

Article

Survey of Current Predoctoral Removable Partial Denture Curriculum in the United States

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Abstract: The purpose of this survey was to determine removable partial denture (RPD) framework design concepts, new materials, and digital technology that are currently being taught in the predoctoral RPD curriculums in the U.S. dental schools. A questionnaire including RPD framework design concepts, materials, and digital technology was created on Qualtrics. The link to the questionnaire was distributed by email in May 2018 to U.S. dental schools. Thirty-nine of the sixty-six schools responded, yielding a response rate of 59%. Most schools are utilizing textbooks by McCracken and/or Stewart as their primary reference (90%). Only a few schools teach incisal rest (24%) and intra-coronal retainers (8%) in the clinic. The majority of schools teach three or less clasp assembly variations for distal extension RPD scenarios and utilize altered cast impression techniques only for selective patient scenarios. Half of schools currently utilize digital technology in their RPD curriculum. Although twenty-five schools (69%) indicated that implant-assisted RPD (IARPD) is being taught in the curriculum, only nineteen of them teach IARPDs in the clinic. Half of schools are utilizing non-metal clasp denture (NMCD) in their curriculum; most of these school provide this treatment as immediate/interim partials or long-term interim partials. Many U.S. dental schools are simplifying RPD design concepts and principles that are being taught. More schools are introducing new concepts and materials such as IARPD and NMCDs while incorporating digital technology in their predoctoral RPD curriculum.

Keywords: dental education; predoctoral; curriculum; removable partial denture



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1. Introduction

Removable partial denture (RPD) education has traditionally been a difficult area to teach and learn [1]. A survey of dentists indicated that they were trained inadequately or only for certain aspects of removable partial denture treatment [2]. There is a clear issue with the design and fabrication procedures for RPDs by general dental practitioners, as 70% of the responding practitioners reported design and survey as the most difficult part of the treatment process [3]. Up to 50–60% of cases received by the laboratories reported having little or no input from the dentist regarding the design of their patient's RPDs [1,3]. This is similar to a survey from 1984, where approximately 78% of the technicians in commercial laboratories designed most or all removable partial dentures [4].

Although there have been no significant changes in materials and design concepts, RPDs remains a challenge to many students and clinicians [1,5]. An increasing number of the population is keeping their teeth. Although there has been a decline in the prevalence of tooth loss and complete edentulism in the U.S, the need for fixed and removable partial dentures is predicted to increase due to the substantial growth of the aging population [2,6–8]. Since implant therapy may not be a feasible option for the increasing partially edentulous population due to high cost, anatomical variations, and/or medical reasons, RPDs will remain a major therapy in the future [6]. Therefore, RPD education is more pertinent than ever.

The success of RPD therapy is largely determined by the patient's compliance and the appropriate fit and design of the RPD to the patient. Poor fit can result in the patient not using the RPD, leading to exacerbated occlusal or positional problems for the patient. The advancement in digital technologies has allowed virtual design, planning, and fabrication of the RPD framework with great efficiency and comparable fit to traditional methods of stone models and casting [9]. Poor design can also decrease the success of RPD treatment by increasing plaque retention and putting significant stress on the remaining abutment teeth and edentulous ridges [8,10]. RPD outcome studies have found that 39% of RPDs were no longer used after 5 years [10]. Patient's satisfaction with an RPD depends on the comfort and how well it functions, which is impacted by the design and quality of the RPD [10]. Therefore, the critical nature of the RPD design and fabrication is evident. RPD design principles must be understood and applied as it remains a vital component to provide successful prosthetic rehabilitation for the partially edentulous patient that cannot be corrected by the current advancement in digital technology.

The American Dental Education Association (ADEA) conducts an annual survey of quantitative data from dental school curriculums such as designated hours or requirements for graduation. A survey of the qualitative data such as concepts, technique, and materials involving RPD curriculum has been completed in Turkish, Spanish, and British schools [11–13]. A 2006 survey to determine the curriculum, techniques, and materials used in U.S. predoctoral RPD programs concluded that predoctoral clinical RPD programs vary from school to school, but many schools share common philosophies on technique and materials [14,15]. However, none of these studies addressed specific RPD design principles and new concepts taught in the predoctoral RPD curriculum in U.S. dental schools.

