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Research Article

Impact of Pre-Practical Theoretical Testing on Dental Students' Manual Tooth Carving Skills: A Preliminary Single-Blind Crossover Randomized Clinical Trial

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ABSTRACT

Purpose: No previous studies have assessed the effect of taking theoretical quizzes before teaching the practical skills on manual dexterity and practical dental anatomy (or any other clinical skills). Therefore, this study was conducted for the first time.

Methods: This single-blind randomized clinical trial of crossover nature was performed on 66 subjects. Thirty-three dental students studying at fourth semester were enrolled. Each of them acted as both experimental and control subjects, due to the crossover design (n=66, 33+33). The control group included students who did not give theoretical tests. The experimental group were informed that they would give theoretical tests every week in a particular day. Each theoretical quiz included four questions from taught materials regarding hints of practical dental morphology. Both groups gave mid-term quizzes regarding anterior and premolar teeth. Afterward, control/experimental groups swapped places. Again, students were routinely evaluated regarding the carving of molar teeth (mid-term) and in the final term exam (any tooth). Learning was measured by evaluating the 'practical morphology' scores of students. The groups were compared using Wilcoxon signed ranks test (α=0.05).

Results: Mean practical morphology scores were 16.64 ± 1.7 in the control group and 17.46 ± 1.27 in the experimental group. This difference was significant ($P<0.05$).

Conclusion: It was shown for the first time that taking regular theoretical tests before teaching practical material might improve students' practical manual dexterity and carving skills.

Keywords: Memory and learning; Education; Anatomy; Dentistry; Theoretical exams; Manual tooth carving skills; Clinical and procedural skills training; Semantic memory; Procedural memory

INTRODUCTION

Learning manual skills is fundamental to health care education; and motor, sensory and cognitive learning processes are essential aspects of professional development [1]. Clinical skills training is a basic part of health care education [2]. Besides teaching these skills in clinical setups, educational programs organize modules for skills training such as cadavers or models of body parts or even virtual reality.

Education is a set of activities that systematically transfer theoretical and practical knowledge. Lack of education leads to loss of manpower, cost, time, and also reduces the efficacy of educated people [3].

Although dentistry is a practice, it depends heavily on the learned theoretical knowledge. An important field of dentistry is to know the anatomy and morphology of the teeth, as it directly influences the dexterity of future dentists and facilitates learning of further fields such as reparative dentistry, prosthodontics,

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radiology, endodontics, pathology, and the concept of occlusion [4].

A method of learning improvement is taking regular exams. These can increase the curiosity and focus of students, force them to study regularly, improve their learning, and extend the retention of the acquired knowledge [5]. Although the importance of frequent theoretical exams on students' theoretical scores is a given, to the best of our knowledge, the effect of taking regular theoretical exams taken before classes on students' manual skills is not studied in any fields of medicine or dentistry. Dental carving is an important part of dentistry; it depends on not only the artistic capabilities of the operator but also on the knowledge of anatomic features and details as well as a proper 3D imagination/therefore, this clinical skill might be favored by theoretical knowledge about the tooth, and hence can be used as a means to test the hypothesis that whether or not learning theoretical aspects of an issue can improve the dental dexterity and the artistic competence of the operator. Therefore, we conducted this study. The null hypothesis was the lack of any effect of theoretical anatomy quizzes taken before each practical anatomy session, on the dental carving skills reflected by practical scores in anatomy.

MATERIALS AND METHODS

This single-blind randomized clinical trial was performed on 66 dental fourth-semester students (33 students who were their own control, in a crossover RCT design). The students consisted of 8 males and 25 females, with an average age of 20.5 years old. The students had been informed of the study, but were not aware of the study goals, protocol details, and group assignments. The protocol of this study was approved by the Research Committee of the Islamic Azad University, Dental Branch of Tehran (thesis registration number: 24118).

