

Original Publication

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Preclinical Course in Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) Digital Dentistry: Introduction, Technology and Systems Evaluation, and Exercise

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Abstract

Introduction: Computer-aided design and computer-aided manufacturing (CAD/CAM) technology is an innovative digital system capable of scanning prepared teeth that are intended to receive crowns, bridges, and inlays and then effectively designing and fabricating restorations. Many dental schools are currently implementing this innovative CAD/CAM technology as part of their curricula and at University of Florida College of Dentistry we created a hands-on elective. **Methods:** The 5-week course requires 2- to 3-hours of time per week for the lectures and labs. The sessions cover an introduction to digital dentistry, technology and systems evaluation, an exercise for scanning, designing, milling, and finishing a single unit ceramic restoration, and a final exam. The students also gave presentations about systems and materials used. The classroom exercises included small-group learning and class debate sessions. **Results:** In 2015, two 5-week sessions included a total of 16 participants (8 each). The overall course satisfaction from the combined two rounds was 4.7 out of 5. Comments for the course have been generally positive, indicating that the course was a successful introduction to CAD/CAM technology. Students' comments showed that they were very impressed by the new technology and interested in implementing it in their practices. **Discussion:** This exercise in the comparison between CAD/CAM and conventional technology resulted in a deeper understanding of digital dentistry systems and ensured that students were prepared in their clinical reasoning to apply their education in real-world decision making after graduation. By integrating this new technology in a core curriculum, preclinical, prosthodontic sophomore course and as a junior elective course, students were provided with the hands-on experience needed to utilize CAD/CAM effectively in patient care.

Keywords

Computer-Aided Design, Computer-Aided Manufacturing, CAD/CAM, Digital Dentistry, Ceramic Restoration

Educational Objectives

By the end of this course, students should be able to:

1. Identify the different operating components of computer-aided design and computer-aided manufacturing (CAD/CAM) systems.
2. Describe the basic functions and operation of the components.
3. Compare and contrast the new digital and the conventional workflows.
4. Compare different CAD/CAM materials and choose the most appropriate for clinical cases.
5. Compare systems and choose the most suitable for the patient's function and needs.
6. Develop the technical skills needed for preparing, scanning, designing, milling, and finishing a single CAD/CAM ceramic restoration.

Appendices

- A. Digital Dentistry Introduction.pdf
- B. Digital Dentistry Exercise Part 1.pdf
- C. Digital Dentistry Exercise Part 2.pdf
- D. Digital Dentistry Exercise Part 3.pdf
- E. CAD CAM Evaluation Form .docx
- F. Digital Dentistry Exam Questions.docx

All appendices are peer reviewed as integral parts of the Original Publication.

Introduction

Computer-aided design and computer-aided manufacturing (CAD/CAM) technology is an innovative digital system capable of scanning prepared teeth that are intended to receive crowns, bridges, inlays, and other restorations. CAD/CAM systems, such as the E4D system, provide a better, faster, and more convenient method for fabricating restorations.¹⁻⁵

In addition, several major dental schools throughout the United States have already adopted this technology for both student education and clinical patient care. Overall, CAD/CAM technology improves the experience of both the professional and the patient by reducing patient visits, which increases efficiency, contributes to a positive practice environment, and may increase clinical productivity.⁶⁻⁸

The goal of this junior course is to enhance student critical thinking and clinical decision making in restorative treatment options using CAD/CAM digital technology.^{1,2} Additionally, it aims to provide a comparison between the workflow of the new and the conventional technologies.³ This resource provides a deeper understanding of digital systems and ensures students are prepared to apply their education in real-world decision making after graduation.

This course was first introduced to the curriculum of the University of Florida College of Dentistry in the spring semester of 2015. It was first implemented as a lab project in the fixed prosthodontics preclinical course for sophomore students. In the summer semester, it was offered to the junior (soon to be senior) students as an elective course. It replaced an older method for teaching CAD/CAM technology that required a one-on-one teaching technique in a clinical setting, without any prior student preclinical training. This limitation in our old approach resulted in education with marginal hands-on participation. Ultimately, by integrating this new technology in sophomore and junior courses at an early stage in the curriculum, we have been able to provide students the hands-on experience needed to utilize CAD/CAM effectively in patient care. In particular, this course provides the opportunity to enhance the application of CAD/CAM technology for same-day, indirect restorations. Likewise, through presentation, simulations, and clinical experience, the course emphasizes the different modalities of treatment, especially the fabrication of esthetic crown restorations.

