AMERICAN DENTAL EDUCATION ASSOCIATION
ADEA JOURNAL OF DENTAL EDUCATION
ADEA THE VOICE OF DENTAL EDUCATION

Comparison of digitally assessed quality of posterior crown preparations with and without previous practice on patient-specific 3Dprinted teeth models

Journal:	*Journal of Dental Education*
Manuscript ID	Draft
Manuscript Type:	Original Article
Keywords:	Educational Technology < Education, Clinical Skills/Topics, Preclinical Skills/Topics, Psychomotor Skills < Behavioral Sciences, Advanced Dental Education < Clinical Skills/Topics
Author designated keywords:	3D printing, digital dentistry, self-confidence

ABSTRACT

INTRODUCTION:

3D-printing technology can provide customizable simulations, but its effects on patient care quality have not been well studied. This study aimed to assess the impact of practicing with patient-specific 3D-printed teeth models on the quality of 'patients' dental preparations performed by students transitioning to clinical training. Accordingly, the quality of posterior crown preparations was evaluated by objectively analyzing digital scans and grades in two groups: the study group, which practiced beforehand with patient-specific 3D-printed teeth models, and the control group, which did not practice with these models.

METHODS:

All seventy-eight fourth-year dental students who had just finished their fixed prosthodontics course at the simulation laboratory with training on phantom heads and without previous clinical experience in crown preparations were invited to participate in the study. sixty-eight agreed to take part and were randomly divided into a study group that practiced crown preparations on 3D-printed models of their own 'patient's teeth and a control group that did not practice with 3D-printed models and started their clinical work straightforward after simulation training. Students completed validated perception questionnaires on self-confidence and clinical skills before and after the protocol, which were compared using a chi-squared test. Crown preparations performed on 3D-printed models and then on patients were digitally scanned and objectively graded by prepCheck® software for critical parameters, such as undercuts, taper, and occlusion reduction. Non-parametric tests were used to compare preparations on 3D-printed models and on patients performed by the study group and those on patients made by the control group.RESULTS:

Initially, both groups reported similar perceptions of self-confidence and clinical skills levels. The study group significantly improved both aspects after the protocol. Analysis of the scanned preparations demonstrated that the study group removed less tooth structure from actual patients

than from the initial 3D-printed models. In contrast, the control group showed excess occlusal clearance in their patients compared to the study group.

CONCLUSIONS:

Practicing patient-specific 3D-printed teeth before performing procedures clinically appears to enhance preparation quality and minimize unnecessary tooth reduction in early clinical experiences.

Keywords: Dental education, 3D printing, clinical skills, digital dentistry

INTRODUCTION

The development of clinical motor skills is essential to train dental students and is a crucial part of the dental curriculum.[1, 2] Thus, the pre-clinical years of the undergraduate dental program concentrate on the development of 'students' psychomotor skills to reach a level needed for the students to transfer to clinical courses with patient treatment.[1]

To be ready for this challenge, students practiced performing treatments with phantom heads and typodonts in simulation laboratories, a protected environment, under ideal working conditions. However, this approach does not always replicate the experience of practicing with live patients.[3, 4]

Previous studies have reported that studying dentistry can be stressful and that pre-clinical to clinical transition work is recognized as a source of stress, fear, and anxiety. [4-10] This is primarily due to clinical exposure; that is, students are exposed to the demands of clinical dentistry combined with academic requirements.[6] There are studies describing the so-called "shock of practice" on students, which is the result of the change experienced when moving from working in a simulated clinical environment with phantom heads or mannequins to providing dental care to real patients.[8]

Traditionally, pre-clinical dental training consists of the students repeating procedures on phantom heads mounted with articulated dental arch models with ivory teeth, virtual learning environments, and lately with 3D-printed teeth.[6, 11, 12] This approach allows students to enhance their accuracy, quality, and efficiency by improving their technical skills and enabling them to reach the level of competence needed for the transfer to clinical work.[1] Despite this training, students do not always feel prepared for clinical exposure and direct patient treatment.[6] With the purpose of bridging the gap between pre-clinical and clinical work, some studies have used patient-specific 3D-printed models, providing a valuable contribution to students' self-confidence and autonomy.[6, 12] However,

despite the reported positive results, whether this protocol produced better quality tooth preparations in patients has not been well studied.

Conventionally, the way of assessing the quality of students' work both in pre-clinical and clinical environments has been through teacher observation, which must be as objective and consistent as possible.[13] However, despite calibration efforts, visual inspection of the assessment of students' work showed significant disparity.[14] The development of intraoral scanning and digital grading software programs has been very useful in dental education, as they allow for automatic analysis of dental preparations, eliminating subjectivity in the assessment process. The software automatically informs students of the quality of a preparation through visual elements, providing immediate and objective feedback.[15-18]

This pilot study, based on deliberate practice theory,[19] aimed to compare fourth-year dental students' posterior crown preparation quality with and without previously practicing the same tooth preparation using patient-specific 3D-printed teeth models; preparation quality was objectively assessed through intraoral scanning followed by digital grading. These students had no clinical experience on their own, as they were starting to treat patients independently and had just been approved for independent clinical work after completing their pre-clinical course. They previously just worked in pairs helping fifth-year students.

