

ORIGINAL ARTICLE

Integrating Digital Denture Technology into a Prosthetic Techniques Curriculum in a Resource-Constrained Institution

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Abstract

Objective: To evaluate a CAD/CAM digital denture setup exercise in a second-year undergraduate preclinical prosthetic techniques course and explore student and dental technician perspectives.

Methods: Students completed an online questionnaire, and four dental technicians participated in a focus group.

Results: Students generally found the platform intuitive and useful for understanding tooth arrangement, self-assessment, independent learning, and confidence. Challenges included digital tooth arrangement, workload, technical issues, time constraints, and limited staff experience.

Conclusion: CAD/CAM technology can supplement preclinical prosthodontic education, but effective integration requires adequate training, educator feedback, and continued hands-on practice, particularly in resource-constrained settings.

Keywords: Digital Dental Technologies, CAD/CAM Dentures, Preclinical prosthetics, Digital Dentistry Curriculum.

INTRODUCTION

Digital innovation and technology in dentistry have advanced significantly in recent years. The increasing integration of digital complete dentures into modern dental education is influenced by several factors, including a notable rise in scientific publications, a growing number of manufacturers producing these prostheses, and wider adoption among practitioners [1-4]. Digital education encompasses web-based learning as well as the use of specialized digital tools, such as digital surface mapping, dental simulator motor skills, and digital radiography.

However, computer-aided design and computer-aided manufacturing (CAD/CAM) technologies, which involve the digital design and automated fabrication of dental prostheses, have not been as extensively adopted in removable prosthodontics as in fixed prosthodontics [5, 3]. Digital clinical and laboratory tools related to removable prosthodontics have gradually been incorporated into

university curricula for both postgraduate and undergraduate programs, alongside traditional manufacturing techniques [6]. As digitization progresses within dentistry, integrating digital workflows into the dental curriculum has become an essential component of contemporary education [7, 2, 4]. Dental undergraduate curricula worldwide have successfully included these digital technologies, although the extent of implementation varies according to local resources and needs [8].

Digital dental education programs focusing on removable denture making, including three-dimensional (3D) printing and intraoral scanning, have been introduced to enhance students' spatial ability, interactive learning, critical thinking, and understanding of clinical correlations [8]. Incorporating a digital program provides a more intuitive learning experience, meeting the expectations of highly tech-savvy dental students, both current and

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incoming cohorts, who are continuously exposed to digital technologies and social media [5]. Additional benefits of digital technologies include enabling dental students to objectively evaluate their work [8] and supporting various learning modalities, such as self-directed, distance, and asynchronous learning [5]. Removable prosthodontic courses have used these digital platforms to allow students to learn and practice denture fabrication and digitally place teeth, without the need for in-person instruction [9].

However, caution is necessary when integrating digital technologies into traditional courses, as well as in determining the appropriate timing for their introduction. While it is essential to prepare undergraduate students for the digital dentistry landscape, they must first establish a strong foundation in conventional treatment strategies and processes before encountering advancements in denture construction [8]. Developing hand-eye coordination and preclinical laboratory skills remains a prerequisite for conventional clinical practice. Traditionally, the preclinical curriculum has been designed to build students' manual dexterity for various clinical procedures within a low-stakes environment, using a standardized approach on typodonts and providing ample opportunity for practice before they begin caring for patients [10].

Complete denture preclinical training provides an essential foundation for Preclinical Techniques (PRT200), a second-year module in the undergraduate dental program at a South African university. The module covers all laboratory procedures involved in constructing complete removable dentures. Arranging complete denture teeth is labor-intensive, costly, and time-consuming for dental schools [9]. Students therefore spend several hours undertaking the practical procedures involved in complete denture construction.

At this dental school, dental technicians teach and demonstrate the necessary preclinical skills for complete dentures, supervised by the academic department. Dental educators deliver the theoretical component of complete denture construction, using various teaching and learning strategies, such as preclinical worksheets, narrated video recordings of all laboratory procedures, and a flipped classroom approach. These methods aim to prepare and equip students with the knowledge needed to fabricate complete dentures.

