An Innovative Method for Teaching Anatomy in the Predoctoral Dental Curriculum

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Abstract: New methods of teaching gross anatomy are being evaluated as medical and dental schools attempt to find time in their curricula for new content without sacrificing essential anatomical knowledge. This article reports on an innovative method of teaching anatomy at New York University College of Dentistry. In 2005, the instructors completely replaced the dissection of wet cadavers with the study of dissected and sliced plastinated specimens. The shift from cadaver dissection to the study of plastinated specimens was accompanied by other changes in the anatomy course: students study in small, consistent groups; frequent, low-impact quizzes are administered; and the role of the computer is increased as a tool for self-directed study. To assess the course, this study considered students’ long-term understanding of anatomy as demonstrated by performance on the National Board Dental Examination (NBDE) Part I, hours of instruction, and student evaluation. The results show that, since 2005, students have had higher NBDE Part I scores, their overall performance has been above the national mean while hours of instruction were 60 percent of the national mean, and student satisfaction increased.

Keywords: anatomy, gross anatomy, dental education, plastinated specimens, gross anatomy laboratory, cross-sectional anatomy

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Dental and medical education programs are struggling to find time in their curricula for new content, while simultaneously looking for ways to manage rising costs. Anatomy has long been considered one of the foundations of medicine, but it has become difficult to maintain the many hours typically allocated to a traditional anatomy course. In dental education, anatomy instruction takes up almost twice as much time as any other area in the biomedical sciences. In recent years, the advantages and disadvantages of various methods of teaching anatomy have been debated, not only to manage resources, but also to improve anatomical understanding. Some programs have minimized the use of cadavers; others no longer use cadavers, but use living anatomy and imaging or virtual learning packages. Some programs use prosections or plastinated specimens. Plastination, a method invented by Gunther von Hagens, makes it possible for prosections or slices of cadavers to be preserved in a safe, strong, dry polymer medium that is odorless and inert.

Some programs that eliminated dissection reported student satisfaction and anatomical knowledge decreased; other programs have reduced or eliminated dissection with success. Teaching method may be a key factor in reducing or eliminating dissection without a loss of anatomical understanding. When the University of California, San Francisco (UCSF) replaced dissection with prosections, student exploration was also replaced with faculty mini-lectures. After two years, UCSF returned to full dissection. In contrast, when Yale School of Medicine successfully shortened the amount of time students dissect, the new course was designed to maintain or increase student exploration and engagement. There is, however, a paucity of data on the effectiveness of various methods of teaching anatomy, in particular in dental schools.

Prior to 2005, New York University College of Dentistry (NYUCD) had a traditional anatomy course, including dissection of human cadavers. Although the college allocated substantial resources (faculty and staff, hours of instruction, space for dissection) to the course, NYUCD was not satisfied with the students’ knowledge of anatomy as reflected in their National Board Dental Examination (NBDE) Part I scores. In addition, the use of cadavers, which are embalmed...
with formaldehyde, a hazardous chemical,\textsuperscript{17} entails the risk of accidental overexposure through fumes or direct contact.\textsuperscript{18,19} Following an incident in which the cadavers were embalmed with an excess amount of formaldehyde, NYUCD administrators and faculty began to explore alternative methods for teaching anatomy. Plastinated specimens seemed like an ideal choice as the specimens allow students to see a high degree of anatomical specificity, yet they are dry, odorless, and non-toxic.\textsuperscript{14,20}

This article reports on the changes in NYUCD’s gross anatomy course as we replaced dissection of cadavers with the study of plastinated specimens. We describe the traditional anatomy course and the design of the new course: students study plastinated specimens in small, consistent groups, and we administer frequent, low-stakes quizzes and incorporate use of online learning. We assessed the overall effectiveness of the course by a) comparing student evaluations of the two courses, b) comparing student performance on the NBDE Part I before and after 2005, and c) comparing the NBDE Part I scores and hours of instruction of NYUCD students with national averages.

