

Dental Students' Opinions of Preparation Assessment with E4D Compare Software Versus Traditional Methods

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Abstract: The aim of this study was to evaluate dental students' opinions regarding the utilization of a new grading software program for student self-assessment and a faculty-grading tool in a preclinical course. Using surface mapping technology, this program, called E4D Compare, yields a digital model of a student's preparation that is color-coded to show deficient areas. The program has now been used for two years at the James B. Edwards College of Dental Medicine at the Medical University of South Carolina, and the students previously assessed with E4D Compare have now entered into the dental clinics. For this study, students were asked to complete an anonymous survey for the investigators to evaluate students' attitudes and opinions on the effectiveness of this software in their preclinical courses to determine if this type of feedback helped them develop clinical skills. The survey also sought to collect students' opinions on the traditional objective criteria-based grading system. The survey was distributed to all members of the Classes of 2014 and 2015; it yielded a 59 percent response rate for the two classes, with a total of eighty-one students responding. Overall, the majority of students preferred the E4D Compare grading system over traditional hand-grading methods. The grading system provided instant, objective, and visual feedback that allowed students to easily see where their deficiencies were and encouraged them to work towards an ideal final product.

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Current dental students prefer real-time information compared to passive learning and tend to place a low value on what they perceive as “old ways” of receiving information.¹ Furthermore, Millennials demand immediate feedback and prefer subjects in which they can receive objective feedback.² It is well known that the traditional way students receive feedback in preclinical dental courses is not immediate, consistent, or objective.³⁻⁸

One of the most important functions of dental educators is to provide accurate assessment of student preparations and communicate that assessment to the student. In this way, students learn what constitutes accurate feedback and will apply that to self-assessment and lifelong learning. It is important that students have confidence in the feedback they receive and value the faculty recommendations so they can use this information to improve their skills before entering into the clinics. Unfortunately, objective feedback is very difficult to obtain with many sources contributing to rater disagreement of student

work including grading scale, rater calibration, bias, training, grader fatigue, and subjective influences.^{4,9-11}

Not surprisingly, there is a general consensus in previous research that there is significant disagreement between graders when evaluating dental work (interrater reliability) coupled with high levels of variability when the same rater evaluates work at different times (intrarater reliability).⁵⁻⁸ Perhaps more essential to lifelong learning is the acquired skill of self-assessment. Interestingly, studies have found that medical and dental students are often incapable of accurate self-evaluation.¹²⁻¹⁷ This is not surprising: if faculty members cannot seem to calibrate themselves, how can students accurately assess their own work, without truly knowing what the ideal is? An important question is whether students realize this inconsistency and learn which faculty are “hawk” (hard) and “dove” (easy) graders.¹⁸ Anecdotally, it appears to us that students favor some graders over others. Consequently, current dental students may have lost faith in the old grading system that has been essentially unchanged

for decades. If a dental student perceives preparation evaluation as subjective or even arbitrary, it may discourage practicing. In our experience, it also often results in students' focusing more on the grade than actual learning or development. This challenge has led some investigators to conclude that if we are going to truly achieve accurate feedback, we need to remove the human element from evaluation and develop computer-based objective evaluation methods.^{7,19}

At the Medical University of South Carolina (MUSC) James B. Edwards College of Dental Medicine (JBECDM), the objective evaluation software E4D Compare has been utilized in a preclinical second-year fixed prosthodontics course for two years with the classes of 2014 and 2015. E4D Compare uses a high-speed laser digital camera to generate three-dimensional models of student work. After digitization, the E4D Compare software analyzes student preparations using surface mapping technology. A 3D topographical map is overlaid on the student preparations, which displays differences or errors in reduction compared to the ideal preparation (Figure 1). In this color-coded difference map, red is overreduced, green is acceptable, and blue is underreduced. Additionally, E4D Compare calculates the percent surface area of each type of error. At MUSC, the percent surface area that is calculated to be acceptable, displayed as green, was utilized for students' "reduction grade," therefore eliminating all subjectivity. It is worth noting that the course director can be as strict as needed by altering the range in microns considered to be an acceptable degree of difference, and this can impact the percent surface area considered acceptable (Figure 2). While only surface mapping technology is being used at MUSC during the early stages of software implementation in the course, E4D Compare also has the ability to evaluate more specific criteria such as undercuts, total occlusal convergence, taper, and occlusal cervical/facial lingual ratios. Three-dimensional surface mapping should take these more specific criteria into account, however, as all preparation errors conceivable are essentially a difference from the ideal.

