Teaching Clinically Relevant Dental Anatomy in the Dental Curriculum: Description and Assessment of an Innovative Module


Abstract: The primary objective of the preclinical dental anatomy course in the predoctoral dental curriculum is to introduce students to cognitive and psychomotor skills related to the morphology and spatial and functional relationships of human dentition. Traditionally, didactic content for the subject is found in textbooks and course manuals and summarized by the faculty in lectures to the entire class. Psychomotor skills associated with recognition and reproduction of tooth morphology are traditionally learned by examining preserved tooth specimens and their cross-sections, combined with producing two-dimensional line drawings and carving teeth from wax blocks. These activities have little direct clinical application. In most cases, students are passive in the learning process, and assessment of student performance is unilateral and subjective. A recently revised dental anatomy module at the University of Illinois at Chicago College of Dentistry integrates independent class preparation with active small-group discussion and patient scenario-based wax-up exercises to replace missing tooth structure on manikin teeth. The goal of the revision is to shift emphasis away from decontextualized technical learning toward more active and clinically applicable learning that improves conceptual understanding while contributing to early acquisition of psychomotor skills. This article describes the rationale, components, and advantages of the revised module and presents a pre-post comparison of student learning outcomes for three class cohorts (N=203).

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Keywords: dental anatomy, educational methodology, psychomotor skills, dental education

Submitted for publication 10/5/10; accepted 1/5/11

Knowledge of tooth morphology and function is fundamental to all aspects of dental practice. As a foundational course in the preclinical dental curriculum, dental anatomy introduces students to the anatomical and morphological characteristics of human permanent and primary dentition. In addition, the course begins to develop students’ psychomotor skills for restoring teeth to proper form and function. Students acquire knowledge to identify teeth, recognize and diagnose tooth anomalies, and treat or manage dental pathology. As summarized in Okeson and Buckman’s “Curriculum Guidelines for Dental Anatomy,” the objectives of the dental anatomy course are to provide students with essential cognitive skills related to tooth morphology and thus prepare them for the National Board Dental Examination Part I and to promote psychomotor skills to competently recreate proper tooth form in restorative clinical procedures (Table 1).

As one of the first courses directly related to teeth and oral function, dental anatomy has a special status in the preclinical curriculum. Students are usually eager to learn the material, but the course is frequently isolated from other pre-patient care courses and presented with minimal or no clinical relevance. As such, the dental anatomy course does little to prepare students for the transition from pre-patient care to patient care. Most dental schools continue to present foundational knowledge in lectures and to develop students’ psychomotor skills through a combination of two-dimensional drawing projects and exercises to carve teeth from oversized wax blocks. As a result, neither knowledge nor psychomotor skills are learned in the context of clinical practice,
thus potentially hindering the student’s ability to later recall and apply learning to actual patient care. These shortcomings of the traditional curriculum have previously been identified.²

As part of a comprehensive predoctoral curriculum revision ongoing since 2002, the University of Illinois at Chicago (UIC) College of Dentistry’s Departments of Oral Biology and Restorative Dentistry introduced a revised module in dental anatomy.³

Highlights are student review of digital content resources prior to class, small-group discussions of clinically relevant topics in place of lectures, and more authentic laboratory exercises to promote psychomotor skills. These modifications allow class time to be used for higher level grand-round style discussions rather than for mere content presentation. The purpose of this article is to describe this innovative approach to teaching dental anatomy.

### Key Components of the Module

The intent of our revision was to enhance the dental anatomy module by incorporating clinically applicable cognitive and psychomotor skills related to human tooth morphology. Specific objectives were to 1) use class time to engage students in small-group discussions by delivering the majority of foundational content outside of class through instructor-provided digital learning resources; 2) horizontally integrate the study of human tooth morphology with the remaining clinically oriented pre-patient restorative dental care curriculum; and 3) facilitate student transition from pre-patient care to clinical practice.

The revised module is offered one-half day per week as students begin their dental education (first year, fall semester). Each session consists of didactic and laboratory components (Table 2). Students are required to study relevant content prior to each class. Content resources have included the following: a course manual developed by module directors; image resources (3-D Tooth Atlas 5.1, Brown and Herbranson, Portola Valley, CA, 2009); a recommended reference text with a CD-ROM containing two-dimensional (2-D) and three-dimensional (3-D) images;⁴ and PowerPoint slide presentations containing detailed instructions for laboratory assignments supported by clinical cases and corresponding criteria sheets. It is mandatory that each student reviews the assigned material before class. To focus students’ preparation on the most important issues, a review sheet with study questions is provided a week in advance, and students are required to present written answers to the questions prior to class.

