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ORIGINAL ARTICLE

Development of a three-dimensional printed model from a digital impression of a real patient for aesthetic dentistry undergraduate teaching

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Abstract

Introduction: The acquisition of skills and manual dexterity in aesthetic dentistry in undergraduate teaching requires preclinical practices with simulation that should approximate real clinical situations.

Objective: We will present a digital procedure for the creation of three-dimensional (3D) resin models adapted to the practices of the Aesthetic Dentistry course.

Material and method: Stereolithography or Standard Tesellation Language (STL) files of a real patient were previously obtained with a 3-shape intraoral scanner. Using the Exocad computer programme for dental prosthesis design, various modifications were made, such as incisor rotation, surface alterations imitating dysplasias or erosions, the creation of diastemas, or even changes in tooth size. The virtual model was printed in resin for use by students. Once the practices were finished, the students and the teachers evaluated the use of the 3D printed models.

Results: The result is the typodont model, in which seven laboratory sessions took place: 1-Restoration of conoid tooth morphology, 2-Cervical abrasion/ erosion restoration, 3-Direct Composite Veneer, 4-Aesthetic correction in a tooth with rotation, 5-Diastem closure, 6-Occlusal abrasions/ erosion, and 7-Maryland bridge. 90.48% of the students evaluated the designed 3D model as the best method for laboratory practice compared to other methods, obtaining a general assessment of 8.3 out of 10.

Conclusion: The method used has provided a reproducible standard analog model for direct aesthetic dental restoration practice, with a good assessment by students and teachers.

KEYWORDS
composite resins, curriculum, dental aesthetics, dental education, dental schools, surveys and questionnaires, teaching

1 | INTRODUCTION

The acquisition of skills in aesthetic dentistry varies according to the curriculum of the different faculties. Sometimes the discipline of dental aesthetics is optional and sometimes compulsory, imparting the skills only theoretically or having laboratory and clinical practices.[1] Dental aesthetics shares competencies with other areas of dentistry such as dental anatomy, dental materials, dental surgery, prosthetics, or orthodontics, which makes it multidisciplinary in nature.

The aesthetic dental problems that a patient can present are highly varied and the origin can be in genetic problems, with alterations in the color, shape, and texture of the dental tissues or problems acquired after the formation of the tooth where we include among other causes those due to loss of dental structure, whether of bacterial, chemical or mechanical origin, trauma, malpositions, etc. Once the aesthetic problem of the patient has been analyzed, the restorative clinical treatment must be carried out, for which aesthetic adhesive dentistry allows rehabilitative treatments to be carried out, returning both the masticatory and aesthetic function to the patient and giving the dentist direct solutions with relatively simple,[2,3] minimally invasive techniques, which are the goals of both contemporary and cosmetic dentistry.[4] The student must acquire the skills and manual dexterity necessary to handle direct restorative treatments during their undergraduate training, which requires preclinical practice with a simulation that must approximate real clinical situations.

In addition to direct techniques, mastery of aesthetic treatment also requires indirect techniques for veneers, inlays, or onlays. The skills for these treatments are obtained through laboratory practices with analog simulation models and practices with virtual simulation. Through simulation with analog models, the student can acquire skills in cavity preparations and in the handling of materials in the restoration phase of the preparations. Such practices are usually carried out in preclinical laboratories with individual natural or plastic teeth or with commercial heads three-dimensional (3D) printed models, in which carvings and fillings can be performed. Virtual 3D haptic simulation allows the practice of carvings and cavity preparations, being able to perform them with the isolated tooth or within the oral cavity of the virtual haptic 3D patient; however, with this method, it is not possible to practice the restorative phase of the treatments, so the two methods (Laboratory practices with analog virtual models and practices with virtual models in 3D haptic simulators) are complementary. But in neither of the two methods, with the models the industry currently offers, does the student have a tooth with structural anomalies such as those that can be found in the real practice of aesthetic dentistry? This is the main reason why we designed a model created through virtual reality with the Exocad program and 3D printed that allows us to have dental alterations like those that can be found in a real patient, in addition to having the patient model digitized with an STL file will enable us to transfer it to the 3D haptic virtual simulator.[5]

The practical activities can be done individually or in groups. Ihm et al.[6] advise teamwork of five or six students, since it especially benefits low-achieving students, concluding that it improves critical thinking as well as a deeper understanding of cosmetic dentistry. At the same time as the regulated activities, the students use other methods for their training, such as clinical demonstrations.[7] He et al.[8] report that 27% of students use YouTube videos, warning those responsible for the acquisition of skills of the possibility of acquiring erroneous knowledge by viewing videos online without scientific rigor.

Therefore, the skills that dentists must acquire during their undergraduate training in aesthetic dentistry must offer them the knowledge and skills necessary to address patients' aesthetic issues according to the clinical case they present, which are undoubtedly different in each case. Theoretical and preclinical education with laboratory practices is required to know the aesthetic concepts that govern this matter,[9–11] master dental anatomy and knowledge of materials and their practical handling, as well as know the indications and limitations of clinical treatments. For this, it is necessary, together with theoretical teaching, the resolution of clinical cases and practical exercises with real clinical simulations. The use of real models with 3D printing is an alternative to carrying out preclinical practices where digital technology and analog simulation practices are used. Examples of this include those used by Giacomini et al.[12] for preclinical training in oral radiology, or by Marsden et al.[13] who, through the reproduction with 3D printing of simulated patients based on real cases, study whether the confidence of the students could be improved, obtaining very satisfactory results and concluding that the cases of simulated patients can be

a useful precursor or complement to traditional patient clinics.

Therefore, the aim of this study was to develop a specific model with dental structural anomalies using 3D printing where students can perform direct aesthetic treatments to correct anatomical problems that may be a consequence of dental anomalies or loss of dental structure due to parafunction.

2 | OBJECTIVE

1. Design and describe the development process of a digital model printed with 3D technology from the file obtained from the scan of a real patient to which changes have been made in the shape, size, and position of the teeth.
2. Use the 3D printed model for seven preclinical practices in the dental aesthetics laboratory.
3. To ascertain the views of staff and students on the use of this 3D printed model in the preclinical practices of dental aesthetics.