The aim of this study was to evaluate students' attitudes and opinions regarding the effectiveness of E4D Compare software in their second-year fixed prosthodontics course. Specifically, we wanted to determine if the students perceived their assessments and experience with E4D Compare as valuable training tools and if this tool assisted in their growth as clinicians.

Materials and Methods

Research approval for this study was obtained from the MUSC Research Institutional Review Board (Pro00018328). E4D Compare was used during the second-year, spring semester course called Fixed Prosthodontics III. In this course, students receive a comprehensive overview of esthetic ceramic restorations with an emphasis on preparation design for anterior and posterior all-ceramic restorations to include full coverage crowns, veneers, inlays, and onlays. Computer-assisted design/computer-assisted manufacture (CAD/CAM) systems are used to improve student competence with several restorations milled and seated. A comprehensive overview of ceramic bonding is reviewed along with modern ceramic material properties. This course follows a progression of courses that begins with Fixed Prosthodontics I, in which students learn how to prepare a tooth for a full veneer gold crown and make provisional restorations. The second course, Fixed Prosthodontics II, includes a review of occlusion and full veneer gold crown preparations. Additional topics in Fixed Prosthodontics II involve taking impressions of preparations, fabrication and delivery of a gold crown, and preparation of a fixed partial denture.

In Fixed Prosthodontics I and II, traditional, faculty-driven assessment has been used for student grading. In these courses, one faculty member provided criteria-based preparation evaluation and gave feedback in the form of a grade sheet that included the proper preparation criteria as a checklist and student deviations from ideal. Grades were on a 0-100 numerical scale. Fixed Prosthodontics III was the first time students had contact with the E4D Compare software, so they were extremely familiar with conventional feedback via hand-grading by faculty members. Training provided for utilization of the E4D Compare software consisted of a one-hour lecture and a three-hour hands-on laboratory session. The E4D Compare software was used through the entire semester as a self-assessment tool. Additionally, it was used by the faculty to calculate the reduction grade for the practical examinations and daily work, for a total of fifteen graded preparations. E4D Compare surface mapping percentages were used as the reduction grade for the preparation that counted for 80 percent of the grade; the other 20 percent was faculty-generated based on areas the software is not yet able to evaluate such as finish line smoothness and overall smoothness.