**Methods**

**Traditional Anatomy Course**

In 2004, the last year in which students at NYUCD dissected, the gross anatomy course consisted of forty-five lecture hours, forty-eight laboratory hours, and seven hours of exam. For laboratory, the class of approximately 240 students was divided into two groups. Five or six students were assigned to each cadaver. Students dissected all regions of the upper body (head thorax, upper extremity, and abdominal and pelvic viscera). Students studied radiographs. Attendance was mandatory and was recorded with an in-lab quiz. Five or six faculty members and the diener (individual responsible for procurement, transportation, and preparation of cadavers) usually assisted students in the lab. In 2003 and 2004, the college rented space for dissection; previously, the college had maintained a 4,000-square foot dissection laboratory. Students took two written exams consisting of fifty to seventy-five multiple-choice questions, two practical exams consisting of forty to forty-five questions, and sixteen pre-lab quizzes. The Blackboard management system was used to post assignments and schedules and learning materials.

**New Anatomy Course**

In 2004, NYUCD invited Gunther von Hagens, scientific director of the Institute for Plastination, to New York to discuss the possibility of creating a collection of plastinated specimens for our gross anatomy course. Dr. von Hagens joined the faculty of NYUCD and spent hours meeting with all the members of the anatomy faculty to fully grasp our needs. The resulting collection consists of eight dissected full bodies, over fifty dissected heads, isolated plastinated brains and spinal cords, several upper and lower limbs, thoracic and abdominal viscera, and hundreds of slices in three planes. All plastinated materials are from cadavers donated to The Body Donation Program of the Institute for Plastination in Heidelberg, Germany. NYUCD paid the institute for the cost of dissecting, processing, and plastinating the teaching collection.

The plastinated specimens exhibit a high degree of anatomical detail. Among the structures and relationships visible on a single specimen (Figure 1) are the three branches of the trigeminal nerve as they leave the ganglion, the maxillary nerve entering the pterygopalatine fossa, the nerve of the pterygoid canal entering the pterygopalatine ganglion, the communicating branch from the zygomatic nerve carrying autonomic fibers to the lacrimal nerve and gland, and the posterior superior alveolar nerves innervating the mucosa of the maxillary sinus before innervating the roots of the molars. On another specimen (Figure 2 and Figure 3), students can observe the deep petrosal nerve leave the carotid plexus to join the greater petrosal nerve and form the nerve of the pterygoid canal before synapsing in the pterygopalatine ganglion. We supplement the plastinated specimens with over sixty real skulls, including several Beauchene (exploded) skulls, other osteological specimens, and plastic models. Each student is assigned a plastic skull to take home for the duration of the course.

At present, the anatomy course uses four classrooms (total size: 1,636 square feet), each of which has direct access to a specimen storage closet (total size: 242 square feet). As the specimens are odorless and inert, the storage closets do not have a ventilation system and are not temperature controlled. We have three full-time faculty members and three adjuncts. In addition, we have a curator who sets up the classrooms, assists with the instruction and administration of the course, and repairs the specimens with silicon and/or acrylic mixtures. When the anatomy course is not in session, the curator is free to pursue other
Students have twenty-eight ninety-minute labs. For lab, the class is divided into sixteen groups, each consisting of approximately fifteen students. Four groups meet concurrently, one group in each of the four teaching rooms. Students are assigned to a lab and an instructor for the duration of the course. The course director divides his time among the four classrooms, actively assisting in the instruction. Students divide themselves into groups of three to five. Group composition tends to be consistent for the run of the course. A lab manual, list of structures to identify, atlas, and online resources are available to students.

Students are required to identify structures on plastinated specimens and anatomical slices. For example, students are asked to cross-reference the attachments and spatial relationships of the pterygoid muscles on a cross-section (Figure 4) and dissected plastinated specimen (Figure 1). Students study consecutive series of cross sections to learn the specific relationships of structures in a particular region. The plastinated slices help students appreciate the presence of connective tissue, which has been removed in the dissected plastinated specimens.

