Application of digital PBL-CBL method in teaching dental implant surgery at the atrophic anterior maxilla

Background. Clinical teaching of esthetic implant-supported restoration at atrophic maxilla is challenging due to the complexity and unpredictability of bone and soft tissue augmentation. The PBL-CBL (problem-based learning/case-based learning) method with a complete digital workflow (digital PBL-CBL method) allows the students to view clinical cases more accurately and measurably. The aim is to evaluate the effectiveness of the new digital PBL-CBL method in teaching complex implant cases in the esthetic area.

Materials & Methods. A complete digital workflow of dental implant therapy was established for patients with severely atrophic anterior maxilla. The digital data of cases done in the new workflow were used as teaching materials in digital PBL-CBL teaching. Fifty-four postgraduate students were randomly selected and divided into three groups, including traditional PBL-CBL group (students taught in a PBL-CBL method with no digital cases), digital PBL-CBL group (students taught in a PBL-CBL method with full digital cases) and control group (students taught in didactic teacher-centered method). After three months of training, a survey of the students' opinions on the corresponding teaching method was carried out through a feedback questionnaire. A theory test was used to evaluate students' mastery of knowledge about tissue augmentation and esthetic implant restoration. A case analysis was designed to test whether the students can apply the knowledge in solving new problems.

Results. The digital PBL-CBL method resulted in a higher satisfaction rate than the traditional PBL-CBL method and the didactic teacher-centered method in all items except for "This approach decreases extracurricular work". Case analysis scores of the digital PBL-CBL group were significantly higher than those of the traditional PBL-CBL group and the control group. For the theory test, the digital PBL-CBL group (61.00±6.80) but not the traditional PBL-CBL group (55.22±9.86) obtained a significantly higher score than the control group (45.11±12.76). However, no significant difference was found between the digital PBL-CBL group and traditional PBL-CBL groups.

Conclusion. Compared with other methods, students taught with the digital PBL-CBL method showed higher satisfaction and better performance in the acquisition of academic knowledge and the ability to solve practical clinical problems. The digital PBL-CBL method provided a promising alternative for teaching complex implant cases at the anterior maxilla.

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Abstract

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Conclusion. Compared with other methods, students taught with the digital PBL-CBL method showed higher satisfaction and better performance in the acquisition of academic knowledge and the ability to solve practical clinical problems. The digital PBL-CBL method provided a promising alternative for teaching complex implant cases at the anterior maxilla.[50]

Introduction

Implant-supported restoration for patients presenting with extended missing teeth and severely atrophic anterior maxilla is regarded as highly complex and risky (Rocchietta et al. 2008). To better provide functional and esthetic results, the treatment protocol for those patients often involves multiple steps, including augmenting the bone vertically and horizontally, prosthetically-guided placement of dental implants, soft tissue management, provisional restoration, and the final restoration (Aghaloo et al. 2016; Checchi et al. 2019). The dentists must determine when and which steps should be taken depending on the condition of the patients.

Besides, several surgical and restorative techniques with different indications are designed for each step. The dentist must choose the appropriate technique for each step, which demands professional knowledge and hands-on practical ability. Even a minor mistake would cause compromised esthetic complications. The above characteristics of implant therapy at atrophic maxilla make it challenging to get the teacher across in dental education.

To prepare dental students for such high clinical demands, dental schools must improve the quality of classroom teaching of dental implant therapy at severely atrophic maxillae.

Learning dental implant therapy at severely atrophic maxilla requires highly creative thinking and a good imagination of the students. All the surgical interventions before final restoration (soft tissue manipulation, bone augmentation, and implant placement) should be guided by the three-dimensional position of the repair presented in the last step, indicating that students must keep the visual final restoration in mind from the very start. However, it will be fabricated months later (Kopp et al. 2003). Besides, the first step, the bone augmentation surgery, is not wholly predictable and is not always able to guarantee the expected result due to graft resorption, especially in the atrophic anterior maxilla (Checchi et al. 2019; Hameed et al. 2019; Mertens et al. 2013; Steller et al. 2022; Uehara et al. 2015). This initial step lays the foundation for the following procedures. Correcting osseous deficiencies allows ideal implant placement and creates a more natural soft tissue profile for better crown anatomy and esthetics (Aghaloo et al. 2016). The unpredictable resorption of first-stage bone augmentation can be compensated by an additional corrective bone augmentation or soft tissue intervention during implant placement and recovery surgery (Checchi et al. 2019). Staged horizontal ridge augmentation with autogenous bone blocks or GBR entailed an additional bone augmentation procedure before implant therapy in 37% of cases (Jensen et al. 2016). It is highly important to detect tissue contour changes concerning the ideal esthetic goal if correction is to be performed timely, which requires good powers of observation. Given the characteristics mentioned above, it is high time to establish a teaching method that

facilitates practical thinking, careful observation, and flexible decision-making of dental students to prepare them for clinical work.

