

## RESEARCH AND EDUCATION

# Comparison of treatment outcomes in digital and conventional complete removable dental prosthesis fabrications in a predoctoral setting

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Computer-aided design and computer-aided manufacturing (CAD/CAM) technology has been available for several years in fixed prosthodontics and continues to increased usage.<sup>1-3</sup> In recent years, it has expanded to include implant and removable prosthodontics.<sup>4-6</sup>

Goodacre et al<sup>7</sup> described the development of this technology using a basic CAD/CAM “proof-of-concept” Lucite with a 3-axis milling machine. Denture bases were subsequently milled from PMMA, and these dentures with milled denture bases were placed in patients.<sup>7</sup> Kattadiyil et al<sup>8</sup> reported the applications of 2 commonly available digital denture systems, the AvaDent Digital Denture (Global Dental Science, LLC [GDS]) and the Dentca (Dentca Inc.) denture. They reported that the effective application of the digital denture systems reduced clinical appointments to 2 from the conventional 5-appointment process. The authors reported 6

## ABSTRACT

**Statement of problem.** Scientific evidence is lacking regarding the clinical effectiveness of digital complete removable dental prostheses (CRDP).

**Purpose.** This prospective clinical study was conducted to compare clinical treatment outcomes, patient satisfaction, and dental student preferences for digitally and conventionally processed CRDP in a predoctoral setting.

**Material and methods.** This clinical study rated and compared CRDP fabricated by predoctoral students, using a 2-appointment digital prosthesis fabrication process as opposed to the conventional 5-appointment process. Fifteen completely edentulous patients were treated in the predoctoral clinic at Loma Linda University School of Dentistry. Fifteen predoctoral (third- and fourth-year) dental students fabricated 2 sets of maxillary and mandibular CRDP for each patient. Each patient received 1 conventional set and 1 digital (AvaDent) set of CRDP. Faculty and patient ratings, patient and student preferences, and perceptions of the conventional versus digital prostheses were recorded and analyzed. The average treatment time for the fabrication of each type of prostheses was analyzed.

**Results.** Significantly higher average scores were observed for digital dentures than for conventional dentures according to criteria evaluated by faculty ( $P=.007$ ). Patients reported significantly higher overall average satisfaction scores with digital dentures ( $P=.001$ ). Patients preferred the digital dentures ( $P<.01$ ). Significantly higher scores were observed for the retention of the digital maxillary complete denture ( $P=.001$ ) compared with that for the digital mandibular and conventional complete dentures. Students preferred digital prostheses compared with conventional prostheses ( $P<.05$ ). The conventional process required significantly more clinical time for each patient than with the digital process of fabrication ( $P<.01$ ).

**Conclusions.** The digital process proved to be an equally effective and more time-efficient option than the conventional process of prosthesis fabrication in the predoctoral program. The digital denture process was preferred and effectively used by predoctoral dental students under faculty supervision. (*J Prosthet Dent* 2015;■:■-■)

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## Clinical Implications

The digital process of fabricating complete removable dental prostheses can be a viable alternative to the conventional process, and its successful application in the predoctoral setting justifies consideration for inclusion in the predoctoral curriculum.

advantages of digital complete removable dental prosthesis (CRDP) over the conventionally fabricated CRDP process: reduced number of clinical appointments, reduced treatment time, reduced fees without compromising quality, absence of polymerization shrinkage resulting in improved fit, easy fabrication of spare or replacement dentures from stored digital data, and reduced patient adaptation time for replacement dentures. A systematic review of CRDP fabrication using computer-aided technology by Bidra et al<sup>9</sup> reported that prospective clinical trials are lacking in this rapidly evolving application and that scientific validation of this technology requires further research.<sup>8</sup> Infante et al<sup>10</sup> reported in detail the technique used to fabricate milled complete dental prostheses (AvaDent) with digital scanning technology. CAD/CAM prostheses have recently been used in implant dentistry as shown in reports by Lozada et al<sup>6</sup> and Kattadiyil et al,<sup>11</sup> which revealed the use of this technology to improve efficiency in both the surgical and prosthodontic phases of treatment.