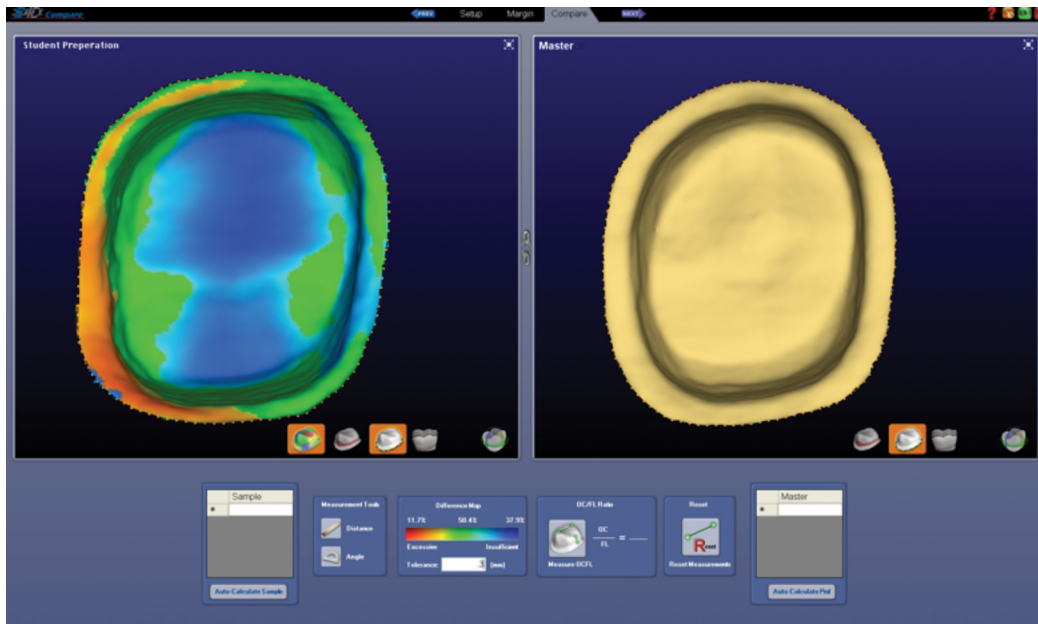


Figure 1. Student's preparation (left) compared to master preparation (right), with surface of student preparation color-coded for errors

Note: Blue indicates underreduction, red indicates overreduction, and green is considered acceptable.

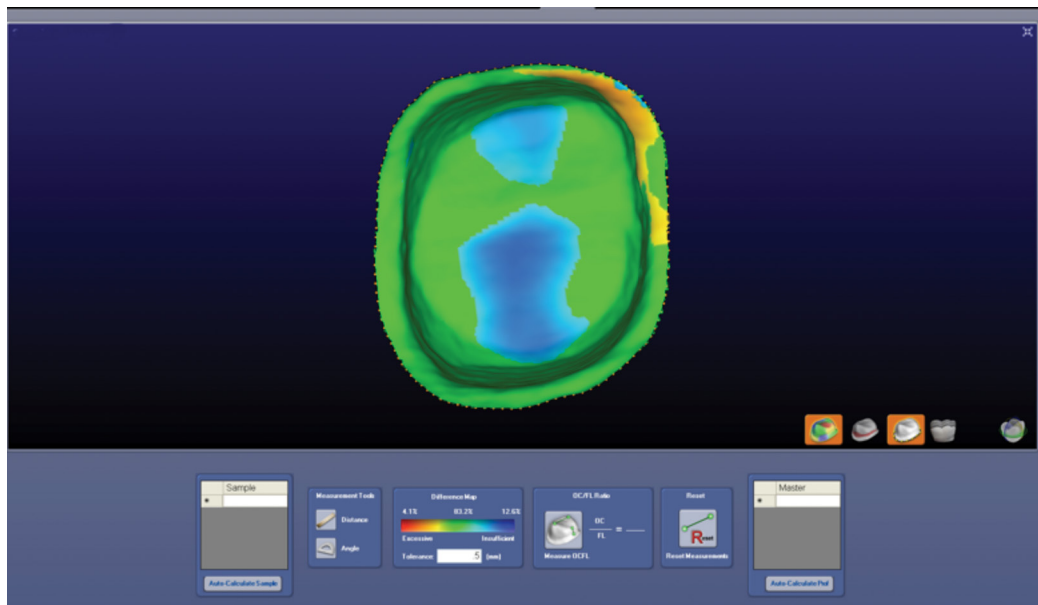


Figure 2. Same student preparation as in Figure 1 compared at less strict tolerance

Note: Instead of counting everything within 300 microns as acceptable (green), the tolerance was adjusted to identify everything within 500 microns as acceptable. This adjustment changed the surface area percentage of errors and provided an opportunity for students to achieve a higher grade.

The software and scanners were made available for students to use twenty-four hours a day to allow assessment of work when faculty members were not available. After the students completed the course and had been in the clinics for several months, they were asked to complete a survey to evaluate their opinions on the utilization of this assessment software in Fixed Prosthodontics III. The six-question, SurveyMonkey survey was anonymous and voluntary, distributed via email. Students completed the survey on their own time and were not required to participate.

Results

The survey yielded a 59 percent response rate for the two classes, with a total of eighty-one students responding. For the purpose of reporting and analysis in this section, the following statistics summarize the combined responses for both classes. Full responses are found in Table 1 and Table 2.

