skill examination and case analysis than the students of grades 2016 and 2017, who received the TT method (Table 1). The DIT method is also more well-known among students since it fosters clinical reasoning, practical skills, and other competencies. The approbation of students in the two grades was quite high (Table 2), even if there was no discernible difference in their recognition of “learning more knowledge” and “increasing comprehensive ability” (p > 0.05).

By completely simulating the whole endodontic and restorative treatment processes for patients with dental pulp diseases, the DIT method helped students develop their clinical reasoning and practical abilities. To achieve the theoretical guidance of the operations and consolidate and develop the theoretical knowledge from textbooks, we specifically delivered a theoretical lecture before the practice
course. Each lesson was spaced about three to four days apart to give students enough time to reflect on the entire treatment procedure and take the initiative to acquire the necessary information to address issues arising during the practice course. This helped students develop their clinical reasoning and problem-solving skills.

The other achievement of this teaching method was to call for all operations on one extracted tooth. According to the study by Decurcio et al., extracted teeth were perceived to be different from artificial teeth by operators, especially considering the inaccurate resin hardness compared to dentin [17]. In practice, it is not easy to acquire extracted teeth, especially those with intact morphology or uncalcified root canals. Therefore, in preclinical practice, it is common to use artificial teeth to complete the root canal treatment technique [28], tooth preparation [29], and restorative techniques [30], which influences students’ realistic texture of operations and may lead to the disconnection between practical courses and clinical practice. Differently, to complete all operations on a single tooth could obtain a more actual experience and simulate the clinical situations as realistically as possible.

To encourage students’ additional reflection on various treatment modalities, the course also mandated that they construct the tooth defect model required for the subsequent step after finishing the initial treatment. The constant thought and consultation process has considerably aided students’ aptitude for self-directed learning and their enthusiasm for learning. To some extent, the DIT method helped students make a better transition from training courses to clinical practice.

**Conclusion**

The DIT method proved its effectiveness in the practice course of endodontic—restorative sequential treatment since it significantly improved students’ quality across the board by completely simulating the entire endodontic and restorative treatment processes for patients with dental pulp diseases, helping students develop their clinical reasoning and practical abilities. Therefore, it is anticipated that the DIT method would be applied and expanded in other fields. However, there are still issues that should be taken into consideration while using this teaching strategy. For instance, preparing extracted teeth with various tooth positions and types of defects for each student while carrying out the aforementioned teaching process requires students to prepare complete treatment protocols and carry out the relevant operations. To conclude, dental educators are encouraged to design more discipline integration practice curricula to better develop dental students’ clinical reasoning and operative skills.

**Declarations**

**Ethics approval and consent to participate**

All experimental protocols were approved by the Ethics Committee of West China School of Stomatology, Sichuan University. All participants involved in this study gave their informed consent. All
methods were carried out in accordance with relevant guidelines and regulations or declaration of Helsinki.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

**Authors' information (optional)**

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**Authors' contributions**

CL and WJ contributed equally to the conception and design of the study, helped carry out the study, analyzed and interpreted the data, and were the major contributors to writing the manuscript. ZX made substantial contributions to the conception and design of the study, and revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

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**Availability of data and materials**

The datasets generated and/or analyzed in this study are not publicly available due to the sensitivity of the personal data of the study subjects as it relates to test scores. The datasets can only be available from the corresponding author on reasonable request.

**References**


Figures
Figure 1

Illustration displaying the DIT method conducted on the Clinsim Clinical Simulation System.

Figure 2

A dental teaching model with an extracted incisor (a, b, and c); an incisor after RCT (d).
Figure 3

The window type of veneer preparation (a, b); the butt-to-butt type of veneer preparation (c, d); the overlap type of veneer preparation (e, f); preparation of a full crown (g, h).

Figure 4

An artificial defect in the crown of an incisor (a); post space preparation (b); impression of post space for post-and-core fabrication (c); cementing the post (d,e); a completed post-and-core preparation (f).