Although application of CAD/CAM technology related to digital denture process in a predoctoral setting has not been reported, Refeis et al<sup>12</sup> published a clinical study of CAD/CAM-generated crowns fabricated by first-year dental students. Both the students and supervising faculty gave positive feedback regarding product quality and overall experience with this technology. This research project was initiated to study and compare the use and effectiveness of CAD/CAM technology in digital CRDP fabrication with those of the conventional method. The study also was designed to determine the preferences of predoctoral dental students introduced to 2 different techniques of prostheses fabrication and their perceptions of the experience.

The primary null hypothesis of the prospective study conducted in the predoctoral clinic at Loma Linda School of Dentistry (LLUSD) was that no differences would be found in clinical outcomes as evaluated by faculty ratings, between conventional and digital CRDP. The following secondary null hypotheses were also addressed: no differences would be found in patient ratings or preferences for conventional versus digital CRDP; and no difference would be found in student preferences or for efficiency between (time spent clinically) the 2 methods.

## MATERIAL AND METHODS

Approval was obtained from the Institutional Review Board of Loma Linda University before conducting this study. Fifteen completely edentulous patients (11 men and 4 women, average 55 years of age) signed informed consent forms before participating in the study. This appointment for initial examination and informed consent was not considered part of the fabrication process. The Prosthodontic Diagnostic Index (PDI)<sup>13</sup> for participants in the study was Type I (2 participants) or II (13 participants). Two sets of maxillary and mandibular CRDP were fabricated for each participant by a third-year or fourth-year predoctoral dental student at LLUSD. The 15 predoctoral students who participated in the study received instruction on the fabrication of digital CRDP by viewing a 26-minute instructional video prepared at LLUSD. The same students had already received instruction on the fabrication of conventional CRDP as part of their didactic preclinical curriculum. For most (11) students, it was their first denture experience, but for the remainder, this was their second or third conventional set of dentures. Each patient received 1 digital (AvaDent) and 1 conventional set (maxillary and mandibular) of CRDP. The first set and type of denture to be fabricated was determined by a coin toss. The digital CRDP were fabricated following the AvaDent digital CRDP protocol, where definitive impressions, interocclusal records, and tooth selection were completed in the first appointment. Records and completed laboratory work authorization forms were sent to GDS. A lingualized occlusal relationship was requested for all CRDPs. Seven students opted for a posterior palatal seal (PPS) engraved for the maxillary digital CRDP, and 8 students chose not to select this option.

GDS scanned the records and submitted a virtual tooth arrangement for preview and approval before fabricating the dentures. The digital dentures were sent to LLUSD and placed at the second appointment (Fig. 1).

The conventional set of CRDP was fabricated with the 5-appointment process: preliminary impressions (first appointment); definitive impressions (second appointment); interocclusal records and tooth selection (third appointment); wax trial placement (fourth appointment); and denture adjustment and placement (fifth appointment). CRDPs were fabricated with the conventional lost wax technique and heat-polymerizing acrylic resin (Lucitone 199; Dentsply Intl). The heat-polymerized CRDPs were finished, clinically remounted, and polished before placement. Students performed the laboratory procedures for conventionally processed dentures (Fig. 2A, B), which included fabricating custom trays and occlusion rims, denture tooth arrangement, and festooning. The dental laboratory at LLUSD processed the acrylic resin by using a long polymerization cycle



**Figure 1.** A, Smile view of patient with digital CRDP. B, Digital maxillary and mandibular CRDP. CRDP, complete removable dental prosthesis.



**Figure 2.** A, Smile view of same patient with conventional CRDP. B, Conventional maxillary and mandibular. CRDP, complete removable dental prosthesis.