A faculty member begins each session with a brief presentation to the entire class during which plans are outlined for the day’s activities. Session topics might include, for example, the major morphologic characteristics of individual teeth, basic concepts of dental occlusion, key aspects of growth and development, and common variations in tooth morphology. The presentation is followed by small-group discussions and laboratory exercises. While one group (approximately twenty students) participates in small-group discussion, the other two groups begin the day’s laboratory activity. The small-group discussions focus on the week’s topic, with special attention to aspects of clinical application, such as clinical criteria for proper tooth restoration, techniques and materials for replacing missing tooth structure, and potential difficulties to anticipate during the laboratory procedures. In the small groups, students can ask questions and discuss the particular laboratory or clinical procedure. The instructor facilitates the discussion and encourages participation by all students.

As part of their laboratory assignment, students practice psychomotor skills by waxing (Classic wax, Renfert, GEO) missing tooth structure to re-establish proper morphology. Manikin teeth (Viade Products Inc., Camarillo, CA) have been manufactured to exhibit various types of preparations based on ideal criteria that will be subsequently introduced in other restorative dentistry courses. These prepared teeth are placed into a soft acrylic manikin base (Viade Products Inc., Camarillo, CA). The teeth demonstrate typical preparations for restoration of Class I, Class II, Class III, and Class IV preparations (Figure 1). In addition, preparations for a ceramic laminate veneer, an MOD onlay, and a full cast crown are provided. Some of the preparations have been modified slightly from what would currently be considered clinically acceptable in order to display sufficient missing tooth structure for the waxing exercise. Each preparation represents a clinical scenario in which a clinician would restore missing structure of the most important morphological feature of the tooth. For example, the incisor preparations require restoration of the incisal edge, marginal ridges, and gingival third of the buccal surface. To ensure that skill development is meaningful, these exercises are integrated sequentially with other components of the pre-patient and patient care.

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Table 1. Summary of curriculum guidelines for dental anatomy

<table>
<thead>
<tr>
<th>Core Curriculum Outline</th>
<th>Cognitive Skills</th>
<th>Psychomotor Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental terminology</td>
<td>Use appropriate dental terminology</td>
<td>Reproduce accurate morphological characteristics of permanent dentition</td>
</tr>
<tr>
<td>Detailed morphology of permanent dentition</td>
<td>Describe the detailed morphology of permanent dentition</td>
<td>Reproduce accurate morphological characteristics of inter-arch and intra-arch tooth relationships using appropriately articulated casts</td>
</tr>
<tr>
<td>Detailed morphology of primary dentition</td>
<td>Describe the detailed morphology of primary dentition</td>
<td></td>
</tr>
<tr>
<td>Describe the morphological differences between the primary and permanent dentition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detailed study of intra-arch relationship of teeth</td>
<td>Describe the intra-arch relationship of teeth and its effect on health of supporting tissues</td>
<td></td>
</tr>
<tr>
<td>Detailed study of eruption sequence</td>
<td>Describe the eruption sequence of primary and permanent dentition</td>
<td></td>
</tr>
<tr>
<td>Detailed study of pulp morphology of each primary and permanent tooth</td>
<td>Describe the pulp morphology of each primary and permanent tooth</td>
<td></td>
</tr>
<tr>
<td>Short, concise, and general overview of tooth development</td>
<td>Describe the development of teeth</td>
<td></td>
</tr>
<tr>
<td>Description of frequent tooth anomalies</td>
<td>Describe the common tooth anomalies</td>
<td></td>
</tr>
</tbody>
</table>


Table 2. Key components of revised dental anatomy module at University of Illinois at Chicago

<table>
<thead>
<tr>
<th>Pre-Class Preparation</th>
<th>In-Class Activities</th>
<th>Laboratory exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent study</td>
<td>Focused review</td>
<td>Laboratory exercise</td>
</tr>
<tr>
<td>• course manual</td>
<td>• brief overview of key points of lesson by module director</td>
<td>• assessment of completed review sheet</td>
</tr>
<tr>
<td>• 3-D resources</td>
<td>• short quiz</td>
<td>• self-assessment and completion of evaluation sheet for previous week's exercise</td>
</tr>
<tr>
<td>• assigned reading</td>
<td></td>
<td>• waxing exercise for current lesson based on clinical scenario requiring restoration of missing structure on manikin tooth</td>
</tr>
<tr>
<td>• slide presentation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Completion of review sheet with study questions

Resources
- PowerPoint slide presentations of instructions and clinical cases
- Reference text (Nelson and Ash, 2009)
- 3-D image resources (3-D Tooth Atlas CD-ROM)†
- Course manual
- Review sheet with study questions

curriculum in which students learn about the rationale and techniques for restoration of various dental defects and lesions.