RPD framework design is challenging, as it requires the clinician to take a myriad of individual variables into consideration to fabricate the best design for the specific patient, and many times, there is no single correct answer. A survey of current trends in RPD education involving framework design philosophies, new dental materials, and concepts would be beneficial for all U.S. dental schools.

The specific aim of this study was to determine RPD design concepts that are currently being taught in U.S. predoctoral programs and whether new concepts, materials, and digital technology are being used in their predoctoral RPD curriculum. Comparing and contrasting the different predoctoral RPD curriculums will help us identify the trends of current RPD education and direction for curriculum changes to be more relevant with the evolving changes in the field.

2. Materials and Methods

A questionnaire including RPD framework design concepts, materials, and digital technology was created (Appendix A). The research protocol (2018-0427) was exempted by the Office for the Protection of Research Subjects and Institutional Review Board (IRB) at the University of Illinois at Chicago (UIC) Office of Research. The survey contained sixteen multiple-choice questions with an option for an open response if the choices did not apply. Most of the questions allowed the selection of multiple answers that pertained to the respective curriculum. The questions were pilot tested by a few on-site faculty members before it was submitted to IRB.

The questionnaire was uploaded to the University of Illinois at Chicago Qualtrics (Provo, UT, USA) platform. An email including the cover letter/consent form with instructions and a link to the UIC Qualtrics questionnaire was sent to one representative at each U.S. dental schools on 30 May 2018.

The preferred individual at each institution was the removable partial denture course director, the removable prosthodontic director, or the restorative chair at each school. The email stated that their participation was anonymous and voluntary. A second email was sent two months later to improve participation for those who had not completed the questionnaire.

Thirty-nine schools responded, yielding a response rate of 59%. Three of the schools partially responded to the survey questions. All data were gathered and entered into Microsoft Excel (Microsoft, Seattle, WA, USA) for analysis. The data were analyzed with descriptive statistics on SPSS Statistics Version 25 (IBM, Armonk, NY, USA).

3. Results

3.1. Textbook Utilized for Curriculum (Question 1)

Thirty-five (89.7%) of the responding U.S. dental schools indicated that they utilize the textbooks by McCracken and/or Stewart as their primary reference for the RPD curriculum. The majority of these schools use a combination of multiple reference texts, including Kratochvill and/or Krol. Six schools (15.4%) reported only using the McCracken's, and twelve schools (30.8%) reported only using Stewart's. Three schools (7.7%) reported using custom course manuals written by their own faculty. One school (2.6%) uses the eHuman removable partial denture digital textbook.

3.2. Rest Seats Used for an Anterior Tooth without Prominent Cingulum (Question 2)

Nineteen schools (50%) reported that the cingulum rest is utilized for an anterior tooth without a prominent cingulum. Of these schools, six of them utilize only the cingulum rest, and the remaining schools use it in combination with other rests. Nine schools (23.7%) reported using lingual ball rests instead of cingulum rest. Of these nine schools, five of them utilized only the lingual ball rest, and four of them use it in combination with other options. Ten schools (26.3%) indicated adding composite to create a rest seat, and only one school (2.6%) used this as the sole method. Seven schools (18%) reported avoiding the use of an anterior tooth without a prominent cingulum as abutment teeth for an RPD.

3.3. Use of Incisal Rest Seats (Question 3)

Nine schools (23.7%) reported that incisal rests are utilized both in the preclinical course and in the clinic. The majority of the schools (60.5%) reported that incisal rests are only taught in preclinical courses and not utilized in the clinic. Six schools (15.8%) reported that incisal rests are not taught in their curriculum at all.

3.4. Stress-Breaking Concepts (Question 4)

Stress-breaking concepts are being taught in twenty-seven schools (71.1%).

3.5. Guide Planes (Question 5)

Twenty-eight schools (71.8%) reported using short guide planes advocated by Krol. Only two schools (5.1%) reported using long guide planes advocated by Kratochvill. The remaining schools (23.1%) reported using guide planes that were in between the two concepts in length.

