Establishing CAD/CAM in Preclinical Dental Education: Evaluation of a Hands-On Module

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Abstract: The aim of this study was to evaluate a hands-on computer-assisted design/computer-assisted manufacture (CAD/CAM) module in a preclinical dental course in restorative dentistry. A controlled trial was conducted by dividing a class of 56 third-year dental students in Germany into study and control groups; allocation to the two groups depended on student schedules. Prior information about CAD/CAM-based restorations was provided for all students by means of lectures, preparation exercises, and production of gypsum casts of prepared resin teeth. The study group (32 students) then participated in a hands-on CAD/CAM module in small groups, digitizing their casts and designing zirconia frameworks for single crowns. The digitization process was introduced to the control group (24 students) solely by means of a video-supported lecture. To assess the knowledge gained, a 20-question written examination was administered; 48 students took the exam. The results were analyzed with Student’s t-tests at a significance level of 0.05. The results on the examination showed a significant difference between the two groups: the mean scores were 16.8 (SD 1.7, range 13-19) for the study group and 12.5 (SD 3, range 4-18) for the control group. After the control group had also experienced the hands-on module, a total of 48 students from both groups completed a questionnaire with 13 rating-scale and three open-ended questions evaluating the module. Those results showed that the module was highly regarded by the students. This study supports the idea that small-group hands-on courses are helpful for instruction in digital restoration design. These students’ knowledge gained and satisfaction seemed to justify the time, effort, and equipment needed.

Keywords: dental education, restorative dentistry, teaching methods, educational technology, computer-aided design, crown

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All-ceramic single crowns are widely and successfully used in modern dentistry, with survival and incidence of complications being acceptable.1,2 Computer-assisted design (CAD) and computer-assisted manufacture (CAM) are a popular method of fabricating these crowns. Precision and fit of CAD/CAM-fabricated all-ceramic restorations meet clinical requirements.3,4 Use of CAD/CAM has become daily routine for many clinicians, leading to major changes in dental practices and laboratories.5

In many current dental curricula, however, metal ceramic fixed dental prostheses are still the most commonly used.6 Because of the development of digital dentistry, attempts are being made to update education in restorative dentistry.7,8 Major challenges include high costs, overcrowded schedule, variety of new materials, and lack of personnel with adequate training to integrate new technology into dental curricula.9

The Heidelberg all-ceramic program is a preclinical course that introduces dental students in their third year to digital restorative techniques. The course consists of resin tooth preparation and conventional impression taking, digital scanning of the gypsum model produced, design and manufacture of a zirconia core structure, and, finally, esthetic veneering of the core with ceramics. Because we had little information about the benefits of digital restoration instruction or our students’ perceptions in this area, the aim of this study was to provide a concise description of the Heidelberg all-ceramic program and to evaluate an important component of the course on hands-on CAD/CAM.
Materials and Methods

Institutional Review Board review was not required because the study began as part of a quality assessment. The Heidelberg all-ceramic program is a mandatory part of students’ regular preclinical education at Heidelberg University in Germany and is provided by the Department of Prosthodontics. Between 60 and 80 third-year dental students participate in this program each year at Heidelberg University Hospital. The program in its current form started in 2013 with 72 students. In 2014, the year of this study, 56 participants were enrolled, with more female students (64.6%). The mean age was 23.2 years (SD 2.7, range 19-30).

Objectives of the Program

The objectives of the program are to provide students with hands-on experience in CAD/CAM techniques and in the handling of ceramics used to veneer core structures. A series of lectures on clinical and laboratory aspects of all-ceramic restorations were given to provide the scientific background. The program was divided into three phases: resin tooth preparation, CAD/CAM of a zirconia core (Figure 1), and esthetic veneering with ceramics (Figure 2).

First, students were assigned to prepare resin teeth in a typodont (Frasaco, Tettnang, Germany) to receive porcelain fused to zirconia all-ceramic crowns. Attention was paid to minimally invasive substance removal. Preparations were made under the supervision of faculty members of the Department of Prosthodontics. After having taken polyether impressions (Impregum; 3MEspe, Seefeld, Germany), casts were produced from type IV gypsum. The steps necessary were demonstrated by a dental technician from the department and monitored by faculty members.

Second, hands-on CAD/CAM was used to digitize the prepared teeth and the neighboring teeth. Laboratory scanners (Cercon Eye; Degudent GmbH, Hanau, Germany) were installed. Students participate in the hands-on CAD/CAM module in small groups of eight students each. After an introduction to the software and hardware, each participant had to scan the prepared models. The students were supported by a faculty member from the Department of Prosthodontics. After digitization of the model, zirconia frameworks were designed for anterior single crowns (Cercon Art; Degudent, Hanau, Germany). The data for the frameworks were sent by email to a milling center (Compartis; Degudent, Hanau, Germany) where the zirconia frameworks were produced. After fitting of the sintered frameworks, they were veneered with esthetic ceramics, with help from experienced dental technicians. The following timeframes were scheduled for the program: the resin tooth preparation took up to two days as this was one of the first preparations for the students. Introduction to the CAD/CAM software and hardware took 30 minutes, and the digitalization took around 15 minutes per student. Time for fitting of the frameworks was planned to be 20 minutes, and the veneering took around four hours.

