

Comparative study on the effectiveness of virtual simulation and jaw model for undergraduate periodontal teaching

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Abstract

Background

To compare the effect of virtual simulation and jaw model on the development of pre-clinical periodontal skills in undergraduate students and to improve future pre-clinical training strategies.

Methods

Sixty volunteer sophomores and juniors from the stomatology at Lanzhou University were enrolled in the current study and randomly divided into four groups: Jaw model (Group J, the control group), Virtual reality (Group V), Virtual-Jaw (Group V-J), and Jaw-Virtual (Group J-V). All of the participants received training on uniform basic periodontal knowledge before completing the first theoretical assessment. Then, they obtained total 8 hours of operation training and completed a second theoretical assessment. Their performance was evaluated using the supragingival scaling processes, and clinical operation scores were graded by a blinded professional using an established standard scoring system.

Results

There was no significant difference in the first theoretical outcomes between the four groups ($P > 0.05$). The second theoretical scores of the V-J and J-V group (60.00 ± 4.47 , 58.33 ± 4.35) were significantly improved as compared with the first theoretical scores (49.67 ± 4.81 , 48.00 ± 4.93 , $P < 0.05$). The operation process scores of students in Group V-J and J-V (72.00 ± 5.92 ; 70.00 ± 3.05) were higher than those in the other two groups (V: 61.67 ± 7.85 ; J: 60.67 ± 2.58). Additionally, the scaling process performance of students in Group V-J and J-V (53.00 ± 3.05 ; 63.40 ± 4.39) was improved as compared with that of students in the other two groups (V: 41.90 ± 5.23 ; J: 47.40 ± 4.31).

Conclusion

The combination of virtual reality and jaw model during periodontal pre-clinical training may improve students' grades and help them develop professional skill. More importantly, we suggest that the jaw model should be applied prior to virtual reality.

1 Background

Virtual reality (VR) provides the possibility to emulate the real world and was first introduced by Ivan Sutherland in the mid-1960s [1]. Currently available immersive VR technologies have been used in different fields, such as gaming [2], transportation [3], military [4], architectural engineering [5], and education [6]. Among them, VR has been increasingly used in various areas of clinical medicine [7]. Findings from previous studies suggest that VR intervention can be used to effectively reduce acute pain

[8] and provide a virtual environment with well-controlled sensory stimuli for the treatment of mental disorders, such as dementia, mild cognitive impairment (MCI), schizophrenia, and autism [9]. In addition, VR technology has also been applied in rehabilitation treatment to improve the posture and gait of individuals with nerve injury [10], and reduces psychological symptoms and helps support emotional health during cancer treatment [11]. Remarkably, the application of VR in the field of stomatology has mainly focused on dental education, maxillofacial surgery, the treatment of oral diagnosis,

and treatment of fear [12]. Adequate pre-clinical training is essential for the successful career development of dentists. Traditional pre-clinical training in stomatology is mainly conducted on the simulation model of the jaw, and the pattern is unitary, which makes the operation not fit with the disease's complex clinical manifestations. And then, students in that training limited by get timely and unrealistic feedback, produces defects contain low efficiency, poor training effect.

Recently, with the growing accessibility of computer-assisted VR technology in dental

research, various dental virtual simulation systems have emerged that are used for oral operation teaching and pre-clinical training in some colleges. There is increasing awareness of the importance of improved teaching skills during undergraduate education. Urbankova et al [13] tested manual agility using tactile VR technology in preclinical dental education and confirmed that the VR simulator played a significant role in identifying students who experience learning challenges in the preclinical phase of dental training. Another study evaluated the validation training simulator for inferior alveolar nerve block and concluded that it was suitable for needle appropriate positioning, insertion depth, and resistance sensitivity of virtual tissues [14]. Obviously, it is essential to establish a sound teaching model for undergraduate education.

Despite the rapid progress in virtual simulation within the field of medical education, its universal access remains limited. Most studies have simulated maxillofacial surgical [15], Local anaesthesia [16], and dental pulp surgical trainings [17], however, few reports have focused on simulated periodontal teaching. Periodontitis has high prevalence and affects 5.4 billion (90%) people worldwide [18]. The routine practice for a soft tissue examination and periodontal intervention treatment consists of periodontal probing, supragingival and subgingival scaling, and root planing, which are all essential manipulation skills for undergraduates. However, students require extensive training in order to acquire these skills.

Unfortunately, the traditional jaw training model often fails to achieve satisfactory results. Thus, in the present experiment, we explored the effectiveness of VR in periodontal pre-clinical training and provided adequate performance mode in basic periodontal education.