3.6. Retainer Clasp Assemblies Used for Distal Extension RPD Scenarios (Question 6)

The RPI class assembly is taught in all schools except one (97.4%). More than half of the schools simplified design concepts by introducing three or less clasp assembly options for distal extension scenarios. The most common clasp assemblies being taught with the RPI clasp assembly are RPA clasp assembly, combination clasp with a mesial rest, and combination clasp with a distal rest.

3.7. Location of Undercut for I-Bar to Engage (Question 7)

When using I-bars, thirty-two schools (82.1%) engage the mid-buccal undercuts only or in addition to mesiobuccal undercuts. Four schools (10.3%) reported engaging the mesiobuccal undercuts only.

3.8. Preferred Retainer Clasp When Placed Anterior to the Horizontal Fulcrum Line (Question 8)

Twenty-three schools (60%) reported using a wrought wire clasp engaging 0.02 inch undercut for a retention clasp anterior to the horizontal fulcrum axis, usually in combination with other options. Three schools (7.7%) indicated they do not place any clasps, and five schools (12.8%) indicated utilizing only a cast clasp engaging 0.01 inch undercut in this scenario. A few schools reported creative ways to decrease stress in the anterior abutment tooth of the fulcrum axis by utilizing cast round clasps or by engaging smaller undercuts: 0.005 inch for cast clasps or 0.01 inch for wrought wire clasps.

3.9. Preferred Retainer Clasp Assembly for Mesially-Tilted Distal Abutment Molar (Question 9)

Ring clasps and Akers clasps to engage 0.01 inch lingual undercuts are most commonly taught for retentive clasps for mesially-tilted distal abutment molars, followed by an elongated rest with bracing clasps and Akers clasps engaging a 0.01 inch buccal undercut created in the tooth. Four schools (10.3%) report using elongated rests without any clasps.

3.10. Digital Technology in the RPD Curriculum (Question 10)

Eighteen schools (50%) utilize digital technology as part of their RPD curriculum. Ten of these schools use digital technology in preclinical courses only, and the remaining eight schools use it in both preclinical courses and clinical care. The digital technology is most commonly used in 3D printing of wax patterns for casting frameworks. All remaining schools indicated their interest in incorporating digital technology as part of their RPD curriculum.

3.11. Non-Metal Clasp Dentures (NMCD) in the RPD Curriculum (Question 11)

Half of the schools are using non-metal clasp dentures in their curriculum. Most of these schools utilize these partials as immediate/interim partials or long-term interim partials, and a few schools use them as definitive partials for selective patient situations only. Most schools did not express interest in introducing NMCDs in their curriculum.

3.12. Implant-Assisted RPDs in RPD Curriculum (Question 12)

Twenty-five schools (69.4%) indicated that implant-assisted RPD (IARPD) concepts are being taught in their curriculum. Of these schools, IARPD treatment is provided as part of patient care in nineteen schools, and all of these schools utilize locator housings for the IARPDs. Of the eleven schools that do not have IARPD as part of their curriculum, half of them were interested in incorporating the therapy in their predoctoral educational programs.

3.13. Intra-Coronal Retainers in RPD Curriculum (Question 13)

Intra-coronal retainers were taught in less than 50% of the schools and usually only taught in lectures. There were three schools (8.3%) providing them as part of predoctoral clinical care.

3.14. Final Impression Techniques for Distal Extension Scenarios (Question 14)

Twenty-two schools (61.1%) reported using altered cast impression techniques only for selective patient scenarios. Seven schools (19.4%) reported teaching the altered cast impression technique for all distal extension (tissue-tooth supported) situations. Seven schools (19.4%) do not teach the altered cast technique.

3.15. Final Impression Material for RPD Metal Framework (Question 15)

Alginate and polyvinyl siloxane (PVS) are used equally amongst the schools for final impressions for RPD metal frameworks. Many schools utilize both impression materials.

