Comparative Effectiveness of Dental Anatomy Carving Pedagogy: A Systematic Review

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Abstract: The aim of this study was to review the effectiveness of methods used for teaching dental anatomy carving to dental students in operative dentistry as evaluated in published studies. This systematic review is described in accordance with the PRISMA statement. Two independent reviewers performed a systematic literature search of research published from January 1945 until May 2014. Seven databases were screened: MedLine (PubMed), Lilacs, IBECS, Web of Science, Scopus, SciELO, and The Cochrane Library. After removing duplicates, only studies using dental carving to assess the practical knowledge of anatomy were selected. The tabulated data were organized by title of article, names of authors, number of students assessed, assessment method, material used, groups tested, main results, and conclusions. The methodology quality was assessed according to the Cochrane Handbook for Systematic Reviews of Interventions. Initially, 2,258 studies were identified in all databases. Five articles met the eligibility criteria and were included in this review. According to these studies, the geometric method, teaching step-by-step along with the teacher, and adjuvant methods such as the use of tutors and teaching through digital media with DVDs proved to be effective in improving learning. There is no standard technique that is widely accepted for the teaching of dental carving, nor is there an appropriately validated method of evaluation to verify whether the teaching methods used are effective for the acquisition of skills and expertise in dental anatomy by students.

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The aesthetic sense of a dentist is a requirement that must be developed from the point at which the dental student starts learning dental anatomy.1,2 Knowledge of tooth morphology and function is of vital importance in the practice of dentistry because it is the basis for a dentist to be able to restore the lost tooth structure with restorative materials. The recovery of function and the aesthetics of the smile comprise several procedures that require technical knowledge, along with artistic sense, manual dexterity, and skill of the professional. In this way, it is possible to reproduce anatomical details to make dental restorations appear as natural as possible, which is fundamental for operative dentistry.3

Within a category of basic subjects, dental anatomy introduces students to the anatomical and morphological characteristics of the human dentition.1,2 As one of the first subjects directly related to teeth and oral function, anatomy plays a special role in the preclinical curriculum. At this stage of the curriculum begins the development of students’ psychomotor skills to properly restore the form and function of teeth. It is from this basic knowledge that students learn to identify tooth surface details to be...
able to recognize and diagnose anatomical dental changes.4

The traditional method of teaching dental anatomy uses lectures, books, manuals, and samples of preserved teeth. In addition to lectures, the tooth morphology is presented to students in practical courses with sculptures of teeth in wax blocks, in which the dimensions of the teeth are generally produced larger than the normal average measures of natural teeth.5 The geometric method is one of the most widely used to teach dental anatomy and consists of the use of a block of wax to define anatomical structures, such as the position of cusps and ridges and the sculpture of teeth.6 Furthermore, pulp anatomy has traditionally been taught using preserved cross-sections of human teeth with radiographs and three-dimensional models produced by the injection of colored resin into the pulp space.7 Among the newer teaching methods, the use of software has several characteristics that may contribute to the learning of dental anatomy. This method can be used anytime and anywhere, and it can be interactive and intuitive. It normally involves an easy-to-use interface, three-dimensional effects, and tests for self-assessment.7 Thus, the learning material can be presented in new and innovative ways, allowing students to learn at their own pace.1

Although learning anatomy through carving has become widely used in the curriculum, guidelines for the teaching of this knowledge vary from school to school. Therefore, the aim of this study was to carry out a systematic review about the effectiveness of the methods used in the teaching of dental anatomy carving to dental students.

### Methods

The study protocol was approved as exempted research by the Research Ethics Committee, Pelotas Dental School, at Federal University of Pelotas (RECPDSFUP Protocol 181/2010). This systematic review is described in accordance with the PRISMA statement.8 Two reviewers (WLOR and RA) performed the literature search for articles published up to May 29, 2014; there was no limit on the initial date. Seven databases were selected: PubMed (MedLine), Lilacs, IBECS, Web of Science, Scopus, SciELO, and The Cochrane Library. The keywords used in the search strategy appear in Table 1. The references cited in the articles were also verified. After identification of the studies in the database, they were imported to Endnote x7 (Thomson Reuters, New York, NY, USA) for removing duplicates and the analysis of titles and abstracts.

After reading the titles and abstracts of all studies initially identified in the databases, two reviewers performed manual screening. After this procedure, potential studies or ones in which there were not enough data in the title and/or abstract for inclusion in this review were selected for full-text reading. Any disagreement regarding eligibility of the included studies was resolved through discussion and consensus between the two reviewers or with a third reviewer (RGL).