PBL and CBL have been described as promising tools for medical and dental education (Koh et al. 2008; Thistlethwaite et al. 2012; Tomaz et al. 2015). PBL (problem-based learning) uses the patient's problem as a stimulator for students to learn problem-solving skills, while CBL (case-based learning) is a group discussion-styled teaching approach based on analysis of authentic clinical cases (Jackson 2003; Tomaz et al. 2015). Previous studies combined PBL and CBL in teaching and found that the PBL-CBL method was more effective than PBL or CBL (Dong & Zeng 2017; Ginzburg et al. 2018; Liu et al. 2020). Whether combined or applied independently, the problem and case used in traditional PBL and CBL are usually described in abstract words or 2-dimensional pictures. These need to be revised to introduce the clinical scene quickly, spark active imagination, and cultivate students' observation skills. In particular, the clinical decision to make timely correction depends on accurately calculating the 3-dimensional discrepancies of bone and soft tissue contour, which is far beyond the scope of words or pictures. The rapid application of digital technology in implant dentistry has been translated into the dental digital workflow (Ben Yehuda et al. 2020; Chochlidakis et al. 2020; Papaspyridakos et al. 2020a; Papaspyridakos et al. 2020b; Rojas Vizcaya 2018), including modern cone-bean computed tomography (CBCT), optical scanning technology, sophisticated CAD software and virtual implant designing software. These digital techniques feature virtual 3D reconstruction of bone, superimposing myriad scans and precisely aligning them with common data points (Li et al. 2021; Roberts et al. 2020; Vandeweghe et al. 2017; Ye et al. 2020), which offer the dental team the opportunity to design the final prosthetic virtually first and plan of bone augmentation and implant placement precisely guided by this virtual preview. The aligning of bone or soft tissue scans at different stages of treatment will precisely reveal the location and volume in graft resorption, providing the students with accurate information to tell when and where additional hard or soft tissue is required and which surgical technique is indicated. Therefore, problems or cases explained with a complete digital workflow allow the students to view clinical cases more accurately, measurably, and intuitively.

This study details a PBL-CBL method with a complete digital workflow (digital PBL-CBL method), which features vivid 3D presentation of final restoration and tissue contour, measurable tissue contour changes, and accurate correction of contour discrepancies using digital tools. This study aims to evaluate the effectiveness of the digital PBL-CBL method in teaching complex implant cases at the atrophic anterior maxilla. 118

Materials and methods

Establishment of the complete digital workflow

Patients who visited the Department of Dental Implantology with teeth missing in the anterior maxilla were included in the database of complex esthetic cases if his/her residual ridge displayed a severely collapsed contour and the CBCT exam revealed a severe vertical and/or horizontal bone defect. The patients expressed an urgent need for esthetic restoration and standard pronunciation and declared that a removable or fixed teeth-supported prosthetic was unacceptable. The clinician deemed the available bone seriously inadequate for implant placement and aesthetic restoration, making it a must to perform bone and/or soft tissue augmentation first. These complex cases established the multi-step complete digital workflow for esthetic implant therapy. Four significant steps were taken:

Step 1. Establish the ideal final prosthetic virtually by aligning 3D intraoral scans with facial photographs. The technician virtually try-in the restoration and modified the shape according to specific facial references and an incisal guide on the 3D virtual articulator. The virtual goal will be easily visualized as the reference for bone augmentation, implant placement, and multiple processes.

Step 2. Make a bone augmentation plan virtually. Align the ideal prosthetic, intraoral scans, and alveolar bone. Measure the volume of predicted bone augmentation by virtual placement of the dental implants and performing bone augmentation. Determine the volume and distribution of bone grafts and choose the optimal bone augmentation technique.

Step 3. Perform digitally guided bone augmentation. Print a surgical guide or a 3D titanium mesh based on the virtual bone augmentation contour. Augment the ridge under the guidance of the surgical guide or using the 3D titanium mesh.