3 | MATERIAL AND METHOD

This research was conducted with the approval of the administration of the ADEMA University School, the University of the Balearic Islands, and the informed consent of the patient for the totally anonymous use of the file obtained from the scan of their teeth.

To select a human reference model for the design of cases for aesthetic dentistry practices, the criteria are:

- That the person is a patient of the clinic for orthodontic or aesthetic dentistry treatment and has given signed consent to transfer their image, records, and molds for scientific studies.
- That the patient does not have restorative, prosthetic, or implant treatments.
- That there is no absence or agenesis of dental organs
- The size and shape of the teeth do not present disproportions from the average.
- The anonymity of the file is guaranteed

We consider that a young patient with complete permanent teeth who needs an orthodontic study is ideal, as it is the situation that most closely matches the requirements, we consider essential.

In the work we present in this manuscript, the file used for the development of the aesthetic model came from a patient undergoing a study for orthodontic treatment who accepted the use of the digital file of the intraoral scan performed for the creation of a virtual model for aesthetic dentistry practices.

3.1 | Model design

A Trios scanner (3-Shape unit) version 1.7.31.1 was used to take digital records of the oral cavity of an adult patient.

The generated files were converted to the STL, which is a file format for computer-aided design and is characterized as being a three-dimensional mesh with no information on the texture or color of the digitized object.

With the Exocad version 3.0 Galway computer design program, the lower mandibular model (Model A) and the upper maxillary model (Model B) were processed.

The changes made were:

a. Extractable lower incisors 3.1 and 4.2
b. Light rotation of 3.1 and 4.2
c. Dysplastic stains or irregularities of 1.1 and 2.1
d. Diastema between 1.1 and 2.1
e. Conoidism 1.2
f. Agenesis of 2.2 and 2.3 instead of 2.2
g. Cervical erosions and abrasions in the posterior sector
h. Erosion and abrasion of the occlusal surface 1.6-3.6

3.1.1 | Lower mandibular model (Model A)

First, applying the so-called "Expert" mode, its "extract pieces" tool was used to remove incisors 3.1 and 4.2 from the model (Figure 1). This modified model had to be saved again in the file, also in STL format.

Second, we proceeded to "Export scene as mesh STL" (Model B) to the main Manager area. In the Exocad design area, we marked that 31 and 42 will be pontic-type artificial pieces (such as those used in the edentulous spaces of a prosthetic bridge).

Applying these criteria, the STL mesh model B with the simulation of incisors 3.1 and 4.2 already extracted was retrieved from the file. The pontic-type artificial pieces 4.2 and 3.1 were then loaded, and we positioned them in the space of the simulated extractions of model B, but already with the desired rotation and inclination for the practice models (Figure 1).

In "Save", it was already filed as a C model, and using the utility "Export scene as mesh STL", it was saved in another separate file.

3.1.2 | Upper jaw (Model B)

Third, to generate enamel defects, reduction in dimensions, or occlusal modifications in the upper jaw model,

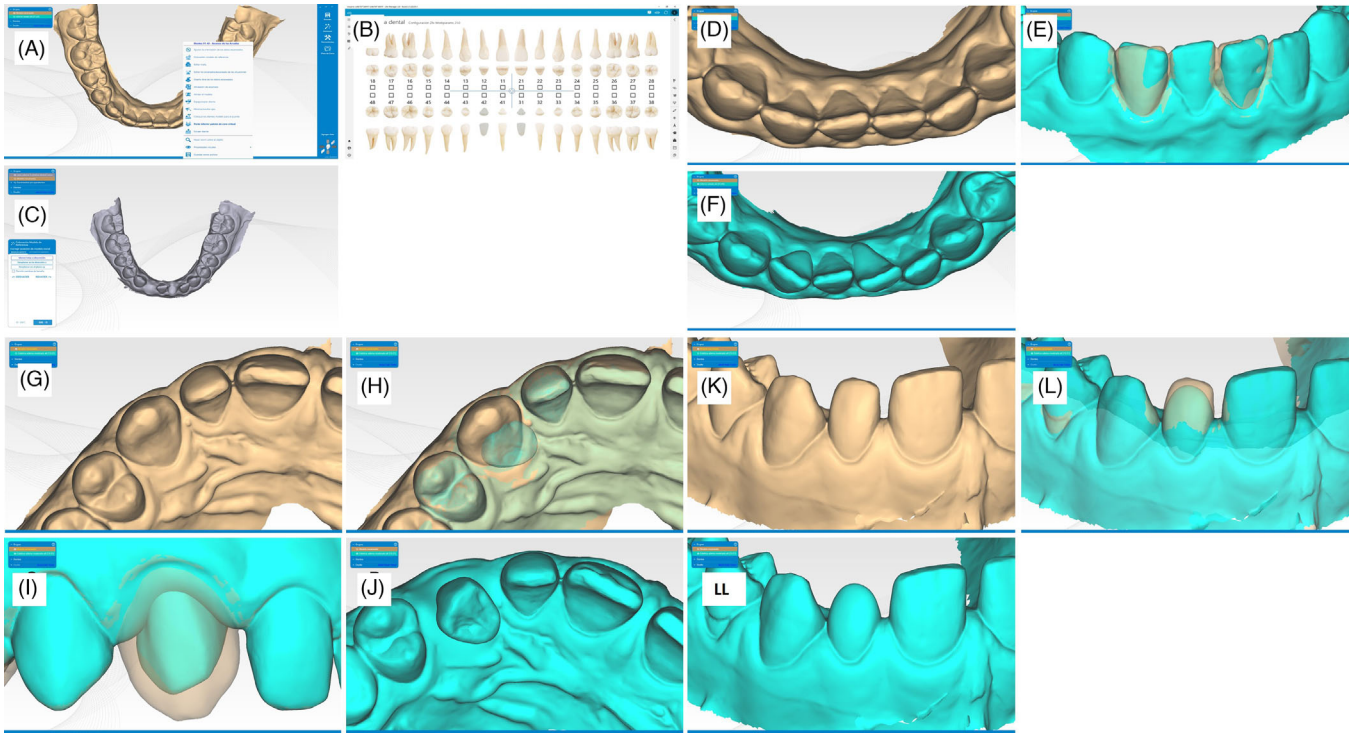

FIGURE 1 (A) Stereolithography or Standard Tesellation Language (STL) file of real patient. (B) Capture of Exocad dental prosthetic design program (C) STL file of the final case prepared to be three-dimensional (3D) printed. (D) To real patient STL file. (E) Simulation with the design program of the desired incisor rotations. (F) File final modification performed. (G) STL file of real patient. (H, I) virtual modeling of a decidual canine. (J) Final STL file of canine change made. (K) Real patient STL file. (L) digital simulation of a conoid incisor. (LL) Conoid tooth STL file.