2 Methods

This study was approved by Ethics Committee of the School of Stomatology Lanzhou University (No. LZUKQ-2019-25), and all students provided written informed consent to participate in this study. Besides, all the experiment protocol for involving humans was in accordance to Declaration of Helsinki.

2.1 Participants

We randomly selected 60 volunteer second- and third-year undergraduate students attending stomatology at Lanzhou University who were in good periodontal condition and did not have any other systemic diseases. The participants were divided into the following four groups (n = 15) at an equal gender ratio: (1) the Jaw model (Group J) was the control group, (2) the Virtual reality (Group V), (3) the Virtual-Jaw (Group V-J), (4) the Jaw-Virtual (Group J-V). The age of the participants ranged from 19–20 years did not differ significantly. Additionally, none of the students received any periodontology knowledge before the beginning of our study, and they all shared the same starting point.

2.2 Study procedure

2.2.1 Theoretical knowledge teaching

A flow chart that illustrates the study design is shown in Fig. 1. Before Exam 1, the students attended 2 hours period of a theoretical knowledge classroom section taught by a periodontist who had more than 10 years of clinical experience. The lecture content comprised tissue anatomy, comprehensive periodontal examination (e.g., probing pocket depth [PPD], bleeding on probing [BOP], and clinical attachment level [CAL]), subgingival scaling, preoperative preparation, and instrument selection (Fig. 2), the lecture was based on the criteria outlined in the Periodontology textbook fourth edition [19]. Exam 1 scores assessed potential learning ability and consisted of multiple-choice questions.

2.2.2 Operation teaching

The students received hands-on operation teaching training that included the following techniques: plaque index record, medical history inquiry, aseptic concept, equipment preparation, chair position adjustment, comprehensive periodontal examination, supragingival scaling, postoperative examination, and oral health education (Fig. 3A/B). The students received hands-on training that lasted approximately 8 hours of training total (2 h/day). Set up left maxillary central incisor (21) and right mandibular first molar (46) as uniform sites. Additionally, the training order of groups V-J and J-V were reversed to eliminate the order factor. Further, the V-J and J-V groups of students were trained on the jaw model (NISSIN) (Fig. 3C) and the virtual reality system (UniDental) (Fig. 3D) for 4 hours respectively in order to explore whether the order of two methods influenced the training outcomes.

2.2.3 Operation examination

The students completed the second theoretical knowledge exam (e.g., Exam 2) after the operation training and performance similar Exam 1. The operation process assessment included content from the Chinese Oral Physician Licensing Exam, such as supragingival scaling. The items and scoring standards are detailed in Table 1: preoperative preparation, operation posture, fulcrum, periodontal probe, and supragingival scaling.

Table 1
Scaling operation score sheet.

Scoring items	Score
Preparation	
Preoperative preparation	
λ Dress neatly, asepsis, necessary preoperative instructions	3
λ Choosing right instruments including periodontal probe and scaler	7
operation posture	
λ sit up straightly and stablely	2
λ The patient's jaw plane is located at or below the elbow	2
λ Adjust the position according to different teeth position	2
λ Use of oroscope in the exploration of lingual and palatal side	2
λ Adjustment of lights in different positions	2
Intraoperative operation	
Holding	
λ Improved writing style	5
λ Combined fulcrum	5
Fulcrum	
λ Alternate use of intraoral and extraoral fulcrum	2
λ No slippage of instrument	2
λ Fulcrum moves with the change of teeth position	2
Periodontal probing	
λ The angle of proximal surface probing	5
λ The angle of lip and palate probing	5
λ The way of buccal probing	5
λ The order of probing	5
λ Correct record	6
Supragingival scaling	
λ Probing and recording of subgingival calculus	6
λ 80 ° angle between blade and tooth surface	5

Scoring items	Score
λ Wrist force	5
λ Direction of force	5
λ Remove the calculus in one piece	6
λ Continuity of scaling	5
λ Probe inspection after scaling	6
Total	100

2.2.4 Supragingival scaling effect

Supragingival scaling removes supragingival calculus, plaque, and color stains using various instruments. Since there was no calculus in the volunteers' mouths, we used the plaque index to assess supragingival scaling in our study. All of the 60 volunteers received periodontal scaling operating randomly by means of pairwise correlation. Then, the supragingival scaling score was calculated as a hundred mark system using the following equation:

$$\frac{\text{Total plaque index before scaling} + \text{total plaque index after scaling}}{\text{Total plaque index before scaling}} \times 100$$

The Turesky modification of the Quigley–Hein index [20], was used to assess the supragingival plaque revealed on six sites (e.g., mesial buccal, median buccal, distal buccal, mesial lingual, median lingual, distal lingual) of each tooth [21] (Fig. 5C/D/E/F).