Student performance in the module is assessed in several ways. To successfully complete the course, students must attend class sessions, actively participate in small-group discussions, and complete all assigned laboratory work. Faculty members use clinical criteria to evaluate projects in the presence of the student. The evaluation also includes review of the student’s self-assessment. Final assessment methods are a multiple-choice examination, a station-to-station problem-based examination (objective structured clinical examination, OSCE), and a performance examination consisting of waxing a full crown on a maxillary molar preparation and self-evaluating the outcome based on clinical criteria.

Rationale for Revised Module

As has been emphasized, a meaningful foundation in dental anatomy includes a cognitive aspect and a psychomotor aspect. The cognitive aspect is comprised of descriptive and conceptual knowledge, including a substantial body of terminology. The psychomotor aspect can be divided into visual skills and motor skills. UIC’s dental anatomy module was revised to improve learning in both aspects by...
making them more relevant to clinical practice and by incorporating more opportunities for students to actively engage in the learning process.

**Cognitive Learning**

The traditional method of learning dental anatomy terminology employs lectures, textbooks, course manuals, and preserved tooth specimens. In addition, pulpal anatomy has traditionally been taught using ground cross-sections of preserved primary and permanent human dentition, radiographs, and threedimensional models produced by injecting colored resin into the pulp spaces. These methods may foster superficial understanding if students are not provided an opportunity to actively discuss what they are learning. Active instructional processes have been shown to improve the quality of learning. The UIC dental anatomy module was revised to increase active learning, primarily through active preparation for class sessions (using a variety of digital resources and a review sheet with study questions) and small-group discussions in class. Small-group discussion allows every student to participate and encourages students to assume some accountability to others through self- and peer evaluation.

In course evaluations, students participating in early versions of the revised dental anatomy module identified the major weakness of the module to be insufficiently structured discussion prior to laboratory exercises, and they expressed a desire for better organized and moderated discussions. This concern has been addressed by presenting a synopsis of the material at the beginning of each class session prior to the small-group discussion. This change balanced our goal to encourage student responsibility for learning with students’ expressed need for more structure, without reverting to the old lecture format in which students remained passive listeners throughout the entire class session. In educational psychology, this type of compromise is called “balancing challenge with support,” and it often takes several iterations of a course revision to arrive at a good balance.

One risk of the revised dental anatomy module is its heavy reliance on student motivation and self-discipline, particularly to prepare for each class session. Regardless of the synopsis at the beginning of each session, the small-group discussions might be unproductive if students failed to prepare for class. In the revised module, students are therefore required to submit responses to study questions prior to class and are quizzed prior to discussion. While students may view assignments and quizzes as additional challenges, such requirements can also serve as structural supports to scaffold the increased expectation that students engage in independent study outside of class.

New information technology has enabled significant changes to curriculum delivery. As a result, students can expand their scope of inquiry and have more control over pacing. Using digital resources to provide didactic information not only provides students with unlimited access to instructional materials, but also changes the role of the instructor. Instead of lecturing, faculty members fulfill the role of content expert by selecting learning resources and guiding students during discussions and laboratory exercises. In addition, as facilitators of small-group discussions, instructors maintain a high level of contact with students, which allows them to monitor student learning.

**Psychomotor Learning**

The widely recognized psychomotor skills required upon completion of the dental anatomy curriculum are 1) visual skill to observe normal 3-D tooth morphology in detail, 2) visual skill to differentiate normal tooth morphology from its deviations, 3) visual skill to envision correction of the deficient tooth morphology into a product that replicates normal tooth morphology, and 4) motor skill to execute the correction. Inextricably coupled with these psychomotor skills is the ability to self-evaluate the process of correction and the product itself compared to the desired outcome.

