Revista Española de Educación Médica

A digital approach for the teaching of dental anatomy: 6-year feedback following implementation during the COVID-19 pandemic.

Un enfoque digital para la enseñanza de la anatomía dental: evaluación tras seis años de su implantación durante la pandemia de COVID-19.

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Recibido: 15/6/26; Aceptado: 15/7/26; Publicado: 17/7/26

Abstract.

Objective: to describe the 6-year feedback of the digital teaching that has been set up since the era of the Covid-19 pandemic in the framework of practical dental anatomy work in a French Faculty. **Methods:** Hands-on dental anatomy sessions (drawing and wax-up exercises) were adapted to be compatible with both face-to-face and distance learning. Pre-recorded videos detailing the entire work process were made available online via the Faculty's website. Student feedback was collected annually between 2020 and 2025 through satisfaction ratings (0–10) for the drawing and wax-up tutorial videos, perceived autonomy after viewing the videos, and a simplified User Experience Questionnaire (UEQ). Continuous variables were compared across years and between genders using two-way ANOVA and Tukey post-hoc tests, while categorical responses regarding autonomous work were analyzed with Fisher's test. **Results:** A total of 457 students responded to the questionnaire over six years (approximately 76 per graduating class), with women representing 69.15% of participants (n=316). Both drawing and wax-up tutorial videos were rated highly each year (global means of 8.66±1.18 and around 8/10, respectively), with no statistically significant differences across successive promotions. Drawing scores did not differ significantly between genders, although a non-significant trend suggested that women rated wax-up videos more favorably than men. UEQ results indicated that overall learning evaluation, as well as hedonic and pragmatic qualities, were rated as "Excellent" by the full cohort and by women specifically, while men rated the pragmatic quality as "Good." **Conclusions:** This six-year experience demonstrates that digital tools initially developed as an emergency response to the COVID-19 pandemic proved durable and well accepted beyond the crisis period. While student satisfaction was consistently high across all cohorts, this report does not allow conclusions regarding actual skill acquisition. This experience may serve as a source of inspiration for educators facing similar challenges, subject to local adaptation and cross-validation before broader implementation.

Keywords: dental anatomy, distance learning, digital teaching, medical education.

Resumen.

Objetivo: describir la evaluación a lo largo de seis años de la enseñanza digital implantada desde el inicio de la pandemia de COVID-19 en el marco de las prácticas de anatomía dental en una facultad francesa. **Métodos:** Las sesiones prácticas de anatomía dental (ejercicios de dibujo y modelado en cera) se adaptaron para que fueran compatibles tanto con la enseñanza presencial como con la a distancia. Se publicaron en línea, a través de la página web de la facultad, vídeos pregrabados en los que se detallaba todo el proceso de trabajo. Se recopilaron las opiniones de los estudiantes anualmente entre 2020 y 2025 mediante puntuaciones de satisfacción (0-10) para los vídeos tutoriales de dibujo y modelado en cera, la autonomía percibida tras ver los vídeos y un Cuestionario de Experiencia del Usuario (UEQ) simplificado. Las variables continuas se compararon a lo largo de los años y entre géneros utilizando un ANOVA bidireccional y pruebas post hoc de Tukey, mientras que las respuestas categóricas relativas al trabajo autónomo se analizaron con la prueba de Fisher. **Resultados:** Un total de 457 estudiantes respondieron al cuestionario a lo largo de seis años (aproximadamente 76 por promoción), y las mujeres representaron el 69,15 % de los participantes (n = 316). Tanto los vídeos tutoriales de dibujo como los de modelado en cera recibieron valoraciones elevadas cada año (medias globales de 8,66 ± 1,18 y alrededor de 8/10, respectivamente), sin diferencias estadísticamente significativas entre las sucesivas promociones. Las puntuaciones de los dibujos no mostraron diferencias significativas entre ambos sexos, aunque una tendencia no significativa sugirió que las mujeres valoraron los vídeos de modelos de cera más favorablemente que los hombres. Los resultados del UEQ indicaron que la evaluación general del aprendizaje, así como las cualidades hedónicas y pragmáticas, fueron calificadas como «Excelentes» por el conjunto de la cohorte y por las mujeres en concreto, mientras que los hombres calificaron la calidad pragmática como «Buena». **Conclusiones:** Este modelo puede servir como marco escalable para integrar herramientas digitales en la formación odontológica práctica, incluso fuera de situaciones de crisis.

