Efficacy of a Step-by-Step Carving Technique for Dental Students


Abstract: This study demonstrates the effectiveness of a step-by-step carving technique that is quickly and efficiently mastered by dental students. Thirty-six final-year dental students volunteered to participate in this study. The students were given pre-prepared lower right first molar simulation teeth that had the occlusal half replaced in carving wax. The study was conducted in three time phases: pre-test (Time 1), participative learning (Time 2), and post-test (Time 3). The pre-test had the students carve the wax with no instruction. Instruction and demonstration of the technique were given at Time 2, and the post-test had the students carve the tooth again with no guidance but with training. A statistically significant increase with a nearly medium effect size was found from Time 1 to Time 2. A statistically significant increase with a medium effect size was found when comparing Time 2 to Time 3. A statistically significant increase with a large effect size was found when comparing Time 1 to Time 3. This technique has proved to be an effective method of simultaneously teaching a large cohort of predoctoral dental students. The technique is consistent with constructivist learning theory.

Dr. Kilistoff is Associate Chair, Clinical Affairs, and Clinical Professor, School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta; Dr. Mackenzie is Clinical Instructor, School of Dentistry, University of Birmingham; Dr. D’Eon is Associate Professor, College of Medicine, University of Saskatchewan; and Ms. Trinder is Research Coordinator, College of Medicine, University of Saskatchewan. Direct correspondence and requests for reprints to Dr. Alan J. Kilistoff, School of Dentistry, Faculty of Medicine and Dentistry, University of Alberta 8C.106Y, 11400 University Ave. NW, Kaye Edmonton Clinic, Edmonton, Alberta, Canada T6G 1Z1; kilistof@ualberta.ca.

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Despite competition from other restorative materials and a reduction or even elimination of its use in some countries, amalgam remains the world’s most commonly used restorative material and retains the potential to deliver cost-effective, high-quality, and long-lasting restorations. In order for this potential to be realized, it is essential that predoctoral dental students are taught the appropriate methods of working with amalgam.

If cavity preparation, placement, and carving techniques are optimized, restorations made in amalgam may last for thirty years or more. While amalgam restorations offer many biological advantages over more destructive indirect techniques, the need for adequate resistance and retention form means that cavities prepared for amalgam restorations are generally less conservative than those for direct placement composite, where preparation may be confined to the visualization and removal of irreversibly demineralized and fragile tooth tissue only. Although amalgam offers many advantages in terms of physical properties and an unparalleled evidence base over more than a century, teaching of amalgam is declining at the predoctoral dental level, and practical skills of new graduates seem poorer as a result.

One particular lost art is that of carving restorations (or shaping in the case of composite) to accurately restore the form and function of posterior teeth damaged by caries or tooth fracture. Over 50 percent of a general dental practitioner’s workload may involve the replacement or repair of existing restorations, many of them relatively large with respect to the amount of healthy residual tooth tissue. If practitioners are unable to shape or carve direct materials accurately, the resultant restorations are likely to have poor longevity and may reduce the life span of teeth. With a view to reversing this trend, this article describes an innovative technique of teaching anatomy to predoctoral dental students using a combination of a didactic lecture and a practical exercise using carving to closely simulate the carving/shaping of direct restorative materials.

Rationale for New Method for Teaching Carving Technique

Prior to this study, tooth anatomy (second year) and operative techniques (years 3 and 4) in the predoctoral curriculum at the College of Dentistry, University of Saskatchewan, Canada, were taught in discrete modules, using standard textbooks, and a mix
of full- and part-time instructors. One of the aims of this study was to assess the effectiveness of integrating wax carving into the predoctoral curriculum to bridge the gap between learning tooth anatomy (using nonclinical educational methods) and applying this knowledge to the carving and shaping of direct restorations later in the course.

Following an introductory lecture, wax added to the lower right first molar of a dentoform was carved using a series of prescribed steps and using common amalgam carving instruments. This carving technique was designed to teach students and dental practitioners how to restore the coronal anatomy of an entire tooth.4 The skills learned may then be applied to similar or less complex restorations and be transferrable when restoring any mandibular or maxillary posterior tooth. Weeks and Anderson suggested that basic learning can be distilled into just three parameters: visual, auditory, and kinesthetic.3 They demonstrated that learning occurs best when all three modalities are applied and that demonstration before and during an educational session delivers the best results. Furthermore, they cautioned against using excessive, repetitive demonstrations that may tend to regiment learning and inhibit mastery of a new task.

