

Teaching the Design and Fabrication of RPD Frameworks With a Digital Workflow: A Preclinical Dental Exercise

Ahmed Mahrous, DDS, MS*, Tarek El-Kerdani, DDS, MSD

*Corresponding author: ahmed-mahrous@uiowa.edu

Abstract

Introduction: The conventional method for teaching removable partial denture (RPD) design using a pencil drawing on a solid cast has always been the basis for teaching RPD design in most dental schools at both the undergraduate and graduate levels. This does not apply to RPD fabrication technology, as more laboratories have recently adopted more efficient and versatile digital techniques to design and fabricate RPD frameworks. **Methods:** At the University of Iowa College of Dentistry, we created a pilot workshop to assess the efficiency of a new approach to teaching RPD design utilizing this new digital RPD technology as a teaching tool for graduate prosthodontics residents. Three first-year prosthodontics residents were enrolled in the workshop, which involved learning the new digital workflow of designing RPD. **Results:** This new teaching approach very successfully achieved its educational goals. The residents reported that the digital RPD teaching approach enriched their knowledge and deepened their understanding of RPD design. **Discussion:** The technique garnered significant interest from the students and seemed to also increase their understanding of the steps involved in RPD fabrication as well as the different components of the RPD.

Keywords

RPD, Digital Workflow, Preclinical Exercise, Digital Educational Resource, Dental, Educational Technology, Prosthodontics

Educational Objectives

By the end of this activity, learners will be able to:

1. Describe the difference between digital and conventional workflows for designing and fabricating removable partial denture frameworks.
2. Develop skills for operating a digital design system.

Introduction

The general approach to removable partial denture (RPD) education and workflows in dental schools has largely remained the same for many years, while RPD fabrication in commercial labs has become digitized. The basic approach to teaching RPD designs and technical steps includes designing the framework on paper or drawing it on a cast, followed by observing a technician manually applying wax components on a refractory cast and then investing it. This classical approach comes with

several constraints, including the limited working hours of dental technicians in the dental school, their ability to teach and explain steps, limited visualization of the working model during the session, and the lack of hands-on experience for the students since they act only as observers. Digital design workflows for RPDs improve greatly upon the conventional RPD manufacturing techniques and decrease the cost of fabrication of RPD frameworks.¹ Additionally, a number of new polymer materials have recently been introduced to the market for producing digitally designed RPDs²⁻⁵ and have been shown to exhibit more overall accuracy when compared to conventionally made RPDs.⁶

To overcome the limitations of the conventional approach and address this educational gap, our team developed a new digital teaching approach. This approach replaces the paper drawing and the manual application of wax on the model with a digital teaching format that provides students with more hands-on experience with digital workflows. The digital teaching module is self-directed and is readily available at their convenience. The image on the screen is 3D, has high resolution with vibrant colors, provides high visibility on several views, and can be magnified to high proportions. In addition, the students can gain their own hands-on experience by using the digital designing tools on the

Citation:

Mahrous A, El-Kerdani T. Teaching the design and fabrication of RPD frameworks with a digital workflow: a preclinical dental exercise. *MedEdPORTAL*. 2020;16:11041. https://doi.org/10.15766/mep_2374-8265.11041

virtual model; their errors can easily be repaired by means of a return button.

At the University of Iowa College of Dentistry, we acquired a digital desktop laboratory scanner and digital design software with a digital RPD design workflow module. The module allows the operator to design an RPD framework on a cast and then send a HIPAA-compliant STL file to the designated lab, to have an RPD framework manufactured and sent back for try-in. This workflow has been tested by faculty and senior graduate students and found to be comparable, if not superior, to the results achieved through the conventional technique. After few cases were completed using the digital workflow, we started preparing a workshop for the graduate students to assess the efficiency of the digital technology as a teaching tool as well as a standard way for the graduate students to fabricate their RPDs. Although all our students were not familiar with this new digital teaching approach yet, the new approach was efficient and accepted by graduate students, and thus, the project could be used on a larger scale in the undergraduate program.

