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Simulation-based local anaesthesia teaching enhances learning outcomes

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Abstract

Objective: The aim of this study was to evaluate the efficacy of simulation-based local anaesthesia teaching strategies compared to the traditional classroom lecture format on the acquisition of knowledge by students.

Subjects and methods: Two groups of 10 students each were included in our study. Each of the dental students was enrolled in their third year of the programme. None of the students had ever received instructions in local anaesthesia. Group I received a 45-min instructional module that was delivered in the classroom in the traditional PowerPoint lecture format. Group II received a 45-min instructional module in the simulation laboratory as a short tutorial that was followed by an integrated practical demonstration and a hands-on practice session using local anaesthesia simulation phantoms. An identical 15-question multiple-choice test was used to test student knowledge acquisition at the end of the given session.

Results: There was a statistically significant difference between the two groups, as the participants in group II had higher score results than those of group I.

Conclusion: In contrast to the traditional classroom lecture format, simulation-based local anaesthesia teaching is an effective tool to enhance the acquisition of theoretical knowledge by students.

Introduction

Simulation-based teaching has become an essential tool for modern dental and medical education (1, 2). In fact, various simulation tools have been used in health care for more than 15 years (3). Simulation is defined as 'a situation for which a particular set of conditions is created artificially in order to study or experience something that could exist in reality' (4).

Unlike conventional teaching methods, simulation-based teaching enhances interest and understanding by transferring the teaching location from a conventional classroom to a virtual reality environment (5). In addition, this technique allows for the creation of specific teaching tasks on demand and provides the opportunity for specific skills to be practised and assessed repeatedly (6). Furthermore, this training can be tailored to overcome individual learning deficiencies, which will lead to increased knowledge retention and enhanced cognitive and psychomotor skills (7).

However, in contrast to conventional teaching methods, laboratory simulation and bench-model training for surgical skill development is expensive, requires a considerable faculty time commitment and is subject to scheduling conflicts (8).

Mannequin heads mounted on metal rods in a traditional laboratory, contemporary simulation clinics and virtual reality or computer-assisted simulation clinics are different simulation models used in dental education (9).

A key issue in the performance of different procedures such as bone removal and tooth sectioning in third molar surgery, preparation of dental cavities, crown preparation and injection of local anaesthesia is the development of the three learning domains, which are knowledge (cognitive skills), psychomotor skills and attitudes.

In oral and maxillofacial surgery, Lund et al. (10) investigated the use of a simulator in third molar surgery through a haptic device, and Web-based virtual Simulation of Patients (Web-SP). The authors used Web-SP for the development of clinical reasoning skills to make the correct diagnosis and treatment planning, while they used the simulator for the development of the practical skills.

In oral radiology, there was more focus on the development of cognitive skills related to interpretation of spatial information in radiographs through the use of a highly interactive simulator program. The study concluded that the decay of cognitive skills over a period of 8 months could be counteracted through the use of simulation teaching strategy (11). The same strategy was applied in improving the cognitive skill components relevant to the capability of dental students to take oral health history in periodontology (12).

Simulation-based dental education has been extensively investigated and applied in teaching and assessment of learning outcomes in restorative dentistry and fixed prosthodontics. Most of the studies have discussed the development of students' technical skills more than cognitive skills (5,13–15).

With regard to the teaching strategies applied to local anaesthesia, Brand et al. evaluated the use of local anaesthesia teaching strategies in European dental schools. The authors reported that most dental schools used a textbook for both the theoretical and practical aspects of teaching and this was frequently supplemented with a syllabus and/or other materials including handouts. They also determined that only a minority of dental schools around the world applied preclinical simulations for local anaesthesia and dental extraction models. Furthermore, there have been limited published studies to date that have evaluated the efficacy of these teaching strategies (16).

In an attempt to improve the curriculum and bridge the gap between theoretical and practical aspects of teaching local anaesthesia to undergraduate students, simulator-aided teaching has been proposed as a way to improve both knowledge acquisition and practical skills. The purpose of this study was to investigate the efficacy of the simulation-based local anaesthesia teaching strategy on the knowledge acquisition of third-year undergraduate dental students.

Subjects and methods

All students enrolled in the third year of a 6-year dental programme were included in the study. Twenty undergraduate dental students were introduced to a new topic, as none of them had ever received instructions in local anaesthesia. A 45-min instructional module was prepared and delivered by an assistant professor of oral and maxillofacial surgery. This instructional module consisted of specific objectives that included a brief introduction to local anaesthesia and step-by-step procedures for four different local anaesthetic techniques (local buccal infiltration, greater palatine nerve block, nasopalatine nerve block and palatal infiltration). The information provided was derived from the course reference, the *Handbook of Local Anesthesia* by Malamed (17).