(9 hours in a water bath at  $73^{\circ}\text{C} \pm 1^{\circ}\text{C}$  followed by 1/2 hour in boiling water as recommended by the manufacturer). The dental laboratory finished the conventional CRDP. All 15 students received supervision and guidance for the laboratory and clinical procedures typical for the predoctoral setting from 4 faculty who had experience in the fabrication of both types of dentures. After fabrication and immediately after placement, the dentures were assessed by 2 experienced and certified prosthodontists (M.K., R.J.). The 14 factors evaluated during assessment

are listed in [Table 1](#). Grading criteria for each of the 14 factors were developed and used to standardize the ratings. The faculty evaluated the maxillary and mandibular prostheses separately for denture base contour, teeth arrangement, fit, retention, extension, stability, esthetics, lip support, and prognosis. The centric relationship, occlusion, occlusal vertical dimension (OVD), phonetics, and overall result were evaluated together with both of the prostheses. A 5-point Likert rating scale from 0 to 4 ([Table 2](#)) was used by faculty and patients to evaluate

**Table 1.** Criteria evaluated by faculty

• Denture base contour	• Vertical dimension
• Tooth arrangement	• Extension
• Fit	• Stability
• Esthetics	• Retention
• Lip support	• Phonetics
• Centric relation	• Overall result
• Occlusion	• Prognosis

**Table 2.** Grading criteria for rating used by faculty and patients

4 = Excellent (no negative findings)
3 = Good (1 negative finding)
2 = Fair (2 negative findings)
1 = Poor (3 or more negative findings; clinically satisfactory)
0 = Remake (clinically unsatisfactory)

**Figure 3.** Digital CRDP showing anterior open occlusal relationship. CRDP, complete removable dental prosthesis.

each criteria. This rating scale is similar to the 5-point Likert scale used by Dias et al,<sup>14</sup> who successfully used this scale to assess patient satisfaction with implant overdentures. An instrument that uses an intermediate response such as a Likert scale has been recommended as an effective method of gauging outcomes.<sup>15</sup> Complications were found for both types of denture techniques. One complication, shown in Figure 3, resulted in an anterior open occlusal relationship for the digital CRDP, and a new digital prosthesis was made for the mandibular arch. In a conventional technique, this complication could have been managed with a clinical remount procedure. The evaluation criteria associated with the anterior open relationship resulted in the lowest score (0) for centric relation, OVD, esthetics, occlusion, overall result, and prognosis for the mandibular arch, even though the complication could also have been managed with a clinical remount of the digital denture. Another complication occurred with a conventional denture that required a relin; this denture was given the lowest score (0) for retention, stability, and occlusion.

Each patient wore each set of CRDPs for 1 week (the first one worn was the first one fabricated, and the second one was worn the following week). Patients then completed a satisfaction questionnaire which included ratings and preferences as options (Table 3). After both of the sets had been worn for 1 week each, patients were asked to choose their preferred set of dentures. Patients also used a 5-point Likert rating scale from 0 to 4 (Table 2) when assessing/grading the dentures.

The predoctoral dental students were requested to provide feedback by responding to a questionnaire

**Table 3.** Patient questionnaire

- Rate each denture as to whether it “stayed in” better” 0-4
- Rate the appearance of each denture 0-4
- Which set of dentures were you able to chew/function with the best? 1 or 2\*
- Which set of dentures was more comfortable? 1 or 2
- Which denture technique was more efficient? 1 or 2
- Which set of dentures did you choose to wear? 1 or 2

\*1, conventional CRDP; 2 = digital CRDP.  
CRDP, complete removable dental prosthesis.

(Table 4). The total clinical treatment time for each fabrication technique was recorded, including any additional clinical time required for remakes or repetitions of procedures.

All statistical analyses were performed with software (IBM SPSS Statistics v22; IBM Corp). To ensure calibration, intraexaminer and interexaminer reliability testing was completed. An intraclass correlation coefficient reliability test was carried out to assess the ratings provided by the 2 examiners (M.K., R.J.) who evaluated the dentures. The overall faculty and patient evaluation scores for the CRDP were compared and evaluated for statistically significant differences using the Wilcoxon signed rank test. Patient and student preferences were analyzed with the Pearson chi-square test or 1-sample binomial test ( $\alpha=.05$  for all tests of hypotheses, unadjusted for multiple testing).