Step 4. Make digital measurements at every revisit following bone augmentation and perform - tissue correction promptly if needed. The revisiting time points include 3 months (T1, size of initial graft resorption), 6 months (T2, implant placement and second bone augmentation if needed), 12 months (T3, soft tissue augmentation if needed and soft tissue conditioning), and 24 months (T4, revisit after final restoration and tissue augmentation if required) after bone augmentation. Digitally analyze the hard and soft tissue contour changes by superimposing intraoral scans and bone contour at different follow-up revisits regarding the initial esthetic prosthetic and bone augmentation goal. If unpredicted graft resorption occurs, perform additional bone augmentation or soft tissue augmentation to correct the defect.

Students and grouping

This study was conducted according to the guidelines set forth by the Declaration of Helsinki and approved by the Ethics Committee of the Affiliated Stomatological Hospital of Chongqing Medical University (No. KQJ2022166). Written informed consent was obtained from all students. Fifty-four postgraduate students were included in this study, who received training between 2020 and 2023 at the Department of Implant Dentistry, the Affiliated Stomatological Hospital of Chongqing Medical University. No students had any experience or training in bone and soft tissue augmentation at atrophic maxilla before. The

students were randomly allocated into three groups, namely the traditional PBL-CBL group (students were trained using the conventional PBL-CBL method), the digital PBL-CBL group (students were trained using the digital PBL-CBL method), and the control group (students were trained using the didactic teacher-centered method). All groups were prepared for a period of 3 months.

Teaching methods

All students attended class sessions on six topics on implant therapy at atrophic anterior maxilla, namely "1. Principle of implant therapy at anterior maxilla", "2. Pre-surgical assessments and treatment plan", "3. Bone Augmentation Techniques", "4. Implant placement", "5. Soft tissue conditioning" and "6. Management of Complications". The curriculum of implant therapy at the atrophic anterior maxilla was completed in 12 sessions, each lasting for eighty minutes. In the control group, the students sequentially attended the sessions in the form of teacher-centered lectures, and the role of the teacher was to dispense final form knowledge.

There was no scheduled discussion time during or beyond the class session. In the traditional PBL-CBL group and digital PBL-CBL group, the students were divided into small groups of 3 or 4 members. Discussions about the topic were held in each of the 24 sessions. The role of the teacher shifted from conventional authority to a case narrator and an expert guide for discussion.

The medical information and the main problem introduced were the same in the two PBL-CBL groups, such as the past medical history, clinical manifestations, X-ray examination results, diagnosis, and treatment processes. PBL and CBL were combined as described in our previous study (Liu et al. 2020). The difference between the two groups is that the problem and case were expressed in abstract words and clinical pictures in the traditional PBL-CBL group. In contrast, those in the digital PBL-CBL group were equipped with the established digital workflow, which includes multiple digital virtual animations, measurable data calculation, and objective analysis. All courses have the same knowledge points, which are repeated and emphasized to the same degree. The three groups' total duration and number of sessions were the same.

Evaluation methodology

The efficiency of different teaching methods was evaluated in the following three ways. Two teachers from the Department of Implantology graded the exams. The graders were blinded to the names of the students and the group they belonged to.

1. Anonymous questionnaire

To evaluate the subjective opinions of the students on different teaching methods, anonymous questionnaires composed of eight questions were filled out by all the students after the training.

The detailed information of the questionnaire is revealed in Table 1.

2. Theory test

At the end of the training, students took the final exam, which included seven questions, namely preoperative assessments of the atrophic ridge, indications for different bone augmentation techniques, principle of guided bone regeneration, characteristics of varying bone graft material, indications of soft tissue augmentation, soft tissue conditioning using interim restoration, and management of complications. The total score was 70 points, 10 points for each question.

3. Case analysis

After the theory test, the teacher presented a new case from the clinical database that was different from the cases discussed earlier in the class. The teacher provided the students with detailed information about the patient and the students were required to answer a series of questions about the key points that had been taught or discussed in the class sessions in a written form. Finally, the papers were graded. The total score was 30 points, 6 points for each question.

Statistical analysis

Pearson's chi-squared test was used to analyze the students' opinions about the teaching methods among the three groups. The scores of the theory test and the case analysis were expressed as mean value ± standard deviation (SD). The Shapiro-Wilk test was used to determine whether the data are normal distribution. The Kruskal-Wallis H was applied to analyze the difference in scores among the three groups. The Kruskal-Walli's test was used for subsequent pairwise comparison between different groups. All tests were two-sided, and $p<0.05$ was considered significant. SPSS version 26.0 was used to analyze the data.