To control for student variability, the students were divided into three groups according to their grade point average (GPA): four students with high GPA (4.0–5.0), 12 students with intermediate GPA (3.0–3.9) and four students with low GPA (2.0–2.9). The participants were randomly assigned according to GPA into two groups with equal number of participants, and the instructional module was delivered in one of the two formats.

Group I (control)

This group included 10 students who received the instructional module in the classroom in the traditional lecture and PowerPoint format.

The lecture was delivered in the form of content-oriented model. It involved three parts. The first part involved three PowerPoint slides, which covered the purpose of the lecture and the lecture outline. The second part of the lecture involved 25 slides and lasted for 30 min. It covered introduction to local anaesthesia, local anaesthetic cartridge, dental needle and the four different local anaesthetic techniques with their anatomical considerations. In this section, the lecturer used photographs to show local anaesthetic cartridge and the dental needle, while videos were used to assist the lecturer in explaining different local anaesthetic techniques. The third part involved the summary and conclusion and lasted for 10 min. During this part, students were allowed to ask questions and to comment on any point that required further explanation.

Group II (test)

This group included 10 students who received the instructional module in the simulation laboratory. The session consisted of three parts. The first part involved a 10-min tutorial, which covered the purpose of the session and introduction to the simulation phantoms (Fig. 1). The second part of the session lasted for 20-min and involved demonstration by a faculty member on syringe assembling and different local anaesthetic techniques. During this demonstration, the faculty member discussed the anatomical considerations, advantages and limitations of each technique. The third part of the session involved hands-on practice by students under the supervision of the faculty for 15 min. The students were encouraged to assemble the syringe and check the local anaesthetic agent in the cartridge, expiry date and needle length. The students also practised the four different local anaesthetic techniques on the simulation models. These models provide a constant objective feedback in the form of an audible alarm when the correct target landmark is achieved (Fig. 2). The students were guided to the correct operator position, phantom head position and the direction of the needle during insertion.

Knowledge acquisition was assessed objectively using the knowledge acquisition assessment test (KAAT, Fig. 3), which consisted of 15 multiple-choice questions divided into two components: the clinical knowledge component (seven items) and the theoretical knowledge component (eight items).

All the questions were retrieved from the (pre-validated) college question bank. This bank contains only the questions, which were previously used, analysed and showed good quality in regard to having multiple distractions, positive discrimination index and appropriate difficulty level. A panel of four experts in oral and maxillofacial surgery followed a blueprint approach for test construction. The KAAT was reviewed to ensure that questions selected were mapped carefully against the content of the teaching sessions, the knowledge given and

Fig. 1. Local anaesthesia models fitted within a phantom head.

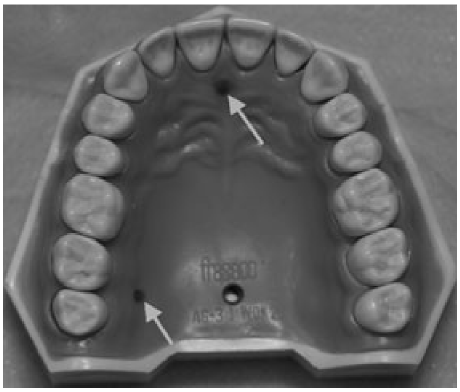

Fig. 2. Local anaesthesia models showing the target points for a nerve block in the palate.

the learning objectives. Next, the KAAT was delivered to both groups immediately following each session to exclude variables that could have arisen from studying the material at home.

The examination panel followed the methodology described by Angoff to determine the pass rate for this test (18). The cut-off score for competence/incompetence decision was 60%.

Statistical analysis

Statistical package for social sciences (SPSS Inc, Chicago, IL, USA) version 17.0 was used for statistical analysis. The scores were presented in terms of mean ranks. Mann–Whitney *U*-test was applied as all the observations from both groups were independent of each other, and the scores were on an ordinal scale. P-value ≤ 0.05 was considered statistically significant result between the two groups. Cronbach's α (alpha) statistical test was applied to check the internal consistency (reliability) of the test scores in both the theoretical and practical components.

Ethical approval

An ethical approval was obtained from the college research and ethics committee, prior to the beginning of the study (Reference number RC-1/15/03/11).

Results

Overall knowledge assessment

Of the participants in group I, the pass rate was 60%, and the mean rank was 6.9. In contrast, all the participants from group II passed the test (pass rate 100%) and had a mean rank 14.1.

There was a significant difference between the mean ranks of overall scores of the two groups ($P = 0.006$).