In the South African context, edentulousness is on the rise [11], and the institution has fostered an environment that supports complete denture construction. Dental students receive comprehensive exposure to both preclinical and

clinical procedures throughout their training. Clinical treatment of edentulous patients begins in the third year, with students expected to complete an average of six full dentures by graduation. Internationally, integrating digital denture construction into the curriculum, either as a supplement to or in conjunction with conventional methods, has become increasingly important [1]. However, in resource-limited settings, insufficient funding restricts the adoption of digital technology in dental education.

Among the laboratory stages involved in complete denture fabrication, understanding the principles of correct artificial tooth arrangement is crucial because it affects both aesthetics and function. Students must not only understand what constitutes an appropriate tooth arrangement but also develop the ability to adjust the positions of teeth in trial dentures prepared by a dental laboratory technician [1].

Currently, several computer programs that guide tooth placement are available. These platforms enable students to learn the art of denture fabrication and place teeth digitally without the need for in-person instruction. They allow students to create and customize dentures using a design that guides tooth arrangement [9]. The digital platform generates a score by comparing each student's tooth arrangement with the "perfect setup". This comparison may help to standardize assessment across faculty members. The availability of such digital technologies or programs allows teaching to remain current and relevant while exposing students to both traditional and digital methods of instruction in tooth arrangement [12]. However, procuring digital technologies for dentistry, including annual licenses, is unaffordable for many dental schools in developing countries. Therefore, innovative strategies are required to integrate digital technologies into dental student training. Despite this financial limitation, the primary researcher sought access and permission to use a limited version of DENTCA™ in the preclinical denture construction course at a South African dental school.

The CAD/CAM Denture Company [13] is one of the digital systems available for the digital setup of artificial teeth. It provides two web-based platforms: (1) DENTCA™ Academy, which includes a selection of exercises for students to practice complete denture tooth arrangement, and (2) DENTCA™ Design, an automated tooth arrangement software program that uses uploaded digital patient information to fabricate complete dentures. The CAD/CAM denture platform was incorporated into

the preclinical prosthetics course to enhance students' education and practical experience without physically using wax and teeth to complete the setup. The aim of this paper is twofold: first, to describe the evaluation of this CAD/CAM digital method as an adjunct to the preclinical training of second-year undergraduate dental students; and second, to explore dental technicians' views of students' performance following exposure to CAD/CAM technology.

METHODS

The study was approved by the Biomedical Science Research Ethics Committee. The research followed a mixed methods paradigm. For the quantitative component, all students who completed the preclinical prosthetics course in 2021 ($n = 77$) were included. An online questionnaire was used to assess students' perspectives on implementing the CAD/CAM exercise before the manual preclinical procedures. The questionnaire was adapted from an instrument used by Schlentz et al. [7]. Modifications involved only changes to terminology specific to prosthetic dentistry and the CAD/CAM software used by students at this university. The scoring system was applied as described in the reference [7]. The questionnaire contained evaluative statements focusing on the online teaching of concepts related to artificial tooth setup; online tutorials explaining the CAD/CAM exercise; the use of CAD/CAM exercises; preclinical videos; demonstrations; laboratory-based, hands-on preclinical setup procedures; and student motivation. Students' responses to the statements were recorded using a five-point Likert scale ranging from 'strongly disagree' to 'strongly agree'.

Data from the questionnaires were captured in an Excel spreadsheet and imported into Stata version 16 [14] for analysis. Descriptive statistics were generated, and chi-square tests were performed for nominal data. Results were considered statistically significant at $p < 0.05$.

For the qualitative component of the study, a focus group interview was conducted with the four dental technicians responsible for preclinical training. The session was facilitated by an independent dental educator with expertise in qualitative research. An interview protocol guided the discussion, with questions exploring the participants' perspectives on exposure to CAD/CAM technology and its effect on student performance in the preclinical course. The discussion was transcribed verbatim and uploaded to ATLAS.ti for analysis. Themes

were identified through thematic analysis and interpreted accordingly.

