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Using a Novel 3D-Printed Foot Model in Simulation-Based Learning of Podiatry Clinical Skills: A Qualitative Study on Students' Learning Experience

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Using a Novel 3D Printed Foot Model in Simulation - Based Learning of Podiatry Clinical Skills: A Qualitative Study on Students' Learning Experience

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Abstract

Background

Undergraduate Podiatry students are expected to perform clinical skills such as sharp debridement safely and competently before graduating. Simulation-based education is a way to provide authentic learning. The aim of this study was to evaluate the student learning experience using a low-cost purpose-designed 3D-printed foot model compared to a commercially available foot model in novice learners.

Methods

Students with no prior training to scalpel skills were recruited. Participants were provided with a 30-minute debridement skill training session, following which they practiced on 1) novel 3D-printed foot model, and 2) commercial foot model. Participants provided qualitative feedback via an anonymous questionnaire.

Results

Ten students participated in this study. Four themes were identified relating to: 1) positive learning experience; 2) confidence level; 3) safety and ease of use; and 4) quality of the foot models. Participants felt that using the 3D-printed foot model provided a superior learning experience to the commercial foot model, with more practice time resulting in increased confidence. Regarding safety and ease of use, the 3D-printed foot model was easier to manoeuvre into various positions.

Conclusion

The novel 3D-printed foot model improved learning experience compared to a commercially available foot model. Further improvements have been identified, and its use can be considered in podiatry skills training.

I INTRODUCTION

Acquiring podiatry clinical skills such as callus and wound debridement, nail cutting, administering of local anaesthetic and minor surgery are a fundamental part of podiatry undergraduate training. These clinical skills underpin many of the treatments that a podiatry student is expected to be able to perform safely, effectively, and competently prior to graduating as required by the Podiatry Board of Australia in the Podiatry Professional Capabilities for Podiatrists (Podiatry Board of Australia, 2022). Demonstrating and practicing on real patients to develop manual dexterity is not always the most convenient and ideal way to introduce students to clinical skills involving sharp instruments. The performance of these skills on real patients for the first time can be stressful and anxiety provoking for students (Van Sickle et al., 2006), leading to poor performance; for example, cutting or injuring the patient due to being nervous (Manning et al., 2018). Therefore, prior to treating a real patient, these podiatry clinical manual skills are repeatedly practiced through simulated conditions such as debriding candle wax and oranges (Banwell, 2021; Causby et al., 2017). In some instances, with students' consent, they are encouraged to keep their nails long or not remove their calluses on their feet so that they can practise nail cutting and callus debridement on each other.

This traditional way of facilitating teaching poses several concerns. The use of simulated items such as wax pieces do not fully mimic the position of the skin lesion on the foot, which will impact on how the scalpel is held in the hand, and how the other hand is used to stabilise the foot. Peer practice, whilst more realistic, limits equity and opportunities to practise as not all students will have callus or skin lesions that require treatment, and some students may not be willing to be a 'volunteer' for fear of getting injured by a peer. Further, students may not be able to receive treatment due to personal, cultural, or medical reasons.

To overcome these issues, the use of simulation has been used to develop and refine students' clinical skills such as debridement, injections, suturing and surgery (Beaubien & Bake, 2004; Gaba, 2004; Lateef, 2010; Morgan, 2006; Van Sickle et al., 2006). Simulation-based learning is a way to achieve cognitive realism, providing authentic learning to students (Roach et al., 2018). Simulated practice also allows students to make and correct their mistakes in a low-risk teaching and learning environment, leading to increased confidence in clinical skills later on (Van Sickle et al., 2006; Weller et al., 2012).