Cognitive apprenticeship6 is the process whereby a master of a skill teaches that skill to an apprentice and is an established paradigm that provides the theoretical basis for the systematic carving technique in this study.7,8 Cognitive apprenticeships have been described as consisting of five components: modelling, coaching, articulation, reflection, and exploration.9 Modelling involves the teacher or more experienced peer carrying out a task so that the students can observe and build the thought processes required to complete the task. The coaching aspect consists of the expert observing the students while they carry out the task they have just viewed, offering guidance and feedback. The articulation component involves finding a way for the students to articulate their knowledge gained in the problem-solving process. Reflection enables the students to compare their problem-solving process with that of the expert. Exploration involves helping the students find methods of problem-solving independently.

Horst et al. described this paradigm as valuable yet underused in dental education.10 They argued that cycling between performing a task and observing an expert or more experienced person performing a similar task leads to an increase in learning and retention. Victoroff and Hogan in a survey of dental students found that the students described demonstrations and observational learning as critical to their learning.11 They also stated that performing the task as soon after observing as possible optimized learning. There are only a few references to carving amalgam restorations in the literature,12-14 but little evidence of their effectiveness. The purpose of this study was therefore to examine the efficacy of a systematic carving technique4 that relies on visual, auditory, and kinesthetic learning.

Methods and Materials

Thirty-six final-year dental students volunteered to participate in this study. The study received ethics approval from the University of Saskatchewan (Beh 06-128), and all participants signed consent forms. The lower first molar was chosen for this study due to its complex dryopithecus fissure pattern. Mastering the restoration of this more challenging tooth shape was determined to yield greater learning potential compared to other posterior teeth exhibiting simpler morphology.4 The participating students were given a dentoform with the selected tooth prepared to the following specifications. The coronal half of the lower right first molar was ground off, and specialized carving wax (Yeti Dental Products, Engen, Germany) was added using a polyvinyl siloxane matrix. The first experimental stage began prior to any instruction so that selected students attempted to reproduce the morphology of a natural lower right first molar to the best of their carving ability. These control samples were then photographed, cataloged, and stored.

Half the cohort completed the carvings two weeks in advance of the experiment and the other half one week before to fit in with the predoctoral schedule. This step (designated Time 1) was to establish a baseline of ability in the participating students. The systemized carving technique was then presented to all of the students in a one-hour lecture,4 and they were given the opportunity to ask questions and seek clarification.

Immediately following the lecture, the students moved to the simulation clinic where they were given a second dentoform, identical to the one used in the original carving session. A practical demonstration combined with verbal instructions was delivered, with the students carving the second simulated restoration along with the instructor step-by-step at a pace suitable for all students (designated Time 2).
These dentoforms were collected, and the work was photographed, cataloged, and stored.

Immediately following this, the students were provided with a third, identical carving model and asked to carve the restoration independently with no time constraints (designated Time 3). Following the completion of this session, the dentoforms were again collected, and the work was photographed, cataloged, and stored.

To enable subjective analysis, each carving was photographed by taking standardized occlusal, buccal, and lingual views using a Nikon D90 digital SLR camera, macro lens, and ring flash. A tripod was used to ensure a constant position in relation to the experimental tooth in order to deliver consistent images using standardized camera settings and magnification. The photographs were then cropped using Adobe Photoshop to give an identical format to each student’s work.

Identifying information was removed from the photographs, and the graders were blinded. To test the calibration of the graders, three photographs (Figure 1) were arbitrarily selected and independently graded by the two graders. The graders scored samples from 0 to 2 on the following scale: 0=feature absent, 1=feature present but incomplete, and 2=feature present and clinically acceptable. The rubric was used to score ten selected features (Table 1) for each sample. The three samples were returned to the main data pool after the calibration exercise. Student number correlation was recorded by a third party not involved in the experiment, and all of the samples were graded independently by the two graders. The results were tabulated, and the key was used to sort the data into the appropriate groups. These data were analyzed, and the results presented.

**Results**

An intraclass correlation coefficient was calculated to determine the degree of absolute agreement...
of practical significance, where 0.2 is a small effect size, 0.5 is a medium effect size, and 0.8 is considered large.