MATERIALS AND METHODS

Ethical approval

The [redacted] Scientific Ethical Committee reviewed and gave the study its full approval (reference number CEC202021).

Participants

All seventy-eight fourth-year dental students (57 females, 21 males, mean age 22.0 years, SD 1.1) from the Integrated Adult Clinic I 2022 who had just finished their course on fixed prosthodontics at the simulation laboratory with training on phantom heads, and therefore had no previous clinical experience in crown preparations, were invited to participate in the study. Before the study started, participants read and signed a written consent document explaining the protocol. Volunteers were randomly divided into two groups utilizing a random formula in Excel®. The first group (study group) practiced crown preparations on their first patient with patient-specific 3D-printed teeth models at the simulation laboratory before performing the same preparations in the clinic on their patients after completing the pre-clinical fixed prosthodontics course. The second group (control group) performed crown preparations on their patients after completing the pre-clinical fixed prosthodontics course but without practicing on patient-specific 3D-printed models. The control group of students practiced crown preparations on patient-specific 3D-printed models of their second patient.

Perception questionnaires

Based on previous studies[3, 12, 20] and our own experience, two draft questionnaires were developed.

The first one (a questionnaire with four Likert-style items) was created to assess both study and control group students' perceptions about their preparedness to perform crown preparations before the study started. The second one (a questionnaire with nine Likert-style items and one open-ended question for 'students' comments) was designed to evaluate the study group's

perceptions of the experience after practicing with the patient-specific 3D-printed teeth models and treating their patients.

During successive feedback from all tutors involved in the study, a draft of both questionnaires that included all relevant questions to the purpose of the study was developed. Subsequently, to ensure the face validity of the forms, the complete protocol was explained to seven fifth-year students who had practiced with 3D-printed models of their patients during the previous year [6] and were asked to complete the pen-and-paper questionnaires and provide feedback.

Study protocol

Study group: After completing the pre-clinical fixed prosthodontics course and when this group of participating students had devised a treatment plan to perform a crown preparation, they scanned the teeth of both jaws of their patients with a CEREC Omnicam (Dentsply Sirona, York, Pennsylvania, USA) and exported the obtained files in stereolithography (STL) format to be designed as solid blocks using 3D design software (PreForm - Formlabs, Somerville, Massachusetts, USA). Subsequently, the STL files were three-dimensionally printed in the same dimensions as a single material using a 3D printer with a photopolymer temporary crown and bridge rigid resin material color Vita A2 (Form3 - Formlabs). In previous studies, the post cured resin has shown a Vickers microhardness of 28.9±2.9[21] and a flexural strength of 138.6 ± 17.1 MPa[22]. As a comparison and according to the manufacturer, the Frasaco® (Tettnang, Germany) typodont has a Shore-D hardness of 90, which would be in the range of 50 to 70 Vickers microhardness.

Before starting their crown restorations in the clinic, students in this group returned to the simulation laboratory to practice crown preparations on their patients' 3D-printed models mounted on phantom heads (Figure 1). Each student received two 3D-printed models on which to practice with the same instruments as those used in the clinic. In the simulation lab, students were given a set of sterilized but used burs to work on the 3D-printed models to compensate for the softness of the resin.

During all practicing sessions in the simulation laboratory, two instructors were available to provide students with feedback. Once finished, the preparation that students had done on the patient-specific 3D-printed models and on their patients under staff guidance were digitally scanned and graded using prepCheck® Pro 5.0.x software (Sirona Dental Systems); the three parameters considered critical by our clinical staff were as follows: undercuts (0.0–0.5 mm tolerance), preparation taper (4° – 12° tolerance) and distance between the preparation and the antagonist tooth (1.75–3.0 mm tolerance, ideal value 2.38 mm). As time was limited for the students, all scanning and analysis were conducted by one experienced instructor.

Furthermore, before starting the practice with the 3D-printed models, this group of students anonymously completed the first questionnaire to assess their perceptions about the preparedness to perform a crown restoration. After practicing with the 3D-printed models, students were asked to anonymously fill in the second questionnaire so that the answers in the first questionnaire about their perceptions of their practical skills and self-confidence, as well as about the utility of the experience, could be evaluated.

Control group: After approving the pre-clinical fixed prosthodontics course and before starting their clinical work, in the same way as the study group, these students anonymously completed the same first questionnaire so that the initial perceptions of both groups could be compared. These students worked directly on their patients under staff guidance once the treatment plan had been approved without practicing on 3D-printed models. Once the crown preparations in their patients were ready and approved, they were digitally scanned and digitally graded using prepCheck® software.

Data analysis

Likert-style answers from the two questionnaires were first descriptively studied. Subsequently, answers from both groups of students (study and control) were compared using a chi-squared test

to assess whether their perceptions about their preparedness to perform indirect restorations before the protocol were the same (Table 1).