Unfortunately, simulation-based learning equipment and models are often extremely expensive (Gaba, 2004); Lateef, 2010; Maloney & Haines, 2016). Commercially available purpose-made podiatry foot models can cost up to $1650 each. This, in turn, reduces the capacity of educational institutions to purchase multiple models. Depending on each cohort's student-to-foot model ratio, students may have to wait for their turn to practice the skills. Long wait times can lead to student disengagement and reduced practise time. For example, for a one-hour weekly practical session during term time, a student may only get 15 minutes of practice time if one foot model were shared between 4 students. Due to the high cost of the commercial foot models, students may also not be allowed to take the models home for self-paced, and self-directed practice. Although using the simulated learning approach increases student engagement, the high cost of the commercial foot model limits the extent to which it can be used. The ideal situation would be to have one foot model per student, which would allow the student to utilise the entire practical session to practice their skills under guidance. Increased practice opportunities have been found to foster better skills development and higher confidence in students, resulting in better management and outcomes for patients (Cant & Cooper, 2010).

3D printing was invented more than 50 years ago and has developed rapidly (Su & Al'Aref, 2018). It has a wide range of applications in the engineering and medical areas, and even in printing devices for personal use (Su & Al'Aref, 2018). In the area of medicine and health, 3D printing is currently used to create medical devices, prosthetics and orthotics and a variety of human body part replicas (Liaw & Guvendiren, 2017). Within the podiatry field specifically, 3D printing has been used to fabricate foot orthoses devices and have been found to be as comfortable and provides supports to the foot comparable with traditional thermoplastic custom made foot orthoses (Ho et al., 2021; Ho et al., 2022). To allow the possibility of maintaining a one-to-one student-to-foot model ratio, a low-cost 3D printed foot model was designed and printed using Thermoplastic Polyurethane (TPU) to substitute the costly commercial foot model (Figure 1). The foot model is described in further detail in the Supplementary File. Each foot model is light weight, weighing approximately 250 grams, and is easily portable. The cost per model (including printing material, technician hours for production, cleaning and assembling) was approximately $100, which is about a tenth of the cost of a commercial foot model.

Figure 1

New 3D-printed foot model with anchor, mimicking patient's foot in a supine position.

Photo by: Dr. Malia Ho

Being a new foot model design, it is unknown how this foot model would compare to the commercial foot model. Thus, the aim of this study was to evaluate how the student learning experience compared when novice learners used this 3D printed foot model or the commercially available foot model. The qualitative nature of this study will also tease out reasons for the similarities and differences.

II MATERIALS AND METHODS

A *Design*

This was a cross-over study design approved by the Human Research Ethics Committee (HREC Approval number: 22537) (Figure 2). Potential participants were recruited via advertisements posted on their student learning portal. They were required to contact the principal investigator who screened each participant's eligibility to be included in the study. The inclusion criteria were students enrolled in a health-related undergraduate course with no prior experience in sharp debridement, and who were able to volunteer their time for the study.

Each session lasted no more than 2 hours and was conducted at one of the practical training rooms at CQUniversity. Participants were provided with a 30-minute sharp debridement skill demonstration session, following which they were required to practise their debridement skills on the commercial foot model (CFM) and the 3D printed foot model (3DPrint). For each session, participants were randomly assigned to Group 1 or Group 2. Group 1 practiced clinical debridement skills using the purpose-made 3DPrint, while participants in Group 2 practised debridement skills using the CFM (control). After 30 minutes, participants from both Group 1 and

2 were asked to complete an electronic online questionnaire immediately after the session. Once the questionnaire is completed, the participants 'crossed over' and practised with the other foot model for another 30 minutes. Participants provided feedback by completing a second questionnaire. The responses were recorded anonymously. Both sessions were conducted in an identical fashion.

B *Participants and Recruitment*

Using a purposive sampling approach, the study was promoted through Unit Coordinators and Heads of Courses of health-related undergraduate courses at CQUniversity. An invitation to participate was posted on the student online learning management system by their relevant Unit Co-ordinator or the Head of Course. Ethical approval was approved by the CQUniversity Human Research Ethics Committee (HREC Approval number: 22537). The participant information sheet was provided to each participant. Written informed consent was obtained from each student prior to the enrolment in the study. No remuneration was offered or advertised for this study.