Methods

We developed this teaching activity based on our successful experience in using digital technology in both designing and fabricating RPD frameworks. Prior to starting the workshop, 10 clinical cases were successfully completed in the graduate prosthodontics clinic using both lab communication protocols, five cases for each protocol. Three master casts from the records of the 10 successfully completed cases were selected for use in this project. The selection was based on the diversity of the designs and was intended to cover more varieties of Kennedy classification for edentulous areas.

We developed a digital RPD design workflow PowerPoint presentation based on the cases for faculty as a reference (Appendix A), and another copy based on one of the cases was created as an introductory presentation for students (Appendix B).

Materials

- Four unidentified solid master casts for patients requiring an RPD restoration presenting clear mouth preparation.
- Desktop 3D laboratory digital scanner, 3shape or similar.
- Compatible design software, 3shape or similar.
- A PC with at least a graphics card of 1GB DirectX 11 (2GB DirectX 11) NVIDIA GeForce 8 GB of RAM and an Intel core i7 or equivalent.
- An open account with the design software provider.

- HIPAA-compliant communication protocol with the lab.
- All forms needed for assessment.

We trained our participating faculty by conducting training sessions. The first session was an interactive video conference with the manufacturing company introducing all the available tools in the system and the various digital design options.

The second session was a hands-on tutoring session on RPD design using the digital RPD design workflow, moderated by the laboratory technician from the designated lab. The session covered a wide variety of topics, from design tools to HIPAA-compliant laboratory communication using an STL file.

As these resources may not be available at other institutions, we recommend reviewing Appendix A with faculty facilitators. Appendix A provides detailed instructions on all the RPD design steps, which can be implemented on a wide variety of cases. Faculty can select solid casts for RPD cases from their records and should practice scanning and designing these cases.

The lecture was situated within the advanced removable technique prosthodontics course, which was part of the first-year curriculum of the advanced prosthodontics program at the University of Iowa College of Dentistry. Three graduate students, all recent graduates, were selected to participate in this exercise. The digital exercise was added to the removable prosthodontics technique course regularly taught in the spring semester of the graduate prosthodontics program at University of Iowa. The residents had had good experience with conventional RPD design and the conventional fabrication process, but no experience in digital RPD design. The residents had some experience in digital dentistry covering the technology for fabrication of fixed restorations only.

The flow of the teaching session is illustrated in [Table 1](#).

The three first-year residents received a lecture from faculty that included an introduction to the system and a step-by-step guide to all RPD components and design principles (see the presentation in Appendix A). After the presentation, a live demo of the digital RPD design workflow was presented. Following the demo, the three residents were given three master casts that corresponded to the three exercises. The students were asked to scan their casts according to instructions. The first exercise was the same case demonstrated in the lecture. It was intended to act as a soft start for the students as they would be following familiar steps already presented in the lecture. Afterward, they were given two more exercises that they had not seen before. The first case came with a detailed step-by-step guide; however,

Table 1. Flow of the Teaching Sessions

Session	Classroom	Lab and Digital Lab
0	Fulfilling prerequisite training for faculty.	Selection of cases, three solid stone models representing Kennedy class I, II, or III, suitable for scanning. Faculty practice scanning and designing.
1	Introduction to digital teaching approach; PowerPoint presentation 2.	Introduction to digital lab, computer software, and scanning and designing demo.
2		Scanning and designing model case 1.
3		Scanning and designing model case 2.
4		Scanning and designing model case 3.
5	Review of lab communication form; final assessment and questionnaires.	

the students were encouraged to look into the guide (printed handout from Appendix B) only when necessary and to try to accomplish the design independently. The time from start to completion was monitored for each student and for each design. After each design was completed, the designs were assessed by the student using a self-assessment form (Appendix C). The instructor assessed the design and evaluated the student's self-assessment. Once the assessment was complete, the RPD design was converted to STL and was ready to be sent to the lab. No cases were actually sent to the lab; STL files were created for training purposes only. STL files did not include any patient information and were labeled by student name and case number. The paper lab authorization form was also a part of the exercise (see Appendix D).

After finishing all three exercises, we assessed the impact of this teaching activity by asking the students to fill out an evaluation form (Appendix E) to express their views on the exercises and their efficacy in meeting the course objectives. The questionnaire contained nine questions. Question 1 had eight subquestions and was directed towards assessing the efficiency of the digital workflow compared to the conventional workflow. A score of 1-5 was assigned to each subquestion of question 1 and to questions 2-6.