RESULTS

Quantitative: Results from the Questionnaire

The questionnaire assessed students' perspectives on implementing the CAD/CAM exercise before the manual preclinical procedures, with the results presented in Table 1. Responses to each question were categorized from strongly agree to strongly disagree. The findings are descriptive, with the percentage for each response indicated in brackets. The questionnaire addressed four dimensions: handling, didactic teaching, motivation, and the overall assessment of the complete denture. Students were able to evaluate their tooth setup immediately, with 16% strongly agreeing and 47% agreeing that this was a *feasible technique*.

Most students agreed that the didactic report generated by the software was easy to understand (agree: 59%; strongly agree: 16%), while only 13% collectively selected disagree or strongly disagree. From a didactic perspective, students indicated that including the CAD/CAM software in future undergraduate programs would be valuable, as reflected by a combined agreement of 74%. The chi-square test of independence produced a nonsignificant result ($p = 0.741641$). Students also agreed that the use of CAD/CAM software should be extended to other complete upper and lower denture procedures in the senior years.

In terms of the *motivation* category, 27% of students indicated that using the CAD/CAM software was a chore, while a further 27% were unsure. However, within the same category, 78% reported improved confidence, and 69% agreed that using the CAD/CAM software would prepare them for future dental practice. Notably, 26% of students were unsure about its preparatory effect. The relationship between confidence in future practice and the inclusion of CAD/CAM software as preparation for professional practice was supported by a nonsignificant result from the chi-square test of independence ($p = 0.0909482$), indicating consistency in students' responses across these variables.

Results for the *handling* category, specifically the ease of software use, showed that most students agreed (53%) or strongly agreed (29%). Regarding the overall assessment of denture setup, students preferred CAD/CAM software evaluation (56%) to clinical supervisor evaluation (44%). This finding was reflected in the *didactic teaching* category,

Table 1: Questionnaire and participants' responses

Categories	Questions (Tick the appropriate response)	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
A: HANDLING						
1.	The menu guidance of the CAD/CAM software is easily to understand.	20 (29%)	37 (53%)	6 (9%)	6 (9%)	1 (1%)
2.	When using the CAD/CAM software, no serious difficulties were experienced.	16 (23%)	30 (43%)	13 (19%)	8 (11%)	3 (4%)
3.	The analysis of the preparation (tooth setup) with CAD/CAM software is feasible.	11 (16%)	33 (47%)	18 (26%)	7 (10%)	1 (1%)
4.	After the demonstration and exercises, I feel confident to use CAD/CAM software by myself.	17 (24%)	35 (50%)	13 (19%)	4 (6%)	1 (1%)
5.	Problems were encountered for anterior tooth arrangement for the full/full set up.	12 (17%)	30 (43%)	9 (13%)	18 (26%)	1 (1%)
6.	Problems were encountered with posterior tooth arrangement for the full/full setup.	15 (21%)	12 (17%)	18 (26%)	18 (26%)	7 (10%)
B: DIDACTIC TEACHING						
7.	The workflow/guidelines of the CAD/CAM software are clear and understandable.	14 (20%)	42 (60%)	9 (13%)	3 (4%)	2 (3%)
8.	Seeing my full/full set up on the monitor and getting an objective analysis with CAD/CAM software, trains my own judgment.	18 (26%)	42 (60%)	9 (13%)	1 (1%)	1 (1%)
9.	The CAD/CAM software report is helpful in improving my own performance regarding full/full setups.	21 (30%)	29 (41%)	14 (20%)	4 (6%)	2 (3%)
10.	The CAD/CAM software report is easy to understand.	11 (16%)	41 (59%)	9 (13%)	6 (9%)	3 (4%)
11.	The CAD/CAM software should be included in future undergraduate programs.	21 (30%)	31 (44%)	14 (20%)	3 (4%)	1 (1%)
12.	CAD/CAM sessions must be extended to other full/full procedures during senior years.	19 (27%)	27 (39%)	20 (29%)	2 (3%)	2 (3%)
C: MOTIVATION						
13.	Using new technologies (e.g., CAD/CAM software) motivated me.	14 (20%)	45 (64%)	9 (13%)	1 (1%)	1 (1%)
14.	Analyzing my own full/full set up with the CAD/CAM software motivated me.	13 (19%)	42 (60%)	13 (19%)	1 (1%)	1 (1%)
15.	I do not think that CAD/CAM software as an additional course component is a chore.	5 (7%)	27 (39%)	19 (27%)	15 (21%)	4 (6%)