2.2.5 Questionnaire survey

At the end of the course, the students completed a satisfaction questionnaire-based evaluation using a 5-point Likert scale (5 = strongly agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree, and 1 = strongly disagree) [22].

2.3 Statistics analysis

Data analysis was performed with the statistical software, SPSS for Windows version 20 (IBM Inc., Chicago, IL). A comparison of each four groups was done through ANOVA in case of data conformed normal distribution and homogeneous variance, if not, a non-parametric test was adopted. Differences between Exam 1 scores and Exam 2 scores were determined using a paired t-test operational assessment was subjected to an one-way ANOVA. Data are presented as the mean ± standard deviation (SD).

3 Results

3.1 Theoretical knowledge

The average first theoretical examination score was 47.33 ± 5.40 . However, there were no significant differences in the first theoretical examination scores between the four groups (V: 46.67 ± 6.45 ; J: 45.00 ± 4.63 ; V-J: 49.67 ± 4.81 ; J-V: 48.00 ± 4.93 ; $P > 0.05$, Fig. 4A).

The second theoretical examination scores were significantly higher than the first theoretical examination scores in each group. (V: 50.67 ± 3.72 ; J: 49.00 ± 4.31 ; V-J: 60.00 ± 4.47 ; J-V: 58.33 ± 4.35 ; $P < 0.01$, Fig. 4B/C). Additionally, the individual scores of students in groups V-J and J-V were significantly higher than those of students in the other two groups ($P < 0.05$, Fig. 4B/C). However, there was no significant differences in academic performance between students in Group V-J and Group J-V.

3.2 Operation assessment

The scoring key points of the actual operation procedure were judged by a professional (over 5 years teaching experiences). The group V-J (72.00 ± 5.92) and group J-V (70.00 ± 3.05) demonstrated a relatively good performance than the other two groups (V: 61.67 ± 7.85 ; J: 60.67 ± 2.58) on the operation process (Fig. 5A).

The supragingival scaling effect in Group V-J and Group J-V (V-J: 53.00 ± 3.05 ; J-V: 63.40 ± 4.39) was enhanced as compared with the supragingival scaling effect in Group J and Group V. (V: 41.90 ± 5.23 ; J: 47.40 ± 4.31). Additionally, the greatest efficacy is Group J-V (Fig. 5B). This finding suggests that initial training with the jaw model and subsequent virtual training strengthens students' performance on clinical competencies. Previous studies have explained that this phenomenon is due to students' abilities to purposefully and selectively master skills in virtual stimulation systems after jaw model training.

3.3 Questionnaire

According to the scores on the Student's Satisfaction Questionnaire, participants in Group V-J and Group J-V were highly satisfied with their training (Table 2). The lowest scoring item in Group J was "Acquisition of knowledge," and only one-third of the students were satisfied. It is easy to understand virtual simulation system interacts with students strongly and simulates the clinical diagnosis and treatment process. The lowest scoring item in Group V was "Improvement of clinical skills," and 27% of the students were dissatisfied, and 40% chose "neither agree nor disagree." Therefore, virtual simulation systems may training lack concrete experience. The highest-rated scoring item in Group V-J and J-V groups are "Combine theory with practice." The training method of jaw model combined with virtual simulation system has achieved excellent results.

Table 2
Results of the survey.

Project Evaluation Score	Groups (Mean ± SD)			
	J	V	J-V	V-J
Course focus	3.53 ± 0.62	3.60 ± 0.71	4.13 ± 0.34	4.07 ± 0.44
Course interest	3.40 ± 0.71	3.60 ± 0.49	4.67 ± 0.47	4.40 ± 0.61
Course richness	3.80 ± 0.40	3.73 ± 0.44	4.33 ± 0.47	4.80 ± 0.40
Combine theory with practice	3.93 ± 0.44	3.73 ± 0.57	4.80 ± 0.40	4.87 ± 0.34
Acquisition of knowledge	3.13 ± 0.72	3.73 ± 0.57	4.20 ± 0.40	4.20 ± 0.54
Improvement of clinical skills	3.87 ± 0.34	3.00 ± 0.89	4.60 ± 0.61	4.47 ± 0.81
The activity of the class atmosphere	3.47 ± 0.72	3.93 ± 0.25	4.33 ± 0.47	4.47 ± 0.62
Improvement of learning motivation	3.27 ± 0.57	3.40 ± 0.49	4.53 ± 0.50	4.33 ± 0.60
Satisfaction with the use of laboratory	3.40 ± 0.80	3.67 ± 0.47	4.47 ± 0.50	4.40 ± 0.49
Interaction between teachers and students	3.67 ± 0.47	3.87 ± 0.34	4.60 ± 0.49	4.67 ± 0.47