Furthermore, two items from the first and second questionnaires assessed the same construct (clinical skills and self-confidence, Q1 and Q2 from Table 1 and Table 2). These were analyzed using a chi-squared test to determine whether there was a difference between students' opinions of the study group before the 3D-printed models' practice and after this experience.

Reports of the digital grading from prepCheck® were obtained from the digitally scanned preparations performed in the 3D-printed models and those in the patient by the study group. Using the non-parametric Wilcoxon test, as the data had a non-normal distribution, the three studied parameters (undercuts, preparation taper, and distance between the preparation and the antagonist tooth) of these two reports were compared to study whether there was a difference between the same type of preparations performed in the patient-specific 3D-printed models and those performed in the patients. Crown preparations in the patients of the control group were also digitally scanned and analyzed with prepCheck® software. Data for these preparations were compared to those from the patients in the study group using the non-parametric Mann–Whitney U test, as the data had a non-normal distribution.

The data were organized into Microsoft Excel spreadsheets (Microsoft Excel, Microsoft Inc., Washington, USA) and statistically processed using SPSS Windows® version 27 (SPSS IBM Inc., USA). *p* values of less than 0.05 were considered statistically significant, and the same researcher grouped all comments from the second questionnaire.

RESULTS

Each group consisted of 34 students (87% of a class of 78 students). Evaluation of the answers in the first questionnaire showed that both groups (study and control) had similar perceptions about the four assessed items (Table 1) (p>0.116). Both groups mostly felt prepared to treat patients according to their clinical skills, self-confidence, and knowledge and felt that the practice they had in the pre-clinical laboratory course prepared them to perform crown preparations on their patients.

The study group's perceptions about their clinical skills and self-confidence increased significantly (p<0.001) after practicing with the patient-specific 3D-printed models, changing mostly from ""agree"" to ""completely agree"", as well as decreasing the ""neutral"" option (Figure 2). Table 2 shows the study group's responses to the second questionnaire after students practiced with patient-specific 3D-printed models. They mostly expressed the opinions that having practiced with their patient-specific 3D-printed models was an enriching experience, that it helped them to develop their practical skills, that it was more realistic than the simulation with typodont, that they would like to practice more often with patient-specific 3D-printed models, and that the time invested was worth it. Not surprisingly, given the hardness of the used resin the majority of participants expressed their perception that practicing with the 3D-printed models was not like drilling dental enamel, but that it was like drilling typodont.

PrepCheck® analysis comparing undercuts in the crown preparations of the study group in 3D-printed models and those performed in the patients showed no difference (p=0.111), with a very low percentage of surfaces having undercuts (Table 3).

When comparing the preparation taper of the study group, there was a significant excess in the percentage of surface reduction in the 3D-printed model preparations compared to those in their patients (p=0.031). The percentage of the surface with adequate reduction was significantly higher

in the preparation performed on the patients (p=0.014), while that of not enough reduction was similar on both occasions (p=0.139) (Table 3).

In relation to the distance between the preparation and the antagonist tooth, the mean percentage of the excess surface reduction the study group made on the patients was significantly less than that on the 3D-printed model (p<0.001). This means that the students removed less tooth structure in the patient, reaching a mean of 42.1% of the tooth surface with adequate reduction (Table 3).

When comparing the study and control groups (Table 4) undercuts, these showed no significant difference (p=0.819), with both being very low. Concerning the preparation taper, the study group showed a significantly higher percentage of a surface with adequate reduction (p<0.001), while the control group removed significantly more tooth structure in the patients when compared to the study group (p=0.011).

Something similar was observed when the distance to the antagonistic tooth was studied. The control group showed a significantly higher percentage of excess reduction than the study group (p<0.001), with the latter presenting a significantly higher percentage of adequate reduction (p=0.044).

From the thirty-four students in the study group, twenty (59%) provided comments in the second questionnaire, that is, after practicing with the 3D-printed models (Table 5). These comments were mostly positive and related to the useful opportunity to practice with their own patient models before performing the actual treatment.

DISCUSSION

The current study aimed to compare fourth-year dental students' posterior crown preparation quality with and without previously practicing the same tooth preparation using patient-specific 3D-printed teeth models by objectively assessing with intraoral scanning followed by digital grading using the prepCheck® system.

Before the study began, both groups of students (study and control) had similar perceptions regarding their clinical skills, self-confidence, and knowledge to perform a posterior crown preparation (Table 1), which means their start point perceptions were comparable. Although they thought their pre-clinical course prepared them to perform crown preparations, there were many students who wanted to practice these skills more with patient-specific 3D-printed models before performing the treatment on their patients. In this regard, some studies reported that dental students feel less confident in crown preparations[23-25] despite this being considered a key skill in predoctoral dental training.[26] In fact, our study group's perceptions about their clinical skills and self-confidence increased significantly after the deliberate practice protocol. Furthermore, the experience was rated as positive, and they highlighted its realism.