The data were tabulated in a spreadsheet format in the software Microsoft Office Excel 2011 (Microsoft Corporation, Redmond, WA, USA) containing the documents of the study organized by title of article, names of authors, number of students assessed, assessment method, material used, groups tested, main results, and conclusions. Due to the high

<table>
<thead>
<tr>
<th>Table 1. Terms used in search strategy in PubMed (MedLine)</th>
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<tr>
<td>Search</td>
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<td>#1</td>
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<td>#2</td>
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<td>#3</td>
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Results

Initially, 2,258 studies were identified in all databases (Figure 1). After removing duplicates, 2,127 studies were excluded for noncompliance with the selection criteria (Figure 2). Thirteen potentially relevant articles were selected for full reading, of which seven were excluded for not using dental carving to assess the learning of anatomy and one study was in a language other than English, Portuguese, or Spanish. Thus, five articles were included in this review.

The demographic data and the materials used for carving of the included studies are shown in Table 2. All articles were published between 1972 and 2013. The chosen material used for the dental carving was wax. The groups tested in the studies, the
This study demonstrated no statistically significant difference among the methods evaluated. However, students reported improvement in self-learning ability and had more flexibility and freedom to schedule classes than in traditional teaching.

Regarding the assessment of risk of bias, Figure 3 summarizes the information used to assess methodological quality of the studies. Only one study was found to have a low risk of bias in the six factors analyzed; it was a randomized study. The other studies analyzed only two or three factors.

Table 2. Information on studies included in review

<table>
<thead>
<tr>
<th>First Author</th>
<th>Year Published</th>
<th>Type of Study</th>
<th>Country</th>
<th>Number of Students</th>
<th>Material for Carving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuller</td>
<td>1972</td>
<td>CPS</td>
<td>United States</td>
<td>20</td>
<td>Wax</td>
</tr>
<tr>
<td>Gansky</td>
<td>2004</td>
<td>NCLS</td>
<td>United States</td>
<td>244</td>
<td>Wax</td>
</tr>
<tr>
<td>Bodi</td>
<td>2007</td>
<td>CLS</td>
<td>Brazil</td>
<td>128</td>
<td>Wax</td>
</tr>
<tr>
<td>Nance</td>
<td>2009</td>
<td>RCLS</td>
<td>United States</td>
<td>73</td>
<td>Wax</td>
</tr>
<tr>
<td>Kilistoff</td>
<td>2013</td>
<td>CLS</td>
<td>Canada</td>
<td>36</td>
<td>Wax</td>
</tr>
</tbody>
</table>

CPS=controlled pilot study; CLS=controlled longitudinal study; NCLS=non-controlled longitudinal study; RCLS=randomized controlled longitudinal study.

Note: For full publication information on studies, see the references.

The earliest study included evaluated only the benefits of a student receiving tutoring for learning dental carving. Among the evaluated methods for teaching carving, the geometric method was found to be effective in one of the included studies. A technique in which the tooth was carved step-by-step along with the professor was found to improve the quality of the carving in another study. The latest study evaluated traditional learning in a laboratory with teachers along with teaching using digital media (DVD). This study demonstrated no statistically significant difference among the methods evaluated. However, students reported improvement in self-learning ability and had more flexibility and freedom to schedule classes than in traditional teaching.

Regarding the assessment of risk of bias, Figure 3 summarizes the information used to assess methodological quality of the studies. Only one study was found to have a low risk of bias in the six factors analyzed; it was a randomized study. The other studies analyzed only two or three factors.

Discussion

All five studies included in this review demonstrated an impact on students' ability to perform dental carving with the methods tested. By analyzing the teaching methods in these studies, we found...
Table 3. Main results of studies included in this review, along with assessment methods used and groups evaluated