4 Discussion

The primary objective of this research was to explore themes related to periodontal operation in a medical clinical teaching unit, based on comparison the traditional jaw simulation and virtual simulation, seeking for higher efficient manner and avert shortcomings in traditional teaching methods allows the students quickly practice new skills lasting the same amount of time [23]. Our experimental results showed that no matter promote theoretical knowledge or acquisition of periodontal supragingival scaling of clinical skills, the combination of virtual simulation and jaw model both were superior to traditional teaching methods. Our results also revealed that the order of the methods (i.e., J-V vs V-J influenced the effectiveness of clinical teaching, and this was especially noticeable for the supragingival scaling procedure.

The transition of theoretical medicine into clinical practice is difficult, however, there is an urgent need for simulation training methods that integrate theory into practice [24]. In previous studies, they offered a means of role play the communication between physician and patient simulate on different clinical specialties largely boosted their memory of theoretical knowledge [25]. Consistent with our results of improved second theoretical scores. Murbay [26] assessed undergraduate performance by introducing a randomized setting in a Moog Simodont virtual system within the pre-clinical stage and found that it significantly improved student's operation level. This type of training would be valuable for students in training programs and for undergraduate teaching. Another scholars have found that students successfully mastered tooth preparation skills using virtual simulation [27]. Further, de Boer IR [28] explained the possible causes which is force dependent feedback might practice hands agility more

improve students' clinical skills when the time reached on enough time. Our experimental and modeling results are consistent with the hypothesis that virtual simulation is beneficial for operation ability. While a single training of virtual simulation cannot achieve the best effects because of differences in the system used, proficiency of the system, and the particularity of dentistry [28, 29].

Studies have reported that virtual technology offers multiple advantages in education, including improved efficiency and quality of study through feedback signals to the brain, sufficient and free training time, and accurate and automatic training data [30]. However, some scholars believe that virtual technology should not be used as an alternative to traditional methods because of excessive critical feedback, lack of personal contact, and technical hardware difficulties that are associated with VR-based training [31]. According to Plessas [32], the guidance and evaluation of professional teachers are still indispensable and virtual systems cannot fully replace traditional training courses. Furthermore, Al-Saud et al [33] randomly divided 63 people without oral professional training into 3 groups: the Device Feedback group, the Instructor Feedback group, and the Instructor Device Feedback group and revealed that skills and error rate in the last group were improved as compared with those in the former two groups. This difference translates into improvements in skill retention and the extension of knowledge to new tasks. The combination of professional guidance and feedback from a virtual simulation system (e.g., VR) is best for junior students to learn and master basic oral operations, which is consistent with our research design and conclusions.

However, the optimal sequence for training with jaw model and virtual simulation system has not been determined. In this study, the best supragingival scaling effect was observed in Group J-V. Jaw model training provides students with concrete experience that allows them to strengthen their operating skills separately. Indeed, studies have reported differences in the levels of performance between novice students (< 1 year) and experienced dental students after training with virtual simulation systems, and current study revealed features that are unique to VR and that may help us understand how these characteristics impact dental education [34]. In addition, there are a small number of students whose theoretical grades does not match the operating scores. According to neurophysiological research, this discrepancy may be related to differences in personal psychomotor skills [35].

There are several strengths associated with this study. Our methodology and findings address the shortcomings of VR periodontal education in the research literature, and may provide a useful reference for future medical teaching models. Furthermore, we cannot observe the therapeutic effects of subgingival scaling over a short period of time, and none of periodontitis patients do want to be treated by students. Hence, it was reasonable for us to explore the teaching method of periodontal operation by supragingival scaling. Most importantly, we used the Turesky modification of the Quigley–Hein plaque index gathering student's training outcomes instead of practical clinical operation direct to patients. This method can be used to assess the teaching effect of supragingival scaling. At the same time, plaque can be identified by its unique color which allows for thorough and accurate supragingival scaling.

