Outsmarting COVID-19 through rapid 3D printing and flipped learning in fixed prosthodontics

A Fortuin,[1] MChD (Prostho); **J H van den Heever**,[1,2] MChD (Prostho); **T C Postma,**[1] PhD

[1] *School of Dentistry, Faculty of Health Sciences, University of Pretoria, South Africa*

[2] *Department of Mechanical Engineering and Mechatronics, Faculty of Engineering and Information Technology, Central University of Technology, Bloemfontein, South Africa*

Corresponding author: *T C Postma (corne.postma@up.ac.za)*

Why was the idea necessary? (What was the problem?)

Fixed prosthodontics comprises an array of advanced clinical skills that dental students need to master before qualification. Fixed prosthodontics involves the rehabilitation of absent and severely damaged teeth by means of dental crowns and complex prostheses such as bridges that are fixed to existing structures in the mouth. These are high-stakes procedures that impact on chewing function and aesthetics, and affect the quality of life of patients.

The complexity of this discipline requires an intense preclinical skills training programme to ensure that students are adequately prepared for real-life fixed prosthodontics to ensure patient safety and clinically acceptable outcomes. Important skills in this discipline include a self-directed professional approach, clinical decision-making, and a thorough understanding of different tooth preparations and dental materials. It is also very important to develop technical ability and psychomotor skills through repeated practice in an authentic context.

Fixed prosthodontics at the School of Dentistry, University of Pretoria (UP), South Africa, normally commences in the second semester of year four. In the past, this course consisted of traditional lectures, notes, practical demonstrations by the instructor and preclinical practice in the skills laboratory. The skills laboratory, equipped with phantom heads and typodonts (models of jaws and teeth), is technologically advanced and could accommodate up to 32 students at a time.

Unfortunately, some of the preclinical skills teaching and learning (even pre-COVID 19) had to take place in clinical areas without phantom heads because of limited access to the skills laboratory owing to high student numbers. The laboratory is shared among all disciplines, with junior students occupying it most of the time. This was not ideal as students had to practise these complex skills in ways that do not simulate the authentic situation. Completed chairside procedures were signed off by the lecturers in paper-based quota (log) books with a focus on ensuring exposure to different procedures.

The COVID-19 pandemic social distancing requirements disrupted these routines because access to the skills laboratory became even more restricted, and lectures and large-group demonstrations became impossible.

This situation required quick and decisive innovation to allow the preclinical training to continue.

What was tried? (Intervention)

The solution to the obstacle was functionalised through inter-university teamwork and collaboration and a complete revision of the educational philosophy.

Through their links with the Central University of Technology (CUT), Bloemfontein, the Department of Prosthodontics became aware of 3D printing technology that could be used to speedily manufacture phantom heads that can be used in alternative spaces outside the skills laboratory, e.g. clinical wards. Moreover, this could be done at a fraction of the normal cost of conventional phantom heads purchased through dental suppliers. The new phantom heads were designed by a prosthodontist who had strong ties with CUT, with input from the Department of Prosthodontics.

The heads were printed in such a way that they could be mounted at the top of a regular dental chair in the place of the head rest. The new phantom heads and their set-up can be viewed by watching the video that can be accessed with the QR code below. Although this feature is not new, it could be done at much lower cost with a few enhancements. This is very relevant in the contemporary reality of severe financial constraints. The phantom heads have an added feature in that the lower jaw that can open and close, as well as soft tissues (mouth and cheeks), are appropriately flexible and shaped to mimic real-life soft tissues. The latter is necessary to teach dental students to safely deflect soft tissues with a dental mirror when preparing cavities with a high-speed drill. Although the first prototype of the soft tissues was a failure because of inappropriate flexibility of the material chosen, the simplicity of the design and printing process allowed for the immediate manufacturing of an improved product. Printed teeth with similar hardness to real teeth are in the pipeline as well to mimic tooth cavity preparation with a high-speed drill in a more authentic way.

The educational approach was adjusted to maximise contact time and to encourage students to take responsibility for their own learning. The Department of Prosthodontics moved away from a lecturer-centred approach – giving lectures and demonstrations – to a student-centred active learning approach with a focus on improving relevance and constructive alignment, a model that is already being applied in developing clinical reasoning skills in the School.[1]

To implement the new educational philosophy, the Department produced a series of videos and other visual materials with the help of Creative Studios, a subdivision of the Department of Education Innovation at UP. The material included videos and other visual material of all relevant techniques and the use of dental materials in a real-life context. Students must come prepared for preclinical sessions by watching the relevant material and then have to apply the skills and knowledge they learned in the simulation setting. Students can view the audiovisual materials on the chairside computer screen or on a mobile device while they work. This is important 'just-in-time' learner support as the teacher-supervisor ratio is often 1:4 or 1:6, which is less than ideal for such complex procedures.