Methods of assessment. Students are given one or two written midterm exams and a written final exam. The midterm exams consist of sixty to seventy questions each, and the final exam has between 125 and 150 questions. Students also have two practical exams, each consisting of sixty questions, as well as a mock practical. The practical exams are similar to those given in a course with dissection: structures are tagged or pinned, and students must identify the structure or answer a question about it. Practical exam questions are evenly divided among dissected plastinated specimens, sliced plastinated specimens, and osteological structures. With hundreds of slices in our collection, students are expected to recognize structures that they are seeing for the first time on exams: it is not sufficient for them to memorize structures on a few slices. Correctly answering a question may require second- or third-order knowledge. A sample question is as follows: cell bodies of preganglionic nerves that synapse in this ganglion (pterygopalatine ganglion is pinned) are found in which nucleus? Students rotate from specimen to specimen, moving through all four anatomy classrooms, and are given one minute to answer each question.

Frequent, low-stakes quizzing is an integral part of the course. Prior to attending every lab, students take an online quiz, consisting of ten to thirty questions. Some questions are taken from previous midterm or final exams, other questions expose stu-
courage students to research subjects independently by not providing them with answers. While each pre-lab quiz is worth only 0.16 percent of the final grade (total worth of all pre-lab quizzes is 5 percent...


Course evaluation. The Office of Academic Affairs asks students to anonymously evaluate courses on a regular basis. Twenty-five percent of the class is randomly selected to participate in the surveys. The anatomy course and the Department of Basic Sciences also anonymously survey students in order to improve course content and teaching methods. This survey is conducted to get students’ reactions to specific aspects of the anatomy course. The Human Investigations Committee of New York University reviewed this study and granted an exemption for educational studies.

Results

Although the cost of acquiring the collection of plastinated specimens was significant, the specimens have a life span of twenty years or longer, and the initial cost was amortized over five years. There are no recurring costs such as those of cadaver acquisition and embalming associated with a dissection laboratory. In addition to being used by first-year dental students for gross anatomy and a single laboratory in the organ systems (physiology) course, the plastinated specimens are utilized by third-year dental students preparing for the NBDE Part I examination, dental hygiene students, nursing students, and occasionally postgraduate students. As the multipurpose classrooms are used for other courses and meetings when anatomy is not scheduled, there are no continuing costs of a dedicated space. Nor do we incur the expense of renting a lab: it would cost approximately $40 a square foot per year to rent a dissection laboratory in Manhattan at the present time.

Student Evaluation of Course and Hours of Instruction

For this study, we compared students’ responses to two statements that best summarize their overall evaluation of the course. Although our method of teaching anatomy has changed, the primary course goals as stated in the course syllabus from 2003-04 to 2012-13 remain the same: to “1) present the detailed structures of the head and neck in their structural and functional relationships, and 2) enable students to recognize the application of anatomical information in clinical dental practice.” In 2003 (the last course evaluation before redesign of the course), 80.5 percent of the students agreed or strongly agreed that the
course met its goals and objectives compared to 91.4 percent of the students in 2005 (the first class that took the new anatomy course) (Figure 5). Although this question is no longer asked on the surveys, the grade that students give to the course on the survey also indicates their overall evaluation. From the first introduction of plastinations, students gave the course higher grades than when they dissected cadavers (Figure 6). We have consistently worked on improving the course, and the most recent course evaluation reflects students’ positive impression of the changes. Students have been consistently positive about the Blackboard website and frequent quizzes and have given the value of plastinated specimens especially high grades (Table 1).

First-year NYUCD students have fifty-nine and a half hours of gross anatomy lecture (including five and a half hours of exam) and forty-five hours of lab (including two hours of exam). Third-year students have an additional six hours of gross anatomy laboratory and two hours of neuroscience lecture as part of the NBDE Part I review course. In 2008-09, the average U.S. dental student spent more than twice as much time as an NYUCD student in gross anatomy lab (Table 2). NYUCD’s lecture hours are 74 percent of the national mean. NYUCD students spend seventy-six hours less class time than the national mean studying gross anatomy.