The study also had multiple limitations. First, the approach we adopted was inevitably one-sided as compared with the general strategies that are used to evaluate periodontal treatment effects, such as probing depth and attachment loss. However, few patients allow undergraduate students to perform these procedures. Additionally, the training time of the experimental subjects may have not been sufficient to fully predict the long-term application effect of the various teaching methods. Future studies will evaluate the long-term application effects of the virtual stimulation system, including the optimal application period in the teaching process. Further, there was a possibility of publication bias for different manipulation systems of VR [36]. Finally, it is necessary to develop more realistic virtual simulation equipment.

5 Conclusions

Our findings indicate that a combination of VR and jaw model during periodontal pre-clinical training may improve students' grades and help them develop professional skills. More importantly, our results suggest that the jaw model should be applied prior to VR in order to assist students and optimize learning.

Declarations

Acknowledgement

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Authors' contributions

BPZ conceived the design. KLZ and BPZ supervised the study. JZ, JWX and MZ performed all the teaching experiments. JWX and JS analyzed the data. JZ, MZ and JWX wrote the manuscript. BPZ and KLZ reviewed the manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by Ethics Committee of the School of Stomatology Lanzhou University (No. LZUKQ-2019-25), and all students provided written informed consent to participate in this study. Besides, all the experiment protocol for involving humans was in accordance to Declaration of Helsinki.

Consent for publication

All participants provided informed consent for publication specially figure 2 and 3.

Competing interests

The authors declare that they have no competing interests.