The boosted perception of self-confidence might have been the main reason for the enhanced clinical performance of the study group in executing the clinical task after practicing with their patient-specific 3D-printed models. As Meisha et al.[27] concluded, self-confidence in clinical procedures predicts future clinical success. In another study with patient-specific 3D-printed models, students expressed that their "self-confidence increased after practicing with the 3D models in a risk-free environment", and that it "…was like working on familiar ground".[6]

Another reason for this might have been the extra time students of the study group spent practicing with their 3D models. However, it should be noted that this was performed in a single session, which could be considered too brief to account for their enhanced clinical performance. Participants in this study practiced performing ten crown preparations on a typodont in the

simulation lab throughout their fixed prosthodontics pre-clinical training, in addition to one performed at the end of the course as part of their final practical skills exam. Passing this, along with other skills and theoretical tests, deemed them ready for clinical work, and they advanced to the next course to work with patients. This is supported by both the study and control groups' perceptions that they possessed the clinical skills necessary to perform the crown treatment on their patients and that they felt that the pre-clinical practice prepared them to perform this treatment on their patients.

Despite this, studies indicate that students find transitioning from pre-clinical to clinical training challenging, expressing desires for more practice time to refine motor skills and feel more prepared for patient treatment.[6] They also call for "…more realistic simulation training, though it is never enough"[28], even while expressing confidence in beginning patient treatment.

The majority of participating students expressed their perceptions that practicing with the 3D-printed resin models was not like drilling dental enamel, though they perceived it similar to carving typodont. A common criticism of practicing with 3D-printed models is the inadequate hardness when compared to natural teeth,[29] indicating that they can only offer a generic experience of what to expect during the actual procedure.[30] Similar to our results, a recent publication comparing students' perception of drilling patient-specific 3D-printed and VR models reported that half of participants did not feel that it was like drilling real dental enamel.[6]

Concerning the preparation undercuts, both groups of students showed minimal and similar values that were not significantly different. This is probably because preparations showed a high percentage of preparation taper. Murbay et al.[31] found in a study with undergraduate students preparing complete coverage dental crowns in a first molar with and without magnifying loupes that the majority of both groups of students had no undercuts. It should be mentioned that the students of the mentioned study had completed demonstrations and hands-on preparations in the simulation laboratory in seven different crown preparations before the study.

Regarding taper, the study group procedures performed on their 3D-printed models and the control group procedures performed on their patients, demonstrated an excess of reduction in similar values: 51.3% in the study group (on 3D-printed models) and 49.3% in the control group (on patients). However, after the protocol of practicing with patient-specific 3D-printed models, the reduction in 'patients' tooth structure was significantly less in study group (33.6%) when compared to that in the control group (49.3%). This indicated that a simulated previous practice in patient-specific 3D-printed models of the crown preparations that students had to perform on their patient, together with a tutor's feedback, helped them to correct the excess of resin material reduction previously noted when they performed the procedure on the 3D-printed models. It should be remembered that the existence of undercuts or overtapers is a major factor leading to a critical deficiency of full-veneer crown preparations [26] and that overtapering during crown preparations could involve pulp damage. Furthermore, and as stated by Strain et al.,[32] as adhesive types of cement can overcome poor technical preparations, there is a need for the preservation of tooth structure.

Strain et al.,[32] in their systematic review, found that it was difficult for dental students to achieve ideal taper angles and that increasing the taper of a preparation results in a more significant loss of coronal tissue and an increased biological cost of the restoration. Alhazmi et al.[33] reported that students prepared tapers of crown preparations with greater values than the ideal range, with the highest values on mandibular molars compared to maxillary premolars. Notably, in the present study, there was no such difference, probably because 88% of the sample were premolars.

A study by Matthisson et al.[1] that used prepCheck® to assess the progress of third-year dental students grinding a maxillary central incisor for crown preparation six times plus a practical examination, showed a mean of 53.0% above tolerance of tooth removal in the first session, which is very similar to the taper excess reduction found in our study (51.3% for the study group in the 3D-printed models and 49.3% for the control group in their patients). Furthermore, during the second session, the percentage of tooth structure removed above tolerance decreased to 37.3%,

which is closer to the 33.6% of our study group when they prepared the crowns in their patients after practicing with 3D-printed models. The study by Murbay et al.[31] with and without magnifying loupes also reported that between 43.9% and 47.5% of the preparations taper of both groups of study was within tolerance. This is similar to the outcome for our study group, which prepared 43.5% of the surface tooth area with an adequate reduction in the patients; the control group only did so for 25.7% of the tooth area in the patients.

Concerning the distance between the preparation and the antagonistic tooth, there was also a significant difference between the excess reduction in the study group when they practiced on the 3D-printed models (20.7%) and when they practiced on their patients (8.2%). Once again, the excess reduction noted in the patients treated by students in the control group (21.2%) was similar to that of patients treated by students in the study group when they first practiced on the 3D-printed models (20.7%). Most importantly, the control group's excess reduction in the patients (21.2%) was significantly higher than that in patients treated by students in the study group (8.2%). This indicated that practicing on patient-specific 3D-printed models with constant feedback can reduce the potential harm to the tooth structure.