Palabras clave: anatomía dental, formación a distancia, enseñanza digital, educación médica,

1. Introduction

The Covid-19 pandemic had disrupted the organization of teaching in dental faculties (1), but also made it possible, with hindsight, to modify the overall approach to teaching (2). The educational programs must be assured in all circumstances and the knowledge dispensed to the students, for example concerning dental anatomy, an essential topic which is taught at the very beginning of dentistry studies. Indeed, it serves as an indispensable prerequisite for the development of other skills in prosthodontics, restorative or aesthetic dentistry (3). Some of the knowledge is delivered during theoretical lectures with a teacher showing schemas, photographs and videos to the students in order to detail the anatomic specificities of all the teeth. However, a practical part is essential to the comprehension of the anatomy in the three dimensions of space. This may involve asking students to draw the anatomy of the teeth and/or to perform addition wax-ups on resin arches.

Delivering a lecture became possible at distance thanks to the many videoconferencing tools available during the Covid-19 pandemic. They allowed the professor to share his screen with a presentation or specific software such as STL visualization software if he wanted to show three-dimensional files. Students could thus continue to attend classes from home. Before the pandemic, some authors noted that this type of e-learning procedures did not seem to have a negative impact on students' education (4) and in 2021, Ullah et *al.* even showed that blended learning led to improved students' satisfaction in comparison with a conventionally administered dental anatomy course (5).

Adapting a practical session is much more difficult. It implies to organize the continuity of the manipulations in autonomy while guaranteeing an indispensable degree of safety for performing the work. The objective here is to describe the 6-year feedback of the digital teaching that has been set up since the era of the Covid-19 pandemic in the framework of practical dental anatomy work in a French Faculty.

2. Methods

Hands-on sessions have been specially designed to be compatible with both face-to-face and distance learning. Two resin arches (Rencast®, Samaro, France) (figure 1) as well as wax-up blocks (GeoAvantgarde wax, Renfert, Hilzingen, Germany) are given to each student at the beginning of their cursus. Depending on the evolution of the pandemic and local health regulations, it was expected that students would be able to perform the wax-ups at the faculty or from home. Thus, in 2020 and 2021, mandatory lockdown periods required students to remain at home and work remotely, whereas outside these lockdown phases (when travel was permitted), students were allowed to attend the Faculty in small groups in order to assess their work and to keep in regular contact with them. From 2022 onward, teaching fully resumed on site, and all students worked in person at the Faculty. The practical workrooms are equipped with dental wax heaters whose spacing allowed for social distancing measures to be respected. Teachers and older students were present to provide advice and help the work progression. Attendance time, necessarily reduced during the first two years of the period considered here, was therefore optimized to remain as close as possible to students' needs.

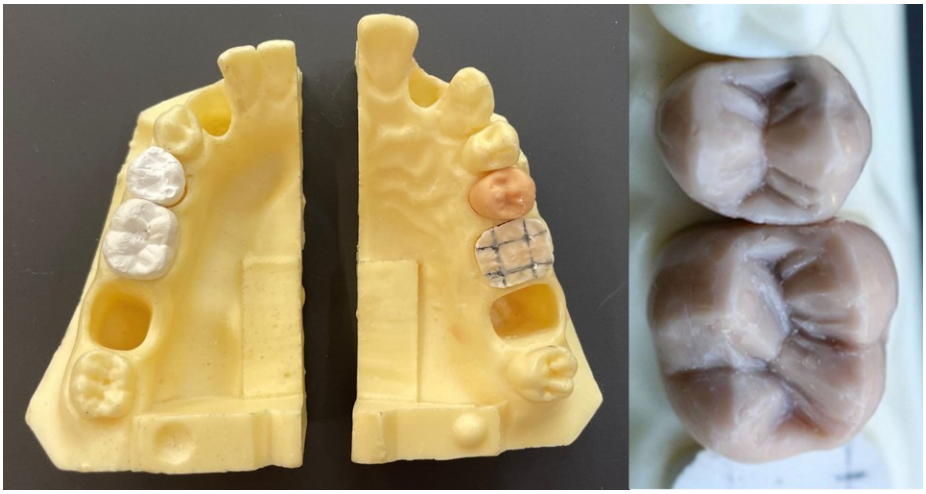

Figure 1. Resin arches and gypsum supports for practical wax-up work.