Agree and strongly agree responses were combined in the following reports, as well as disagree and strongly disagree. Among the survey respondents, 95 percent reported there were inconsistencies in the preparation feedback provided by different faculty members, and 72 percent reported there were inconsistencies with multiple types of feedback from the same faculty member. A majority of students (84 percent) reported that they know who the “hard and easy graders are,” and 74 percent reported believing that their grades depend on who does the grading. This finding contrasted with the 85 percent who responded that they agreed or strongly agreed that E4D Compare provides more consistent grading than hand-grading by faculty members.

When asked about the differences between traditional faculty grading and E4D Compare grading, only 58 percent of the participants reported that traditional grading sheets provided accurate feedback about why preparations were deficient. This contrasted with 91 percent who reported that E4D Compare grading was more accurate than faculty grading. Notably, 88 percent agreed or strongly agreed that they trusted the results of E4D Compare. Benefits of E4D Compare grading included the following: 79 percent responded that the software provided more feedback, and 90 percent said that the software helped them to understand where their preparations were deficient. Significantly, 89 percent agreed or strongly agreed that E4D Compare grading helped them be better clinicians (Table 3).

After a content analysis of the students’ comments on the open-ended questions, several themes emerged. Fifty-three percent of the respondents stated that the software improved their awareness of over- or underreduction. One student noted, “E4D does not allow you to look over mistakes that otherwise you may continue to make. Without E4D Compare you may never realize your preps are underreduced until you get back shoddy crowns from the lab.”

The second theme that arose from the comments was that E4D Compare helped the students to see where their problem areas were. For example, one student said, “The 3-dimensional aspect of the E4D made it very easy to see where the prep was deficient, and after seeing it on the computer, it was easier to start noticing the faults of the prep by eye and correct them without the use of the computer.” Another noted, it “gives a close up look at the prep that may be hard to visualize by other means.”

A third theme that emerged was that of using E4D Compare to gain consistent and accurate feedback. One student commented, “The accuracy of the grading software enabled me to know exactly where I was deficient or excessive in preparations so I could better judge how to cut my preps in the future, and it helped in making me faster by being able to know areas where I tended to have the most issues over multiple preps.” Another said, “It helps me see my prep from all possible angles and to accurately measure my reduction and finish lines.”

Finally, the fourth theme that emerged involved increased practice and/or multiple practice attempts to perfect the preps that the students made due to E4D Compare. One student commented that E4D helped this student to become a better clinician because “it made me practice a lot this semester.” Another noted, “I practiced more before projects were due,” and yet another commented that “it made me become a perfectionist with my preps.”

Discussion

Today’s dental students have been raised in a society that incorporates technology in nearly every aspect of their lives. Yet within the realm of dental education, faculty members seem reluctant to change the manner in which feedback is given to students even though they were possibly frustrated by the same lack of consistent and accurate feedback during their educational experiences. The results of this study indicated that the dental students

Table 1. Students' agreement with statements regarding preparation grading

Statement	Class	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	N/A
There are inconsistencies in preparation feedback between DIFFERENT faculty members.	2014	53%	43%	0	5%	0	0
	2015	42%	54%	0	2%	2%	0
There are inconsistencies in numerical grades between DIFFERENT faculty members.	2014	50%	45%	0	5%	0	0
	2015	46%	49%	2%	0	2%	0
There are inconsistencies in preparation feedback for THE SAME faculty member.	2014	8%	60%	15%	18%	0	0
	2015	20%	56%	12%	12%	0	0
There are inconsistencies in numerical grades for THE SAME faculty member.	2014	10%	65%	15%	10%	0	0
	2015	20%	61%	10%	5%	2%	2%
I know who the "hard" and "easy" graders are.	2014	30%	53%	8%	10%	0	0
	2015	40%	45%	3%	13%	0	0
A large part of my grade depends on who happens to be grading my preparation.	2014	25%	53%	15%	8%	0	0
	2015	33%	40%	18%	10%	0	0
Traditional grading sheets (done when the faculty member grades my preparation by hand) provide accurate feedback about why my preparation was deficient.	2014	5%	59%	18%	18%	0	0
	2015	5%	49%	20%	20%	7%	0

Note: Percentages may not total 100% because of rounding.