which would allow students to practice their treatment by applying composites, the oral scan of the STL file had to be uploaded, the "Expert" function was chosen, and by applying the right button on the digital image, we proceeded to the data-free design. This is a function that allows the original files to be modified with different brushes and intensities and can also apply color layers to the images that facilitate computer design (Figures 1 and 2).

From the designs thus modified, with the "Exocad model creator" application, hollowed-out models are generated to improve the efficiency of the 3D printers for extruding hot melt plastic.

3.1.3 | Printing

In this case, the printer used was Anycubic Photon S. We prepared the models so that as many as possible fit on the printing tray, placing supports that ensured stability and precision.

We sliced the file on a USB flash drive at 50 microns for printing. The resin used with Anycubic Photon S was Anycubic Sensitive Resin White.

We moved the file prepared for printing to the printers with a USB flash drive and started manufacturing. Once the printing was finished, we carefully removed the models from the tray and placed them in the Anycubic Wash. This cleans the models with isopropyl alcohol. We dried them well and cured them with UV light as well as with the Anycubic Wash Cleaning and Curing Machine (Figure 3).

3.2 | Preclinical laboratory practices with the 3D printing laboratory model

The practices took place after having explained the theory corresponding to each one and having conducted seminars and clinical sessions where contemporary aesthetic concepts are taught, practicing facial and dental morphology analysis with the consequent study of the smile.

The preclinical laboratory practices carried out were:

a. Restoration of conoid tooth morphology
b. Cervical abrasion/ erosion restoration
c. Direct Composite Veneer
d. Aesthetic correction in a tooth with rotation
e. Diastema closure
f. Occlusal abrasions/erosion
g. Maryland bridge

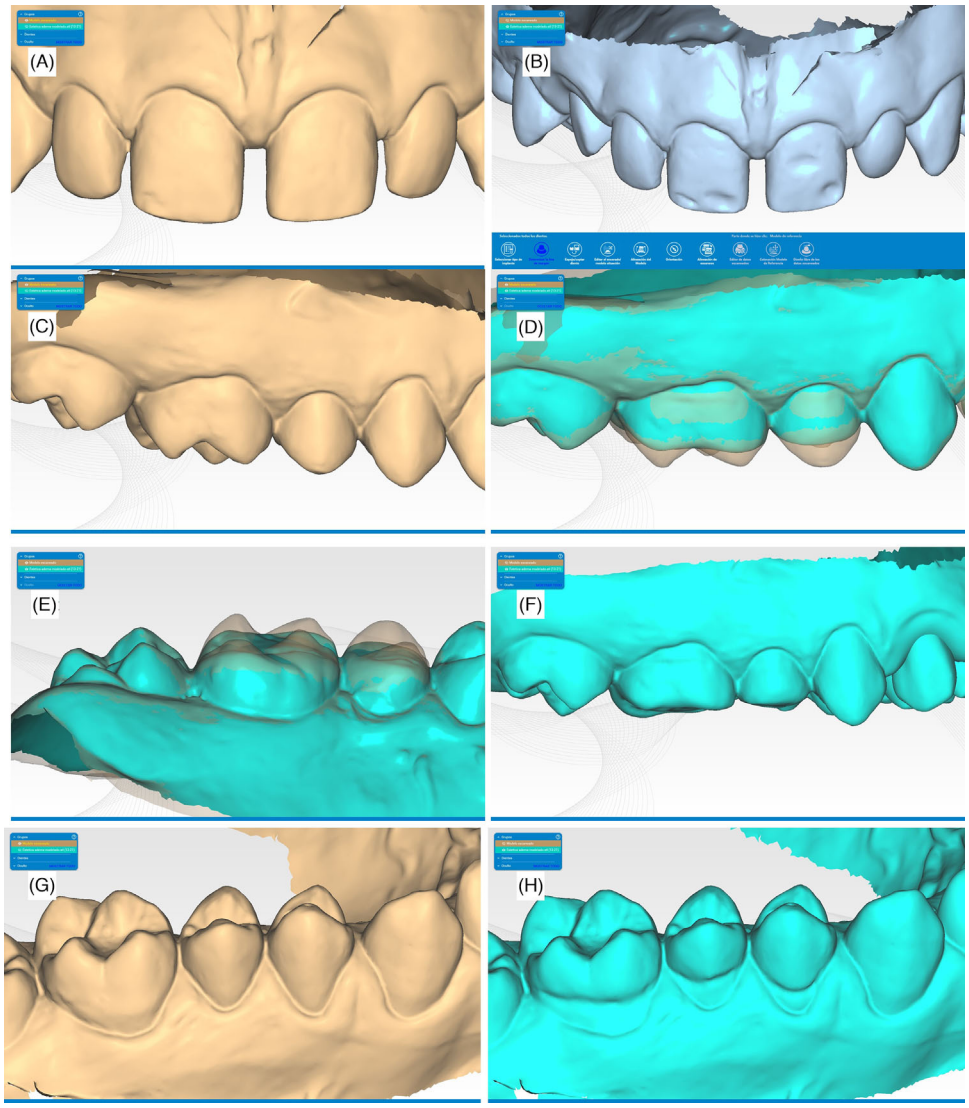

FIGURE 2 (A) Stereolithography or Standard Tesellation Language (STL) file real patient. (B) Final case with surface defects. (C) STL file real patient. (D, E) Superposition of the occlusal modifications of molar and premolar. (F) Final STL file (G) real case. (H) Class V is similar in the necks of premolars and molars.