Table 1: Questionnaire and participants' responses (Cont'd)

16.	Sessions on CAD/CAM can provide greater confidence for practice if included in the dental program.	17 (24%)	38 (54%)	13 (19%)	1 (1%)	1 (1%)
17.	Sessions on CAD/CAM use throughout the dental program will prepare students for future practice.	18 (26%)	30 (43%)	18 (26%)	3 (4%)	1 (1%)

D: OVERALL ASSESSMENT

If you consider the following aspects of the assessment of your full/full setups, which type of assessment would you prefer? (Tick the appropriate box: <i>DENTIST</i> or <i>CAD/CAM software</i>)		DENTIST	CAD/CAM software
18.	Less time	25 (36%)	45 (64%)
19	Enjoy practicing more	45 (64%)	25 (36%)
20.	Greater fault tolerance	14 (20%)	56 (80%)
21.	More tips/better feedback	47 (67%)	23 (33%)
22.	Easier handling	31 (44%)	39 (56%)

in which students indicated that using the CAD/CAM software enhanced their judgment, with 60% agreeing and 26% strongly agreeing. The easy-to-understand report generated by the software further supported this perception (strongly agree: 16%; agree: 59%).

The CAD/CAM-generated report was also considered helpful in improving performance (strongly agree: 30%; agree: 41%) and motivating students by enabling them to analyze their own setup (strongly agree: 19%; agree: 60%). These positive responses were primarily attributed to the introduction of the new software (strongly agree: 20%; agree: %), indicating that the integration of digital technology into a traditionally hands-on preclinical didactic and skills development course was well received. The chi-square result ($p = 0.831453$) indicated consistency among students' receipt of objective analysis from the CAD/CAM software, development of independent judgment, and confidence in continuing to use the software.

Students perceived the software as requiring less time to assess full upper and lower setups (64%) than dentists (36%) and therefore regarded the software as more fault tolerant (80%). By contrast, dentists were perceived as having a low level of fault tolerance (20%). However,

students expressed a stronger preference for practicing and repeating the full upper and lower setups when assessed by dentists (64%) rather than by the software (36%). One possible explanation is that human interaction with dentists provided more effective and relatable feedback (67%) on both current and future setups. These findings suggest that students valued feedback from dentists who

identified their mistakes and provided detailed, specific guidance on the errors encountered.

Dentist supervision and feedback were especially important during anterior tooth setup, which students identified as the most difficult stage to complete using the CAD/CM software (agree: 60%; disagree: 27%). In contrast, responses regarding the posterior teeth were nearly evenly split (agree: 38%; disagree: 36%). Most students (74%) reported feeling confident in independently using the software, particularly after the demonstration; however, challenges with arranging the anterior teeth remained. A chi-square test of independence was conducted to examine the relationship between students' confidence in using the software and their ability to arrange anterior and posterior teeth. The association between these variables was statistically significant ($p = 0.000208$).

Qualitative Results from the Focus Group Interviews

Two major themes emerged from the focus group interviews: *advantages* (Theme 1) and *challenges* (Theme 2) of using CAD/CAM in PRT200. Participants also provided feedback on broader issues affecting the course.

Theme 1: Advantages of CAD/CAM Integration

Participants highlighted several advantages of incorporating CAD/CAM into the PRT200 course, including its contribution to teaching and learning:

“Technological devices are aiding the teaching process of the PRT200 course; therefore it can be seen as a benefit”.