Table 2. Students' agreement with statements regarding E4D Compare grading

Statement	Class	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	N/A
Students should have their preparations graded by E4D Compare during the first year of the dental curriculum.	2014	35%	40%	10%	15%	0	0
	2015	37%	42%	10%	12%	0	0
E4D Compare should be available to students for use on personal computers.	2014	65%	35%	0	0	0	0
	2015	49%	42%	5%	2%	0	2%
Students should learn how to scan preparations for electronic grading during the first year of the dental curriculum.	2014	55%	40%	3%	0	0	3%
	2015	49%	46%	2%	2%	0	0
Computer preparation evaluation with E4D Compare is more accurate than having a faculty member grade by hand.	2014	63%	33%	0	5%	0	0
	2015	42%	34%	12%	10%	0	2%
Computer preparation evaluation with E4D Compare provides me with more feedback than having a faculty member grade by hand.	2014	40%	43%	5%	13%	0	0
	2015	42%	34%	12%	10%	0	2%
Computer preparation evaluation with E4D Compare provides more consistent grades than having a faculty member grade by hand.	2014	53%	38%	8%	3%	0	0
	2015	42%	39%	7%	12%	0	0
The E4D Compare three-dimensional analysis of preparation mistakes helps me to understand where the preparation is deficient.	2014	63%	25%	3%	8%	0	3%
	2015	63%	29%	2%	0	0	5%
I trust the results of E4D Compare software.	2014	45%	45%	8%	3%	0	0
	2015	29%	56%	12%	2%	0	0
It would be beneficial to use E4D Compare to self-assess my preparation before turning it in for final evaluation/grading.	2014	67%	31%	0	3%	0	0
	2015	61%	32%	0	2%	0	5%

Note: Percentages may not total 100% because of rounding.

reacted favorably to the implementation of the E4D Compare computer grading system, with 89 percent of respondents believing that this form of grading helped them to be a better clinician. After using the system for a semester to grade crown preparations, the students viewed it as a way to get timely and consistent feedback on their work. Of the several trends that appeared in the student feedback, two themes emerged as reasons in favor of continued use of this evaluation system.

The first theme reflected the students' appreciation of the ability to get immediate, consistent feedback at any time when using the E4D Compare software. Unlike an educator, the computer is available to students at any time. This is a stark contrast to the limitations of faculty-student ratios and the busy schedules of both faculty and students outside of scheduled classroom/laboratory times. Since there are limited numbers of faculty members who teach in a specific course and they often have other responsibilities that demand their attention, there are times when they are inaccessible for grading and feedback. Students indicated that because of twenty-four-hour access to E4D Compare, they were able to practice more since a mechanism of feedback was available during alternative hours. This software gave the students a way to essentially perform self-assessment, allowing them to obtain feedback on work done outside of normal school hours. One student stated, "Using E4D [Compare] allowed me to perfect my crown preps. I would do 10+ preps until I got the grade I wanted, and we all know practice makes perfect!" Another student thought that the E4D Compare software itself did not make him or her a better clinician; rather, its availability increased the number of times the "prep/feedback/correction" cycle took place.

Likewise, the students indicated that they appreciated the consistency of the grading and the way it removed any possibility for bias or an instructor's personal preference from the grading process. Multiple students made the observation that different professors grade differently. Lack of uniformity in grading has been a consistent challenge in dental education. Mackenzie et al. discussed sixteen sources contributing to disagreement in the evaluation of students' work.¹⁰ Efforts to calibrate faculty members prove challenging, particularly when many dental schools rely on part-time faculty to fill in human resources gaps. Utilizing this grading software allowed the students to get a more accurate and consistent form of feedback than faculty grading. In the survey, 92 percent of the respondents believed

Table 3. Students' agreement with statement "E4D Compare grading helped me to be a better clinician"

Response	Class of 2014	Class of 2015
Strongly agree	45%	51%
Agree	43%	39%
Neither agree nor disagree	5%	2%
Disagree	5%	0
Strongly disagree	3%	7%
Not applicable	0	0

Note: Percentages do not total 100% because of rounding.

the E4D Compare software to be more accurate than faculty hand-grading.