In case of necessity, these students had all the necessary material in their personal kits to continue the work on their wax-ups from home. Only a heat source was necessary. Kitchen gas stoves are common, but they have the disadvantage of blackening metallic instruments. Alternatively, inexpensive wax heaters are widely available online. An even cheaper, though less practical, option is the use of an alcohol lamp or household candles. Videos had been pre-recorded to visually and audibly detail the entire work process. They were uploaded online in the "Not listed" format on the Youtube platform (Google, Alphabet Inc, San Bruno, CA, USA) and then integrated directly on the faculty's website dedicated to teaching (Moodle Learning Management System). Students have access to it from home and can advance at their own pace.

The same process was undertaken for the dental anatomy drawings. Each week, two teeth must be drawn from different points of view in space. The work was easier to develop at home as it only required a pencil and drawing paper. An example of video, explaining the instructions for

drawing a mandibular premolar, has been recorded here in English for the purposes of the article, and is available on https://youtu.be/U6mr2FWC3Ig.

Following the implementation of these different courses, the feedback of the students were collected every year between 2020 and 2025. At first, they had to give an overall satisfaction rating (between 0 and 10) to answer the question "How clear do you find the drawing/wax-up videos?". Next, they were asked if they felt capable of working by themselves after watching the first videos. Finally, their more personal feeling concerning the practical trainings were evaluated using the simplified version of the User Experience Questionnaire (UEQ) (6). Student feedback was collected anonymously and on a voluntary basis, as permitted in France for course evaluations, without the need for specific ethical approval.

A descriptive analysis of student responses over the years is thus provided. A comparison based on the gender of participants is also presented: continuous variables (numerical scores) have been compared using two-ways anova tests (after verifying the normality of the distribution of values and the equality of variances) and Tukey post-hoc tests, while the categorical answers for the question of autonomous work were treated with Fisher's test. To further address the temporal heterogeneity introduced by the successive changes in teaching conditions, a linear mixed-effects model was additionally applied to satisfaction scores (drawing and wax-up), with teaching condition (distance/hybrid learning: 2020-2021 *vs*. in-person: 2022-2025) and gender as fixed effects, and cohort year as a random effect. Effect sizes for the one-way ANOVAs were reported as eta-squared (η^2).

3. Results

After six years of implementing these digital tools for dental anatomy teaching, 457 students have responded to the questionnaire, representing approximately 76 per graduating class. The gender distribution was heavily skewed towards women, who accounted for 69.15% of participants (n=316). This trend was consistent across all years.