A statistically significant increase with a nearly medium effect size was found from Time 1 (M=8.46, SD=3.73) to Time 2 (M=10.20, SD=3.68), t(31)=2.41, p=0.022, d=0.47. Thus, students were able to create better restorations during training in the new restoration technique.

A statistically significant increase with a medium effect size was found when comparing Time 2 to Time 3 (M=12.45, SD=4.28), t(31)=4.27, p<0.001, d=0.56. This indicates that students were able to create even better restorations upon their third attempt.

A statistically significant increase with a large effect size was found when comparing Time 1 to Time 3, t(31)=5.54, p<0.001, d=0.99. Thus, students’ ability increased greatly from baseline to Time 3. Results are shown in Figure 2.

To check that the sample size was adequate, a power calculation was performed with the following results. From T1 to T2, with our sample size, the power was 0.83. Ideally, the power should be at least 0.80 to indicate an adequate sample size. The total sample size needed for a power of 0.80 would be thirty. From T2 to T3, our power was 0.93. In order to achieve a power of 0.80, our sample size would have needed to be twenty-one. From T1 to T3, our power was 0.99. In order to achieve a power of 0.80, we would have needed eight students.

Table 1. Grading rubric for ten selected features

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<thead>
<tr>
<th>Feature</th>
<th>Score</th>
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<tbody>
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<tr>
<td>Shape of Cusps</td>
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</tr>
<tr>
<td>Central Groove</td>
<td>2</td>
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<td>Central Fossa</td>
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Note: Graders scored each feature as follows: 0=feature absent (or would cause restoration failure); 1=feature present (but incomplete/poorly defined/malpositioned/may have negative impact clinically/not clear operator understands feature); or 2=feature present (clinically acceptable/clear that operator understands anatomy/perfect).

between the two graders. Values about 0.75 indicated excellent reliability. Results showed high levels of reliability (0.81 for Time 1; 0.82 for Time 2; and 0.90 for Time 3), which showed that the two raters gave very similar ratings across all three time points. Therefore, the scores of both raters were averaged for each time point.

Paired-samples t-tests were conducted to measure changes across all three time points. Effect sizes were calculated using Cohen’s $d$ to obtain a measure of practical significance, where 0.2 is a small effect size, 0.5 is a medium effect size, and 0.8 is considered large.

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our relatively strong effect sizes, we had a sufficient number of students.

Discussion

The results of this experiment demonstrate significant improvements in carving after technique instruction. Students improved significantly from baseline (Time 1) to making a restoration alongside the instructor (Time 2). Students demonstrated further improvement when performing the carving on their own (Time 3). These results lend support to the effectiveness of cognitive apprenticeship employed in this study. All three learning modalities (visual, auditory, and kinesthetic) were used in the presentation of the carving technique. A pre-practice demonstration was presented using photographs (visual) of each stage accompanied by a verbal description (auditory) of each photograph. An intrapractice demonstration was given followed by time for the students to complete a carving on their own (kinesthetic). The results confirm the hypothesis that a combination of all three modalities delivers optimum outcomes.

Limitations of the study include the use of only two raters and not allowing practice time before the final attempt; these should be reconsidered in further studies. With the compressed schedule of current dental curricula, time to allow the students to practice for a few weeks was unavailable for this study. Even though there was no practice time, the study revealed a significant improvement, of large effect size, in student carving scores. Another limitation of the study is the lack of a control group, which would have allowed comparison of the extent to which students who received instruction benefited compared to a group without instruction. Nonetheless, the significant increases in carving quality over a very short period of time attest to the effectiveness of the carving technique. Further research based on this promising approach to dental training is required.

Additional testing of the subjects at a later date could be used to determine the long-term value of this educational protocol. The study may also be extended to include other posterior teeth, upper and lower, on both left and right. Future research directions could involve a cross-over or factorial design to help identify whether visual, auditory, or kinesthetic teaching methods or which combinations facilitate the greatest achievement. The relationship of wax carving to significant clinical improvements in amalgam (and composite) restoration morphology merits further study.

Conclusions

This innovative educational technique was found in our study to be an effective method of teaching predoctoral dental students wax carving of one tooth. The technique is consistent with constructivist learning theory, and the encouraging results suggest further development on a wider scale. As a result of the positive outcomes of this study, pilot testing of the feasibility of integrating and assessing the techniques described here have begun, and initial student feedback is uniformly positive.

REFERENCES