C *Equipment and Materials- Foot Models*

The 3DPrint used was the one developed by the research team which was clamped to the end of a plinth (Figure 1). The commercially available foot model used in this study was the *Medical Foot Simulator* (Kyoto Kagaku Co. Ltd., Japan, 2020). The CFM was positioned at the end of a plinth on the swivel stand that was provided when purchased.

D *Procedure- Debridement Skills Training and Practice Session*

All participants were provided with basic training for debridement skills. All skills were demonstrated to participants prior to practising by two Australian Health Practitioner Regulation Agency (Ahpra) registered clinical educators (MH, JN). Participants were supervised by clinical educators (MH, JN) throughout the sessions. To ensure students' safety, each group was limited to six participants (clinical educator to student ratio = 1:3).

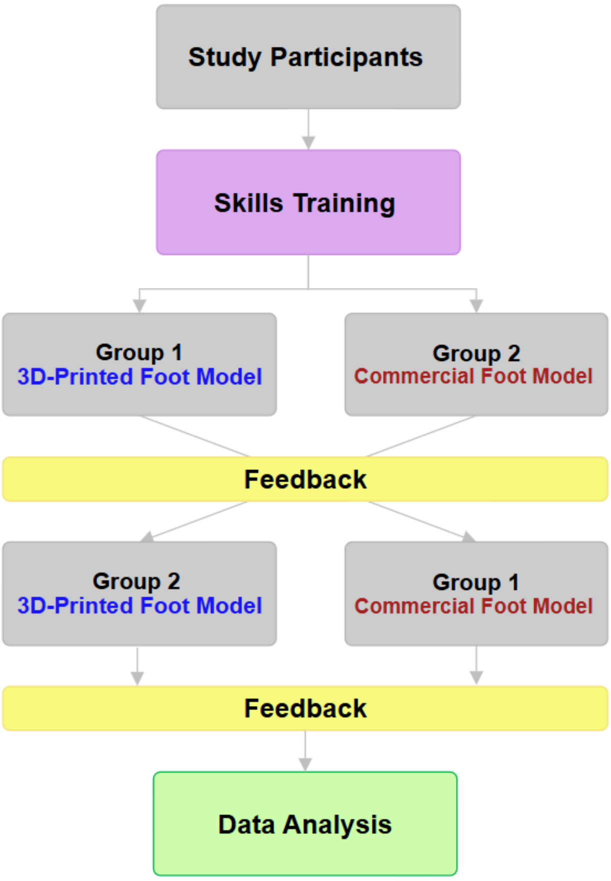
E *Data Collection*

The two questionnaires used in this study were developed by two researchers (MH, JN), who are academics and registered podiatrists experienced in learning and teaching, simulation education, and podiatry clinical practice. The questionnaires were reviewed by a third researcher and registered podiatrist (AE) to ensure the questions were clear and succinct. The questionnaires were also presented to a small group of five third-year Podiatry students to ensure that there were no errors or unclear or poorly articulated questions. Based on this feedback, changes to the questions were implemented and a final questionnaire was agreed upon by all authors.

The two questionnaires for each simulation group consisted of five open-ended questions evaluating the participants' experience practicing their newly learnt clinical debridement skills on the two foot models. (Supplementary File 3). The questions were uploaded on an online platform, Padlet, and participants were provided with a link. Accessing the Padlet page allowed participants to type in their responses on their own device or on a desk top computer provided. Participants were able to view their own responses, and the responses of others, and 'like' the responses if they agreed. The responses were captured in real time. This is similar to how a focus group interview may be conducted, but with the assurance of anonymity for the participants. At the end of each of the two sessions, the responses were downloaded for analysis.

Figure 2

A schematic representation of the participants through the study.