Each practice occurred on a different day, allocating a maximum time of 3 h. The practices were supervised and evaluated by two professors. To carry out the practices, the 3D model was fixed to the head 3D printed model using a base with a screwed piece that allowed the assembly and disassembly of the models.

The objective of each practice was the restoration of the normal anatomy of the teeth through direct restorative treatments. The contralateral tooth of the arch was taken as a model, trying to reproduce the shape, polish, and color.

The materials used for the practices were:

a. Milling cutters for grinding and polishing turbines
b. Dental adhesives
c. Microhybrid and nanohybrid composites
d. Opaque composites
e. High aesthetic composites
f. Polishing cups and discs

The teachers used rubrics for the evaluation of the different practices, assessing the shape, color, and polish in the different restorations (Table 1).

After completing all the practices, a questionnaire was created with the Survey Monkey program to assess the students in the preclinical laboratory practices carried out using the new 3D model. The questionnaire was created by the team of teachers and sent by mail to all dental aesthetics students in the fourth year of the Dentistry degree at the ADEMA University School (University of the Balearic Islands) at the end of the course (July 2021).

FIGURE 3 Models printed with a three-dimensional (3D) printer.

A total of 21 students (value $n = 21$) who had completed the preclinical practices accessed the survey anonymously through a link.

The objective of this questionnaire was to know the students' opinions on the use of the 3D printed model. Questions were asked on a scale from 0 to 10 about whether the 3D printing model was able to reproduce the characteristics of the teeth in terms of shape, polish, and color according to the rubric provided to the students (Table 2). Likewise, questions were asked about the difficulty that students encountered in the different practices, despite not being important in terms of the objectives of this study.

A rubric has been provided to the students to respond to the survey (Table 2).

Teachers and students also expressed their opinions on the use of the 3D model once the practices were finished by freely expressing their opinions.

4 | RESULTS

Figures 4 and 5 show some of the treatments carried out by the students. The results of the scoring of the practices by the teachers are shown in Table 3.

The results of the assessment of the 3D printed model by the students are shown in Table 4. The participation rate was 100% ($n = 21$).

In terms of the students' expectations regarding the preclinical practices in Dental Aesthetics, 71.43% (15) recognize that they acquired the ability to perform direct aesthetic treatments, 19.05% (four) admit the possibility of performing direct aesthetic treatments, and 9.52% (two) state that they have difficulty performing direct aesthetic treatments. Note that, 90.48% (19) consider that the best model for carrying out the practices is the one created with 3D printing, of a real digitized case, compared to other commercial models with normal morphology or models made by the students with natural teeth.

On a scale from 0 to 10, the average rating of the 3D-printed model was 8.3. In the evaluation of the repro-

TABLE 1 Teachers rubric.

Teachers' rubric	Not satisfactory	Not very satisfactory	Satisfactory	Very satisfactory
Shape	**1-2-3** Absence of the anatomical characteristics of the dental group	**4-5** Has the anatomical characteristics of the tooth, but has defects in the proportions of the tooth	**5-6-7** Has the characteristics of the tooth and complies with the proportions, but is not similar to the contralateral	**8-9-10** Has the characteristics of the tooth, complies with the proportions, and is similar to the contralateral
Polish	**1-2-3** The teeth have not been polished	**4-5** The teeth have been polished but do not have the correct texture	**5-6-7** The teeth have been polished, and have the correct texture, but lack shine	**8-9-10** The teeth have been polished, and have the correct texture and shine
Color	**1-2-3** The color of the tooth has not been reproduced	**4-5** The color of the tooth has been reproduced uniformly	**5-6-7** The color of the tooth has been reproduced, differentiating the cervical and incisal areas	**8-9-10** The color of the tooth has been reproduced, differentiating the cervical and incisal areas and the degree of opacity
Time for the practice	**Insufficient** Could not finish the practice	**Enough** Finished the practice on time	**Excessive** Finished the practice half an hour before the scheduled time	

TABLE 2 Rubric of the students to answer the survey.

Question 1	**Mark YES if you agree with the statement**	**Mark NO, if you do not agree with the statement**			
Question 2	**0%** Impossibility of performing direct aesthetic treatments	**50%** Difficulty performing direct aesthetic treatments	**75%** Possibility of performing direct aesthetic treatments	**100%** Ability to perform direct aesthetic treatments	
Question 3	Mark only one answer				
Question 4	**1-2** It does not allow the performance of practices	**3-4** It allows the realization of all the practices with difficulty	**5-6** It allows some practices to be carried out with difficulty	**7-8** It allows the realization of all the practices with ease	**9-10** It allows the realization of all the practices easily and didactically
Question 5 Shape	**1-2** I was not able to reproduce the shape of the tooth	**3-4** I was able to reproduce the shape of the tooth, but it had defects in the proportions	**5-6** I was able to reproduce the shape and the proportions of the tooth, it had defects in anatomical characteristics	**7-8** I was able to reproduce the correct characteristics of the tooth and comply with the proportions, but it was not similar to the contralateral	**9-10** I was able to reproduce the correct characteristics of the tooth and comply with the proportions, and it was similar to the contralateral
Question 6 Polished	**1-2** I was not able to polish my tooth	**3-4** I was able to polish tooth with difficulty	**5-6** I was able to polish the tooth	**7-8** I was able to reproduce the polishing with the anatomical texture	**9-10** I was able to reproduce the polishing with the anatomical texture and shine
Question 7 Color	**1-2** I was not able to reproduce the color of the tooth	**3-4** I was able to reproduce the color uniformly	**5-6** The color of the tooth was reproduced, differentiating the cervical and incisal areas	**7-8** The color of the tooth was reproduced, differentiating the cervical and incisal areas, the luminosity, and the degree of opacity	**9-10** I was able to reproduce the anatomically perfect color of the tooth
Question 8 Hours time	**Insufficient** I could not finish practice	**Enough** I finished the practice in the time allotted	**Excessive** I finished the practice half an hour before the scheduled time		
Questions 9–11	Mark only one answer				

duction of the anatomy, it scored 8.83, in polished 8.35, and in color 7.09 (Figure 6).