<table>
<thead>
<tr>
<th>First Author</th>
<th>Evaluated Group</th>
<th>Assessment Method</th>
<th>Main Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuller</td>
<td>Two groups of ten students selected from among those who had the best and worst grades (control group, n=5; experimental group, n=5). The group with low performance after the initial assessment received a tutor from the other group.</td>
<td>Each student completed six practical exams and two projects covering various aspects of carving, tooth morphology, and occlusion. Practical exams counted 10 points each, and the two projects scored 20 and 10 points. It was not specified in the study what was assessed regarding the carving.</td>
<td>Students who initially had low performance and received tutoring significantly improved their performance during the semester. No significant benefit or decrease in performance was observed in those who served as tutors.</td>
</tr>
<tr>
<td>Gansky</td>
<td>244 students newly admitted to the university who took the Manual Dexterity Test (MDT) were compared regarding their academic performance in preclinical subjects.</td>
<td>The evaluation was made by the MDT, consisting of a carving test of a block for two hours. The teachers evaluated the blocks.</td>
<td>The MDT identified some students who had difficulty in preclinical subjects. However, the test did not predict in a significant way who performed better in the preclinical subjects.</td>
</tr>
<tr>
<td>Bodí</td>
<td>Two groups: one made the carvings without having had prior contact with dental anatomy (control group), and a second group received information by the geometric method.</td>
<td>Each student was evaluated by three teachers using 15 questions that assessed the presence of adequate anatomical accidents, receiving a score corresponding to the total affirmative items. The scores were calculated proportionally so that the values varied from 0 to 10.</td>
<td>The geometric method allowed for the best possible results. Students with better initial skills had better use of the method, achieving higher results than those less skilled. Moreover, even the least skilled student managed to achieve satisfactory performance (above average).</td>
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<tr>
<td>Nance</td>
<td>Two groups: one with 36 students (control group) received traditional learning of dental carving in the laboratory with tutors; the second group of 37 students (experimental group) received step-by-step instruction through digital media (DVD with instructions).</td>
<td>The carving was evaluated through a record with pre-established classifications regarding replication of tooth size, anatomical mistakes, and finishing. Based on specified criteria, students and teachers gave a grade to the carving ranging from 0 to 4. Any score below 2.0 was considered unsatisfactory or unacceptable.</td>
<td>The learning needs of students can be met through the fusion of learning through teaching software with a traditional laboratory. Students considered the digital method to be helpful for improving their self-learning ability and that it enabled greater flexibility and freedom of time for classes.</td>
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<tr>
<td>Klistoff</td>
<td>Each student had to carve three teeth: the first was carved without previous instruction (Group 1), the second with theoretical and practical step-by-step instruction along with the teacher (Group 2), and the third after instructions on the second tooth but without presence of teachers and with unlimited time (Group 3).</td>
<td>The three groups of teeth were photographed, catalogued, and stored. A pre-set score, which evaluated anatomical mistakes, was used. Analysis of the three groups using the photographs was subjective. The coefficient of intra-class correlation was calculated to determine the degree of absolute agreement between the two grades.</td>
<td>Group 3 demonstrated a statistically significant improvement in the quality of dental carvings after the step-by-step instruction over the two other groups. The step-by-step technique proved to be an effective teaching method.</td>
</tr>
</tbody>
</table>

Note: For full publication information on studies, see the references.
exercises that include creating drawings of teeth and sculpting dental elements into blocks of wax using carving tools. All of the studies included in this review used wax for the carving. This material has advantages such as low cost, easy handling, good reproducibility, varied color options, and the possibility of reuse. However, this material also has it possible to identify some practical alternatives for the teaching of dental carving, from use of the geometric model to newer methods such as learning through digital media with DVD instruction. On the other hand, considerable improvements are needed regarding quality research in this area, particularly with regard to the means of assessing dental carvings adopted by national dental curriculum guidelines and whether this evaluation is in compliance with the required development of the dental student. This development includes improving the digit-motor ability of students, using materials and instruments for dental carving, and fixing the anatomical knowledge and the importance of the relationship form and function through the static sculpture of dental elements. Some specific criteria help students develop a critical sense of the quality of a dental carving (e.g., correct number and size of cusps and the adequate presence of the following anatomical aspects: marginal crests, lingual fossa, incisal edge inclination, convergence of free and proximal faces, main groove, pits, main furrow) and could therefore help students make the best restorations and dental prostheses because this critical sense is necessary for dentists.

Each included study used a different method for evaluating improvements in learning dental carving, leading to heterogeneity in their results. As there is no standard method to assess students on practical knowledge of dental anatomy, dental schools use methodology models that may not be effective in evaluating the quality of learning in carving. Thus, the choice of the most effective methodology for teaching and evaluation of dental carving requires further investigation, especially with well-designed, randomized studies that may provide a higher degree of evidence of effectiveness of the learning technique used.