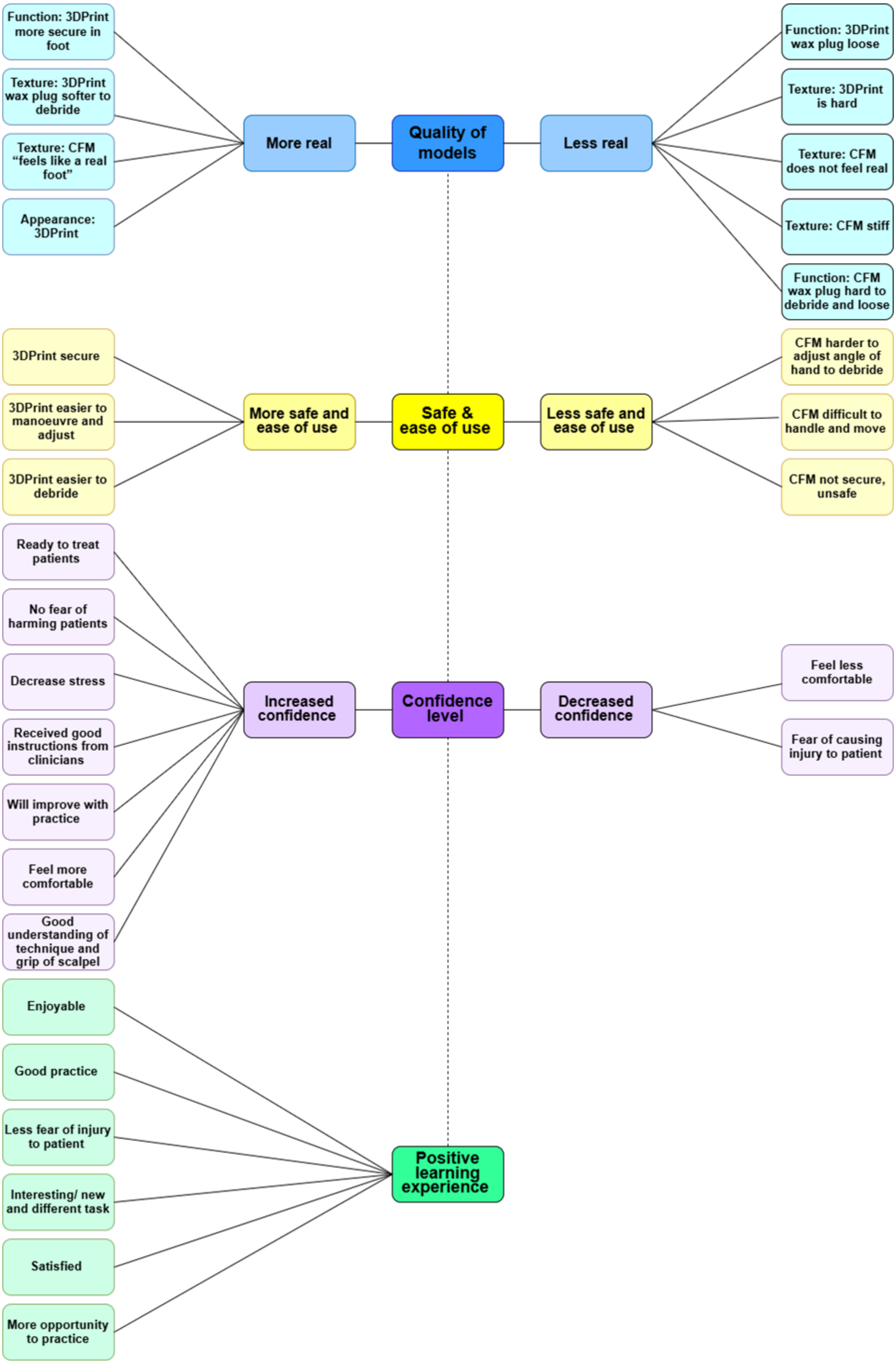
F *Data Analysis*

A qualitative research approach was used to understand the participants' learning experience using the 3DPrint compared with the commercial foot model during the clinical skills sessions. Clarke, Braun and Hayfield's (2015) inductive approach were applied for data analysis (Braun & Clarke, 2013; Clarke et al., 2015). The 6-step framework provided a useful and rigorous approach for exploring the perspective of research participants while allowing the data analysis to be analysed from the bottom up and be driven by the data itself instead of the research question, which may render the analysis to biases (Clarke et al., 2015; Morgan, 2006). The 6-steps for this approach include: 1) familiarisation with the data; 2) generating initial codes; 3) searching for themes; 4) reviewing themes; 5) defining and naming themes; and 6) producing the report (Braun & Clarke, 2019; Clarke & Braun, 2013; Clarke et al., 2015). The framework was adapted as many of participants' responses were short sentences. The responses were analysed by the first author to identify themes and subsequently reviewed by the second author to discuss the themes identified and to reach consensus. This was then reviewed by the third author independently and all discrepancies were resolved by discussion until consensus was reached. A content analysis map was generated from this process (Figure 3).

G *Results*

Following analysis, four themes were identified from the data to achieve an understanding of the participants' experience. These themes identified included: 1) positive learning experience; 2) confidence level; 3) safety and ease of use; and 4) quality of the foot models (Figure 3).

Figure 3 Content analysis map



1 *Positive Learning Experience*

When learning debridement skills using both foot models, all participants described the learning experience as being equally positive. Even though the task was difficult, the use of foot models resulted in students being very engaged, rather than feeling anxious and nervous.

> "It was quite difficult to slice away the callus due to high resistance. However, it was good for practicing the first time."

> "It was a really interesting learning experience and extremely satisfying."

> "I really enjoyed using the 3D model to debride the callus - it was super satisfying and easy to complete!"

Although participants had no prior experience in using a scalpel to debride prior to this study, participants felt that the task was achievable and expressed readiness to treat a real patient under supervision of a clinician.

> "…. it was a great learning experience! I feel like I could have a go on a real person whilst supervised."