The present study had some limitations. As raised by the students, when practicing with 3D-printed models, it is not possible to distinguish different tissues, such as gingiva, fillings, and decay, and models are printed in one block, making it difficult to remove approximal surfaces. These factors make the practicing on the model different from working in a real environment. Furthermore, the resin material used to print the 3D models is softer than tooth enamel, although similar to that of typodonts. The cost of implementing the 3D printing machinery as well as that of the resin itself must be considered. Finally, the small sample size and the fact that the study was performed in a single school does not allow for generalizations.

CONCLUSION

'The study compared a group of dental students that practiced with patient-specific 3D-printed teeth models to a control group that did not. Initially, both groups had similar perceptions of their self-confidence and clinical skills. However, after the study group practiced on 3D-printed teeth models replicating their own patients, their perceptions of self-confidence and clinical skills significantly increased. The deliberate practice protocol with patient-specific 3D-printed models was found to enhance preparation quality and preserve tooth structure in early clinical experiences.

Acknowledgments: This study was funded by a grant from the [redacted]

Disclosure: The authors declare that they have no conflict of interest with any products presented in this article.

The data pertaining to the findings of this study are available on request.

REFERENCES

1. Matthisson L, Zitzmann NU, Zaugg LK, Joda T. Potential of intraoral optical scanning to evaluate motor skills' improvement for tooth preparation: A prospective cohort study. Eur J Dent Educ 2022:26(4):669-75.

2. Jofré J, Michel M, Quintana P, Fuentes J, Conrady Y, Valenzuela D, Asenjo-Lobos C. Mental training in dentistry: A scoping review. Eur J Dent Educ 2023:00:1-7.

3. Lee B, Kim JE, Shin SH, Kim JH, Park JM, Kim KY, Kim SY, Shim JS. Dental students' perceptions on a simulated practice using patient-based customized typodonts during the transition from preclinical to clinical education. Eur J Dent Educ 2022:26(1):55-65.

4. Kashbour WA, Kendall J, Grey N. Students' perspectives of early and gradual transitioning between simulation and clinical training in dentistry and their suggestions for future course improvements. Eur J Dent Educ 2019:0:1-11.

5. Collin V, O'Selmo E, Whitehead P. Stress, psychological distress, burnout and perfectionism in UK dental students. Br Dent J 2020:229(9):605-14.

6. Tricio JA, Kleiman SE, Eiriksson VI, Vicuña DP, Cacciuttolo FR, Jorquera GA, Córdova CG, Gualda JI, Gutiérrez MF, Villalón PA, Orsini CA. Students' and tutors' perceptions of a deliberate simulated practice using patient-specific virtual and three-dimensional printed teeth models: A pilot study. J Dent Educ 2022:86(8):1006-14.

7. Botelho M, Gao X, Bhuyan SY. An analysis of clinical transition stresses experienced by dental students: A qualitative methods approach. Eur J Dent Educ 2018:22(3):e564-e72.

8. Serrano CM, Botelho MG, Wesselink PR, Vervoorn JM. Challenges in the transition to clinical training in dentistry: An ADEE special interest group initial report. Eur J Dent Educ 2018:22(3):e451-e7.

9. Alzahem A, Van der Molen H, Alaujan A, Schmidt H, Zamakhshary M. Stress amongst dental students: a systematic review. Eur J Dent Educ 2011:15(1):8-18.

10. Gorter R, Freeman R, Hammen S, Murtomaa H, Blinkhorn A, Humphris G. Psychological stress and health in undergraduate dental students: fifth year outcomes compared with first year baseline results from five European dental schools. Eur J Dent Educ 2008:12(2):61-8.

11. Serrano CM, Wesselink PR, Vervoorn JM. First experiences with patient-centered training in virtual reality. J Dent Educ 2020:84(5):607-14.

12. Towers A, Dixon J, Field J, Martin R, Martin N. Combining virtual reality and 3D-printed models to simulate patient-specific dental operative procedures—A study exploring student perceptions. Eur J Dent Educ 2022:26(2):393-403.

13. Schepke U, van Wulfften Palthe ME, Meisberger EW, Kerdijk W, Cune MS, Blok B. Digital assessment of a retentive full crown preparation—An evaluation of prepCheck in an undergraduate pre-clinical teaching environment. Eur J Dent Educ 2020:24(3):407-24.

14. Sharaf AA, AbdelAziz AM, El Meligy OA. Intra-and inter-examiner variability in evaluating preclinical pediatric dentistry operative procedures. J Dent Educ 2007:71(4):540-4.

15. Renne WG, McGill ST, Mennito AS, Wolf BJ, Marlow NM, Shaftman S, Holmes JR. E4D Compare Software: An Alternative to Faculty Grading in Dental Education. J Dent Educ 2013:77(2):168-75.

16. Jorquera G, Sánchez JP, Sampaio CS, Atria P, Fernández E. Improvement preclinical and clinical skills for dental preparations using assisted training software. Eur J Dent Educ 2021:25(4):856-63.