### Board Scores

Students’ NBDE Part I scores have improved since we redesigned the course and introduced plastinated specimens. The first students to take the redesigned anatomy curriculum were the graduating class of 2008. They took anatomy in spring 2005 and the NBDE Part I from August through December 2006. Comparing the NBDE Part I scores for the Class of 2008 with the scores for students who took the exam the previous year, we see an increase of seven points in the average Anatomic Sciences score. The failure rate in Anatomic Sciences decreased from 37 percent to 11 percent. Although there was improvement in all four disciplines (Anatomic Sciences, Biochemistry-Physiology, Microbiology-Pathology, and Dental Anatomy and Occlusion), no other discipline approached the decrease in failure rate achieved in Anatomic Sciences.

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the ways in which NBDE Part I results are reported. In 2007, the JCNEDE began to report raw scores rather than providing standardized scores in the four disciplines. Therefore, we cannot directly compare discipline scores after 2007 with scores from previous years. However, the percentage of students who scored above the national mean in Anatomic Sciences has increased dramatically since we implemented changes: from 14 percent in 2005 to 79 percent in 2011.

Factors in addition to changes in the course have probably contributed to higher NBDE Part I scores. There has been improvement in the Dental Admission Test (DAT) scores for incoming students.
Figure 7 shows changes in the academic average of DAT scores of entering students and improvements in the percentage of students who scored above the national mean on the NBDE Part I. Although the scales are not comparable, the figure suggests a relationship between improvements in the two sets of scores. However, changes in board scores did not always follow changes in DAT scores: board scores have steadily improved, whereas improvement in DAT scores has not been as consistent. The Office of Academic Affairs instituted changes in academic policy to improve board scores: the most pertinent changes in policy are requirements that students must take the exam within a short time period and must pass the NBDE Part I before they can have a full schedule in the General Dentistry Clinic. In addition, we began to provide students with review materials and enhanced the NBDE Part I review course, in particular the gross anatomy section.

As of this year, the JCNDE reports whether or not students have passed the boards, but not the scores of passing students. Although we do not know individual student’s scores, the mean score of NYUCD students in Anatomic Sciences was 0.9 standard deviation above the national mean in 2012 and 1.5 standard deviations above the national mean in 2013. There were no failures among NYUCD students taking the boards in 2010, one failure out of 226 students in 2011, one failure out of 238 students in 2012, and no failures in 2013.

**Discussion**

This study is the first report of a gross anatomy course in a college of dentistry that has completely replaced dissection of cadavers with the study of plastinated specimens. The current course format has

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### Table 2. Comparison of hours of instruction in gross anatomy in U.S. dental schools and at New York University

<table>
<thead>
<tr>
<th>Type of Instruction</th>
<th>Mean for U.S. Dental Schools</th>
<th>New York University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didactic</td>
<td>83.3</td>
<td>61.5</td>
</tr>
<tr>
<td>Lab</td>
<td>104.8</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>188.5</td>
<td>112.5</td>
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**Sources:** For mean for U.S. dental schools (N=57): American Dental Association, 2008-09 Survey of dental education, vol. 4, Figure 14a. For New York University: NYUCD head and neck anatomy course syllabus, 2012-13 (time allocated for exams is included) and NYUCD NBDE Part I review syllabus, 2011-12. There is a discrepancy between the number of hours of instruction for NYUCD in the ADA 2008-09 survey and the hours we report here. The authors were not the source of data for the ADA survey.

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Note: The academic average of DAT scores of the class graduating in 2007 is used as the baseline score. NBDE Part I scores are reported for students taking the exam for the first time.
been operating for over seven years, and its impact can be assessed. Student satisfaction has increased; students’ long-term retention of anatomical knowledge, as evidenced by improvement in NBDE Part I scores, has improved; and resources are used more efficiently.