3.16. RPD Clinical Requirements for Graduation (Question 16)

Twelve schools (33.3%) of the schools require a minimum of two RPDs for graduation. Six schools (16.7%) require four or more arches, while five schools (13.9%) did not have any specific requirements.

4. Discussion

Traditional RPD design concepts are being taught in the U.S. predoctoral curricula as demonstrated by the textbooks being used in a majority of schools (Stewart, McCracken, Kratochvil and Krol). Seventy-seven percent of responding schools are utilizing Krol or Kratochvil RPD design principles, similar to the 84% reported in 2003 [15].

Dental school curriculum time related to prosthodontics has declined significantly over the years [2]. Therefore, teaching methodologies that are effective, efficient, and practical are necessary [5]. Schools have attempted to do so by simplifying RPD design concepts and principles. Only nine schools (23.7%) reported utilizing incisal rests in the clinics. Although 27 schools (71.1%) reported teaching stress-breaking concepts, the high response rate may have been due to inclusion of stress-relieving clasp assemblies in addition to the usage of movable joints between the denture base and direct retainer, as the definition was not clarified in the survey. Intra-coronal retainers are being taught in the clinics of only three schools (8.3%). The majority of schools reported teaching three or less variations of stress-releasing clasp assemblies for distal extension scenarios. Fewer schools are teaching altered cast impression technique today (80.5%) compared to 96% in 1984 [4], and it is mostly used for selective scenarios. The practicality of teaching the altered cast technique may be brought into question [5], as only 6.2% of laboratory technicians reported its use in practice [4].

Although implant-assisted RPD (IARPD) was introduced many years ago and can significantly improve patient satisfaction, the integration of IARPD therapy into the predoctoral curriculum has been slow. Considering that a significant number of general dentists are now providing IARPD therapy and the fact that it is a satisfying treatment for partially edentulous patients [5,6], IARPD should be integrated into more predoctoral curriculums.

Digital technology has been widely adopted in fixed prosthetics through implant therapy, CAD/CAM indirect restorations, and surgical planning. Although the development of digital technology in removable prosthodontics has been slower, it will continue to increase as a result of improved learning, efficiency, and quality of treatment for our patients in the future [6,8]. Fifty percent of the schools have already incorporated digital technology into their RPD curriculum, and all remaining schools expressed interest in incorporating it in the future. This is a significant increase from only 19% of schools that had reported incorporating digital technologies from the RPD curriculum survey in 2001 [15]. Of the schools that had incorporated digital technology, eight schools utilize it in the clinic, mainly for fabricating metal frameworks. The use of digital technology in the RPD curriculum will increase in the future, including the use of digital impressions and digital software to survey and design frameworks. The application to framework designs, new materials, and improved precision and accuracy are likely to improve the outcomes for our educational programs and patients [8]. As described by Campbell et al. (2017), there is a need for clinical innovation in removable partial denture therapy, and digital dentistry offers this potential [8].

NMCDs have been gaining popularity with the rise of patient demand and desire for esthetics and a metal-free option [16]. However, NMCDs may cause damage to the remaining teeth and supporting tissues due to lack of rigidity of the material and as conventional design concepts such as occlusal rests and bracing are not or cannot be incorporated. Most schools did not express interest in incorporating conventionally, thermoplastically processed NMCDs (e.g., Valplast) in their curriculum. However, in order to respond to the growing demand of patients and the increasing use of NMCDs in private practice, dental schools need to incorporate NMCDs in their curriculum along with strict guidelines for indications and contraindications, design, and clinical use of such dentures; a metal

major connector with metal rests and proximal plates incorporated within a NMCDs may provide enough rigidity for long-term use. The introduction of digital dentistry provides access to a new world of medical-grade polymer framework materials, such as arlketone polymer (AKP), as an alternative metal-free option for RPD patients in the future. These high-performance polymer frameworks, coupled with computer design and manufacturing (CAD/CAM), have a potential to introduce a new level of accuracy, precision, and esthetics while maintaining adequate physical and mechanical properties [8].