The inclusion criteria were studying dentistry at the 4th semester and agreeing to participate in the study. All the students had been admitted into the university through a national university entrance exam (among more than 1 million applicants). Students who were studying dentistry not by passing the entrance exam (by other means, such as studying abroad and then repeating their education at national universities) were excluded. As well, students who had previous experience in dental carving (experiences or university degrees in dental prosthesis) were excluded.

Routines of teaching at the anatomy and morphology department

Dental anatomy/morphology is taught as two different fields of theoretic and practical. The routine method of the practical teaching at this department is as follows. First, the carving method for a given tooth is taught orally to the students. The teeth list includes 14 teeth (the incisors, canine, premolars, and molars excluding the third molar, all from both arches). The order of teaching is as follows. It begins with the anterior permanent teeth (maxillary central) continuing to the maxillary lateral, then mandibular central and lateral, followed by maxillary canine, and afterwards maxillary premolars (both), followed by mandibular premolars, then maxillary molars (both first and second) and finally mandibular molars.

Afterwards, in the same session, tooth carving is demonstrated by a faculty member. The tooth is carved on dental wax in front of the students while they observe the carving through a large screen mounted high on the wall and is visible for all students. During carving the tooth, the method is explained in detail to the students. Also, students' questions are answered at any time, and discussions are allowed and encouraged. This method is for teaching the practical morphology.

There is also a theoretical dental anatomy and morphology, which is taught parallel to the practical method, and focuses on the theoretical details of dental anatomy. The lessons taught at the theoretical classroom are 2 sessions advanced, meaning that when for example maxillary canine is theoretically taught, about 2 weeks later its carving will be taught.

Four teachers were responsible for teaching the practical lessons (in a rotational fashion) to all the 80 students including the 33 enrolled students. The whole class is always divided into two groups, since the department has 2 separate rooms with independent teaching facilities. This way the efficacy of teaching improves. Each tooth was taught by a single teacher (at subsequent sessions) to both the control and experimental groups, in similar conditions.

Sample

Overall, the experimental students were those who would give theoretical exams before starting the practical session. For example, when they were to learn carving the maxillary canine, they would give a theoretical quiz regarding the anatomy of maxillary canine. The control participants were those who did not take any theoretical exam before the practical class, as the routine department routine. There were originally 34 students to be divided into two groups of 17, matched according to age and gender. However, since one of the students dropped the anatomy class in the middle of the semester, the study continued with a group of 16 and a group of 17. Since the study was crossover, each group of 16 or 17 would become both control and experimental during the whole semester.

Group names were as follows: Group A and B: The groups with 17 and 16 students, respectively. The indices 1 and 2 mean the first and second midterms, respectively.

In the first half of the semester, the group with 17 students (A1) would be experimental and the group of 16 students (B1) would be the control. In the second midterm, the group of 16 students (B2) would be the experimental, while the group of 17 students (A2) would be the control.

Randomization

A single teacher (The first author) was responsible for both the random assignments and taking theoretical exams. Students were assigned to the control/experimental groups based on a random table, unless they were willing to attend classes in specific days, in which case they would be excluded from the study and replaced by other willing students meeting the inclusion criteria.

Blinding

The students were not told anything about being in which group and they did not know if taking exams is a treatment, nor were they familiar with basics of research methodology. Moreover, the list of enrolled students was not disclosed to the teachers. Therefore, when scoring students' dental carvings, the teachers did not know if the evaluated tooth model had been carved either by a student excluded from the study, or a student assigned to the control group, or an experimental subject.

Matching

The matching was performed both vertically and horizontally: Once between the two groups of 16 students (who swapped places in the second midterm). The second time, each student in the first experimental group would act as his/her own control, when he/she would become a control participant (perfect matching of genetic, IQ, and many environmental factors). The same happened to students who were first assigned to the control group but would later become their own perfectly matched experimental subjects (again perfect matching).