Regarding the time they had to carry out the practices, 95.24% (20) considered it adequate, and only 4.76% (one) considered it excessive. No student stated they lacked time to carry out the different practices.

The most liked practice in the performance was the direct composite veneer for 38.10% (eight) of the students, followed by the Maryland bridge being 23.81% (five), diastema closure 19.05% (four), morphology correction of the conoid tooth 14.29% (three), and tooth rotation correction 4.76% (one) (Figure 6).

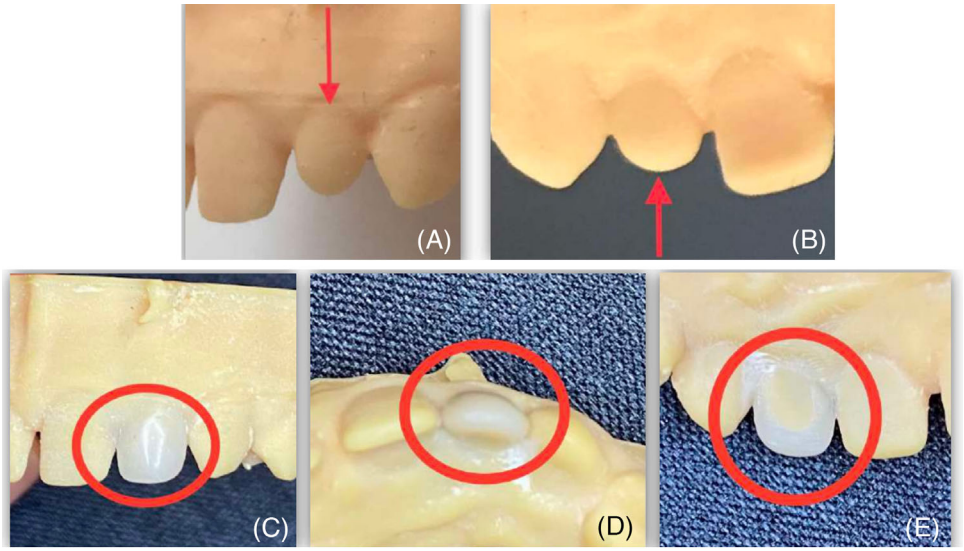

FIGURE 4 Treatment of Conoidism 12 performed in the 3D model. (A) Frontal view before starting the treatment. (B) Palatal view before starting the treatment. (C) Detail of the frontal view after finishing the treatment. (D) Detail of the occlusal view after finishing the treatment. (E) Detail of the palatal view after finishing the treatment.

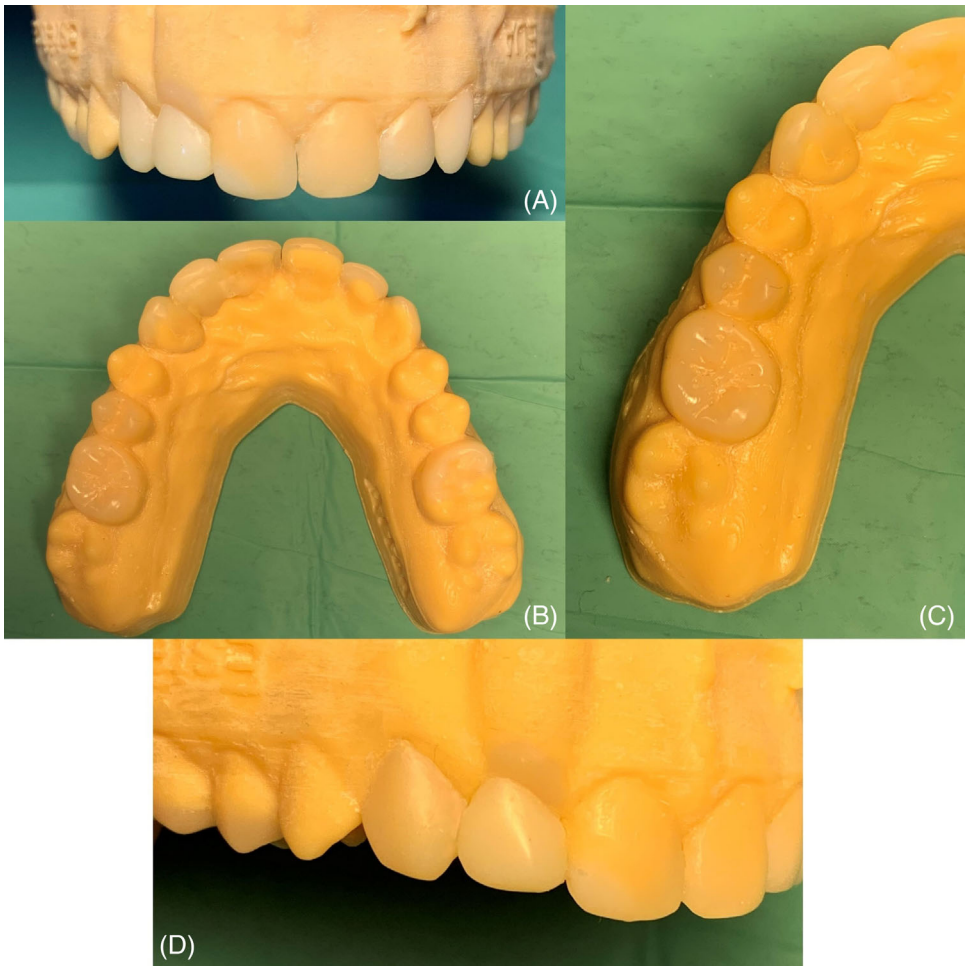

FIGURE 5 Diverse treatments performed in the three-dimensional (3D) model. (A) Frontal view with the closure of interincisal diastema 1.1–2.1, veneer of 1.2, and modeling of 1.3 and 2.2 y 2.3. (B) Occlusal view of the 3D printed model with occlusal modeling of 1.6 and 1.5, and palatal view of the anterior sector. (C) Detail of the occlusal restoration of 1.6 and 1.5. (D) Lateral view of the first quadrant with the treatments performed in 2.1, 1.1, 1.2, 1.3, 1.5, and 1.6.