17. Miyazono S, Shinozaki Y, Sato H, Isshi K, Yamashita J. Use of digital technology to improve objective and reliable assessment in dental student simulation laboratories. J Dent Educ 2019:83(10):1224-32.

18. Yu W, Zhu Z, Su T, Weng W, Xu C. A pilot study on the use of a novel digital real-time evaluation system in undergraduate preclinical training of tooth preparation in fixed prosthodontics. Eur J Dent Educ 2022:0:1-7.

19. Ericsson KA. Acquisition and maintenance of medical expertise: a perspective from the expert-performance approach with deliberate practice. Acad Med 2015:90(11):1471-86.

20. Sinha A, Osnes C, Keeling AJ. Pilot study assessing 3D-printed teeth as a caries removal teaching tool. Eur J Dent Educ 2022:26(2):329-36.

21. Crenn M-J, Rohman G, Fromentin O, Benoit A. Polylactic acid as a biocompatible polymer for three-dimensional printing of interim prosthesis: Mechanical characterization. Dent Mater J 2022:41(1):110-6.

22. Nam N-E, Hwangbo N-K, Kim J-E. Effects of surface glazing on the mechanical and biological properties of 3D printed permanent dental resin materials. Journal of Prosthodontic Research 2023:D 22 00261:1-10.

23. Ali K, Slade A, Kay E, Zahra D, Tredwin C. Preparedness of undergraduate dental students in the United Kingdom: a national study. Br Dent J 2017:222(6):472-7.

24. Hattar S, AlHadidi A, Altarawneh S, Hamdan AAS, Shaini FJ, Wahab FK. Dental students' experience and perceived confidence level in different restorative procedures. Eur J Dent Educ 2021:25(1):207-14.

25. Pandarathodiyil AK, Mani SA, Ghani WMN, Ramanathan A, Talib R, Zamzuri AT. Preparedness of recent dental graduates and final-year undergraduate dental students for practice amidst the COVID-19 pandemic. Eur J Dent Educ 2023:27(1):78-86.

26. Park CF, Sheinbaum JM, Tamada Y, Chandiramani R, Lian L, Lee C, Da Silva J, Ishikawa-Nagai S. Dental Students' Perceptions of Digital Assessment Software for Preclinical Tooth Preparation Exercises. J Dent Educ 2017:81(5):597-603.

27. Meisha DE, Al-dabbagh RA. Self-confidence as a predictor of senior dental student academic success. J Dent Educ 2021:85(9):1497-503.

28. Tricio J, Garcés G, Vicuña D, Orsini C. Contrasting student and staff perceptions of preclinical-to-clinical transition at a Chilean dental school. Eur J Dent Educ 2023:27(4):773-83.

29. Dobroś K, Hajto-Bryk J, Zarzecka J. Application of 3D-printed teeth models in teaching dentistry students: A scoping review. Eur J Dent Educ 2023:27(1):126-34.

30. Towers A, Dixon J, Field J, Martin R, Martin N. Combining virtual reality and 3D-printed models to simulate patient-specific dental operative procedures—A study exploring student perceptions. Eur J Dent Educ 2021:n/a(n/a).

31. Murbay S, Neelakantan P, Li KY, Pow EHN. Effect of magnifying loupes on tooth preparation of complete coverage crown: A quantitative assessment using a digital approach. Eur J Dent Educ 2023(0):1-7.

32. Strain KJ, Mackie J, Bonsor SJ, Macfarlane TV. Crown Taper Angles Achieved by Dental Students: A Systematic Review. J Dent Educ 2018:82(11):1203-12.

33. Alhazmi M, El-Mowafy O, Zahran MH, Uctasli S, Alkumru H, Nada K. Angle of convergence of posterior crown preparations made by predoctoral dental students. J Dent Educ 2013:77(9):1118-21.

Figure 1. Patient-specific three-dimensional (3D)-printed jaws mounted on a phantom head.