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Figures

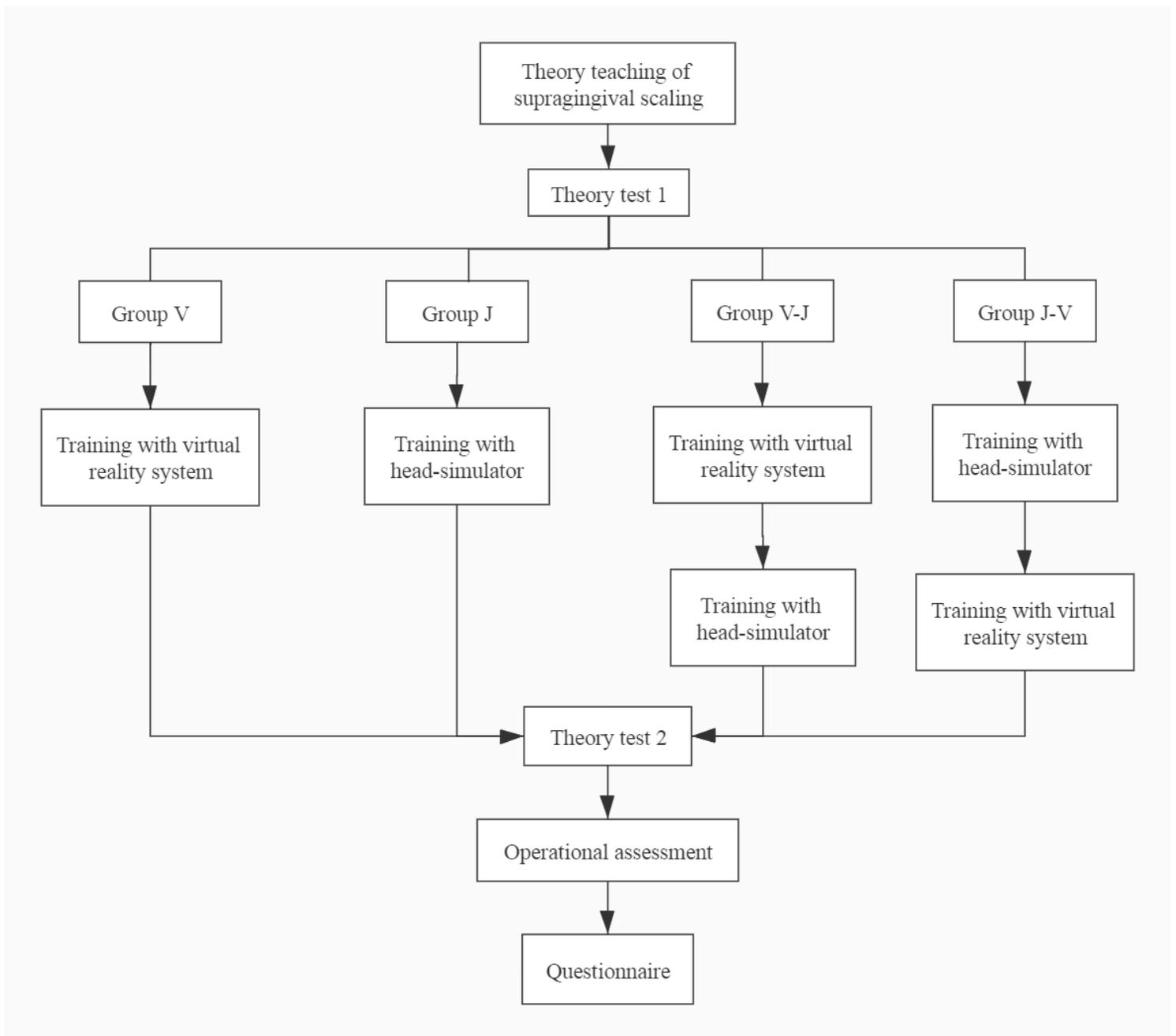


Figure 1

Flow chart of design

A**B****Figure 2**

Representative pictures display theory teaching. (A) Participants are taught theoretical knowledge during 2 h by clinical dentist with more than 5 years of experience. (B) Participants watch operation teaching video.

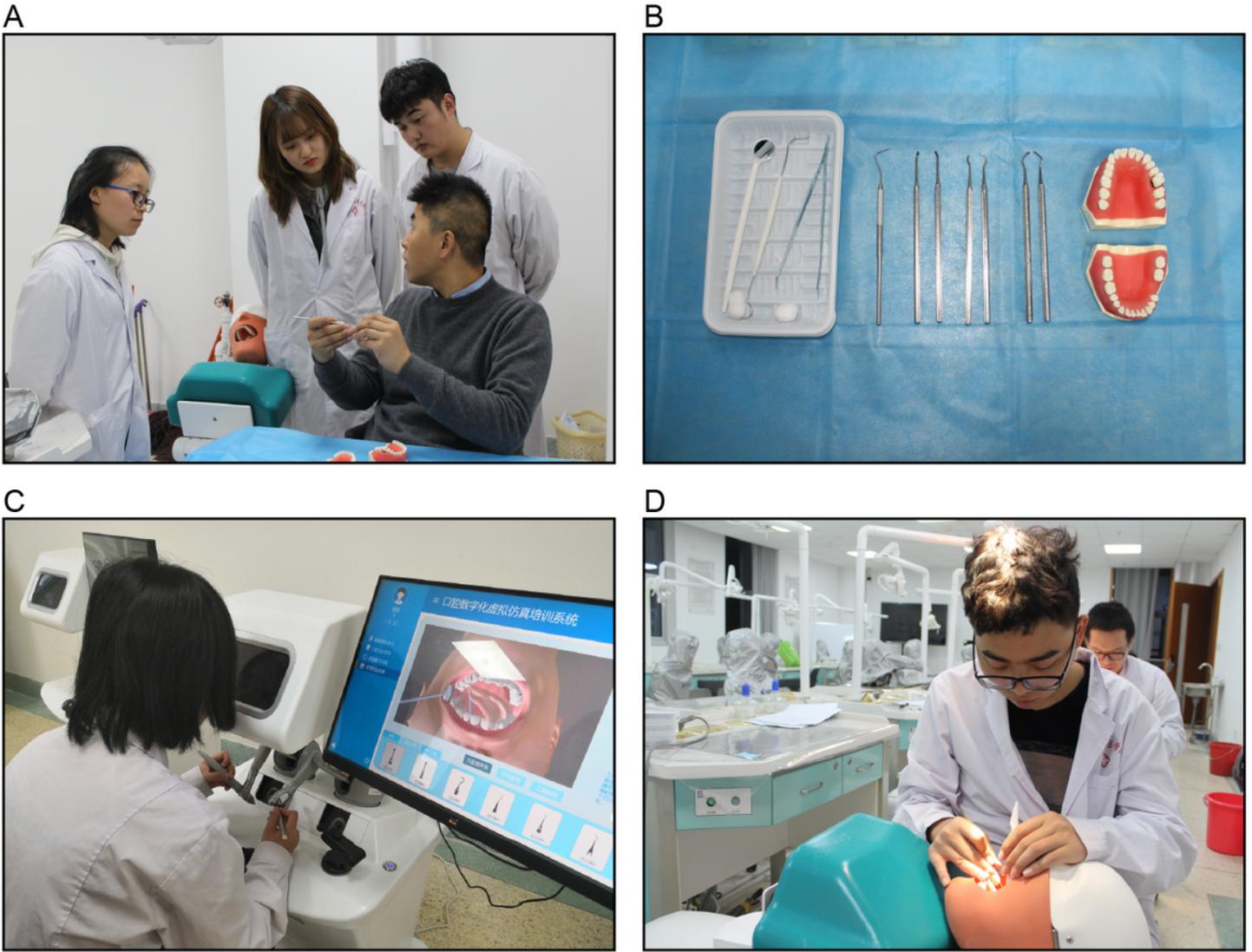


Figure 3

Operation training of supragingival scaling. (A) Demonstrate key points of operation on the jaw simulator. (B) Manual supragingival scaling tools. (C) Training on virtual reality system. (D) Training on the jaw simulator.