Matching between the groups A and B: For teaching a given tooth, the teacher's skill and experience was the same for both groups A and B (a single teacher would teach a single tooth to both groups). The auxiliary educational devices were the same for both groups as well (per each tooth). The time of the teaching each tooth was equal between the two groups (in different days, for example if one group was taught at 10 o'clock, the other group would be taught at this time of another day).

The factors age, gender, classroom space, and temperature were matched between the A and B students. The factors IQ, artistic talent, family conditions were ignored, although since students had passed through a difficult filter of university entrance exam, they might be somehow normal or above normal in terms of intelligence.

Crossover matching (repeated-measures matching over time): The control group in the first midterm was B1 which consisted of students who would become the experimental participants in the second midterm (B2). Therefore, apart from the 3-month growth and seasonal changes, there was almost perfect matching between the experimental group B2 and the control group B1 in terms of age, gender, IQ, genetics, socioeconomic factors, etc. This is because B1 and B2 were the same persons. In the same way, there was a perfect matching (IQ, genetics, everything else) between the experimental group A1 and the control group A2.

However, the teacher and the lesson taught would not be the same for the matched groups of A1 and A2, or for B1 and B2.

Experimental treatment: Regular (frequent) theoretical exams before practical classes (in the experimental group only)

The experimental subjects were told before each practical session to study specific parts of their book (Concise dental anatomy) relevant to the upcoming tooth. For each tooth, the whole chapter relevant to that tooth had to be pre-studied. They were told that they would be tested at the next session (right before starting the session) regarding the studied material. They were told that the score of this exam would affect their score of 'theoretical' dental anatomy and morphology.

The theoretical exam consisted of 4 questions to be answered in 4 minutes. After the exam, they correct answers would be told to each student in person. A total of 10 theoretical exams were taken from the experimental students.

The control students were treated completely in a routine manner (no pre-studying, no theoretical exams).

Independent variable (Experimental treatment): Theoretical quizzes before practical session

The sole independent variable was taking regular theoretical quizzes (as the intervention). In the routine method of teaching the practical anatomy and morphology, no theoretical or practical exams are taken before teaching a new tooth. There is also no theoretical exam during the semester, until the final exam. In the control group, this routine was carried out. In the experimental group, theoretical quizzes were taken. Each quiz consisted of 4 questions, from the material taught in the theoretical class as well as any other points stated in the relevant chapter of the morphology textbook. The material to be studies would be declared one week prior to the quiz. The questions were descriptive with short answers (one or two items per answer). Each quiz was to be answered within 4 minutes. The quiz would be held before the class, in an isolated room, by a single teacher (The first author) who was the only person not blinded of the randomization.

Dependent variable (Outcome): The score of students at practical exams

The outcomes were the scores of the student at each of the three midterm practical anatomy exams as well as the final practical anatomy exam.

Routine of the practical exams: No midterm theoretical exam is taken. There are three midterm practical exams. They are taken in separate sessions, once after teaching the mandibular canine, once after the mandibular premolar, and finally after the mandibular molar. Each midterm exam concerns with the tooth taught between the previous exam up to now. The tooth to be carved in each session is selected by simple random sampling from a list of the anterior teeth (first exam), premolars (second exam), and molars (third exam). After the third midterm exam, there are two or three weeks only for training and QA. Afterwards the final exam will be held, which is similar to the midterm exams, but the randomly selected tooth can be any of

the 14 teeth. The duration of each practical test (either midterm or final) is one hour, and the selected tooth at each exam is the same for all students. The time of each of the 4 exams was 1 hour. The tooth would be selected randomly (detailed above) for all the students (one tooth for all students, at each exam) either included in the study or not. Each of the carved teeth was assessed by all the five teachers of the department, based on pre-determined criteria. The teachers were blinded of each other's scores. Then the average score of 5 scores for each tooth carved by a student would be assigned to that tooth, as its main score for that exam. Therefore, there would be 4 average scores (because of the 4 practical exams taken within the semester).