Participants acknowledged that the opportunity to practice their debriding skills on each other were limited, unlike other practical skills such as joint assessments in physiotherapy which could be repeated multiple times. Learning clinical skills using the foot models allow the participants to contextualise their learning even when peer practice was not possible.

> "It's a good opportunity to practice, obviously you can't practice on people in class like we can in physio…."

2 *Confidence Level*

Participants expressed an increase level of confidence after having the opportunity to use the foot models to practice debriding. This was reported following the use of both the CFM and 3DPrint models. One participant reported after the CFM simulation session:

> "A lot more confident in terms of holding the scalpel [sic] and understanding the technique."

> Another participant reported the same immediately after using the 3DPrint:

> "It was easy to use, and it increased my confidence in debridement."

Participants suggested that this increasing level of confidence may possibly be associated with being able to practise on a simulation foot model in the first instance without the fear of injuring or harming a patient:

> "It was pretty good experience as I could practice debridement without hurting a patient."

Participants expressed that practising debridement skills with a foot model while learning the new skill helped them feel less pressured compared to the thought of having the patient present in front of them:

> "It was really good, it's pretty close to handling a real patient without the pressure of actually managing a living person with movement and pain, I'd feel more confident after using this."

Not only do participants report increase in confidence in debriding, but participants also report increase confidence in communicating the treatment procedure with patients and other healthcare professionals should this be required. Following the 3DPrint simulation session, one participant expressed:

> "I do feel like I understand the process and might be confident discussing the process with patients in a MDT [multidisciplinary team] referral or something."

3 *Comparison of Safety and Ease of Use of Foot Models*

Participants compared and reflected on the ease of use of the two-foot models, reporting that the foot models may be easier to manoeuvre than a real person's foot.

> "…obviously, it may not be as easy to just move a person's foot in the positions you could with the model…"

Between the two foot models, it would seem that the general consensus is that the 3D printed foot model was easier to handle and use compared to the commercial foot model:

> "I believe the 3D printed foot model for deriding [sic] corns and calluses was (sic) quite efficient and easy - I like the movement of the foot and how easy it was to move the foot and put it into position."