Testing CAD/CAM Skills: Study Design

For this study, we wanted to assess the value of the hands-on CAD/CAM module to the program, so we designed a quasi-randomized study to compare the examination scores of students who participated in the
module with those who had not. The class of third-year students was divided into two groups (a study group and a control group), depending on the students’ schedules. Prior knowledge about all-ceramic single crowns was assumed to be equal in the two groups because everyone had attended the same lectures. Furthermore, all students had performed the resin teeth preparations and had produced gypsum casts.

The study group (32 students) completed the hands-on CAD/CAM module, during which they digitized the casts and designed zirconia core structures. The control group (24 students) learned about the CAD/CAM process by means of a video-supported lecture. For the video, the steps of providing a patient with two all-ceramic crowns in the posterior region had been filmed in advance. This patient had required restoration of a premolar as well as of an implant with single crowns. The 60-minute lecture started with a general introduction to CAD/CAM techniques; then, the case was presented and possible treatments were discussed with the students. The questions raised by these students aimed at the periodontal treatment before crown preparation and at the different possible materials for the crowns. Subsequently, the clinical workflow and the laboratory steps were presented, and screenshots of the manufacturing were shown. After presenting the results of the patient case, additional information was given concerning theoretical aspects, such as zirconia transformation toughening and chipping problems. Then, these students raised questions regarding the difference between metal ceramic and all-ceramic crowns, regarding costs and implant placement. Overall, we tried to convey similar information to the control group and the study group. The introduction of the patient case was used to stay on a practical step-by-step level, similar to the hands-on case.

The two groups then took the same written examination to assess their knowledge and acquired competence. The examination consisted of 20 multiple-choice questions and covered topics such as properties of the various ceramic materials (for example, fracture toughness of zirconia), clinical indications, and limitations of digital procedures in the dental practice and the dental laboratory. The number of correct answers was counted for each student for an intergroup comparison. The hypothesis was that students who had participated in the hands-on CAD/CAM module would outperform the students in the control group on the written examination. After the written examination, members of the control group also participated in the hands-on module and
digitized their casts to enable participation in the ceramic veneering.

**Evaluation and Statistical Analysis**

The module was evaluated by the whole class by means of a questionnaire with 13 rating-scale questions. On the first ten questions, positive claims regarding the organization, structure, and content of the module were listed with response options ranging from 1=not true at all to 5=totally true. The next two questions asked about students’ interest in the topic before and after the module on a three-point scale. Another question asked students to rate the module on a six-point scale from 1=extraordinarily poor to 6=extraordinarily good. Finally, three open-ended questions invited students’ comments about what
interest had stayed the same (Figure 4). The mean value for overall impression was 5.1 on a scale of 1 to 6, with 87.5% ranking it either 5 or 6 at the top of the scale (Figure 5). The open-ended questions revealed several aspects to be improved in future classes. According to the students, the context of the module should be better coordinated, e.g., the dental materials lectures should be on ceramics when the module takes place. Furthermore, the participants wished to have more time for discussion of modern all-ceramic systems.

Discussion

Competence in digital restoration techniques is commonly regarded as being of major importance for future dentists. In this study, we evaluated one approach to integration of CAD/CAM into the dental curriculum.

During development of this hands-on module, two major problems were identified. As is usual for courses with participation of small groups, the

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Results

Out of the 56 students enrolled in the program, 48 students took the written exam. The results on the exam were significantly different (p<0.001) for the two groups. The mean number of correct answers was 16.8 (SD 1.7, range 13-19) for the study group and 12.5 (SD 3, range 4-18) for the control group.

There were also 48 students who evaluated the hands-on module (response rate: 85.7%). Overall, the module was very highly rated. Mean values on the five-point scale ranged between 4 and 5 (Figure 3), indicating that students evaluated the statements as being almost totally true to their experience with the module. With regard to development of interest in digital dentistry, 52.1% of the students reported being more interested in CAD/CAM after the module than before; the remainder responded that their interest had stayed the same (Figure 4). The mean value for overall impression was 5.1 on a scale of 1 to 6, with 87.5% ranking it either 5 or 6 at the top of the scale (Figure 5). The open-ended questions revealed several aspects to be improved in future classes. According to the students, the context of the module should be better coordinated, e.g., the dental materials lectures should be on ceramics when the module takes place. Furthermore, the participants wished to have more time for discussion of modern all-ceramic systems.