Finally, by furthering the integration of CAD/CAM technology into our educational curriculum and expanding our clinical capabilities with this new service, we have increased the overall number of patients treated in the clinics and have provided more opportunities for clinical and preclinical research collaborations studying the effectiveness of this technology in patient care.

Methods

This course is designed for juniors in the summer semester who have completed at least one fixed crown using conventional technology (all the way from diagnostic work to tooth prep, impression, and cementation) and have at least started a second crown.

In 2015, the following course was taught as a summer semester elective course to a group of junior students. The course was taught in two rounds, each running 5 weeks. Students were selected from the pool of applicants based on their progress in clinical requirements and past competent exposure to conventional crown fabrication technology. For the year 2015, 21 junior students applied for the course; from these, 16 students were selected. The selected students participated in the course in two consecutive rounds of eight students per round. The course could also be integrated into the larger preclinical course on fixed prosthodontics for sophomore students.

The contents of this resource cover an introduction to digital dentistry, technology and systems evaluation, an exercise, and a final exam. The course sessions timetable is detailed in the [Table](#).

Table. Course Timetable

Session	Lecture	Lab
Introduction, evaluation, and points of comparison	75 minutes, including a short break.	120 minutes. Preparation of tooth #13 for ceramic crown.
Debate one, four systems presentations	Total of 60 minutes for four 15-minute presentations, followed by 30 minutes for debate and discussion.	90 minutes to finish all preparations.
Exercise part 1: scanning and Exercise part 2: designing ^a	75 minutes, including a short break.	90 minutes for scanning, model orientation, and designing.
Debate two, four materials presentations	60 minutes for four student presentations, followed by a 30-minute debate and discussion.	90 minutes to finish model orientation and designing and be ready to send to mill.
Exercise part 3: milling and finishing	30 minutes for lecture.	150 minutes for milling crowns for all students.
Finishing, crystallization, and glazing	No lecture.	180 minutes to continue milling, demo and exercise for staining, crystallization, and glaze firing of all crowns.
Final exam and project due	30 minutes for a 30-question multiple-choice exam.	Finish all crowns.

^aBased on an optimum faculty-to-student ratio of 1:4. For lower ratios, it is recommended that part 1 and part 2 be taught in separate sessions.

Introductory Presentation

The introductory presentation (Appendix A) has two parts. First is an overview of CAD/CAM technology featuring an emphasis on workflow and the advantages and disadvantages of CAD/CAM versus conventional technology.^{3,9-11} Next comes a discussion of critical criteria used to evaluate CAD/CAM systems. The presentation is structured to be taught by trained and experienced faculty, but the presentation material and content compensate for any lack of experience in CAD/CAM technology on the faculty's part. More information on faculty prerequisite training is provided below.

Technology and Systems Evaluation

The students are divided into four groups; each group is assigned the task of evaluating one of the four CAD/CAM systems. Based on the points of comparison highlighted in the presentation, each group of students is asked to give its own presentation highlighting its system's features.⁹⁻¹⁴

For the first presentation, students evaluate any of the four systems of their choice. For the second presentation, students evaluate any four materials of their choice that are capable of producing CAD/CAM crowns.

The introductory presentation highlights several points of comparison between the systems. Some important points include the following:

- The ability to apply preexisting designs to the restoration.
- The ability to produce quality restorations in esthetic zones using specially designed software.¹²
- The availability of a virtual articulator that is capable of accepting occlusal records and duplicating mandibular movements.¹³
- The ability to produce quality accurate restoration for an affordable price.¹⁴
- Software with realistic colors.
- The ability to build restorations based on a specific occlusal scheme, such as canine guidance. If the system does not offer a virtual articulator, a solution for this problem is presented in a recent article cowritten by the present author.¹⁵
- The availability of an opened system that provides an efficient way of producing fast lab-made restorations by creating an electronic stereolithography file that can be sent to a nearby lab.
- The availability of good customer support, educational courses, training, and educational materials.