> "The commercial foot was more difficult to manoeuvre and grip I think due to the bulk of the foot, and the inability to move it as easily."

> "Commercial one was harder to adjust angle of my hand position though, it was pretty similar (sic) overall."

Participants also reflected on the stability of the two-foot models on the patient treatment chair and suggested that the commercial foot model was less secure on the patient chair compared to the 3DPrint. Participants indicated that the 3DPrint appeared safer to practice with:

> "I think the 3D one being secured to the bed is a little safer considering scalpels are sharp, it manoeuvres a bit easier and the softer wax was good to practice technique without getting stuck like the commercial model."

> "It doesn't feel as secure on the table, especially with the harder wax it feels like it could tip over and maybe the 3D one would be a bit safer?"

4 *Quality of the Foot Model*

In terms of realism, participants described the skin texture of the CFM as more real compared to the 3DPrint:

> "The skin texture [of the commercial foot model] feels more real."

> "It was really interesting, obviously it's a lot harder (plastic is hard, not difficulty hard) than a real human foot, but it's good to get the feel for how you can arrange the patient and orientate the scalpel and feel how a callous might feel."

> "Skin texture is obviously always going to be a challenge to replicate, and maybe movement through the foot itself (moving toes and midfoot) but it is really good."

In terms of the wax plug, participants generally felt that the 3Dprint wax plug was more representative of real callus, compared to the CFM.

> "I thought the wax was quite soft and might be an accurate representative of a foot / callus that has been soaked. Overall thought this was a great learning experience."

> "It was quite difficult to slice away the callus due to high resistance."

Participants suggested that further improvement should be considered for both foot models mainly to implement movable toe joints, and to create more realistic looking skin lesions.

> "Skin texture is obviously always going to be a challenge to replicate, and maybe movement through the foot itself (moving toes and midfoot) but it is really good."

> "Fake calluses could be made more like real calluses or warts to have dot or different colour of spot underneath the calluses."

III DISCUSSION

The 3D printed foot model used in this study was a prototype. Considering consumer feedback in the design of teaching resources is vital in ensuring that the material used is fit for purpose (Turner et al., 2020). This study aimed to compare the 3D printed prototype with an existing commercially available foot model. The result of this study shows that the use of foot models for simulated training increases student learning experience and confidence. The novel 3D printed foot model is comparable to the commercial foot model in achieving this. The 3D printed foot model was more easy to use and more realistic than the commercial foot model. Some improvements were suggested that could help inform further development of the 3D printed foot model.

A *Improved learning experience*

It is common for undergraduate podiatry students to feel stressed and not confident if they feel they are inadequately prepared to treat patients (Banwell et al., 2021). The use of a foot models to increase practice opportunities seem to provide a positive and valuable initial learning experience. Studies have shown that consistent practice using simulation-based learning enhances proficiency and confidence (Elendu et al., 2024). This agrees with the findings of our study, where participants using both foot models immediately reported positive learning experiences and a sense of not being afraid to use this skill on a real person, given more time to practice. The positive learning experience may stem from students feeling that they are allowed to continuously develop these skills without the initial fear of embarrassing themselves in front of the patient, and without the fear of injuring themselves or the patient. Although participants found both 3DPrint and commercial foot models equally engaging. This highlights the need to ensure that students have easy and ready access to these foot models. Ensuring that the foot models are affordable may be key to providing this access.

B *Improved confidence using foot models*

Our study found that the 3D printed foot provided increased confidence in debriding skills where students generally felt immediate confidence in the skill they had just learnt. In this aspect, both foot models provided the same benefit to students. Simulation skills sessions have demonstrated to have generated an increase confidence in the health students (Beaubien & Baker, 2004; Manning et al., 2018; Van Sickle, 2006). Students who have higher confidence have been found to perform better academically and this has significant positive impact on student's competencies as a future clinician (Turner et al., 2020). This finding supports the use of the 3DPrint foot model together with, or in place of the current commercial foot model.