## RESULTS

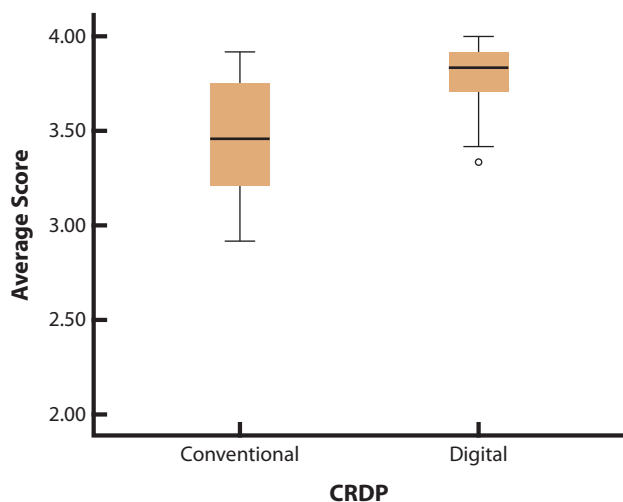
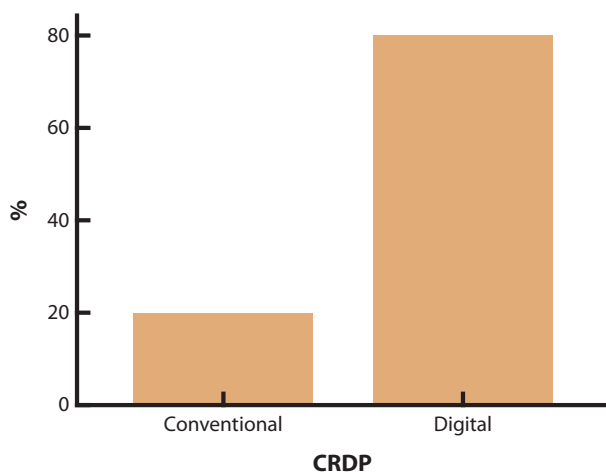
The criteria evaluated and analyzed for both types of CRDPs are presented in Table 5. Significantly higher average scores ( $P=.007$ , Wilcoxon signed rank test) were recorded for the digital CRDP than for conventional CRDP (Fig. 4).

Significantly higher average patient response scores (used to determine overall patient satisfaction) were seen for the digital CRDP (Wilcoxon signed rank test,  $P=.001$ ) (Fig. 5). No significant patient preference rating was noted regarding appearance (esthetics) of the digital and conventional CRDP (Wilcoxon signed rank test,  $P=.763$ ). A significantly higher preference for the digital CRDP was seen for comfort, chewing efficiency, prosthesis selected, and efficiency of technique (Pearson chi-square,  $P<.01$ ) (Fig. 6). Results are shown in Table 6. Significant differences were not seen between related digital and conventional CRDP scores ( $P=.248$ ) and related patient and faculty scores ( $P=.705$ ), using the Wilcoxon signed rank sum test (Figs. 7, 8).

**Table 4.** Student questionnaire

- Which denture technique (conventional or digital) was technically easier to perform? 1 or 2\*
- Which denture technique (conventional or digital) would you like to use in your practice? 1 or 2
- Which denture technique (conventional or digital) would you be more confident in performing without faculty supervision? 1 or 2
- Additional comments:

\*1 = conventional CRDP; 2 = digital CRDP.  
CRDP, complete removable dental prosthesis.

**Figure 4.** Average score from evaluated criteria given by faculty. CRDP, complete removable dental prosthesis.**Figure 6.** Patient preference for CRDP. CRDP, complete removable dental prosthesis.