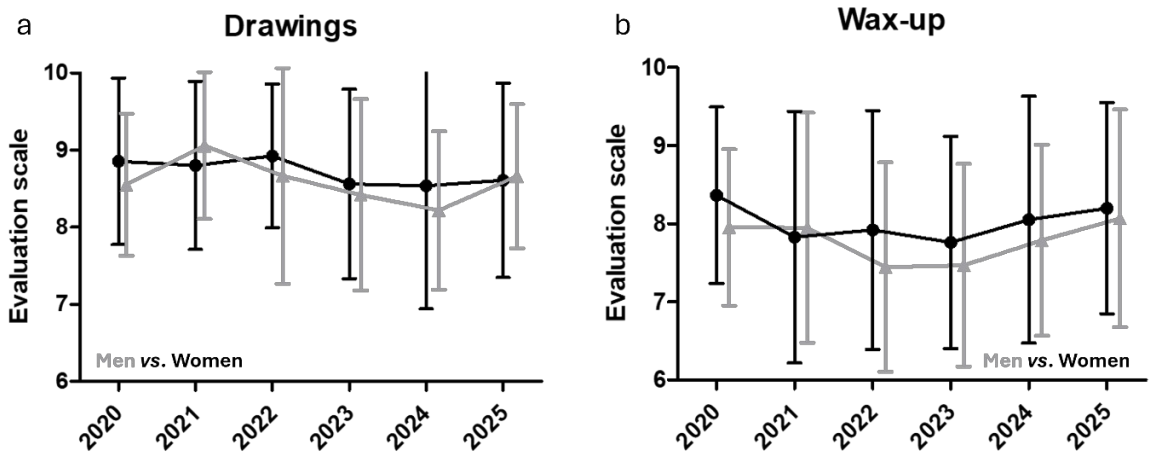

Figure 2. Changes over the years in the scores given by male students (in gray) and female students (in black) to video tutorials of drawing (a) and wax-up (b) practical works.

It appears that the teachings have been well accepted by the students (figure 2). The drawing works received each year an average rating over 8/10 (global mean 8.66±1.18) with no statistically significant difference across the successive promotions (7.96±1.4; p=0.1). The wax-up practical works were also ranked around 8/10 every year (p=0.07 between the years). Interestingly, drawing works were graded similarly for men and women (respectively 8.52±1.08 *vs.* 8.72±1.22; p=0.09) while a trend, although not significant, emerged year after year showing that women preferred practical

wax-up videos when compared to men (always below 8 for men *vs.* more variable scores for women; p=0.07). According to the UEQ analysis tool, the overall learning evaluation as well as the hedonic and pragmatic qualities were rated as 'Excellent' (Figure 3a). It appeared to be adapted to the concrete action of practical works and stimulating for the students. These excellent scores were all confirmed when analyzing precisely the responses of women. Men, on the other hand, rated the "pragmatic" quality of the teaching as "Good" (figures 3b and 3c).

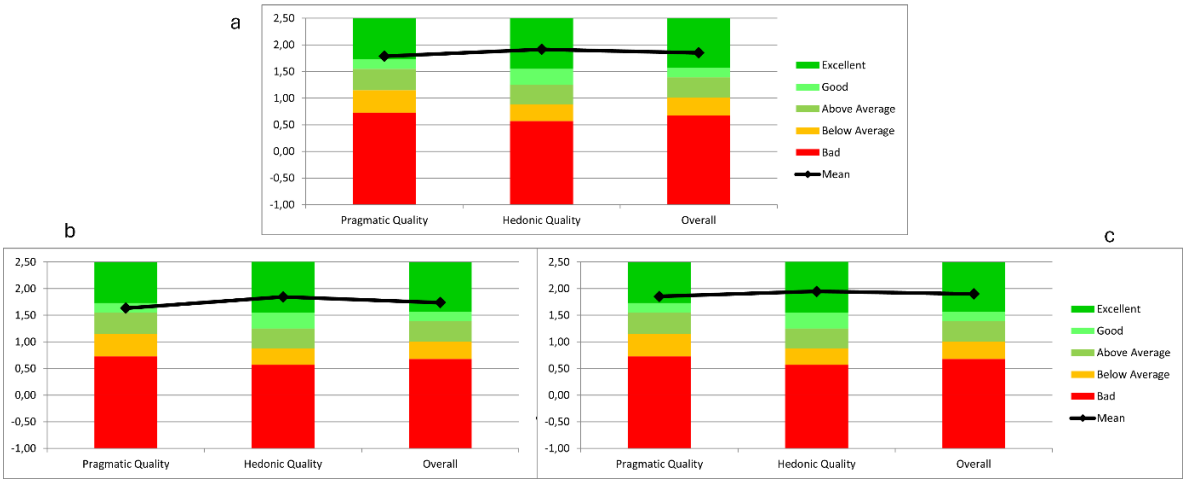

Figure 3. Results of the USEQ analysis tool for all the students (a), men (b) and women (c).