The second theme related to the fact that the visual aspect of the E4D Compare software program gives specific graphic feedback to students as to where and by how much their work differs from the ideal. Students commented that the visual indicators included in the software gave them an increased awareness of flaws in their work. The software indicates over- and underreduction of tooth structure through color mapping that shows the exact location and size of the error. These visual indicators leave little doubt as to where errors lie. Unlike verbal instructor comments, this exact feedback allows students to visually pinpoint errors common to their own preparation technique and eliminate them. Haj-Ali and Feil discussed this "knowledge of results" as an integral part of the learning process.⁴ Seeing their crown preparations on a computer screen helped our students to better evaluate minor flaws in their work and to appreciate the importance of preparation aspects such as smooth finish lines and lack of undercuts. Also, the ability to rotate digital models of the students' preparations enabled the tooth to be viewed from many different angles, making flaws in their work easier to visualize.

A critical aspect of the learning experience is having students trust that the feedback on their work is accurate. Our survey showed that 88 percent of the respondents trusted the results of the E4D Compare grading system. Given the objective source, they know they are getting impartial feedback and that the areas the software deems as needing improvement are indeed deficient.

Notably, even though the students had an overall positive attitude towards the grading software, they also noted the continued need for a human element in the grading process. The computer grades the preparation solely based on surface area comparisons

to an ideal preparation, and the feedback relates only to how much tooth structure has been removed and from which part of the tooth it was taken. However, preparation aspects such as smoothness of the finish line and presence of undercuts are not factored into the software's grading process. These are important factors of a crown preparation and should not be ignored in the grading process. E4D Compare does not replace the wisdom of an experienced clinician, and the students admitted that time and feedback from an instructor were key in completely evaluating the success of a preparation. One commented, "I think it's the best way to grade, but maybe having the professor grade the finish line separate or maybe have E4D be a percentage of the grade and the professor's opinion be a percentage as well." The E4D Compare software helps faculty members arrive at an objective evaluation, but it is not a replacement for educators' judgment and experience.

Likewise, some students expressed concern over the dimensions of the "ideal" preparation against which they were being graded, asking how they could be sure this instructor-created "ideal" preparation had the exact proper amount of reduction in all areas. Ideally, machine-produced standard preparations would be available with exact reduction parameters for various types of crown preparations. Until then, it is up to the keen eye of an experienced clinician to create "master preparations."

In addition to the students' perceptions, the faculty members involved in this endeavor reported similarly positive feedback. One instructor remarked, "It works. Students can clearly self-assess their work and we've seen a tremendous increase in student practice." Another faculty member commented, "Through this software, preparation evaluation can truly be generated in a completely nonthreatening, consistent, and objective manner. . . . When using E4D Compare as an assessment tool, students are able to clearly view their preparation errors as it relates to a 'faculty preparation' in three dimensions. They are inspired to do better rather than discouraged." Most importantly, E4D Compare seems to refocus students on the clinical aspects of their work rather than the reasons driving a numerical grade. "The students have different questions now," noted one faculty member. "Rather than asking questions about why they received certain grades, the questions now focus on materials and techniques for improvement." From an educational perspective, this redirected focus may be a contributing factor behind a concluding

comment from one of our faculty members: "E4D Compare has changed dental education forever. Students now demand feedback this way."

Conclusion

Although limited to two classes at one dental school, this study demonstrated the students' overall positive reception of a preparation grading and surface mapping software program for preclinical crown preparations. While there are some limitations to the E4D Compare software, such as evaluating certain general aspects of a preparation like smoothness, the implementation of this method of grading has numerous positive aspects. According to the student feedback collected in this study, E4D Compare provides instant, objective, and visual feedback that allowed students to easily see where their deficiencies were and encouraged them to work towards an ideal final product. It was also perceived by the vast majority of our students to be a tool that helped them become better clinicians. Further research should look into how to minimize or eliminate the limitations of this grading system and how this method of grading can be effectively applied to other courses in predoctoral dental education.

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