Compared to the mean minimum RPD clinical requirement for the graduation of eleven units in 1990 [2], U.S. dental schools currently require fewer units for graduation. According to an RPD curriculum survey from 2006, 18% of dental schools did not have RPD clinical requirements for graduation [14]. This is similar to our result of 14%. A curriculum survey of Turkish dental schools reported that 94% of schools had requirements for graduation, and the mean number was eight units [12]. The mean minimum number of RPD requirements ranged between two to five in Ireland and the United Kingdom [17]. These numbers are similar to the results from our survey and those from Petropoulous and Rashedi (2006) [14]. From our survey, one-third of the responding schools require two RPD units for graduations, while only six schools (16.7%) require four or more arches. The decrease in RPD requirements may be attributed to the decrease in curriculum time and other factors such as access to implant therapy.

Based on the survey results, the authors suggest the following to consider in improving RPD curriculums:

- Incorporation of digital technology to improve the effectiveness of teaching through 3D visualization software in surveying, design, and treatment.
- Update curriculum to reflect common practices in private practice such as teaching IARPDs.
- Simplifying RPD metal framework design concepts to facilitate full understanding of difficult concepts.
- Frequent update of RPD curriculum to carefully remove obsolete concepts or materials and to incorporate new concepts and materials that will contribute to improved quality of dental education for students.

The limitations of this study include the limited number of responses to the survey and the fact it was self-reported data from each school. Thirty-nine of sixty-six U.S. dental schools responded to the survey, and the self-reported data were not verified. However, more than 50% participation was achieved, and results were consistent with previous surveys [14]. Therefore, the published data can help visualize the trends in the RPD curriculum within U.S. dental schools and the direction for future curriculum change. Since the survey was conducted in 2018, it is likely that changes in RPD curriculums had occurred, especially in regard to the adoption of digital technology.

The removable prosthodontic curriculum survey by Taylor et al. was divided into six geographic regions for comparison [4]. Due to the anonymous nature of our survey, the results could not be divided geographically or by other institutional differences (e.g., private vs. public school). The influence on the curriculum of geographical and other institutional differences may be beneficial in future studies to establish variations in RPD design principles, adoption of new materials, concepts, and digital technology.

5. Conclusions

U.S. dental schools reported RPD design principles and concepts that are being taught with varying degree of similarities and differences. Traditional concepts from McCracken, Stewart, Krol, and Kratochvill are still being utilized. More than half the schools are teaching three or less clasp assembly options for distal extension scenarios. This may be an attempt to simplify RPD metal framework design concepts and principles to provide more efficient and effective teaching in response to the decline in curriculum time in prosthodontics. Some traditional treatments and materials such as the incisal rest, polysulfide impression material, and intra-coronal retainers are becoming less relevant and new

treatment concepts such as IARPD, digital dentistry, and NMCD are being incorporated into the RPD curriculums. Future studies may identify the extent of digital technology incorporated in to the RPD curriculum in regard to surveying and design. The use of digital technology will become more relevant with the development of high-performance medical-grade polymer framework materials as an alternative metal-free option for RPD patients in the future.

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Informed Consent Statement: Not applicable.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Survey of Current Predoctoral Removable Partial Denture Curriculum

- (1) Which textbook is used? Select all that apply.
 - a. McCracken
 - b. Stewart's
 - c. Kratochvill
 - d. Krol
 - e. None
 - f. Other, Please describe _____
- (2) Which rest seats are advocated for anterior teeth that are not on maxillary canines? Select all that apply.
 - a. Cingulum rest
 - b. Lingual ball rest
 - c. Incisal rest
 - d. This scenario is avoided
 - e. Other, Please describe _____
- (3) Are incisal rests taught in the preclinical course and demonstrated in the clinic?
 - a. Yes, both in the course and clinic
 - b. Preclinical course only
 - c. It is not part of the RPD curriculum
- (4) Are stress-breaking concepts for RPD design included in the curriculum?
 - a. No
 - b. Yes
- (5) Regarding RPI clasp design, do you advocate the Kratochvil (RPI—Long Proximal Plate), Krol (Short Proximal Plate) theories, or somewhere in between?
 - a. Kratovil
 - b. Krol
 - c. Between (2/3 the proximal surface)
 - d. Other, Please explain _____
- (6) Which retainer clasps for distal extension RPDs are taught and preferred in the curriculum? Select all that apply.
 - a. RPI: Mesial rest, Distal Proximal plate, I-bar