The linear mixed-effects model applied to account for the temporal heterogeneity revealed no significant effect of teaching condition on either drawing scores (β=-0.21, 95% CI (-0.50; 0.08), p=0.157) or wax-up scores (β =-0.16, 95% CI (−0.55; 0.24), p=0.439). Furthermore, eta-squared values derived from the one-way ANOVAs were very low for both drawing (η^2=0.020) and wax-up scores (η^2=0.022), indicating negligible between-year variance and supporting the stability of student satisfaction across all teaching modalities.

4. Discussion

The technical feasibility of remote practical learning has been successfully launched and continued thanks to digital tools. Such a pedagogic procedure allows pedagogical continuity in the learning of dental anatomy during a pandemic period and beyond. These teaching methods were well received during the Covid-19 lockdowns, and even today, students continue to express excellent satisfaction with the teaching materials provided. This is proven by the consistently high scores observed across six cohorts, which suggest not only initial acceptance but also long-term stability in student satisfaction with digital practical instruction. The UEQ is an internationally validated instrument originally developed by Laugwitz et al. (6) to assess user experience across pragmatic dimensions (usability, clarity, efficiency) and hedonic dimensions (stimulation, novelty). Although initially designed for software evaluation, it has been successfully applied in health education contexts to evaluate digital learning tools. Onyeka et al. used it to assess an e-learning platform for pain management education among undergraduate medical students (7), and Abedi et al. recently employed it to evaluate a web-based educational system for nursing skills development (8). Its use in the present study, aimed at evaluating students' experience with video-based practical teaching materials, is therefore consistent with an established and growing body of literature in health professions education.

From a pedagogical point of view, drawing dental shapes in two dimensions and then building a wax-up in three dimensions allow students to develop a three-dimensional representation of the anatomical structures they will need to manipulate in their future careers.

These practical works can only take place in parallel with the theoretical courses whose importance in the learning of dental anatomy is no longer to be proven (9). However, the asynchronous video format promotes self-directed learning by allowing students to set their own pace and review the content as often as needed, which can make it easier to understand complex spatial tasks such as wax modeling.

In this context of multimodal teaching methods, the issue of how evaluations should be conducted during the semester remains unresolved. It is of course possible to grade students' work. But when some of their productions are done outside the university, in distance learning, it is difficult to know whether students have received help from relatives who are already familiar with dental practice. In this case, the decision not to grade the work may reduce performance-related stress and thereby discourage students from having the practical work completed by someone else, although it does not entirely eliminate the risk of disengagement or delegation due to lack of interest. At the end of the semester, the students are evaluated with multiple choices questions directly on an online platform, but this only takes into account the acquisition of their knowledge. The control of skills seems to be more complicated, that's why the use of digital tools to rate the quality of wax-ups, for example, could be of great help. Moreover, it is less time-consuming for the teacher and it offers a higher rate of reliability and agreement on the way to grade the work (10).

Digital tools in the broad sense could also be used to modify theoretical teaching. Virtual reality (VR), augmented reality (AR), mixed reality (MR) and blended active-learning designs are the main innovations described in the international literature concerning the improvement of cranio-facial and dental anatomy teachings. Natalia Sinou et *al.* shown in 2023 that the use of VR tools to simulate dissections was equivalent to studying cadavers or atlases in anatomy education with comparable learning outcomes (11). The main implementation barriers included cost, usability, and incomplete evidence for entire replacement of cadaveric dissection. Shuliand Niu et *al.* recently remembered that 3-dimensions anatomy models' effects on long-term retention by the students and final exam performance remained limited (12). Although still difficult to apply to practical teachings, the value of new tools in theoretical education undoubtedly lies in the enthusiasm they generate among students, encouraging interest in the lessons (13). Future developments in this field may allow AR and MR to enhance and increase student engagement in digitally supported practical teaching.