C *Quality and ease of use of the foot models*

The participants found the 3D printed foot model easier to use compared to the commercial foot model. However, there were still shortcomings in both models in terms of realism. Whilst the commercial foot had a silicone-like skin texture that mimicked real skin more, the 3D printed foot model had a wax plug that mimicked callus more. As part of the consumer co-design process, data collected from this study has provided useful feedback on how the 3D foot model can be improved to increase the realism factor of the foot model. Participants suggested that the overall texture of the 3DPrint could be improved so that it closer resembles a real foot, and suggested that if some joints were movable, that would also further increase its realism. Feedback also included that the wax plugs may not feel like real callus. It is envisioned that the appearance and texture of the wax plugs can also further be improved to feel more like thick skin.

D *Limitations*

There may be a possibility that participants may feel pressured to provide positive responses as the research team members are podiatry educators within the institution. To mitigate this, students were recruited from a range of health related courses and responses were collected via Padlet rather than face to face interviews. In addition, the responses were anonymous so the identity of the person who provided feedback was not known. This is evident where not all feedback were positive.

Additionally, this study was limited to the training and practice of sharp debridement skills only and captured the immediate student learning sentiments. Further longitudinal studies will be useful to see if these positive sentiments carry on throughout the course of study, and if clinical skills and patient outcomes improve over the course of the participants' course. In this study, it was not possible to follow through to assess the participants' skill competency as not all of them were podiatry students. Future studies could investigate if competency and confidence could be improved with the use of 3D foot models.

Although we have stated that the 3D printed foot model is a low-cost foot model, we had only taken into consideration the cost of printing materials. The scope of this study focused on the student's user experience. Future studies conducting a cost-benefit analysis may be useful to support the use of 3D printed models in education.

IV CONCLUSION

The findings of this study demonstrates that the novel 3DPrint designed for this study can provide a positive first learning experience for students and can build their confidence for future learning of other more complex clinical skill. This study also collected feedback for further refinements to the current 3DPrint. Podiatry schools offering undergraduate and postgraduate course should consider using 3D printing technology to produce low cost 3DPrint to compliment the teaching of clinical skills and better prepare students for clinical placement. Further studies are required in the future to further assess and validate the long-term effectiveness of the low cost 3DPrint in podiatry education.

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Supplementary File 1

Details of the 3D printed foot model

To hold the foot model in place, an anchor was printed using Acrylonitrile Butadiene Styrene (ABS) that provides a firm support for the model to be screwed on and attached firmly onto the end of the patient chair to simulate the patients position when sitting in a podiatry chair (Supplementary Figure 1). The foot model was designed to be manoeuvred into different positions on the anchor such that it mimicked the patient's foot in prone, supine, abducted and adducted positions (Supplementary Figure 2). A mould was custom designed so that melted wax could be poured in to create wax plugs to simulate callus (Supplementary Figure 3). These wax plugs would fit into purpose made apertures in the foot model allowing multiple repeated practice opportunities by replacing the wax plugs (Supplementary Figure 4). The commercial foot model used as the control was the Medical Foot Simulator (Kyoto Kagaku Co. Ltd., Japan) shown in Supplementary Figure 5.

Supplementary Figure 1

3D-printed anchor that secure 3D-printed foot model to podiatry plinth.

Photo by: Dr. Malia Ho

Supplementary Figure 2

New 3D-printed foot model with anchor, mimicking patient's foot in a prone position.

Photo by: Dr. Malia Ho

Supplementary Figure 3

3D-printed mould to create wax plugs to simulate callus and wound lesions.