Results

Complex esthetic cases used in the digital PBL-CBL method

Twenty-six cases with one to six teeth missing in the anterior maxilla were included in the clinical information database for the digital PBL-CBL method. In fifteen cases, 3D-printed titanium meshes were fabricated for guided bone regeneration. Four patients received onlay bone block grafting with a 3D-printed surgical guide. Eighteen patients underwent second bone augmentation simultaneously with dental implant placement at T2. Six patients received connective tissue grafting before soft tissue conditioning. These cases can cover all the techniques and theoretical knowledge in courses in esthetic implant therapy. A case of guided bone regeneration under the guidance of 3D-printed titanium mesh was displayed below to show the digital workflow in detail.

The patient was a 26-year-old female patient who had #23 tooth extracted 5 years ago. A clinical exam revealed good oral hygiene and an average smile line (Fig. 1ABC). The frontal and occlusal view of the residual ridge displayed a severely collapsed contour and gingival recession at #24 tooth (Fig. 1BC). The preoperative CBCT reveals a severe vertical and horizontal bone defect with a bladed alveolar crest (Fig. 1D).

Step 1. The first step was to create an ideal final prosthetic. The shape and form of the teeth were modified according to the facially generated esthetic principles and occlusal function (Fig. 1EF).

Step 2. The preoperative CBCT DICOM data of dual jaws were imported into Mimics Research 21.0 (Materialise, Leuven, Belgium) for 3D reconstruction (Fig. 2A). The aesthetic prosthetic established in Step 1, the dental implant model, and the reconstructed 3D model of jawbone were transferred into 3-matic Research 13.0 (Materialise, Leuven, Belgium) for simulation of restoration-oriented implant placement (Fig. 2B). The alveolar bone defect was virtually reconstructed considering the minimal bone tissue needed surrounding the implant, the ideal alveolar bone contour and soft tissue condition. The augmented bone surface was then over-thickened to reconstruct the horizontal and vertical contour, establishing the bone augmentation goal that matches the specific prosthetic goal (Fig. 2C). Based on the virtual reconstruction of hard tissue, the titanium mesh for bone augmentation was designed and produced (Fig. 2DE)

Step 3. The titanium mesh was tried on and adjusted to the optimal position (Fig. 3AB). Particulate autogenous bone chips and deproteinized bovine bone were mixed with injectable platelet-rich-fibrin. The space between the titanium mesh and bone surfaces was compactly filled with the bone graft (Fig.3C). The wound was closed with no tension (Fig.3D).

Step 4. Result-focused analysis and timely correction were performed at 3 months (T1), 6 months (T2), 12 months (T3), and 24 months (T4) after bone augmentation. At T1, the augmented ridge contour digitalized by intraoral scans was superimposed on the preoperative contour, showing vertical tissue collapse mesial to tooth #24 (Fig. 4AB) although superimposing of bone contour on the original condition revealed significant improvement in bone volume (Fig. 4C). When superimposed on the ideal bone contour, the bone contour at T1 failed to match the goal on the top of the ridge, leaving a vertical bone defect of 2.47 mm in height (Fig. 4D). Six months after the first bone augmentation (T2), soft tissue resorption continued that the titanium mesh can be seen through the overlying gingiva (Fig. 4A). Superimposition of ridge contour revealed more vertical and horizontal contour collapse compared with that at T1 (Fig. 4B). Superimposition of bone contour on the original (Fig. 4C) and ideal bone condition (Fig. 4D) showed improvement in horizontal bone volume after grafting but unmet vertical bone dimension requirement at T2, which required an additional bone augmentation. The clinician deemed guided bone regeneration simultaneously with implant placement to be suitable for the patient (Fig. 5). Superimposition of the actual and the planned location of implants showed good accuracy of the guided surgery (Fig. 5GHI).