TABLE 3 Teacher evaluation results.

Practice carried out on a 3D-printed model	Practice grades	Time for practice	Teachers
Restoration of conoid tooth morphology	8.6	2 h 30 min	2
Cervical abrasion/erosion restoration	8.8	2 h	2
Direct composite veneer	8.2	2 h 30 min	2
Aesthetic correction in the tooth with rotation	8	2 h	2
Diastema closure	9	2 h 30 min	2
Occlusal abrasions/ erosion	8.3	2 h 30 min	2
Maryland bridge	8.9	3 h	2

Diastema closure was considered the most difficult for 45% (9) of the students, followed by the Maryland bridge being 35% (seven), rotation correction 15% (three), and the direct composite veneer 5% (one). (Figure 6)

On the other hand, the treatment they considered the least difficult was the restoration of cervical abrasions for 80.95% (17) of the students, followed by 4.76% (one) of the students each for the direct composite veneer, restoration of occlusal abrasions/erosion, correction of the morphology of the conoid tooth and Maryland bridge (Figure 6).

The practice teachers stated that it was very useful to have a model with dental alterations susceptible to direct aesthetic restorative treatments. In their opinion, some of the practices, such as tooth rotation, cannot be carried out uniformly or only done so with difficulty on commercial models for the entire student group. They also considered that the 3D printed model brings students closer to the real aesthetic problems that patients may present.

5 | DISCUSSION

Digital technology is advancing in all fields of dentistry, both in the area of diagnosis and treatment, as well as in the teaching aspect of dentistry, allowing the development of new learning and evaluation techniques.[14–16] Models based on real clinical cases that can be used for the acquisition of practical skills with augmented reality or conventionally through 3D printing are being developed. The health professions use these simulated reality digital technologies to acquire skills in areas, particularly surgical or invasive interventions on the patient. Dentistry faculties are facing a new scenario that involves a significant change in learning techniques. The method of creating virtual models and 3D printing benefits from the point of view that it opens new possibilities in learning, either through the virtual creation of patients or through the reproduction of real cases without modifications.

A student who must carry out a complex clinical case can reproduce the patient through 3D printing and practice the treatment before facing a real clinical case. This is done on patients who must undergo complex surgeries in the hospital. In our environment, the oral cavity, the patient can be digitized in a non-complex way and, through 3D printing, have models to carry out practices prior to the actual treatment or skills acquisition practices.

Planning the practical activities necessary to achieve competencies in the different subjects varies depending on the teaching team and the resources of the different dental schools. The role of the dental educator in undergraduate practices should be to support and guide the student in acquiring the skills required to resolve real clinical cases in the future. According to the research by Chuenjitwongsa et al.,[17] Domain 2 of the curriculum, which represents the practical aspects of teaching and learning in dentistry, should be directed towards reflective practice, which helps students become aware of their learning, enabling them to join experience with knowledge, acquiring deep learning that facilitates the integration of basic knowledge and skills in practice. Feedback needs clear and structured communication between students and educators, but it is undoubtedly essential to improve practical skills. The 3D printed model designed by the teaching team and presented in this work allows practices to be carried out from reflection and feedback, integrating theoretical knowledge, with simulated real clinical situations that bring the student closer to the real clinic.

It is necessary for teachers to take into account the recommendations of the pan-European consensus of the ADEE Special Interest Group for Pre-Clinical Operative Skills, Field et al.,[18] among other recommendations, which emphasise the importance of creating activities that create a safe environment where students can become proficient by realizing their mistakes, creating activities that can longitudinally enable the acquisition, and strengthening of skills in different disciplines. From this point of view, the 3D printed model we present in this manuscript complies with the recommendations because it establishes treatments where we reinforce skills from other subjects like dental anatomy, dental surgery, and dental materials through the use of adhesive techniques such as restoration,

TABLE 4 Survey and results.

Question 1	**Participation in this survey is voluntary and anonymous. Participation implies authorization of the study and publication of the results for educational purposes. The student agrees to answer honestly according to their opinion**		
	Yes	21	100.00%
	No	0	0.00%
Question 2	**Regarding the practices carried out during the academic year in the subject of Dental Aesthetics, by what percentage do you consider your expectations were met?**		
	100% of my expectations	15	71.43%
	75% of my expectations	4	19.05%
	50% of my expectations	2	9.52%
	0% of my expectations	0	0.00%
Question 3	**What do you consider to be the best type of model to carry out Dental Aesthetics practice?**		
	Model made by the student with natural teeth	2	9.52%
	Model with resin teeth with normal morphology	0	0.00%
	Model with resin teeth with morphological alterations	19	90.48%
Question 4	**How would you rate the 3D printed model designed for Dental Aesthetics practice?**		
	9-10	15	71.43%
	7-8	5	23.81%
	5-6	1	4.76%
	3-4	0	0.00%
	1-2	0	0.00%
Question 5	**When performing dental reconstructions on the 3D printed model designed for Dental Aesthetics practice, rate your degree of satisfaction in the reproduction of the shape of the teeth**		
	9-10	15	71.43%
	7-8	5	23.81%
	5-6	1	4.76%
	3-4	0	0.00%
	1-2	0	0.00%
Question 6	**When performing dental reconstructions on the 3D printed model designed for Dental Aesthetics practice, rate your degree of satisfaction in reproducing the polish**		
	9-10	12	57.14%
	7-8	6	28.57%
	5-6	3	14.29%
	3-4	0	0.00%
	1-2	0	0.00%
Question 7	**When performing dental reconstructions on the 3D printed model designed for Dental Aesthetics practice, rate your degree of satisfaction with the color reproduction**		
	9-10	6	28.57%
	7-8	8	38.10%
	5-6	5	23.81%
	3-4	1	4.76%
	1-2	1	4.76%
Question 8	**You consider the time you had to carry out the Aesthetics laboratory practices**:		
	Excessive	1	4.76%
	Enough	20	95.24%
	Insufficient	0	0.00%