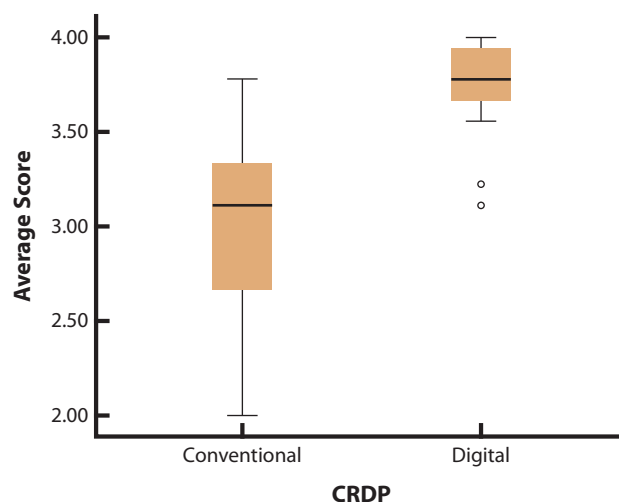
All students included in the study responded to a questionnaire (Table 4) after placement of the digital and conventional CRDP. They expressed a significant preference for the digital CRDP as being easier to perform (Fig. 9) than the conventional CRDP ( $P=.007$ , 1-sample binomial test). Students also expressed a significant preference for digital dentures as the technique they would use in their practice ( $P=.035$ , 1-sample binomial test). However, a significant preference was not recorded

**Table 5.** Faculty evaluation

- Denture base contour\*
- Tooth arrangement
- Fit\*
- Esthetics
- Lip support
- Phonetics
- Occlusion
- Centric relation
- Vertical dimension
- Extension\*
- Stability\*
- Retention\*
- Overall result\*
- Prognosis

Ratings were analyzed with the Wilcoxon signed rank sum test.

\*Significantly higher rating for digital CRDP.  
CRDP, complete removable dental prosthesis.

**Figure 5.** Average satisfaction score given by patients. CRDP, complete removable dental prosthesis.**Table 6.** Patient response

- Rate which denture "stayed in" better\*
- Rate the appearance of your dentures
- Which set of dentures were you able to chew/function with the best?\*
- Which set of dentures was more comfortable?\*
- Which denture technique was more efficient?\*
- Which set of dentures did you choose to wear?\*

Ratings were analyzed with the Wilcoxon signed rank sum test, and preferences were analyzed using the chi-square test.

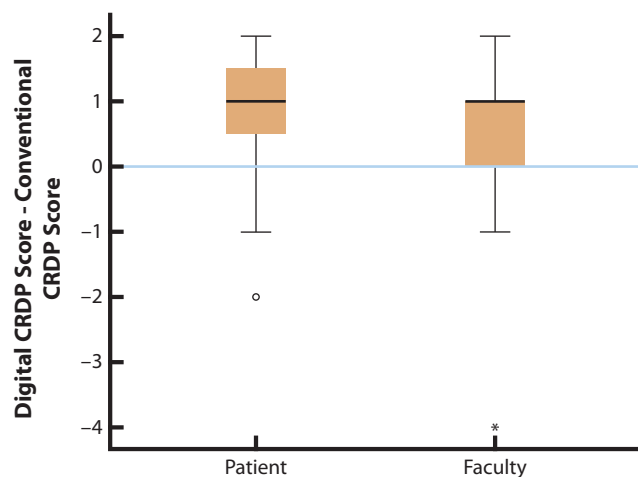
\*Significantly higher ratings and preferences for digital CRDP.  
CRDP, complete removable dental prosthesis.

in response to the question "which denture technique would you be more confident in performing without faculty supervision?" ( $P=.174$ , chi-square test). Table 7 shows the results of student responses.

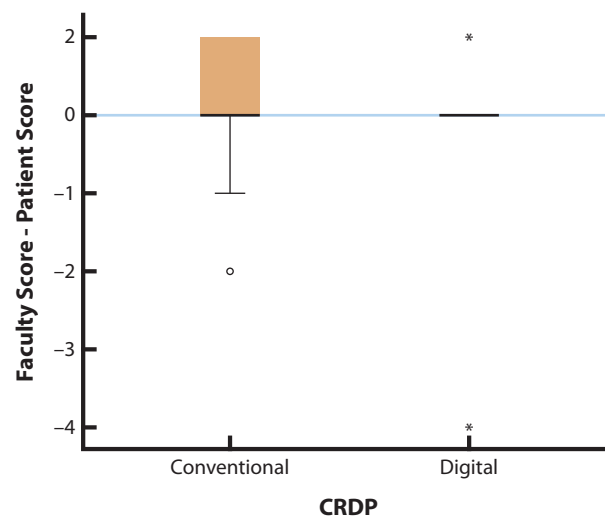
The conventional denture process required significantly more clinical time (Fig. 10). The average clinical time was 205 minutes longer for the conventional denture than for the digital denture (Wilcoxon signed rank test,  $P=.003$ ).