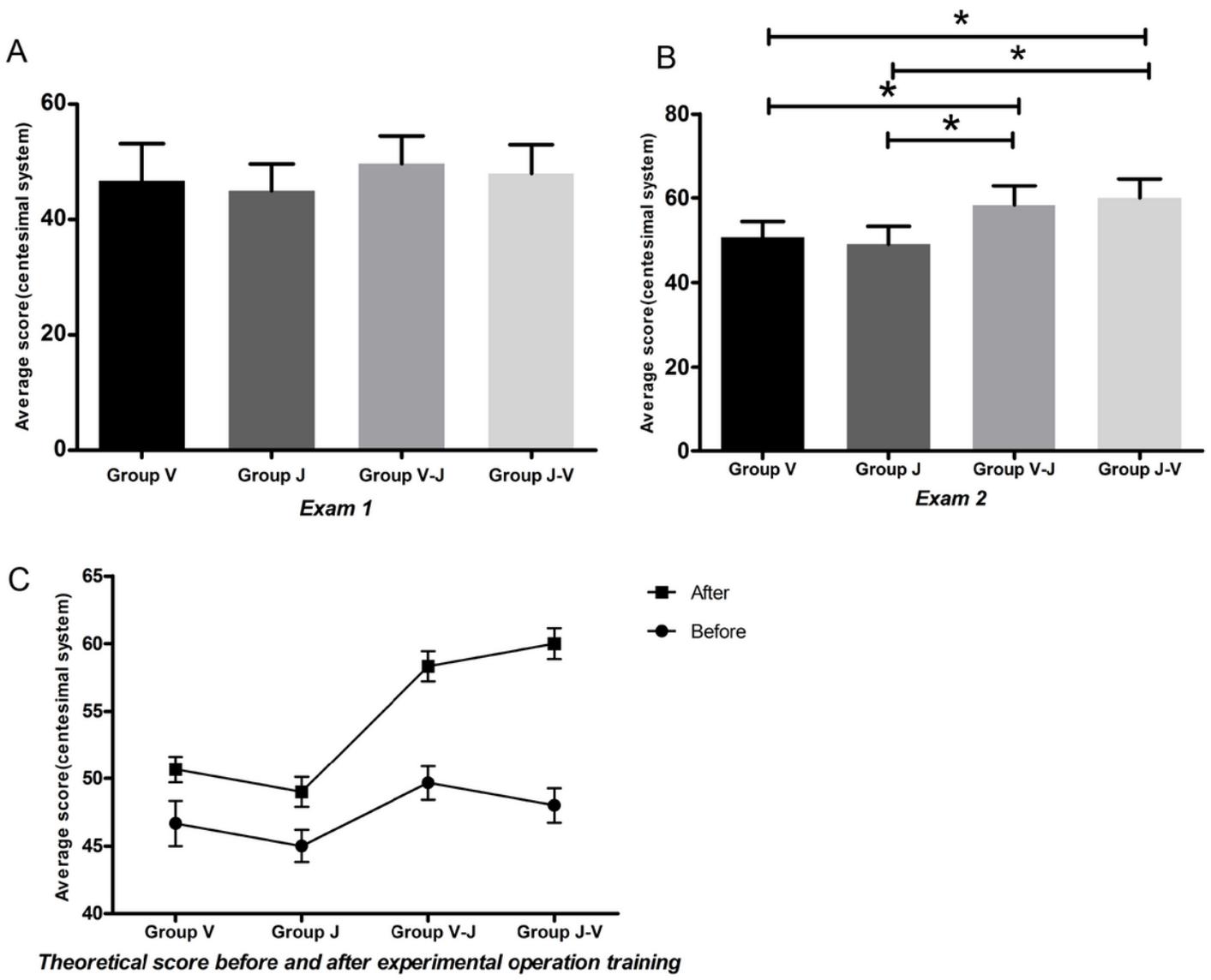


Figure 4

Theoretical score. (A) No significant difference in the first theoretical test analyzed with t-test, one-way ANOVA, correlation analysis and NSK. ($P > 0.05$) (B) The scores of Group V-J and J-V both higher than V and J in the second theoretical test. ($P < 0.05$) (C) Comparison of the first and second theoretical scores ($P < 0.05$). The gap of Group V-J and J-V is more obvious. ($P < 0.01$)