Choose the most appropriate answer **1. The maximum recommended dose of Lidocaine HCL plain is:** **A. 4.4 mg/ kg.** **B. 6.6 mg/kg.** **C. 2.2 mg/kg.** **D. 8.8 mg/kg.**	**6. The most painful maxillary injection is** **A. Nasopaltine nerve block.** **B. Greater palatine nerve block.** **C. Maxillary buccal infiltration.** **D. Maxillary nerve block.**	**11. For a right greater palatine nerve block, a right hand administrator should sit** **A. Facing the patient at 8 o clock position.** **B. Facing the patient at 11 o clock position.** **C. Behind the patient.** **D. On the left side of the patient.**
2. Which technique of injection is preferred if hemostasis is a primary consideration for the use of anaesthesia during extraction of maxillary 1st, and 2nd molars? **A. Local infiltration.** **B. Posterior superior nerve block.** **C. Greater palatine nerve block.** **D. Topical anaesthesia.**	**7. Which technique of injection is preferred for extraction of a tooth with a periapical infection?** **A. Local infiltration.** **B. Nerve block.** **C. Field block.** **D. Topical anaesthesia**	**12. For a left greater palatine nerve block, a right hand administrator should sit** **A. Facing the patient at 8 o clock position.** **B. Facing in the same direction of the patient at 11 o clock position.** **C. Behind the patient.** **D. On the left side of the patient.**
3. In 1.8 ml cartridge containing 2% Xylocaine **A. There is 4 mg of lidocaine per ml of solution.** **B. There is 36 mg of lidocaine per cartridge.** **C. There is 20 mg of lidocaine per cartridge.** **D. There is 18 mg of lidocaine per ml solution.**	**8. Anesthesia on the palate in the area of maxillary first premolar may prove inadequate after grater palatine nerve block because** **A. The greater palatine nerve does not supply the palatal soft tissue opposite the premolar.** **B. There may be a cross innervation from the Nasopalatine nerve.** **C. Supplemental buccal infiltration is necessary for this area.** **D. The root may be curved more toward the canine area.**	**13. In Nasopalatine nerve block, the syringe should make** **A. A 45-degree angle with the incisive papilla.** **B. A 90-degree angle with the incisive papilla.** **C. A 0 degree angle to the incisive papilla.** **D. A 30-degree angle to the incisive papilla.**
4. The palatal bone opposite the maxillary 2nd molar is supplied by **A. Greater palatine nerve.** **B. Nasopalatine nerve.** **C. Posterior superior alveolar nerve.** **D. Infraorbital nerve.**	**9. In greater palatine nerve block, the syringe should make** **A. A 45-degree angle with the palate.** **B. A 90-degree angle with the palate.** **C. A 0 degree angle to the palate.** **D. A 30-degree angle to the palate**	**14. For a nasopalatine nerve block, a right hand administrator should sit at** **A. 10 o' clock position facing in the same direction of the patient.** **B. Facing the patient 7 o'clock position.** **C. On the left side of the patient.** **D. It doesn't matter in which side to sit.**
5. The grater palatine foramen is most frequently located on **A. Anterior half of second molar.** **B. Posterior half of second molar.** **C. Anterior half of third molar.** **D. Posterior half of third molar.**	**10. In greater palatine nerve block technique, the needle of choice is:** **A. 27gauge long needle.** **B. 30 gauge short needle.** **C. 27 gauge short needle.** **D. 25 gauge long needle.**	**15. In palatal infiltration anesthesia, the area of insertion should be** **A. The attached gingiva 5-10mm from the free gingival margin.** **B. The palate at the mid palatine raphe.** **C. The free gingival margin.** **D. In the interdental papilla.**

Fig. 3. Knowledge acquisition assessment test.

Clinical knowledge assessment

Of the participants in group I, the pass rate was 50%, and the mean rank was 8.85. In contrast, the pass rate of the students in group II was 70%, and their mean rank was 12.15. There is no statistically significant difference between the means of each group (P = 0.194). Cronbach's α = 0.93, which indicates excellent reliability.

Theoretical knowledge assessment

Of the participants in group I, the pass rate was 30%, and the mean rank was 6.6. In contrast, the pass rate of the participants in group II was 80%, and their mean rank was 14.4. The test found a statistically significant difference between the means of each group (P = 0.003). Cronbach's α = 0.71, which indicates acceptable reliability.

Discussion

The purpose of this study was to evaluate the efficacy of the simulation-based local anaesthesia teaching method compared to the conventional lecture method on the acquisition of knowledge by students.

With the introduction of phantom head models that can be used to mimic different scenarios in oral surgery, such as the injection of local anaesthesia or a dental extraction, it has been necessary to redesign teaching strategies to better suit the topics being presented. As a result, teaching strategies have been aimed at improving the acquisition of knowledge as well as the cognitive and psychomotor skills of students, while avoiding unnecessary overloading of students' schedules and the repeated presentation of the same topics, which requires more lecturers' time.