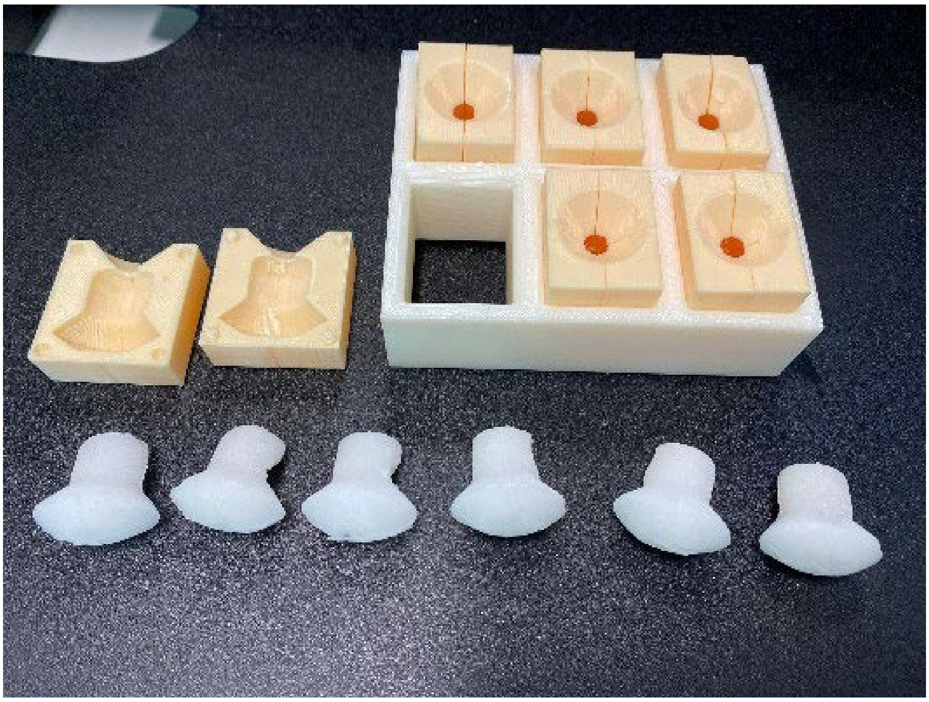

Photo by: Dr. Malia Ho

Supplementary Figure 4

Wax plug placed in customised aperture in the foot model.

Photo by Dr Malia Ho

Supplementary Figure 5

Commercial Foot Model, Medical Foot Simulator. Image adapted from Kyoto Kagaku Co. Ltd. (adapted from Kyoto Kagaku Co Ltd. with permission).

This foot model made from soft resin is accompanied with replaceable corn and callosities to assist users to practice clinical skills such as removal of callus.

Supplementary File 2

Procedure details

Participants were showed how to:

a) load a scalpel blade on a scalpel handle;

b) grasp the scalpel handle with the dominant hand to ensure a good grip of the handle when debriding;

c) position the non-dominant hand away from the scalpel blade to prevent any accidental injuries

d) hold and pull back the toes with the non-dominant hand to achieve 'skin tension';

e) place the scalpel blade against the 'callus lesion' and slowly cut away the 'callus'.

f) To ensure safe practise, upon completion of the task, all scalpel blades were removed using the BladeFLASK Scalpel Blade Remover.

Supplementary File 3

Questionnaire for each simulation group

Questionnaire for *3D Printed Foot Model* Simulation Group
1. Can you describe your experience using the 3D printed foot model for debriding corns and calluses? 2. Do you think you will feel more or less confident debriding callus on a real person after practicing on the 3D printed foot model? Why? 3. In your opinion, how has using the 3D printed model impacted your learning experience? 4. How do you think the 3D printed foot model can be improved? 5. How does this compare to practicing on the commercial foot model?

Questionnaire for Commercial Foot Model Simulation Group
1. Can you describe your experience using the commercial foot model for debriding corns and calluses? 2. Do you think you will feel more or less confident debriding callus on a real person after practicing on commercial foot model? Why? 3. In your opinion, how has using the commercial foot model impacted your learning experience? 4. How do you think the 3D printed foot model can be improved? 5. How does this compare to practicing on the 3D printed foot?