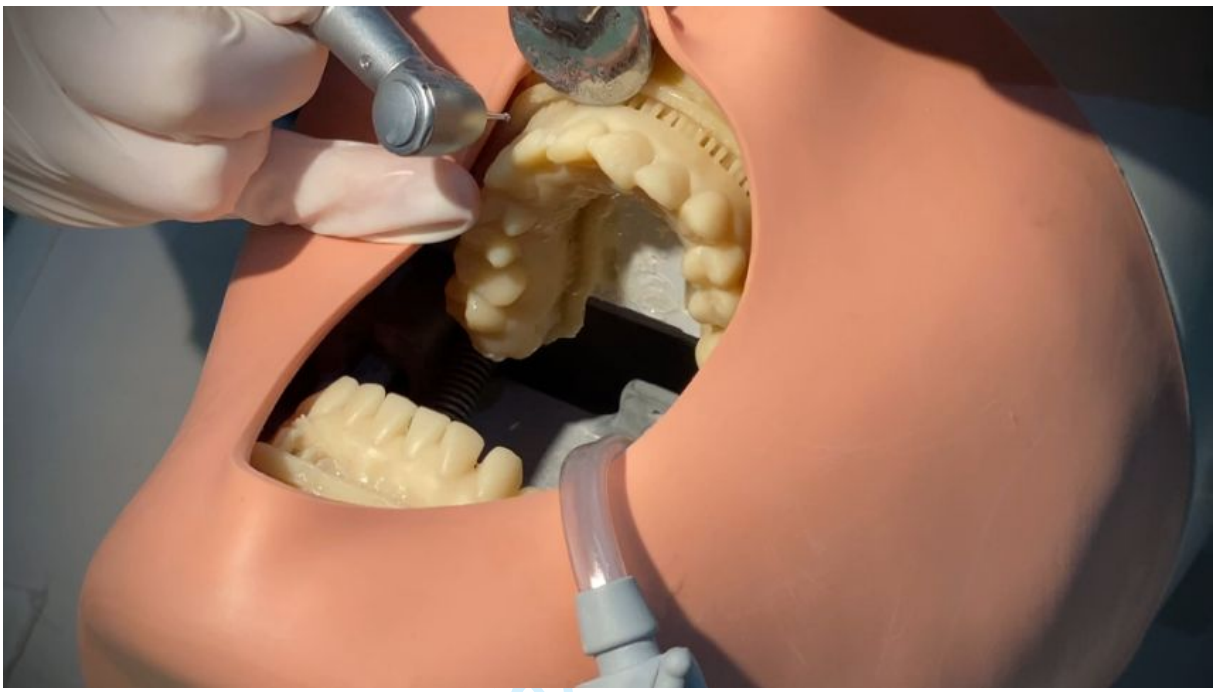

Figure 2. Study group (N.34) perceptions about their clinical skills and self-confidence before and after practicing with patient-specific 3D-printed teeth models. *p* value of the difference between their perceptions (chi-squared test).

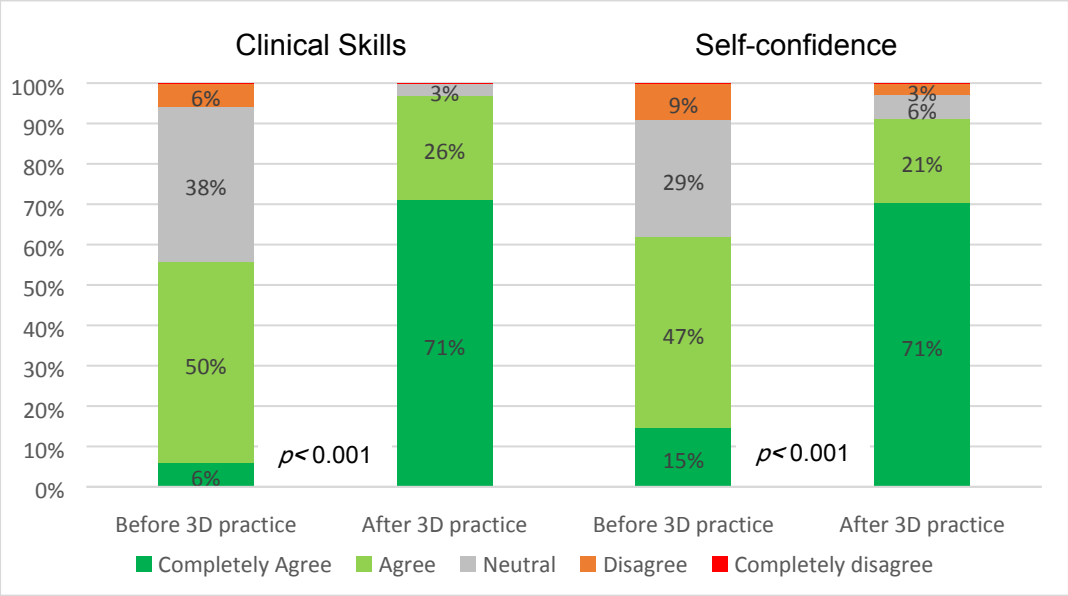

Table 1. Percentages of the responses of the students in the study (N.34) and control (N.34) groups in the first questionnaire, that is, before treating patients and practicing on 3D-printed models (study group) and before treating patients (control group). *p* value of the difference between the study and control groups (chi-squared test).

Statement		Study Group					Control Group					*p* value
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	
Q1	I feel that I have the clinical skills to perform this treatment on my patient	5.9%	50.0%	38.2%	5.9%	0%	5.9%	67.6%	23.5%	2.9%	0%	0.489
Q2	I feel that I have the self-confidence to perform this treatment on my patient	14.7%	47.1%	29.4%	8.8%%	0%	5.9%%	58.8%	23.5%	11.8%	0%	0.553
Q3	I feel that I have the knowledge to perform this treatment on my patient	8.8%	64.7%	20.6%	5.9%	0%	0%	70.6%	11.8%	17.6%	0%	0.116
Q4	I feel that the pre-clinical practice I did prepared me to perform this treatment on my patient	14.7%	47.1%	29.4%	8.8%	0%	5.9%	58.8%	23.5%	11.8%	0%	0.398

Table 2. Percentages of the responses of students in the study group (N.34) in the second questionnaire, that is, after having practiced with the patient-specific 3D-printed teeth models of their own patients.