Simulation-based local anaesthesia teaching may influence the student's level of confidence during the administration of their first injection to a patient. This may be due to the fact that simulation-based teaching better presents the difficult process of local anaesthetic administration, as the first injection of a patient is often difficult for dental students (19).

In our study, the participants in simulation laboratory group scored significantly higher on the 15-question multiple-choice test than did the participants in traditional lecture group. This could be supported by many different theories of learning, which suggest that learning is promoted when relevant experience is activated (20). Experience provides the main motivation for learning, and new knowledge is established from reflection. The experiential learning process using simulation techniques allows learners to reflect critically on how they felt during the exercise (21).

Participants in simulation laboratory group were supervised during their practice in the simulation laboratory. Launer (22) stated that supervision forms the most important part of professional learning. It may play an essential part in motivating students and in preventing stress and burnout.

Active, self-directed approach is likely to have a much greater impact on students' learning than passive, lecture-based approach. Only about 5% of what is taught in lectures is actually retained, and too many people use lectures for imparting large quantities of detailed information that could easily be picked up, and more effectively, by reading a textbook (23). This was clear in our study as students who learned in the simulation laboratory through an active approach scored significantly higher in the theoretical knowledge component than students who were taught through the conventional lecture format. Another explanation for this finding could be based on situated learning theory that suggests that there should be a balance between the explicit teaching of a subject and the activities in which the knowledge learnt is used in an authentic context (24).

Conventional lecture could swamp the memory with too much information delivered too fast or exceed reasonable concentration limits. Overload of information will lead to a lack of capacity for retention. The capacity of the memory relies on a fully engaged concentration generated by motivation for the learning task in hand (25). This could explain why students in traditional lecture had lower scores in the theoretical knowledge component as these students were overloaded by information that exceeded their concentration limits, while students in simulation laboratory had more memory capacity because they were motivated by applying their knowledge during practice in the simulation laboratory.

A similar study on restorative dental procedures was carried out by Buchanan (26) and investigated a virtual reality-based technology that provides, for the teaching of restorative dental procedures, consistent, unbiased feedback based on an evaluation of the tooth preparation to the tenth of a millimetre. This technology was compared to the traditional teaching strategy that involves the use of stations equipped with a light, handpiece connection and a post with an attached dentoform, as well as instructor feedback. This study found that the results of the practical examination slightly favoured the experimental group of eight students, but this was not statistically significant (26). Although these results share some similarities to those of our study, there are some differences. For example, the control and the test groups of this referenced study were equally allowed to develop psychomotor skills, while in our study, to promote better knowledge acquisition, we tried to link the knowledge provided to the application of the knowledge.

In our study, we used training units that were constructed based on the Frasaco working model AG-3, Tettning, Germany, which were used in the study by Brand et al. (27) that investigated the preclinical use of this model for local anaesthesia teaching and the subsequent clinical administration of a local anaesthesia. This study suggested that the use of preclinical training models for local anaesthesia teaching may have beneficial effects, as the investigators found that dental students who received an injection from a fellow student who had been trained using the training model scored their fellow students' confidence significantly higher than did the students who were treated by students without this training (27). However, this study addressed the use of models on the effect of the clinical administration of local anaesthesia, whereas we investigated the effect of the use of these models for simulation-based teaching on the acquisition of knowledge by students.

In our institute, the cost of each simulation unit is € 2.000–€ 4.000. This cost is not high when compared with DentSim simulation unit, which costs up to $70,000 per unit (1). The use of

Frasaco working model AG-3 does not require much on-site staff training, which excludes any hidden cost. Unlimited number of students can use the same model, and there is no need to replace any parts in the simulation unit once installed except the model batteries, which indicates very minimal overhead cost.

Our study also has limitations: the study failed to show a statistical significant difference between the two groups in relation to the clinical knowledge component. This may be due to the limited number of questions and the small sample size. We used two groups of 10 students each. This sample consisted of all the students registered for the third year of the dental college.

Owing to the limited number of studies assessing the efficiency of simulation-based local anaesthesia teaching, we would recommend large-scale multicentre studies to further assess the influence of these teaching strategies on different learning outcomes.

Conclusion

In contrast to the traditional classroom lecture format, simulation-based local anaesthesia teaching is an effective tool to enhance the acquisition of theoretical knowledge by students.

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Conflict of interest

We the authors of this work declare that we have no dual commitment or any possible conflict of interest at the time of submission. These include financial interests.

Ethical approval

We confirm that the ethical committee of our institute has approved this work, and it is in agreement with the guidelines of the Helsinki Declaration as revised in 1975.

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