The groups are advised to use all available resources to gather information about their assigned system. Resources include publications, local sales representatives, and the websites for the specific systems. Student presentations take place within a single session and last no longer than 15 minutes each. After the four presentations are completed, faculty moderate a classroom debate so students can compare the systems and draw final conclusions. Note that no examples of a student's presentation or debate are included in this resource. Course directors should conduct this session according to their own point of view.

Following parts one and two of the exercise, students are instructed to complete the same process to review and debate the four CAD/CAM materials. Students are instructed to present an overview of each material, its clinical application, and its physical properties.

Preclinical Exercise

The preclinical exercise for this course requires students to prepare, scan, design, mill, and fire ceramic crowns for typodont tooth #13. This exercise is presented in a three-part step-by-step presentation (Appendices B, C, and D) covering all the steps from tooth preparation to the finished restoration ready for cementation.

The presentation is available in a PDF format that can be easily printed as a step-by-step manual or handout. The final restoration is graded using a standard single unit restoration form (Appendix E) with a 72% or higher pass mark, fulfilling the psychomotor criteria for the course.

Final Assessment

This course culminates in a written examination (Appendix F) composed of 30 multiple-choice questions. Feedback and corrections should be made available to the students. Course directors should determine grade distribution and passing grade at their own discretion. At the University of Florida, this course was graded with a pass or fail grade dependent on the written exam and project completion.

Required Materials and Armamentarium

In addition to the standard equipment provided in a prosthodontic preclinical lab, the following are necessary for the implementation of this course:

- Kilgore typodont or similar product.
- Complete CAD/CAM system, including scanner, design computer complete with updated software, milling system, programmable crystallization firing oven, and ceramic staining and glazing kit.

For reference, our school completed this exercise using the E4D-Planmeca system. The E4D system includes an introductory kit with all equipment and materials needed to do the project. This particular system, however, is not necessary for teaching the course. The course can be conducted using any system with comparable capabilities.

Milling blocks are a necessity to complete any CAD/CAM milling exercise. These blocks are necessary to complete the exercise regardless of the type of system used. Students obtained boxes of e.max blocks (size I12) suitable for this particular exercise from the leasing office. In our school, inside the building is a retail store for a major distributor of dental supplies that provides additional blocks to the students as needed. Any dental store inside a dental school building should be able to supply milling blocks compatible with the system the school uses. Furthermore, some students were interested in gaining more experience and elected to do an extra exercise using alternate materials.

Faculty Prerequisite Training

Faculty teaching this course should have basic knowledge of CAD/CAM technology as well as experience with digital dentistry system operation and with the most common materials used to fabricate CAD/CAM restorations. All faculty who participated in teaching this course had previous experience in CAD/CAM technology and were familiar with the basics of operating any system. If faculty need additional training, they can choose from many training courses available online. Also, our course director conducted two 3-hour faculty training sessions on scanning and designing using the Appendices available in this resource. Some of the faculty participated in the characterization and firing exercise as observers.

Equipment-to-Student Ratio

In our successful implementation of this course in 2015, every two students shared one scanner, one computer, and milling blocks. Using two milling machines, we were able to mill all the needed crowns in two lab sessions. Only one firing oven was used for crystallization, staining, and glazing crowns. Most crowns need an average milling time of 9 to 12 minutes; however, this depends on the complexity of the anatomical design and does not consider maintenance and time to change burs.

Faculty-to-Student Ratio

Due to the need for close supervision and one-on-one tutoring, a faculty-to-student ratio of one to four or less is highly recommended.