Figure 3. Students’ responses to first ten questions on questionnaire about the hands-on module (N=48)

Note: Response options ranged from 1=not true at all to 5=totally true.
hands-on CAD/CAM module was time-consuming and needed intense support and supervision by faculty members and dental technicians. The cost of the equipment should, furthermore, not be underestimated. An external partner provided not only the optical scanners for digitization of the models but also the chance to use a milling center for production of the cores. This was very valuable because of the large number of restorations to be milled. Despite the cooperation of this company, the costs for the zirconia blanks had to be recovered from the students; this might not be possible at every university.

Nonetheless, the results obtained support continuation of the module. The participants gained knowledge of and interest in the topic. The evaluation revealed high satisfaction, emphasizing the benefit of

Figure 4. Students’ interest in CAD/CAM before and after the module (N=48)

Note: Even though students’ interest in CAD/CAM fabrication was high before the module, it had increased or stayed the same afterwards. No students indicated their interest had decreased.

Figure 5. Students’ overall impression of the module (N=48)

Note: Students ranked the module on a scale ranging from 1=extraordinarily poor to 6=extraordinarily good. No students selected the lower three options (1-3).
the learning approach. Most importantly, the students with hands-on experience outperformed the other students on the examination.

The effect of the hands-on CAD/CAM module on student knowledge was assessed by use of a written multiple-choice examination, which may be a limitation of the study because the examination was not validated beforehand. It was developed to identify clinically relevant topics, for example, limitations of the use of various dental ceramics. However, the relevance of the questions was discussed by two of the authors (FSS and UKD), who are faculty members in the Department of Prosthodontics, and were included in the test on the basis of mutual agreement.

In the study group, self-directed work with the scanners under the supervision of a faculty member resulted in a significant increase in knowledge compared with the control group. A systematic review previously established that intensive small-group education enhances students’ performance on examinations. The difference was significant for a sample size as small as this one. The ratio of one faculty member in close contact with eight students made it feasible to answer individual questions arising when working through the hands-on procedures and to get feedback, especially with regard to the preparations. Even though the CAD/CAM process was presented to the control group in a video-supported lecture, that groups’ results on the examination were poorer. It can be speculated that performing the steps by hand clarifies many issues. Moreover, students in small groups do not hesitate to ask when there are uncertainties. Another aspect is the total time that was spent in the two groups: when concentrating on the hands-on course only, each student spent around 45 minutes including introduction time. As the participants in the hands-on group also watched their colleagues digitalize, it must be concluded that the net involvement with the subject was longer in the hands-on group than in the control group. It is probable that this contributed to the results.

Furthermore, an investigator bias cannot be fully excluded. The hands-on module was delivered by only one educator (FSS) who knew the contents of the exam. It is possible that he may have given more information about the exam to the students in the hands-on group, to whom he was in longer and closer contact, than to the students in the control group. This may have influenced the results of the written exam.

Another significant limitation of the study was that the evaluation results cannot be divided into the study and control groups. We can therefore only point to the general positive impressions all the students had of the module. Since both groups ultimately participated in the module but under varying, uncontrolled circumstances, no inter-group comparisons were possible. Future studies should conduct the evaluations separately to avoid data corruption between the two groups and allow a systematic comparison.

The evaluation questionnaire was a modification of an evaluation form regularly used in Heidelberg University. Use of this instrument revealed a high level of satisfaction with the module. Despite being on a high level at the beginning, interest in the topic increased among most of the participants. This might be interpreted as proof of the eagerness to learn of preclinical dental students. The free-text feedback requesting better coordination of the dental materials lecture with the hands-on CAD/CAM course will be considered for next year’s course.

Dental education must reflect the development of digital dentistry in dental practices worldwide. In predoctoral education, CAD/CAM has frequently been reported as a teaching tool, but most studies have concentrated on investigating the possibilities of digitizing student preparations and assessing their quality with the help of computer software. Attempts have also been made to provide patients in clinical courses with student-made CAD/CAM restorations. Such an attempt has been reported to be successful not only for the dental school but especially for the students themselves.

These reports and our current findings support continued instruction in CAD/CAM in dental education. Nevertheless, because of the nature of the module, the cost and the time and effort expended are evident problems. More research and other efforts are necessary to find new fields for implementing CAD/CAM in dental education and new ideas of how this might be achieved sustainably.

Conclusion

This study evaluated a hands-on CAD/CAM module in a controlled trial that divided a preclinical class of 56 students into study and control groups. Both groups participated in lectures, preparation exercises, and production of gypsum casts of prepared resin teeth; the study group also participated in a hands-on CAD/CAM module in small groups. The results on a written examination showed significantly
higher scores for the study group. This study suggests that, despite being demanding in time and equipment, small-group hands-on courses are helpful for instruction in CAD/CAM-based dental restoration. Benefits for the learning process and high student satisfaction seem to justify the efforts.

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Disclosure

The authors declared no conflicts of interest.

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