Finally, this study presents several limitations that should be acknowledged. First, as this work constitutes a longitudinal educational experience report, it was not designed as a comparative intervention study, and no control group was included. This prevents any causal attribution of the observed satisfaction levels to the digital tools specifically, as opposed to other contextual or temporal factors. Such a design choice was inherent to the real-time pedagogical adaptation required by the pandemic context, which made prospective randomization impossible. Second, the evaluation relied exclusively on subjective feedback collected through satisfaction ratings and the UEQ, without objective measure as primary outcomes. Although objective performance data such as the grades obtained by students on their wax-up exercises over the six-year period (and even older ones) are available, we deliberately chose not to make these the primary outcome of this report. Indeed, they reflect a combination of manual dexterity, prior experience, and individual effort rather than the effectiveness of the digital tools. In the absence of a control group, such data would not allow any valid inference regarding the added value of the digital teaching format. Consequently, no conclusion can be drawn regarding the actual impact of this teaching approach on students' technical skill acquisition. Third, the data were collected from a single French Faculty, operating under specific national health regulations, *i.e.* mandatory national lockdowns in 2020 and 2021 which legally required students to remain at home, and which thus directly drove the decision to develop remote-compatible practical kits and pre-recorded video tutorials. These regulatory specificities may differ substantially from those experienced in other countries, institutions and

educational systems. They may thus limit the direct transferability of our approach without prior local adaptation and cross-validation. Finally, the six-year study period encompassed substantial changes in teaching conditions (alternating between full distance learning, hybrid formats, and a full return to in-person teaching), which introduces a degree of heterogeneity that could not be fully controlled for in the analysis. It should be noted, however, that the consistently high satisfaction scores observed across all six cohorts despite these different teaching conditions may be interpreted as an indicator of the robustness of student acceptance of the digital tools, regardless of the broader educational context.

From an educational standpoint, the very low eta-squared values observed for both drawing and wax-up satisfaction scores indicate that the teaching modality (*i.e.* fully remote, hybrid, or in-person) accounted for a negligible proportion of the variance in student satisfaction. This finding carries a practically meaningful implication: the acceptability of the digital tools developed in response to the pandemic crisis does not appear to depend on the specific teaching context in which they are deployed, suggesting that their integration into practical dental anatomy curricula may be considered independently of broader organizational constraints. Future studies including a control group and objective assessment of practical performance would help to better establish the educational value of these digital tools.

5. Conclusions

- This six-year experience demonstrates that digital tools, including pre-recorded instructional videos and remote-compatible practical kits, can successfully sustain dental anatomy education across highly variable teaching conditions, from full lockdown to in-person resumption. It may serve as a source of inspiration in case of similar challenges, but local adaptation and cross-validation would be necessary before broader implementation, particularly in educational systems operating under different regulatory or institutional frameworks. In our study, even if student satisfaction is emphasized over the real acquisition of technical skills, both drawing and wax-up tutorials remained consistently high (around 8/10) over the six cohorts, with overall, hedonic, and pragmatic UEQ ratings reaching "Excellent," particularly among female students who represented the majority of respondents.
- The main take-home message is that digital teaching resources, initially developed as an emergency response to the Covid-19 pandemic, proved durable and well accepted well beyond the crisis period, supporting their integration as a permanent, scalable complement to practical dental training rather than a temporary substitute. Future studies in other preclinical disciplines requiring hands-on skill acquisition could explore similar digital approaches, provided that objective performance outcomes are systematically evaluated to better establish their educational value.

Funding: The implementation of the teachings described in this article was fully funded by the authors' institution (University of Toulouse).
Declaration of conflict of interest: The authors declare that they have no conflict of interest.
Author contributions: AP: Formal analysis, Investigation, Data Curation, Writing Original Draft. TC: Conceptualization, Resources, Writing Original Draft, Visualization, Funding acquisition. DO: Conceptualization, Investigation, Resources. MM: Methodology, Validation, Writing Review & Editing. XD: Methodology, Resources. LD: Investigation, Writing Review & Editing, Visualization. LP: Investigation, Writing Review & Editing, Visualization. SJ: Investigation, Writing Review & Editing, Supervision. JD: Software, Visualization, Supervision, Project Administration.
IA tools: Out of respect for the work of the authors of this manuscript, the initial text was written entirely without the help of artificial intelligence tools. The only three software programs used in parallel with the writing were Zotero® (Digital Scholar, Vienna, VI, USA) for the layout and

organization of the bibliography, ChatGPT® (OpenAI, San Francisco, CA, USA) for proofreading the English, and Compilatio® (Compilatio, Chavanod, France) to verify the absence of plagiarism and the originality of the text.

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