Results

The overall course satisfaction from the combined two rounds was 4.7 out of 5. Comments for the course have been generally positive, indicating that the course was a successful introduction to CAD/CAM technology. Students' comments showed that they were very impressed by the new technology and interested in implementing it in their practices. A summary of student comments includes the following:

- Debate sessions were very helpful and prepared students to make an educated decision on the system they would buy for their office.
- Sometimes lab sessions seemed to be too short; additional lab time would be helpful.
- Students who used an alternate material found that the additional project was a positive learning experience. Students recommended expanding the exercise to include a variety of materials in the future.
- Some faculty members were still on a learning curve as the technology is fairly new.
- Although the software operation ran smoothly, the process of milling had several interruptions that sometimes slowed down the progress of the lab sessions.
- Custom characterization and application of surface glaze on the ceramic restoration made for a unique artistic experience.

All students completed the entire exercise, from scanning to firing and finishing the restoration, on time. Six students out of the 16 in both rounds elected to do an additional exercise using Empress CAD material to gain more experience. All the students passed the written test and received a passing grade in the course. Towards the end of the course, three students were able to do clinical cases on patients in our new CAD/CAM clinic under the supervision of the course director. Each of the three students completed a single CAD/CAM clinical restoration using the E4D system, from tooth preparation to final cementation, in one 3-hour session.

Discussion

Prior to implementing this course at the University of Florida College of Dentistry, education in CAD/CAM technology required a one-on-one setting, which was difficult to achieve with an increasing number of students and a limited number of professors knowledgeable in the system. These limitations in our old approach resulted in education with marginal hands-on participation. Having most of our faculty complete online training courses and participate in the two hands-on training sessions conducted by the course director resulted in providing them with the necessary knowledge and skill to teach this technology on a wider scale.

Ultimately, by integrating this new technology into the junior courses at an early stage in the curriculum, we were able to give students the hands-on experience they needed to utilize CAD/CAM effectively in patient care. The skill and knowledge learned in the course helped increase students' productivity in the CAD/CAM clinic in their senior year. In particular, this course was able to enhance the application of CAD/CAM technology for same-day, indirect restorations. Likewise, we were able to emphasize the different modalities of the treatment, especially the fabrication of esthetic crown restorations.

The course showed tremendous success for the junior students. They demonstrated good computer operation and problem-solving skills, in contrast to the sophomore students. Critically, as shown in our school when the course was taught to sophomore students as a preclinical exercise only, basic comprehension of conventional technology and preclinical psychomotor skills were both limiters to successful introduction of CAD/CAM technology.

The junior students demonstrated great interest in the subject during peer student presentations and found the debate that followed the presentations to be very informative. This type of flipped classroom small-group peer learning was well received by the students.

The lab sessions for staining and glazing that followed the milling process progressed slower than expected. The fixed prosthodontic curriculum at the University of Florida College of Dentistry offers limited exposure to lab work. However, with CAD/CAM technology, the dentist is in charge of all the laboratory procedures. In this exercise, the students were exposed for the first time to the process of custom characterization of a ceramic restoration using surface stains and glaze, along with firing the restoration. These sessions required more attention and one-on-one tutoring; however, students found this process to be a unique artistic experience.

Based on the financial records obtained from the senior financial officer of the Department of Restorative Dentistry at the University of Florida College of Dentistry, the CAD/CAM clinic's revenue increased by 27.4% in fiscal year 2015-2016, compared to prior to implementing this course in 2014-2015. This was due to students' increased enthusiasm in offering patients CAD/CAM restorations, as well as their improved ability at educating patients about the advantages of the CAD/CAM workflow for these restorations in comparison to the conventional workflow time frame. Additionally, the willingness of greater numbers of faculty to supervise the workflow of these restorations is continuously expanding.

Starting in the summer of 2015, students treated patients in the CAD/CAM clinic up to 2 days per week. Trained faculty provided coverage for the CAD/CAM clinic up to twice a week as a part of their weekly schedule. Based on course evaluations, this course was very well received by the students and clearly succeeded in preparing them to do clinical cases in the CAD/CAM clinic. The course improved their knowledge and skills and contributed to increased clinical productivity.

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Ethical Approval

Reported as not applicable.

Disclaimer

The author denies any conflict of interest with any manufacturer of products used in this course. No compensation was provided to the author, including no free or discounted equipment, nor were there any other potential perceived conflicts.

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