Traditional ways of developing students’ psychomotor skills in the anatomy curriculum involve exercises that include creating drawings of teeth and sculpting dental elements into blocks of wax using carving tools. All of the studies included in this review used wax for the carving. This material has advantages such as low cost, easy handling, good reproducibility, varied color options, and the possibility of reuse. However, this material also has
limitations, especially related to the challenge of portraying the three-dimensional relationships of dental morphology because the dimensions of teeth carved in wax differ significantly from the real size of the tooth, rendering the skills promoted in this activity questionable. In addition, the objective of developing visual skills is hindered because the method cannot provide students with adequate examples of the ideal shape of teeth and their deviations from normal. Methods that use models of actual size teeth, such as outlines of teeth in a gypsum model or an artificial dental mannequin (which we described as the build-up technique), were not evaluated in any study included in this review. This method may be more suitable for teaching anatomy because it allows for development of proportion perception by students, which is essential to better perform restorative procedures. However, there is still no scientific evidence that this method improves students’ skills in dental carving.

Beginning dental students are usually eager to learn dental anatomy and sculpture, but the subject is often isolated from others related to pre-patient care, with little or no clinical relevance. Thus, there may be gaps in student achievement during the transition from pre-patient care to patient care. As a result, neither knowledge nor psychomotor skills are acquired in the context of clinical practice, hindering the student’s ability to later recall and apply learning to patient care. In addition, there is still a tendency toward higher demand for aesthetic restorations, which makes many professionals seek training courses to improve their technical skills in dental anatomy. Competence in anatomy and practicing with excellence are fundamental to dental sculpture. Thus, theoretical and practical support for dental carving students could be improved, strengthening instructional practices and recycling knowledge, especially prior to students’ beginning clinical activities. Moreover, constant training and certification are important for licensed dentists and/or teachers, especially to ensure current knowledge and to update aspects inherent to sculpture.

Among the evaluated methods, the geometric method is an established one that gives students a spatial view of the tooth to be carved during the process of learning the practice of sculpture. This method, as an aid in teaching carving, provides better results, favoring learning of the technique as well as reproduction of dental anatomy. The manual training improves students’ perception of anatomy. Moreover, even less skilled students early in a dental curriculum can perform satisfactory carvings after being taught with the geometric method.

For teaching dental anatomy, new methods are being introduced to facilitate learning by carving. Teaching with digital means and/or software has shown promising results, introducing interactivity and independence in learning experiences and demonstrating that this use of technology can be beneficial for learning. A digital method was evaluated in one of the studies included in this review: in it, a DVD with instructions on teaching carving was used. However, this software does not replace the conventional way of teaching, despite being an interesting adjunctive tool that could be used more often. According to results of that study, the learning needs of students can be best met by traditional laboratory teaching along with teaching by digital media and software. The advantages of digital media and software include access to information anytime and anywhere, providing the student with flexible hours for studying independent of the teacher. The material can also be revised several times, in contrast to traditional learning directed by a traditional instructor with material presented only once.

Regarding the quality of the studies included in this review, most were longitudinal, and only one was randomized. One limitation of our review is the degree of evidence obtained by non-randomized studies. For more concrete evidence of the actual effectiveness of teaching methods used, it is critical to conduct randomized controlled trials with an appropriate design. It is also important to conduct further studies evaluating various methods used to teach dental carving, from the traditional method to the digital one using software. Systematic reviews are invaluable tools for clinical practice, providing a critical approach to scientific knowledge with the aim of answering a clinically relevant question based on the best scientific evidence available or to demonstrate the lack of scientific evidence. Besides, this type of study may point out improvements in methodological standardization for further research.

In the future, combining the traditional technique and a method of teaching using software may be promising. This approach is attractive to students because it allows for more independent learning, anytime, anywhere, and at the student’s preferred pace. Even the use of tutors can be a useful method since it was shown as an effective approach in a study included in this review. Although the use of tutors allows for additional learning time beyond the timetable established by the academic curriculum,
such adjuvant methods can benefit not only students who have greater difficulty with the technique but also those who aim to optimize their skills in dental carving. Additional teaching projects for enhancing dental anatomy education can be useful in developing professionals who are more likely to spend their time in practice restoring aesthetics and dental function in their patients.6

Conclusion

The results of this review suggested there is no standard method that is widely acceptable for the practical teaching of dental anatomy using wax carving, nor is there an appropriately validated evaluation method to verify whether current teaching methods are effective for student learning. Furthermore, the quality of the included studies emphasized the need for well-designed, randomized, and controlled longitudinal trials that compare the impact of various methods on students’ ability to perform dental anatomy carving.

REFERENCES