Standardizing the practical exams: The study participants took the exam together with the rest of the students divided into two groups of 40 students. The conditions of testing (light, air conditioner, the time of the exam (at the same time and day), etc.) were similar in both classrooms. Also, exams were standardized in terms of monitoring and prohibiting cheating. In practical exams, cheating could be done by preparing a well carved tooth before the exam session and delivering it, instead of the exam specimen. Cheating would be punished by a zero score. Monitoring was done by two teachers at each classroom, and it was reinforced by closed-circuit cameras (2 cameras per classroom) which also recorded the exam session. Wax blocks had colors determined randomly for each student by the department. This made cheating more difficult. Finally, it was possible to ask all the students to leave some part of the root uncarved; this extent would be similar for all students, and would be determined randomly between zero (complete root carving) and full root (none of the root would be carved).

Rating the carved specimens: All 4 wax specimens related to the 4 practical exams of each of 80 students were evaluated at the end of the semester, in a single session. Five teachers rated each of the 4 exam specimens carved by each student. The first student to be evaluated was randomly determined by each teacher. They rated the next students on an ascending alphabetical order. Each evaluator rated the specimens (on a scale of 0 to 20) independently, and without the knowledge of other evaluators. The scores depended on the correct proportions as well as properly carving the anatomical details. The magnitude of score pertaining to each of the 4 exams of each student was calculated by taking the average of the scores given to that specimen by all the 5 evaluators. This was done by the single teacher responsible for the randomization. Since this was a legal action, and students' scores needed to be accurately calculated, there was no bias or misconduct in average calculations. None of the five evaluators knew the names of the students. Only the first author knew the students visually but not their names.

Statistical analysis

During the whole study period, 2 practical exams were taken from all students when they were assigned to the experimental group (n=16+17). Also 2 exams were taken from all students when they were allocated to the control group throughout the study period (n=17+16). The average of the 2 experimental exams was calculated for the 33 students. The average of the 2 control exams was computed as well for the same 33 students. The average scores were compared using a Wilcoxon signed ranks test. The level of significance was set at 0.05.

RESULTS

Students ranged in age between 19 and 32 years old (average=21.2). Of them, 36%, 54%, 9%, and 0% were respectively very interested, interested, least interested, and not interested in dental anatomy lessons. Of them, 54% were very interested in dentistry, 42% were interested in dentistry, 3%were least interested in dentistry, and 3% were not interested in dentistry.

The practical score of the total experimental group was about 0.8 score (out of a maximum score of 20) better than the total control (Table 1). The difference was statistically significant according to the Wilcoxon signed ranks test ($P<0.05$).

Table 1: Descriptive statistics and 95% CIs of the practical anatomy scores (out of 20).

Group	N	Mean	SD	CV (%)	95% CI	
Control	33	16.64	1.7	10.22	16.06	17.22
Experimental	33	17.46	1.27	7.27	17.03	17.89

Note: N: Number; SD: Standard Deviation; CV: Coefficient of Variation; CI: Confidence Interval.

DISCUSSION

The findings of this study indicated that taking regular theoretical exams before practical classes might improve the practical learning of the students. The reason for this might be a better understanding and/or retention of the practical points, when the theory of the subject is studied beforehand. Although this looks like a simple event, it is not at all simple, and also is not clear cut.

Knowledge can be explained as tacit knowledge, understanding, facts, and proficiency, often associated with sensory experiences: Knowledge built on understanding is qualitative and deals with perceiving the underlying meaning. Factual knowledge is theoretical, and is based on evidence. Tacit knowledge or familiarity is usually based on experiences obtained from the senses. Skills or proficiency includes both motor and intellectual skills (e.g. problem-solving) and is a sort of non-verbal performance knowledge regarding what to do and how to do it