Participants also emphasized the importance of prior exposure to CAD/CAM systems:

"Students need to have prior knowledge of the CAD/CAM system, before engaging in the PRT200 course. This prior knowledge aids in the understanding of the course".

Furthermore, participants noted the value of early practice using CAD/CAM prior to laboratory sessions:

"Students need to practice on CAD/CAM before going into their practical sessions in the lab".

The integration of digital technology offers several advantages, including facilitating the teaching process for this preclinical course and allowing students to visualize an ideal denture tooth arrangement.

Theme 2: Challenges Associated with CAD/CAM Use

Participants also identified challenges associated with using CAD/CAM in PRT200. One concern involved the perceived limitation of the software in accurately replicating clinical reality:

"Although CAD/CAM is a great visualization tool, it is impractical in the extent that students can only place teeth in segments/quadrants. They therefore experience frustration when they cannot do this in reality".

Technical challenges were also reported:

"Technical issues lecturers and students have faced when using CAD/CAM".

Participants further highlighted limitations in staff exposure and experience with the system:

"We lacked exposure and experience to the CAD/CAM system. How can we teach students how to use CAD/CAM if they have not used it extensively themselves?"

Some of the challenges of CAD/CAM highlighted were limitations of the CAD/CAM systems, time constraints within the prosthetic course, pressure to finish the course, and frustration experienced by students.

General Comments Related to PRT200

In addition to CAD/CAM-specific challenges, participants expressed broader concerns about the PRT200 course. Unrealistic student expectations were noted as a source of frustration:

"Students have unrealistic expectations when it

comes to the module and completing tasks. This leads to them experiencing frustration".

Time constraints within the module were also highlighted:

"The PRT200 module is only done over four days according to the lecturers. This includes learning how to use the CAD/CAM system, doing practical sessions, and studying".

Students reported frustration when they were unable to complete the conventional tooth setup, particularly when comparing these outcomes with the more successful digital setups. Broader course-related constraints further contributed to their frustration with the PRT200 module.

DISCUSSION

The integration of technology into courses and practical modules is becoming increasingly important as education becomes more digitalized. CAD/CAM software enables students to practice arranging teeth virtually for complete upper and lower dentures. Students generally reported positive attitudes toward the usability, educational value, and motivational impact of CAD/CAM, especially in preclinical skills such as denture tooth arrangement. Increased motivation among students using digital complete denture software was attributed to repeatable, engaging, and clinically relevant exercises, as well as a greater perceived sense of competence, autonomy, and interest [15, 3].

Dental technicians also recognized the value of digital tooth setup technology as a supplement to traditional teaching and practice. A previous study found that digital and conventional custom tray assessments complemented each other by distinguishing between conceptual understanding and motor skills [6].

Students typically described the software as intuitive and easy to learn in terms of handling; however, technical difficulties persisted, particularly with anterior teeth. The findings suggest that while the software is user-friendly and provides effective guidance, additional hands-on preclinical practice or software refinement may be necessary to address specific clinical competencies.

Regarding the didactic value of CAD/CAM, students reported that digitally visualizing and assessing their setups enhanced comprehension and facilitated deeper learning. The software is designed to foster independent learning, increase student motivation, and simultaneously evaluate theoretical knowledge and practical skills [16]. Students noted that the software increased motivation and

helped build confidence for clinical practice; however, approximately one-third regarded it as an additional workload.

Dental technicians also expressed concerns about the increased demands placed on students. They identified challenges such as time constraints and pressure to complete the prosthetics course, which must be addressed to successfully incorporate this technology into the curriculum. These concerns indicate the importance of balancing its integration with the existing course structure. Overall, students viewed CAD/CAM as a valuable addition to artificial tooth setup because of its efficiency and objectivity, but they still valued personal feedback and engagement from technicians and dental educators. These findings point to the potential benefits of combining digital accuracy with human insight. Many dental schools support a hybrid approach that combines digital and traditional workflows rather than transitioning entirely to digital methods [15].