- b. RPA(C): Mesial rest, Proximal Plate, Akers (Circumferential) clasp
 c. Combination clasp with mesial rest
 d. Combination clasp with distal rest
 e. Other, Please explain _____
- (7) What is preferred with the retainer that is placed anterior to the horizontal axis fulcrum line as in Kennedy class II modification scenarios? Select all that apply.
- a. Cast clasp engaging 0.01" undercut
 b. Wrought wire clasp engaging 0.02" undercut
 c. Cast clasp that embraces the tooth at height of contour (no engagement)
 d. Other, Please explain _____
- (8) What location is the undercut for the I-bar to engage?
- a. Mesio Buccal
 b. Mid Buccal
 c. Dist Buccal
 d. Other, Please explain _____
- (9) What is the preferred retainer clasp assembly for mesially tilted distal abutment molar? Select all that apply.
- a. Mesial rest, Ring clasp engaging ML 0.01" undercut
 b. Mesial rest, Akers clasp engaging DB created 0.01" undercut, Lingual reciprocal (bracing) arm
 c. Mesial rest, Akers clasp engaging DL 0.01" undercut, Buccal reciprocal(bracing) arm
 d. Extended mesial rest to half of the occlusal plane, embracing clasps on buccal and lingual without engaging undercuts
 e. Other, Please explain _____
- (10) Is digital dentistry a part of the RPD Curriculum?
- a. No
 If no, are you interested in incorporating digital dentistry in the RPD curriculum in the future? Yes _____ No _____
- b. Yes,
 If yes, check all the areas where digital dentistry is incorporated in the RPD curriculum.
 Preclinical courses only _____
 Preclinical courses and in the clinics _____
 Digital intraoral impressions _____
 Conventional impression and scanning of the master cast _____
 Framework design with design software _____
 Milled frameworks _____
 3D printed wax pattern is cast in a framework _____
 Other _____
- (11) Are non-metal clasp dentures (NMCD) such as thermoplastic resin, PEEK (poly-ether-ether-ketone) RPD frameworks taught in the RPD curriculum? (These are NOT interim resin partials with wrought wire clasps)
- a. Yes
 If yes, how is its use advocated? Select all that apply
- i. Immediate/Interim RPD
 ii. Long-term interim (transitional) RPD
 iii. Definitive RPD for selective cases
- b. No
 If no, are you interested in incorporating NMCDs in the RPD curriculum in the future?
 Yes _____ No _____

- (12) Are implant-supported RPDs included in the curriculum?
- a. No
If no, are you interested in incorporating implant supported RPDs in the RPD curriculum in the future? Yes _____ No _____
- b. Yes
If Yes,
Which attachment system is used? _____
- | | | |
|-----------------------|---|---|
| Lecture only | Y | N |
| Preclinical technique | Y | N |
| Clinics | Y | N |
- (13) Are intracoronal retainers (semi or precision attachments) taught in the curriculum?
- a. No
b. Yes
If Yes,
What kind of internal retainers are used?
- | | | |
|-----------------------|---|---|
| Lecture | Y | N |
| Preclinical technique | Y | N |
| Clinics | Y | N |
- (14) Which of the impression techniques do you teach for mandibular Kennedy Class I and II scenario? Select all that apply.
- a. Altered cast impression (two-step) for all extension cases
b. Altered cast impression (two-step) for selective cases
c. Single step impression with selective pressure
d. Single step
e. Other, please explain _____
- (15) Which impression material is used for the RPD final impression? Select all that apply.
- a. Alginate
b. Polyvinylsiloxane
c. Polysulfide
d. Other
- (16) How many RPD prosthesis are clinical requirements for graduation?
- a. 1
b. 2
c. 3
d. 4 or more
e. Other, Please explain _____

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