(Continues)

TABLE 4 (Continued)

Question 9	**Which of the following treatments performed on the Aesthetics 3D printed model did you like the most?**		
	Diastema closure	4	19.05%
	Direct resin veneer	8	38.10%
	Cervical abrasions	0	0.00%
	Occlusal abrasions	0	0.00%
	Conoid tooth modelling	3	14.29%
	Tooth rotation correction	1	4.76%%
	Maryland Bridge	5	23.81%
Question 10	**Which of the following treatments performed on the Aesthetic 3D printed model do you consider the most difficult for you?**		
	Diastema closure	9	45.00%
	Direct resin veneer	1	5.00%
	Cervical abrasions	0	0.00%
	Occlusal abrasions	0	0.00%
	Conoid tooth modelling	0	0.00%
	Tooth rotation correction	3	15.00%
	Maryland Bridge	7	35.00%
Question 11	**Which of the following treatments performed on the Aesthetics 3D printed model do you consider the easiest for you?**		
	Diastema closure	0	0.00%
	Direct resin veneer	1	4.76%
	Cervical abrasions	17	80.95%
	Occlusal abrasions	1	4.76%
	Conoid tooth modelling	1	4.76%
	Tooth rotation correction	0	0.00%
	Maryland Bridge	1	4.76%

modeling, and polishing of reconstructions. Additionally, they must apply the concepts of aesthetics, proportion and dental harmony learned in classes and theoretical seminars, especially in the practices of direct resin veneer, conoid tooth modeling, and the Maryland Bridge.

During the academic year, the students in this study participated in a weekly practice in which they performed the programmed activity on the 3D-printed model. This teaching was complemented with sessions of real clinical cases and practices in haptic simulators of cavity preparations of indirect restorations (inlays, onlays, overlays, and endocrowns). This way, each student carried out each direct aesthetic practice on the 3D printed model only once; however, in our opinion, the diversity of treatments confronts the student with situations where they need to call upon different skills, gaining a broader view of aesthetic direct restoration treatments even if they have only performed each treatment once. Research by Dawson et al.[19] on whether the number of treatments performed by undergraduates is indicative of greater skills acquisition concludes that a 'numerical requirements' approach cannot be used in isolation as a valid measure of an individual's competence, since it may only mean that the student is proficient in easy cases, but not that they have increased their general competences. The seven practices carried out by the students allowed them to practice skills in handling materials, anatomy, modelling, polishing, etc., but in different clinical situations, not repetitively with the same preclinical practice.

Having standard models facilitates equality in the resolution of cases among students and at the same time equates the difficulty in carrying out the practices, which makes the evaluation by the teaching staff more objective. With the model we present, the students all faced the same aesthetic problem, carrying out the same practical activity since they started from the same aesthetic defect, be it in shape, volume, etc. Research like that by Lynch et al.[20] on the attitudes of some European dental undergraduate students about the placement of direct restorative materials in posterior teeth underscores the differences in criteria among students from three European universities, finding differences in evaluation and teaching methods. The same was concluded by Grindrod et al.[21] in academic training in paediatric dentistry. We agree with the need to