The ridge contour seemed vertically improved 6 months after the corrective surgery (T3) (Fig. 4AB). However, a minor horizontal bone defect remained distal to #22 tooth when superimposed on the ideal contour (Fig. 4D). The clinician decided there was no need for additional surgical correction as the abundant vertical bone volume suggested complete filling of the interproximal space after restoration and the minor horizontal contour defect could be corrected by soft tissue conditioning using provisional crown (Fig. 5J). Three months after soft tissue conditioning, the provisional was replaced with the final restoration, and the contour of the ridge was greatly improved as viewed intraorally (Fig. 5K). Good esthetic result was achieved as viewed intraorally (Fig. 5L). Nine months after the final restoration (T4), X-rays revealed no evident resorption in peri-implant bone level. Superimposition of the ridge contour showed stable and abundant bone volume (Fig. 4AB), suggesting the aesthetic goal established in Step 1 was realized.

Digital PBL-CBL vs. Traditional PBL-CBL/ didactic teacher-centered method

A total of 54 students (30 men and 24 women), aged between 23 and 27 years (mean: 24.6 years) were included in this study. Students were able to follow up. There was no significant difference among the three groups about gender and age. All students followed the schedule and attended the lectures or discussions on time.

Table 1 shows the rate of satisfaction with different teaching methods. Students in the traditional PBL-CBL group reported a higher satisfaction rate than those in the control group in all items except for "This approach decreases extracurricular work" and "This approach helps me master theoretical knowledge." According to the students, the traditional PBL-CBL method increases extracurricular work and shows no advantage in delivering theoretical knowledge. With the assistance of problems and cases expressed in a full-digital way, the digital PBL-CBL method resulted in a higher satisfaction rate than the traditional PBL-CBL method and the didactic teacher-centered method in all items except for "This approach decreases extracurricular work". Students reported similar opinions on the amount of extracurricular work in the traditional PBL-CBL and digital PBL-CBL groups. Statistical significance between the two groups was detected for items "This approach makes learning more targeted and more interesting," "This approach helps me improve clinical skills," and "This approach facilitates clinician-patient communication" (Fig. 6), suggesting digital assistance amplifies the advantages of traditional PBL-CBL method and benefits practical thinking and clinical problem-solving abilities according to the subjective opinions of students. Statistical significance between the control group and the digital PBL-CBL group was detected for items "This approach is efficient", "This approach makes learning more targeted and more interesting", "This approach enhances my ability to analyze and solve problems", "This approach helps me improve clinical skills" and "This approach facilitates clinician-patient communication" (Fig. 6), suggesting compared with the didactic teacher-centered method, the digital PBL-CBL method improves students' subjective initiative, self-learning skills, clinical skills and communication skills according to the subjective opinions of

students.

Table 2 shows the scores of the theory test and the case analysis. Traditional PBL-CBL method resulted in higher scores in theory tests and case analyses than the didactic teacher-centered method. However, the differences achieved no statistical significance (Fig. 7). With digital assistance, the advantages of the traditional PBL-CBL method in upgrading scores were further improved, with the difference between the digital PBL-CBL method and the didactic teacher-centered method being significant in both theory test and case analysis (Fig. 7). Particularly, digital PBL-CBL method led to significantly higher scores than the traditional PBL-CBL method in case analysis (Fig. 7), suggesting digital assistance benefits master of practical thinking and clinical problem-solving abilities. When the theory test and case analysis were evaluated as a total score, the digital PBL-CBL method showed apparent advantages over the didactic teacher-centered and traditional PBL-CBL methods. At the same time, no significant difference was detected between the control group and the conventional PBL-CBL group.

Discussion

Although the application of digital tools is widespread in routine dental care, this trend towards digitization has yet to be extended to dental curricula, making it challenging to prepare future dentists for digital work-life (Zitzmann et al. 2020). The traditional PBL-CBL method is a promising tool for leadership training, biochemistry experiment teaching, and dental education (Dong & Zeng 2017; Ginzburg et al. 2018; Liu et al. 2020). To maximize the efficiency of the traditional PBL-CBL method, we combined PBL and CBL using fully digital clinical cases in teaching implant therapy at the atrophic anterior maxilla. According to the students' feedback, the digital PBL-CBL method won over the traditional PBL-CBL method. Many students believed digitalization made learning more efficient and targeted, enhanced their problem-solving ability, improved clinical skills and facilitated patient communication. This superiority was echoed by higher scores of theory test and case analyses in the digital PBL-CBL group, proving that the digital PBL-CBL method was more effective than the traditional PBL-CBL method in teaching complex dental implant therapy.