Answer choices varied from *strongly agree* or *very convenient* (5) to *strongly disagree* or *very inconvenient* (1). A mean was produced for each of the eight subquestions of question 1; these were added together, resulting in a total score out of 40 points. This was added to the scores from questions 2-6, resulting in a total score out of 65 points. Questions 2-7 were designed to assess depth of knowledge and understanding of

Table 2. Results of the Grading (n = 3)

Question	M Score
1	
a	4.0
b	4.7
c	4.7
d	4.0
e	4.7
f	4.3
g	4.3
h	4.0
2	5.0
3	5.0
4	5.0
5	5.0
6	5.0

RPD design based on the digital exercise. Questions 8 and 9 allowed residents to add comments (Appendix E).

Results

Three residents completed all exercises on time, received a passing grade, and filled out the course assessment questionnaire. Exercises 1, 2, and 3 were completed in an average of 82, 61, and 22 minutes, respectively. All residents verbally expressed that the activity was effective in teaching the RPD design. Results of the grading are shown in Table 2, and a breakdown of the student self-assessment results for the first, second, and third exercises is shown in Table 3.

For question 7, all students indicated that the digital exercise helped them develop a deeper understanding of all components of the RPD. A simple thematic analysis of the written comments for questions 8 and 9 follows:

- Software helped in understanding of RPD:
 - “More understanding of the concepts of RPDs.”
 - “I get a better understanding of internal and external finish line.”
- Suggestions:
 - “I think we should do more digital designs. This will help is get a better look at how to design RPD. I am thinking of print the framework in plastic and use that for framework try in exercise.”

Table 3. Student Self-Assessed Scores for Exercises 1-3 (n = 3)

Student	Exercise		
	1	2	3
1	3.2	3.4	3.6
2	3.4	3.8	3.8
3	3.6	3.7	3.7

Discussion

To address a lack of student involvement in the fabrication of the RPD frameworks as well as students' difficulty understanding RPD design and the details of RPD components, we developed a new digital teaching approach. This approach replaces the paper drawing and the manual application of wax on the model with a digital teaching format that provides students with more hands-on experience. It is important to note that this report is intended not to compare the fit accuracy of conventional versus digitally designed frameworks but instead to be an educational resource to assess the efficiency of the digital method in teaching RPD design and fabrication.

Our group taught a new technique to the students, who reported through their answers to the questionnaire and assessment form as well as verbally that they appreciated it. The results of the assessment form and the final questionnaire indicate that all five learning objectives were met. The assessment form made the students critically understand the advantages of the digital design workflow in comparison to a conventional RPD workflow. The digital teaching approach successfully replaced the conventional didactic portion of RPD design with a better hands-on 3D virtual model experience.

Based on the results of question 6, all students agreed that the digital exercise gave them an overall deeper understanding of RPD design. Being involved in all aspects of the design up to the stage of being ready to print the RPD pattern made the students more enthusiastic about the technology and eager to progress with more exercises using it.

The steps of setting up an account, scanning a model, and creating the STL scored less than perfectly in the questionnaire, based on answers to questions 1a, 1b, and 1h. This indicates that the students encountered initial difficulties in these steps, which also made them take more time to perform the exercises. These issues improved in exercises 2 and 3. The amount of time taken to complete the exercises significantly improved over the course of the project, and students noticed the difference. The amount of time exercise 3 took (22 minutes) was about 73% less than that required by exercise 1 (82 minutes). This indicated that students' technical skills improved at a rapid pace as they overcame initial difficulties in the abovementioned three steps. So, in a matter of hours, students turned from novices to experienced operators. This outcome was expected given that students in this millennial generation are more acquainted with computer operations and have more inherent computer skills developed through their history of playing video games. Moving fast from one step to the next as the

exercise progressed demonstrated how the students built their problem-solving skills and developed a deeper understanding of the system's operation and the components' application. This created more confidence in the students that they could safely use this software on their own, with limited supervision or after hours, which in turn could expand their learning experience.

Student comments showed a clear appreciation for the technical efforts made by the dental technician in fabricating the framework. Comments also demonstrated that students understood they had to be very clear about their instructions to the lab in the lab authorization form.