Feedback from the technicians indicated that students experienced frustration when they were unable to perform equally well using both the digital software and the hands-on setup. Significant differences were apparent between the motor skills required for hands-on work and those required in the digital environment. Other researchers have also raised concerns that integrating digital technology may occur at the expense of mastering fundamental skills in conventional denture fabrication [2]. The student results revealed strong acceptance of and enthusiasm for CAD/CAM software within the preclinical course. Students reported that the technology was motivating and beneficial for learning, although challenges related to tooth setup, handling, and perceived workload persisted. More effective integration of CAD/CAM into the curriculum, supported by guidance from educators and technicians, has the potential to improve both learning and engagement, aligning with the perspectives of other students [3].

To address the concerns identified, careful consideration must be given to the timing of digital setup and training, with clear specification of the intended digital learning outcomes. Findings from a previous study indicate that students who completed digital training before undertaking the manual activity achieved higher scores for the manual custom tray [6]. These results align with the technicians' perspectives, indicating that students benefit from practicing with the CAD/CAM denture setup before completing hands-on practical procedures.

Digital technologies require adequate time for educators to

familiarize themselves with the learning process before students engage with the technology [16]. The acquisition of skills, such as depth and spatial perception and fine motor abilities supported by theoretical understanding, has traditionally formed the foundation of teaching. Incorporating software for artificial tooth arrangement as a supplementary tool helps reinforce theoretical knowledge. For example, students must understand the theory related to the position and angulation required when setting the central incisor on the occlusal table, the height of the lateral incisor relative to the central incisor, and the incisal height and angulation of the canine before undertaking digital tooth arrangement.

Digital tools can complement traditional hands-on teaching, enabling students to develop spatial ability and clinical reasoning [6]. Integrating digital tools as adjuncts to traditional courses reinforces students' theoretical knowledge. Preclinical instruction may incorporate 3D design software and simulation tools to develop spatial skills and improve design precision [15]. Furthermore, students benefit from the flexibility to engage with these tools independently, at their own pace, and to self-assess, thereby fostering self-directed learning. Incorporating digital methods into the conventional preclinical curriculum creates opportunities for students to progress in removable prosthodontics, with the additional advantages of personalized and self-paced learning [9]. Combining digital and manual practical sessions also broadens the range of available learning media [6].

CONCLUSION

The findings of this study indicate that dental students favor incorporating CAD/CAM digital methods as a supplementary component of the preclinical training in the second-year undergraduate dental prosthetic techniques course. Similarly, dental technicians support the integration of this software, agreeing that it provides considerable educational benefits alongside the hands-on preclinical course. Feedback from both students and technicians highlights the need for careful consideration of timing, curriculum adjustments, and comprehensive software training to maximize the educational benefits of this integration.

Integrating technology into preclinical courses enables students to receive repeated objective evaluations from software, fostering the development of their judgment and increasing their confidence throughout the digital learning process. Incorporating digital technologies into student

training can improve both the quality of education and the overall learning experience [16]. Based on the feedback, CAD/CAM software should be further applied to additional upper and lower denture procedures in the senior years.

It is important to recognize that digital technologies require significant financial investment [15, 16]. Consequently, faculty and researchers in resource-constrained settings must explore alternative strategies, establish partnerships, and seek additional funding opportunities to facilitate student access to digital technologies, thereby enhancing learning and clinical practice. The university's overarching aim is to equip dental students to be both contextually responsive and globally competitive [17].

Blending traditional and digital approaches to complete denture fabrication is essential for preparing dental students for the complexities of contemporary practice, where adaptability and proficiency in both methods are increasingly valued [15]. Integrating digital technologies can significantly enhance the quality of education, particularly through self-directed learning tailored to individual pace and needs. Furthermore, the successful incorporation of digital technologies into conventional curricula across both preclinical and clinical settings requires ongoing interdisciplinary research, clinical application, and support, with a focus on the influence of these advancements on patient outcomes.

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