Previous studies pointed out that CBL could have been more effective in conveying the existing knowledge system, typically in a didactic teacher-centered approach (Allchin 2013; Jamkar et al. 2006). As PBL was able to cover approximately 80% of what could be accomplished in a didactic approach in the same period (Albanese & Mitchell 1993; Berkson 1993), we combined CBL with PBL by interrupting cases with a series of well-contextualized questions or problems in teaching maxillary sinus floor elevation surgery and proved that the combined PBL-CBL method (the traditional PBL-CBL method) was even advantageous over the didactic approach in conveying existing knowledge system (Liu et al. 2020). In this study, however, the traditional PBL-CBL method showed no advantage over the didactic method in delivering theoretical knowledge when used to teach complex surgeries at atrophic maxilla according to the student's opinions and theory test. This conflict may be attributed to the different curricular contents. The surgical and prosthetic manipulation at the atrophic maxilla is more complex and flexible than maxilla sinus lifting, requiring more solid knowledge, vivid imagination, and improved observation abilities. When cases or problems were contextualized with digital hardware and software, the efficiency of traditional PBL-CBL method in getting across standard curricular content was significantly enhanced as more students (88.9%) believed that digital PBL-CBL method helps them master theoretical knowledge than the traditional PBL-CBL method (55.6%) or the didactic approach (61.1%), and the digital PBL- CBL method (61.00±6.80) scores higher than the traditional PBL-CBL method (55.22±9.86) or the didactic teacher-centered method (45.11±12.76) in theory test. These results suggested that digitalizing clinical problems and cases could help cover standard curricular content and assist students in forming a comprehensive and organized understanding of esthetic implant therapy.

Case analysis was designed to test students' ability in practical thinking, careful observation, and flexible decision-making. The traditional PBL-CBL method raised scores of case analysis about maxillary sinus lifting compared to the didactic teacher-centered method (Liu et al. 2020). However, in this study about esthetic implant therapy it showed no superiority to the didactic teacher-centered approach in case of analysis, indicating problems or cases explained in traditional words or pictures may need to be more potential to manage teaching tasks of high complexity and flexibility. The major difficulty in restoring missing teeth at the atrophic anterior maxilla is to augment the ridge according to the 3D position of final prosthetics and make timely corrections in case of unpredicted tissue collapse following augmentation. In the traditional PBL-CBL method, the students are usually told directly by the teacher when and how to perform a particular surgical or prosthetic technique through the presentation of words or pictures rather than making the critical decision through careful observation and calculation by themselves. With the assistance of digital hardware and software, students can preview the 3D bone contour, the soft tissue contour, and the ideal final prosthetic at any moment during the treatment period. By superimposing myriad scans and precisely aligning them with common data points, students can calculate the amount of tissue augmentation accurately guided by the 3D position of the ideal final prosthetic and make timely correction when contour discrepancies appear due to tissue resorption. In our study, the results of case analysis showed that students in the digital PBL-CBL group were more likely to use the acquired knowledge spontaneously to solve new problems than those who acquired the same information through lectures or traditional PBL-CBL method, proving the digital tools in teaching would stimulate students' imagination, practice their observation ability, and sharp their logic based on objective data.

Extracurricular work is an essential factor interfering with students' interest in a particular course (Chen et al. 2023). According to the students' opinions, fewer students thought that the traditional PBL-CPL or digital PBL-CBL method decreases extracurricular work compared with the didactic teacher-centered method, as they must spend more time searching for background information and learning how to use the digital tools. To take full advantage of the digital PBL-CBL method, the faculty members should be trained more vigorously to simplify pre-class preparation and help develop the student's capacity to search for information and mastering digital tools.

There were some limitations in the study design and methodology in this preliminary study. First, a Yes/No scale was used in the questionnaire to gain feedback about the new hybrid method, which only resulted in rough calculations. A Likert Scale would be more appropriate and accurate to scale responses and detect differences in survey research. Second, we analyzed results from only one clinical department within our institution. These results may have been different beyond our institution. Third, the sample size of students needed to be bigger, which caused difficulties in statistical analysis, especially for the anonymous questionnaire. Further randomized controlled trial with a large sample size is required to confirm the efficiency of the digital PBL-CBL method.

Conclusion

Students learning dental implant therapy at the anterior maxilla with the digital PBL-CBL method exhibited better acquisition of academic knowledge and higher competence in case analysis compared with those learning with the traditional PBL-CBL method and the didactic teacher-centered method. The digital PBL-CBL method may be a promising new mode for teaching complex surgical techniques in implant dentistry.