## DISCUSSION

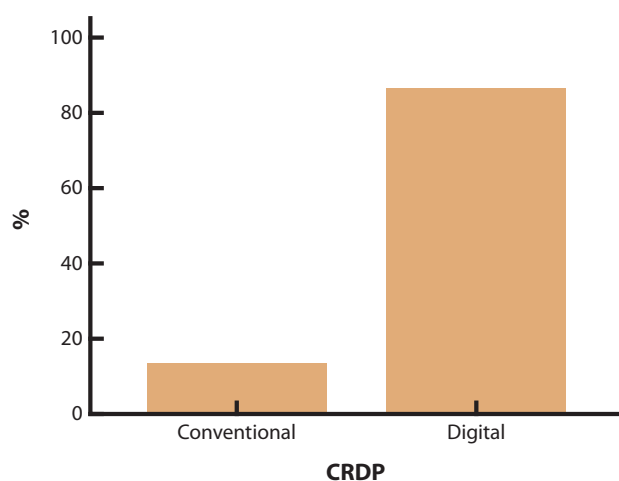
The primary null hypothesis of the prospective study, that no differences would be found in the clinical outcome, as evaluated by faculty, between the conventional and digital CRDP, was rejected. The secondary null



**Figure 7.** Comparing related digital and conventional CRDP scores. CRDP, complete removable dental prosthesis.



**Figure 8.** Comparing related patient and faculty scores. CRDP, complete removable dental prosthesis.



**Figure 9.** Student response to the question "which technique was easier to perform?" CRDP, complete removable dental prosthesis.

hypotheses that no differences would be found in overall patient satisfaction between the conventional and digital CRDP or in student preference and efficiency (time spent clinically) between the 2 methods of fabrication were also rejected. This prospective study rated and compared CRDPs fabricated by predoctoral students with a 2-appointment digital denture process with the conventional 5-appointment process. Outcomes assessment data were collected that evaluated the prostheses, patient preferences, student preferences, and clinical times involved in fabrication.

Data analysis revealed significantly higher ratings by faculty for the digital CRDP relative to the denture base contour, fit, extension, stability, retention, and overall result. However, no significant differences were found in other categories such as quality of tooth arrangement, esthetics, lip support, occlusion, phonetics, accuracy of centric relation, appropriate OVD, and prognosis. The

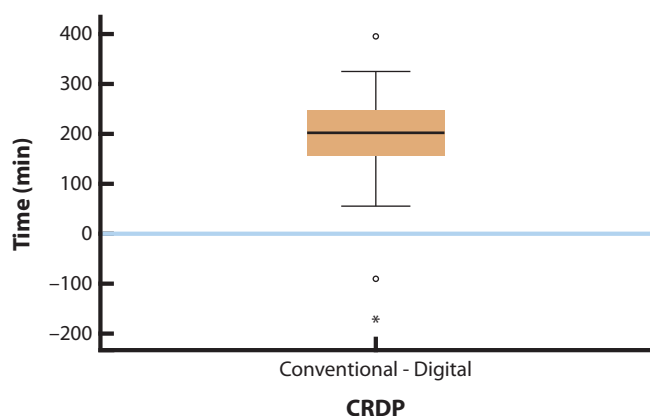
**Table 7.** Student response

- Which denture technique (conventional or digital) was technically easier to perform?  
Significant preference for digital CRDP (one-sample binomial test)
- Which denture technique (conventional or digital) would you like to use in your practice?  
Significant preference for digital CRDP (one-sample binomial test)
- Which denture technique (conventional vs. digital) would you be more confident in performing without faculty supervision? 1 or 2\*  
No significant preferences were seen for either conventional or digital CRDP (chi-square test)

\*1 = conventional CRDP; 2 = digital CRDP.  
CRDP, complete removable dental prosthesis.

significantly higher rating for retention in the maxillary arch for the digital CRDP could be explained by improved fit due to the absence of polymerization shrinkage and the unique method of milling the digital prosthesis from a prepolymerized block of acrylic resin. Further studies are needed to quantify these findings objectively. The effectiveness of the PPS was not evaluated in this study. All conventional dentures featured a PPS area, and only 7 of the 15 digital CRDPs used PPS. The need for or lack of need for a PPS in digitally processed CRDPs warrants study, as the dentures made in this study without a PPS were not judged to be inferior in fit or retention to those with a PPS.