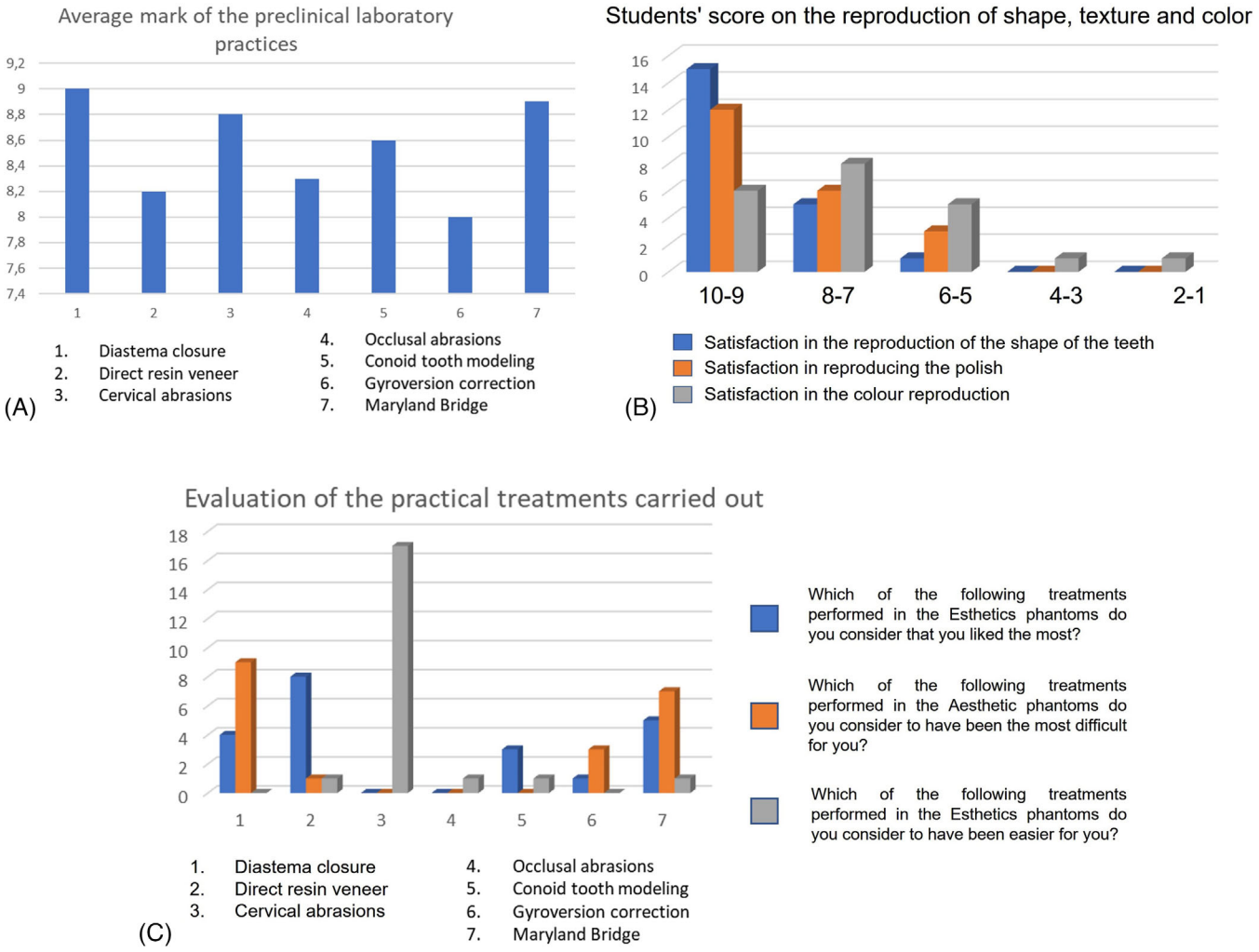

FIGURE 6 (A) Histogram of the average marks of the 21 students in the seven practices assessed. (B) Histogram of student opinion regarding the reproduction of the shape, polish, and color of the restorations carried out on the 3D printed model. (C) Students' assessment of the practices carried out in the 3D printed model in terms of what they liked doing the most, the greatest difficulty, and the least difficulty.

standardise these practices, for which we consider it necessary to have reproducible models that can be used in the acquisition of different skills, such as the one developed in this research. New technologies with the use of virtual simulators also offer the opportunity to create standardised practical activities that would help homogenise academic training and demonstrate an improvement in learning outcomes, as well as a more objective and rigorous evaluation of practical activities.[22–24] It could be a future objective of the ADEE Special Interest Group for Pre-Clinical Operative Skills that European universities develop a single programme of pre-clinical practices with reproducible models by 3D printing. This way, European students would have the same pre-clinical practical training in all universities and there would be no differences in their training.

The preclinical exercise with a virtual simulator has very good results in the surgical preparation of the cavities.[25] However, mastery of the necessary modeling in aesthetic restorations requires non-virtual practices like the one proposed in this model, designed so the student can model and restore anterior and posterior teeth, restoring the morphology and anatomy of the tooth, from the management of color, shape, and polish. These parameters have been evaluated by students with good results. The treatments where students feel safer and with a higher level of confidence within clinical restorative dentistry treatments, according to the conclusions of the research by Hattar et al.,[26] are direct restoration and simple endodontics. They show a lower level of confidence in indirect restorations and complex endodontics, specifically in the cavity carving phase of indirect restorations. To increase this level of confidence in carving skills, the use of virtual haptic simulators can be of great help, since through the use of preforms in the initial phase of the skills acquisition, it guides the student in the carving form. Note that, 71.43% of the students in this study

stated that after completing the practices, they considered they had the ability to perform direct aesthetic treatments. Therefore, we consider that these practices were useful for the acquisition of skills in clinical direct aesthetic restoration situations not belonging to Black's classification of preparations, having a higher level of difficulty.

The development of new digital learning methods in different skills[27,28] helps reduce the errors that students may make when undertaking clinical practices, aiding the transition between laboratory and clinic. The use of 3D-printed typodonts, designed for real patients, has yielded good results. Lee et al.[29] conclude that 80% of the students who used these typodonts prior to the practice on real patients obtained positive feedback about this method. In our work, we also use personalised typodonts printed on 3D printers to carry out the preclinical practices. Note that, 90.48% of the students valued this typodont as the best to carry out the 7 preclinical practices of dental aesthetics compared to commercial typodonts or plastic teeth. Towers et al.[30] also describe the use of specific models of 3D printed patients, in which practices occur under the supervision of a teacher and finally the realization of the practice on a real patient, giving great value to practices on 3D typodonts with teacher supervision. The positive evaluation of the 3D printed patient-specific typodonts not only has a good evaluation by the students, the teachers also value this learning method very positively, as with our results. Tricio et al.[31] recently published another similar work in which they also use 3D printed models obtained from the digital impression of the patient, on which students practice indirect preparations in the laboratory under the supervision of teachers. The students also make the preparations in virtual reality simulators, and finally they make the preparations in the patients. The evaluation of the students and the teachers is very positive, with the students considering that the best method for learning is the simulated practice in the laboratory with the 3D printed models obtained from the digital impression of the patients.

Three-dimensional printed models can also be used in teaching caries removal. Chaudhari et al.[32] report their experience with a group of fifth-year students, in which they used 3D printed models with caries lesions simulated by means of a low-density area within the printed tooth. The results of their research conclude that the students valued the practice in the laboratory with simulated reality with the 3D models very positively, believing that their anxiety would be reduced when treating their first patient with caries.

Towers and Karl 77 below[7,29] highlight the importance of teachers in supervising practices, and this should make us reflect on the importance of the role that teachers play in motivating students to learn. In our research, the students carried out the practices under the supervision of two teachers who reviewed the different steps of each practice. Teachers require training programs in new technologies that enable them to instill critical thinking and clinical judgment in students, guaranteeing patient safety.[33]

Having learning methods and techniques in preclinical practices that provide the student with skills acquisition in such a way that they have the mastery and sufficient confidence to minimize the mistakes they might make when treating a real patient. All methods of learning available to us as teachers are needed, obtaining great benefits from simulated reality with 3D printed[34] models and digital or haptic virtual reality; improving both methods are future goal for teachers. Further studies are required to enable us to make a critical and objective assessment of learning methods in preclinical operative skills.

6 | CONCLUSIONS

With the limitations of this study, we can conclude that:

1. The method used to make the modifications in the original digital file of the real patient made it possible to perform the indicated dental transformations.
2. 3D printing of a modified real patient file provided a reproducible standard analog model for direct aesthetic dental restoration practices.
3. 90.48% of the students evaluated the digital 3D printed model as the best method for undertaking direct reconstruction dental aesthetic practices, giving the model an overall assessment of 8.3.
4. The use of specific models obtained with 3D printing can be of great help for students in the transition between the laboratory and the clinic because, in the teachers' opinion, it brings the student closer to real cases.

AUTHOR CONTRIBUTIONS

All authors contributed to this manuscript and read and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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