Statement		Study Group				
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Q1	I feel more prepared in my clinical skills to treat patients after practicing with the 3D-printed model of my patient	70.6%	26.5%	2.9%	0%	0%
Q2	I feel that I have greater self-confidence to perform this treatment on my patients after practicing on the 3D-printed model of my patient	70.6%	20.6%	5.9%	2.9%	0%
Q3	Having practiced with the 3D-printed models was an enriching experience	64.7%	32.4%	2.9%	0%	0%
Q4	Having practiced with the 3D-printed models did not help to develop my practical skills	5.9%	8.8%	0%	20.6%	64.7%
Q5	I feel the experience of having practiced with 3D-printed models was a more realistic simulation than practicing with pre-clinical typodont	35.3%	26.5%	20.6%	17.6%	0%
Q6	I would like to be able to practice more often with patient-specific 3D-printed models before performing this treatment on my patient	31.0%	43.3%	11.0%	8.8%	5.9%
Q7	I feel that practicing with the 3D-printed models was like drilling typodont	13.5%	47.1%	33.5%	5.9%	0%
Q8	I feel that practicing with the 3D-printed models was like drilling dental enamel	0%	3.8%	35.1%	55.2%	5.9%
Q9	I do not think the time invested in practicing with 3D-printed models was worth it	0%	0%	2.9%	20.6%	76.5%

Table 3. Comparison of the study group (N=34) results (%) by parameter for each criterion in those preparations performed first in 3D-printed models and then on patients. *p* value of the difference comparing the studied criterion (Wilcoxon test).

Parameter	Criterion	Mean	SD	*p* value
Undercut	Presence of undercuts in the 3D model	0.01	0.02	0.111
	Presence of undercuts in the patient	0.03	0.04	
Preparation taper	Adequate reduction in 3D the model	31.4	15.6	0.014
	Adequate reduction in the patient	43.5	20.6	
	Not enough reduction in the 3D model	17.3	14.6	0.139
	Not enough reduction in the patient	22.9	18.0	
	Excess of reduction in the 3D model	51.3	24.5	0.031
	Excess of reduction in the patient	33.6	22.4	
Distance between the preparation and the antagonist tooth	Adequate reduction in the 3D model	42.1	16.4	0.095
	Adequate reduction in the patient	51.9	23.9	
	Not enough reduction in the 3D model	37.2	20.9	0.561
	Not enough reduction in the patient	39.9	20.6	
	Excess of reduction in the 3D model	20.7	17.9	<0.001
	Excess of reduction in the patient	8.2	15.6	

Table 4. Comparison of the study (N=34) and control (N=34) group results (%) by parameter for each criterion in preparations performed on patients. *p* value of the difference comparing the studied criterion of both groups (Mann–Whitney U test).

Parameter	Criterion	Mean	SD	p value
Undercut	Presence of undercuts in patients in the study group	0.03	0.04	0.819
	Presence of undercuts in patients in the control group	0.04	0.05	
Preparation taper	Adequate reduction in patients in the study group	43.5	20.6	<0.001
	Adequate reduction in patients in the control group	25.7	14.7	
	Not enough reduction in patients in the study group	22.9	18.0	0.980
	Not enough reduction in patients in the control group	25.0	22.1	
	Excess reduction in patients in the study group	33.6	22.4	0.011
	Excess reduction in patients in the control group	49.3	28.1	
Distance between the preparation and the antagonist tooth	Adequate reduction in patients in the study group	51.9	23.9	0.044
	Adequate reduction in patients in the control group	43.0	21.8	
	Not enough reduction in patients in the study group	39.9	20.6	0.128
	Not enough reduction in patients in the control group	35.8	27.1	
	Excess reduction in the patients in the study group	8.2	15.6	<0.001
	Excess reduction in the patients in the control group	21.2	23.7	

Table 5. Study group comments after following the deliberate practice protocol for working with patient-specific 3D-printed teeth models.

It was a helpful and excellent experience
It helped me to be a lot more self-confident when treating patients
It helped me to better understand the practical concepts of performing tooth preparations and where I need to improve
Being able to practice before performing the treatment on the patients was enjoyable
It helped to reduce anxiety when treating patients
It helped me to develop practical skills and improved the quality of the preparation in the patient and, therefore, their treatment
Practicing with 3D-printed models differs from working with the patient as it is impossible to distinguish gingiva, fillings, and decay
It was a helpful experience, especially when entering the clinic and starting to treat patients
It helped me to better understand the concepts of crown preparations
The approximal surfaces are difficult to remove as teeth are in one block and are a single color
There is a lot to gain and nothing to lose when practicing with 3D-printed models
It is a good way to practice and improve the skills necessary to treat each patient as he or she deserves