The traditional ways to learn psychomotor skills in the dental anatomy curriculum are “bench-type” exercises, including creating line drawings of teeth and sculpting teeth out of wax blocks using carving instruments. Line drawing exercises have several limitations, most significantly the challenge of portraying 3-D relationships of tooth morphology. Carving wax teeth that differ significantly from actual size is a very difficult task with a questionable value in terms of the skills that are fostered. In addition, the objective to develop visual skills is hampered because the method fails to provide students with enough examples of both the ideal form and its deviations.

**Visual skills.** Visual discrimination has been suggested as a prerequisite skill for determining the appropriate goals and strategy for a correction. In the case of dental morphology, visual discrimination demands a thorough knowledge of normal/ideal 3-D tooth morphology, including the terms describing it;
normal/ideal 3-D intra- and inter-arch relationships of the teeth; and deviations from ideal. To succeed in visual discrimination tasks, students need to observe and analyze several examples of both ideal tooth morphology and its possible deviations (acceptable and unacceptable), including its intra- and inter-arch relationships.\(^{12,13}\)

One of the most important educational tasks for acquiring visual discrimination skills is learning to distinguish the “ideal” from its clinically important deviations from normal. The traditional learning method is limited to examining preserved human teeth and their cross-sections or plastic replicas. A common problem is finding a sufficient number of intact and well-preserved human teeth, and thus dental anatomy courses may rely entirely on manikin teeth, often with unrealistic tooth morphology. A major deficiency of this method is the inability to provide students with a variety of specimens, thus hampering development of their ability to discriminate the “ideal” and normal from clinically unacceptable tooth morphology.

Studies comparing visual recognition skills acquired by traditional and computer-based curricula in dental morphology have found that the latter can be a valuable tool to prepare students for the next learning objective and the acquisition of motor skills.\(^{6,12}\) Visualization technology has the potential to improve on traditional techniques for teaching visual discrimination, provided that the software program and the computers it runs on meet certain requirements. We suggest the ideal dental anatomy software program should provide students with the following:

1. an extensive resource to learn dental terms related to tooth morphology;
2. interactive 3-D tools to visualize and learn normal external tooth and pulp cavity morphologies;
3. an extensive library of 3-D images of tooth and pulp morphologies that deviate from normal; and
4. progressive evaluation of knowledge in the form of quizzes that provide immediate feedback.

Given the demands of 3-D programs, students’ computers must also possess sufficient random access memory and processing capacity to enable rapid loading and fluid manipulation of images, or they might experience frustrating delays that reduce their motivation to continue using the program. Many of the students in the revised dental anatomy module reported that the *3-D Tooth Atlas* (Brown and Herbranson, 2009) was informative and useful, but slow and cumbersome to use on their home computers. For this reason, as of fall 2010, we have replaced the *3-D Tooth Atlas* with a textbook and accompanying CD as the primary source of didactic content.

**Motor skills.** To make the laboratory exercises more meaningful and to integrate them better with the rest of the pre-patient and patient care curricula, we replaced wax block carving with exercises to restore missing morphology of manikin teeth.\(^{18}\) To ease the transition to the clinical environment, the exercises are performed in a patient simulation laboratory.\(^{19}\) The exercises are designed to isolate specific tooth morphology and emphasize its significance from the restorative, esthetic, and periodontal perspectives. In addition, students develop motor skill strategies to recreate normal tooth morphology and restore clinically acceptable preparations (e.g., amalgam preparations for Class I and II lesions; resin composite preparations for Class IV and V defects; facial laminate veneer; MOD onlay; complete crown) in a manner similar to the actual clinical procedure. By adding emphasis on the desired motor skill performance (knowledge of the procedure) and knowledge of the performance itself (the entire process with the anticipated outcome),\(^{20}\) the exercises add entirely new objectives to a dental anatomy course. In the process, students also gain experience with dental instruments and various restorative dental materials and their manipulation. Most importantly, the exercises are designed to develop students’ ability to visually differentiate normal tooth morphology from its clinically unacceptable deviations and the ability to engage in a clinically relevant self-assessment protocol.