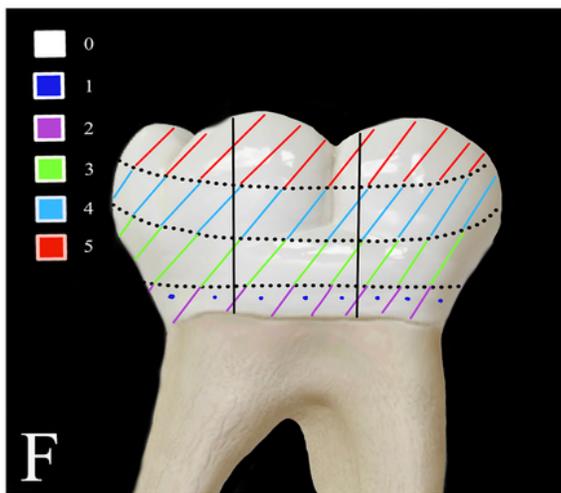
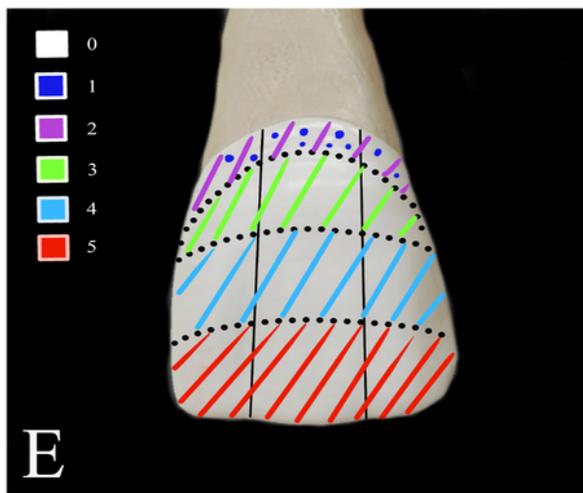
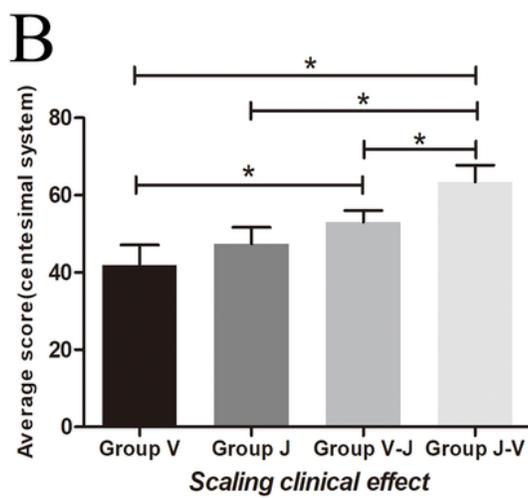
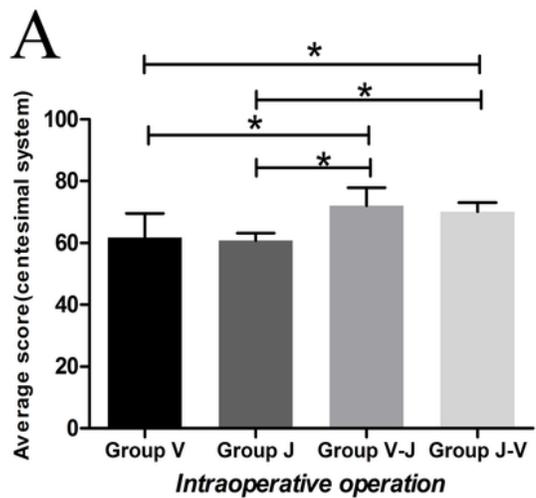


Figure 5

Operational assessment. (A) Group V-J and J-V received lower subjective score than the V-J and J-V's score. ($P < 0.05$) (B) Group J-V show the best performance about scaling effect than V ($P < 0.01$) and J ($P < 0.01$) (C/D) Scaling is indicated by periodontal plaque indicator. (E/F) Corresponding scoring standard of Quigley-Hein index.