The average/overall response scores used to determine patient satisfaction revealed significantly higher satisfaction with digital CRDP. Patient preferences for the CRDP selected to wear was significantly higher for the digital CRDP in all categories assessed (Table 7), except for the category of "appearance of the dentures," which did not reveal a significant difference in rating. The predoctoral students chose the digital dentures as their preference for the easier of the 2 techniques and expressed significant preferences for digital dentures as a product they would carry over to their clinical practice



**Figure 10.** Time comparison between two methods of fabrication. CRDP, complete removable dental prosthesis.

(Table 7). However, students did not express a significant difference in confidence in performing the fabrication procedures for either type of dentures without any faculty supervision, suggesting they felt both techniques involved a learning curve. Because the only purpose of the study was to evaluate student performance and preferences in a predoctoral setting, the null hypothesis was rejected. However, further studies will be needed to determine how this preference carries over to a private practice setting without faculty supervision.

Significant differences were noted in clinical treatment times as the conventional fabrication process required significantly more clinical time (approximately 3.5 hours more) for each participant than the digital fabrication process. This finding could have financial implications for clinicians. However, this study did not evaluate the cost effectiveness of the 2 types of prostheses, which warrants future research.

The limitations of the study include the inability to effectively blind participants, faculty, or students to the type of prosthesis. Previous experience and reduced number of appointments for 1 CRDP process allowed patients to deduce which type of prosthesis was being made. The inherent drawback of not being blinded is that the novelty bias of a new product with a unique method of fabrication could have influenced patient and student responses. Another limitation of this study was the small sample size of participants. However, significant results were observed for our primary hypothesis, which suggests that the sample size was adequate. Larger studies, however, are warranted to confirm the effect size. Increased sample size could have provided more power and generalizability.

Students adapted well to a new method of fabricating complete dentures that used digital technology. Written comments from the students revealed that a large number associated certain advantages and disadvantages

with the digital process. Some students (7) listed “no required laboratory work” as an advantage. Six students indicated “improved festooning and denture base finish” compared to what they had been accustomed to producing as students. Some of the disadvantages cited by the students were “lack of esthetic trial placement” and “difficulty in evaluating the digital preview pictures.” Five students felt that the conventional method offered an advantage as the dentures could be more “personalized.”

Both the students and patients mentioned that they found the digital preview images more difficult to interpret than the actual wax trial placement provided in the conventional technique. The previews were mailed electronically for review and were not considered an extra appointment. The trial placement is indeed an option for the AvaDent digital CRDP but was not used in this study. It would also have increased the 2-appointment process to a 3-appointment process, and one of the purposes of this study was to determine how the process would work with only 2 appointments. All completely edentulous patients selected for the study in the predoctoral program were classified as PDI Type I or Type II. This could have affected the treatment rendered. How effective both techniques would be in PDI Type III and IV patients, which are more complex to manage, remains to be seen.

Applications of digital denture technology and its consistency and effectiveness in meeting the needs of dental students have not been previously reported; this study represents the first such report. More studies are needed to further validate the results of the study. The authors believe that the application of digital technology in the fabrication of CRDPs will continue to improve and should be introduced in the predoctoral curriculum so that students can develop an understanding of its advantages and disadvantages. The authors also believe that the use of this technology will increase as the initial treatment outcomes were comparable with those of conventional prostheses.

## CONCLUSIONS

Within the limitations of the study, the following conclusions were drawn:

1. Digital CRDPs can be an effective and time-efficient option for completely edentulous patients in the predoctoral program.
2. The digital denture process was preferred and used effectively by predoctoral dental students under faculty supervision.

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