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**Evaluation of the Revised Module**

Student course evaluations identified the major strengths of the new module as its clinical relevance, the quality of its didactic content and laboratory exercises, and the sequencing of the module in relation to the rest of the pre-patient and patient curricula. To evaluate the effectiveness of the revised module, we conducted a statistical comparison of student learning performance before and after the change, using identical assessments. The data used in the study were originally collected for educational purposes only and retained for legal purposes. Plans to analyze the data were approved by the UIC Institutional Review Board (Research Protocol #2010-0013). Scores on the following assessments were analyzed pre- and post-revision:
1. station-to-station problem-based final examination (OSCE), including tooth identification (an assessment of cognitive skill objectives) (three cohorts, 203 students);
2. written final examination (an assessment of cognitive skill objectives) (three cohorts, 203 students); and
3. waxing the occlusal morphology of tooth #30 using Peter K. Thomas approach (an assessment of psychomotor skill objectives in the occlusion module) (four cohorts, 264 students). Waxing projects were evaluated by two experienced instructors (JB, CL), who were calibrated and who had been teaching the same occlusion module for the last nine years.

In all cases, we compared outcome measures from the combined two years immediately preceding introduction of the revised module to those of the second year after its implementation. Comparison of the academic achievement of the students in cognitive and psychomotor skills between the two pre-revision classes (2005 and 2006) showed no statistical difference at 0.05 level (OSCE: $F=1.37, P=0.25$; written: $F=0.048, P=0.95$; PKT wax-up: $F=2.014, P=0.16$). To avoid potential confounds due to the inherent challenges of transitioning to a new module, we did not include scores from the initial implementation year in the analyses. After removing identifiers, we pooled the data by the two versions of the module, verified their normal distributions, and statistically compared their outcomes using one-way ANOVA.

Results for the analysis of student learning outcomes are presented in Table 3. Scores on both the final written examination and station-to-station OSCE showed no significant change after the introduction of the revised module, indicating that the cognitive learning outcomes of the dental anatomy course were unaffected by the changes made. Students’ psychomotor skill performance, however, improved notably as shown by a statistically significant increase in scores on the final tooth morphology waxing project, which is part of the subsequent occlusion module.

### Conclusions

Documenting the impact of course revisions is fraught with challenges because of the wide variety of factors that impact student achievement and that can cause a course to differ from year to year even without a revision. Likewise, some outcomes cannot be readily tracked because they had not been assessed prior to the change and may represent new educational goals. UIC’s dental anatomy module was revised in anticipation of a comprehensive restructuring of the predoctoral curriculum that will be implemented in fall 2011. As such, it reflects the educational philosophy of the new curriculum to emphasize independent learning, small-group discussion, and authentic presentation of all topics in the context of patient care. In addition, the module and its evaluation reflect guidelines for dental anatomy by articulating both cognitive and psychomotor learning objectives, including foundational terminology and concepts, visual discrimination, and motor skills associated with restorative wax-up tasks, all of which are essential to dental practice.

The outcomes of the revised dental anatomy module suggest that, when given appropriate structural supports, students are substantially more capable of

### Table 3. Results of one-way ANOVA comparing assessment of students’ cognitive and psychomotor skills pre- and post-revision of the dental anatomy module

<table>
<thead>
<tr>
<th>Assessment (Type of Skill)</th>
<th>Final Written Exam (Cognitive)</th>
<th>OSCE (Cognitive)</th>
<th>PKT Wax-Up (Psychomotor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Number of students</td>
<td>134</td>
<td>69</td>
<td>134</td>
</tr>
<tr>
<td>Mean score</td>
<td>84.43</td>
<td>84.70</td>
<td>86.22</td>
</tr>
<tr>
<td>SD</td>
<td>7.01</td>
<td>6.16</td>
<td>8.41</td>
</tr>
<tr>
<td>F ratio</td>
<td>0.77</td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Significance</td>
<td>0.380</td>
<td></td>
<td>0.903</td>
</tr>
</tbody>
</table>

*Note: Outcomes are reported from two courses, Biology of Human Dentition and Occlusion, in the two years pre-revision (2005, 2006) and the second year post-revision (2008). 2007 was the first year of the revised module.

*Significant at $p<0.05$
learning through independent study than previously acknowledged in traditional courses. Their cognitive skill assessments demonstrated no significant decline despite a dramatic shift from lectures to independent class preparation. In addition, the psychomotor skills outcomes of the revised module suggest that students not only can tolerate authentic laboratory exercises early in the pre-patient care curriculum, but also can benefit from such exercises by developing meaningful psychomotor skills that improve performance in a subsequent course, potentially easing the transition to the patient care portion of the predoctoral curriculum.

REFERENCES