As we are not reporting on the results of an experimental study, but rather evaluating an ongoing course in a large dental school, there are confounding factors. In considering improvement in NBDE Part I scores, it is impossible to fully account for the effect of changes in the DAT scores of incoming students or the effect of changes in academic policy that increased the consequences of NBDE Part I failure. There was, however, more improvement in the scores for Anatomic Sciences than in any other discipline, suggesting that the redesign of the course was an important factor.

Neither are we able to isolate and consider the individual components of the course. The effectiveness of the course, however, may be due to the very interaction of the components. The large collection of plastinated prosections and cross-sections makes it possible for students to work in small, self-selected groups, engaging them in active inquiry and developing their small-group, problem-solving abilities. We designed the course to preserve positive aspects of students’ experiences in a traditional course. The type of reasoning and discussions that go on between students in a dissection laboratory takes place among our students: what could this structure be? Where is it going? What is its relationship to other structures? Juxtaposing the sliced and prossected specimens promotes three-dimensional thinking, focuses attention on anatomical relationships, and deepens students’ knowledge of cross-sectional anatomy and their ability to interpret computed tomography (CT) sections. Thanks to the extensive size of the collection, students are exposed to a wide range of variations and some pathology. Without small, student-centered classes, the study of plastinations might have resulted in diminished anatomical knowledge and student satisfaction as occurred in other programs that reduced or eliminated dissection. As their benefits become apparent, an increasing number of dental schools are adopting small-group, student-centered learning models in various parts of their curricula.

To further encourage self-directed study, we increased the role of computer-assisted learning. Extensive use of computer-aided instruction is an effective learning tool. Students use the Blackboard online management system to access resources and assignments and to take pre-lab quizzes. Online quizzes highlight important concepts, give students immediate feedback, and allow students to assess their own mastery. We instituted “exit quizzes” at the end of every laboratory session to discourage students from falling behind in their study and ensure high attendance rate at laboratory sessions. Recent studies have shown that information retrieval, which occurs during assessments, is a critical factor in long-term retention of knowledge.

Perhaps the most valuable resource in a dental school is time. NYUCD students spend 60 percent of the time of an average U.S. dental student in gross anatomy laboratory and lecture, yet in 2011 (the last year in which individual scores were released) almost 80 percent scored above the national mean in the Anatomic Sciences section of the NBDE Part I. These results suggest a highly effective use of time for students studying plastinated specimens. Nnodim et al. report similar, but less dramatic, time-saving results with prosections: a course using prosections took 74 percent of the time of a dissection program, but five years later, retention was comparable or slightly better among students who studied prosections. Courses without dissection that require a high level of anatomical detail tend to use wet prosections rather than plastinations. Our students, however, have access to odorless specimens with great detail. The specimens are available not only to first-year students, but to more advanced students preparing for national exams and postgraduate students needing to refresh or increase their knowledge. Furthermore, as the anatomy classrooms are used for other purposes, the study of plastinated specimens has made our use of space more economical.

Conclusion

We made substantial changes in our anatomy course at New York University College of Dentistry: dividing students into small, consistent groups, replacing dissection with the study of plastinated specimens, making cross-sectional anatomy an integral part of the course, increasing online learning, and increasing the number of low-stakes quizzes. In addition, there was improvement in the DAT scores of incoming students, and the college instituted changes in academic policy aimed at improving NBDE Part I scores. Our conclusion, therefore, is not that replacing dissection with study of plastinated specimens will lead to positive results, but rather that the study...
of plastinated specimens can be a highly successful replacement for dissecting cadavers in dental school. Our experience suggests the importance of pedagogical methodology and of maintaining a large, high-quality collection of plastinations including cross-sections. As none of our students, including those interested in surgery, have experience dissecting, further research should examine the performance of our graduates in residency programs.

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REFERENCES