For faculty who would like to implement this teaching approach in their respective schools, a starting point would be investing in this or similar software. Faculty should fulfil their prerequisite training prior to teaching this approach to students. Direct contact to the software manufacture to provide video conferences to faculty was very helpful to our group of faculties. Similar sessions can be easily arranged for faculty in other schools.

The limitations of this report are the fact that there were only three students involved in the pilot study and that additionally, the evaluation of impact relied on the questionnaire only, with no comparison of scores being done, and thus, no conclusions on the effect on learning able to be extrapolated. The main limitation of the teaching approach is the financial investment that a school needs to make to provide students with this technology. As technology is continuously progressing, the digital component in every curriculum is constantly growing. This emerging teaching approach can gradually replace the current approach as a more effective teaching tool. Given the success of this technology as a teaching tool, dental schools should be encouraged to embrace it a new and emerging tool in dental education, gradually replacing conventional teaching tools and providing good return on the long-term financial investment.

In summary, we developed a new approach for teaching RPD design and fabrication using digital technology. In the future, we plan to implement this teaching approach as the primary method for teaching RPDs, replacing the conventional pencil-drawing technique.

Conclusions

Implementing this teaching module enabled students to understand the difference between digital and conventional workflows for designing and fabricating RPD frameworks and to develop skills for operating a digital design system. The digital teaching approach was very favorably perceived by

the students as an efficient tool for learning RPD design. Most aspects of the design were considered very convenient by the students. Creating an STL file was considered a moderately challenging task for the students. They had a fast learning curve in operating the digital system and utilizing all its tools. They also built more enthusiasm for the technology and were eager to progress more by doing more exercises using this technology.

Appendices

- A. RPD Exercise 1, 2, and 3 Faculty Guide.pptx
- B. RPD Exercise 1 Student Copy.pptx
- C. Student Self-Assessment Form.docx
- D. Sample Lab Authorization Form.pdf
- E. RPD Course Evaluation.docx

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

Ahmed Mahrous, DDS, MS: Assistant Professor, Department of Prosthodontics, University of Iowa College of Dentistry; ORCID: <https://orcid.org/0000-0001-5436-8247>

Tarek El-Kerdani, DDS, MSD: Clinical Professor of Prosthodontics, University of Iowa College of Dentistry

Disclosures

None to report.

Funding/Support

None to report.

Ethical Approval

Reported as not applicable.

References

1. Ye H, Ning J, Li M, et al. Preliminary clinical application of removable partial denture frameworks fabricated using computer-aided design and rapid prototyping techniques. *Int J Prosthodont*. 2017;30(4):348-353. <https://doi.org/10.11607/ijp.5270>
2. Meenakshi A, Gupta R, Bharti V, Sriramaprabu G, Prabhakar R. An evaluation of retentive ability and deformation of acetal resin and cobalt-chromium clasps. *J Clin Diagn Res*. 2016;10(1):ZC37-ZC41. <https://doi.org/10.7860/JCDR/2016/15476.7078>
3. Fueki K, Ohkubo C, Yatabe M, et al. Clinical application of removable partial dentures using thermoplastic resin—part I: definition and indication of non-metal clasp dentures. *J Prosthodont Res*. 2014;58(1):3-10. <https://doi.org/10.1016/j.jpor.2013.12.002>
4. Panayotov IV, Orti V, Cuisinier F, Yachouh J. Polyetheretherketone (PEEK) for medical applications. *J Mater Sci Mater Med*. 2016;27(7):118. <https://doi.org/10.1007/s10856-016-5731-4>
5. Sadek SA. Comparative study clarifying the usage of PEEK as suitable material to be used as partial denture attachment and framework. *Open Access Maced J Med Sci*. 2019;7(7):1193-1197. <https://doi.org/10.3889/oamjms.2019.287>
6. Arnold C, Hey J, Schweyen R, Setz JM. Accuracy of CAD-CAM-fabricated removable partial dentures. *J Prosthet Dent*. 2018;119(4):586-592. <https://doi.org/10.1016/j.prosdent.2017.04.017>

Received: November 6, 2019

Accepted: June 17, 2020

Published: October 30, 2020