The assessment of student performance included the provision of formative feedback and simulated 'workplace-based' assessment to perform procedures with or without assistance. This is done on the GoodX Dental Studio software (GoodX, South Africa), available at chairside, and also used during clinical teaching. Clinical teachers provide detailed task-level and self-regulation feedback as required.[2] The immediate availability of electronic assessment data saves much time when creating statistics and drawing inferences on the students' development of competence over time. The statistics also help to inform assessor inconsistencies that can be addressed without delay. Paper-based records (quota books) are now purely used as a back-up recordkeeping system.

Lessons learnt

We as lecturers were sceptical about whether the change in educational philosophy would work. We did not believe that students would take responsibility for their own learning and we felt we had lost control. Placing the onus on students to take control of their own preparation before a preclinical session through self-study, in their own time, was in fact very successful, and it took just one week to inculcate this behaviour. It clearly helped students to take responsibility for their personal clinical output, it increased the efficiency of the preclinical training, and made the transition from preclinical to clinical teaching and learning much better. The main role of the lecturer moved from being an instructor to being somebody who offers feedback and provides guidance.

The audiovisual materials negated the need for group demonstrations. Demonstrations are often overwhelming and always contain too much information to remember. The new methods negated the need for a group of students to stand around a chair/bench to watch a live demonstration, which they can hardly see in detail. Students can see the detail much more clearly using the audiovisual material, and they can access it when they need the information.

It also became evident that the main phantom head laboratory cannot provide the same learning experience because of its generic set-up outside an authentic clinical area. The computer screen situated at each phantom head is linked to the central computer that is used as a presentation station operated by the lecturer, by default facilitating a lecturer-centred approach. GoodX Dental Studio Software is therefore not available for individual assessment and the students do not have access to the system to watch the videos while they work. Students will therefore have to use their own mobile devices for this purpose but this is not ideal as many students do not own appropriate mobile devices (e.g. smart phones or tablets). These issues need to be addressed in the skills laboratory to allow for the same teaching and learning experience that can be offered in the clinical setting.

The use of 3D printed technologies in combination with blended learning approaches allowed for preclinical simulation and assessment within the authentic clinical environment, which helped students to get used to the clinical environment before engaging in real-life fixed prosthodontics.

The School of Dentistry learnt much from this innovation and there are already new ideas in the pipeline, such as the manufacturing of custom-designed typodonts based on real-life 3D scans to recreate paedodontic (deciduous/children's) teeth, teeth that contain root canal systems and typodonts that can be used to simulate exodontia (tooth removal) techniques. The last is already in a planning phase.

Collaboration with CUT allowed rapid production of 3D-printed phantom heads at a fraction of the normal cost, allowing flexibility and an improvement in the 'authenticity' of the simulation process. This symbiotic relationship between the two institutions is mutually beneficial and has unlimited potential to be expanded to other disciplines.

We also learnt that continual competency-based assessment in the preclinical period is very important in the development of competencies to ensure a smooth transition from the preclinical to the clinical environment. Mere exposure to procedures in the preclinical setting is simply not good enough.

What will I keep in my practice?

This innovation worked so well that the entire approach will remain but will be enhanced through student feedback and by implementing the planned improvements mentioned in the previous section.

What will I not do?

The only process that can be discarded is the back-up paper-based record-keeping that has become obsolete. Such systems only waste time because electronic systems provide information of better quality, instantaneously, and reduce the requirement for laborious manual processing of records to determine student output.

Declaration. None.

Acknowledgements. The authors acknowledge Dr Tshepiso Mfolo and Creative Studios for the manufacturing of the video linked to this publication.

Author contributions. AF and JHvdH were responsible for the conceptualisation and functionalisation of the project, under the guidance of CP. CP, AF and JHvdH respectively contributed 70%, 20% and 10% to the report.

Funding. None.

Conflicts of interest. None.

Evidence of innovation

1. Postma TC, White JG. Developing students' clinical reasoning skills: Correlates of perceived relevance of two teaching and learning approaches. Eur J Dent Educ 2017;21(1):52-57. https://doi.org/10.1111/eje.12178
2. Hattie J, Timperley H. The power of feedback. Rev Educ Res 2007;77(1):81-112. https://doi.org/10.3102/003465430298487

Accepted 30 April 2021.

Afr J Health Professions Educ 2021;13(3):197-198. https://doi.org/10.7196/AJHPE.2021.v13i3.1504