[6]. Learning is a function of inherent factors such as intelligence and talents as well as extrinsic factors including teaching methods/tools, exam taking, and numerous sociocultural parameters [7]. Motor learning is the learning of new movements or their changes [8]. It is a set of processes associated with training and experience, resulting in alterations in the ability to produce effective movements. It is not simply motor processes [9]. However, it develops through a synchronized set of sensational, cognitional and motor functions in a way that the learner becomes able to distinguish similarities through variations [10]. Observations of differences of a phenomenon result in experience-based knowledge. During learning manual skills, or so-called embodied knowledge, the senses of touch, tactile sensation, in addition with visual and audio perception are involved [11]. Through feedback, sensory input is compared with previously stored experiences [12]. Practice and repetition is needed for the sensory information to create memories in brain's implicit functional systems, which will be used automatically without conscious control [13]. Besides experience and proprioceptive feedback, learning of clinical skills might have a theoretical basis mainly from cognitive and sociocultural perspectives [14]. The sociocultural environment includes social (interactions among students and teachers), physical (physical layout, space, and type and number of participants in it), and cultural characteristics (beliefs about the value of anatomy or dentistry and hierarchical roles of participants) [15]. Different interactions between participants may highly affect the results [16]. Successful understanding of dental carving needs the learning of at least two components: The 3D tooth form, and the method of carving. In the practical class, students not familiar theoretically with the 3D form would allocate some of their learning and memory capacity to learning the tooth form instead of the carving method; whereas, students more familiarized with the tooth form would focus better on the practical hints. This way, theoretical quizzes improve dental students' readiness/preparedness to engage in tooth carving practical session and therefore derive in better performance in the subsequent practical assessments. If proved efficient, this can have implications in any clinical practices needing a theoretical basis.

Regular exams might enhance learning by persuading students to study. Nevertheless, this learning never perfectly remains, and improving its retention by active and continuous re-learning is a challenge in academia. Exam taking improves learning and the retention of the learned stuff and provides feedback for the efficacy of learning to both the learner and educator. Perhaps quizzes can improve learning by acting on these stages, as it is shown that unannounced quizzes can improve learning [17]. Although there are no studies on the effect of pre-teaching theoretical exams on the quality of practical manual learning, there are studies which show the efficacy of pre-teaching examination in improving the learning.

A skill or competence might be defined as the ability to do something [18]. Practical wisdom is the ability to know what is meaningful in a situation and the ability to act appropriately from that knowledge in the right place at the right moment. Learning of clinical skills might have a theoretical basis mainly from cognitive and sociocultural and perspectives. Learning practical and manual skills requires experience, which is regular repetition with feedback on what has been done. The sense of touch, including proprioception, provides feedback on performed actions. Experienced knowledge is a combination of thought, feeling and action, tacit and theoretical knowledge, practical wisdom, intuition, experience and personal maturity [19]. Four stages of psychological conscious competence learning model suggests that learners are first unaware of how little they know, or unconscious of their incompetence. When they understand their incompetence, they consciously seek to learn a skill, and then consciously use it. Finally, the skill might be performed without conscious thinking, which is called unconscious competence. Skills competence is shown by consciously knowing facts and having understanding, but also by conscious and unconscious practical knowledge and practical wisdom [20].

This rather sophisticated and preliminary design was difficult to conduct and hence limited by some factors. It was not possible to match the difficulty of carving more sophisticated posterior teeth with simpler anterior teeth. On the other hand, more difficult teeth were taught when students had acquired some degree of manual dexterity. In any case, the matching between the two student groups (in terms of the taught lessons) ruled out these confounding effects. Moreover, although none of the teachers knew students' names, one of the teachers took the examinations and might be accidentally exposed to some names. Therefore, we declare the whole group of teachers as not blinded. Finally, future studies should calculate sample sizes based on pilot studies. Finally, it was better to evaluate more variables. Future more comprehensive studies are warranted in this regard.

CONCLUSION

We showed for the first time that, given our limitations, taking theoretical exams before teaching practical dental carving (sculpting) classes might improve the learned manual skills. Clinical teachers are recommended to conduct theoretical exams regarding the manual skill to be taught, right before its class, in order to make the student read up relevant theoretical parts in depth.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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