Application of 3D-printed models in procedural training for dynamic hip screw fixation and intraosseous vascular access: An original article

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Learning Point of the Article:

Low-cost 3D-printed and model-based simulation can provide accessible, realistic procedural training for dynamic hip screw fixation and intraosseous vascular access, supporting early hands-on exposure to orthopedic and emergency procedural skills.

Abstract

Aims and Background: Simulation is increasingly used in medical education, but commercially available procedural trainers can be expensive, difficult to replace, and inconsistently accessible. This study aimed to develop and evaluate low-cost model-based training systems for dynamic hip screw (DHS) fixation and intraosseous (IO) vascular access, with emphasis on the educational value of three-dimensional (3D)-printed models.

Materials and Methods: A 3D-printed IO model was designed to accommodate a 20 mL syringe with a nominal diameter of 20.5 mm. A DHS procedural training session was delivered using 12 sawbone models, two demonstration kits, and two power tools. Medical students received introductory teaching, undertook supervised practical training, and provided qualitative feedback on ease of use, realism, and educational value.

Results: Students reported that the IO model was easier to use and more realistic than standard overused trainers, particularly in reproducing the resistance encountered during needle insertion. Participants described the DHS session as highly impactful and reported improved understanding of the procedure and increased appreciation of orthopedic surgery. The approximate production cost of the 3D-printed models was £2 per model.

Conclusion: Low-cost 3D-printed and model-based simulation appears to offer a practical adjunct for IO access and DHS fixation teaching. Further validation using larger cohorts, structured feedback tools, objective skill assessment, and pre- and post-session outcome measures is required.

Keywords: Three-dimensional printing, simulation training, dynamic hip screw, intraosseous access, orthopedic education, procedural skills.

Introduction

Simulation-based learning is now an established component of medical education. It can range from role play and part-task trainers to computer-based simulation, virtual reality, and high-fidelity mannequins with variable physiological parameters [1,2,3]. It's central value is that learners can practice clinical decision-making and technical skills in a controlled environment, receive feedback, and learn from errors without exposing patients to avoidable risk [4].

Simulation also supports interprofessional learning, repeated exposure to uncommon procedures, and standardization of educational delivery. Within Miller's pyramid of clinical

Access this article online

Website: www.jocr.co.in

DOI: https://doi.org/10.13107/jocr.2026.v16.i09.8134

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Submitted: 21/06/2026; Review: 05/07/2026; Accepted: August 2026; Published: September 2026

DOI: https://doi.org/10.13107/jocr.2026.v16.i09.8134

competence, simulation helps learners progress beyond knowledge acquisition toward demonstration of procedural capability before entering clinical practice [5].

Three-dimensional (3D) printing has expanded rapidly within medicine. Patient-specific 3D anatomical models generated from computed tomography data have been used to support communication within multidisciplinary teams, pre-operative planning, surgical rehearsal, custom implant design, and procedural training [6,7,8,9]. In medical education, 3D-printed models may be particularly useful where learners need hands-on experience with procedures that are technically demanding, infrequently encountered, or expensive to simulate using commercial equipment [10,11,12].

This educational simulation project aimed to develop and evaluate low-cost procedural training models for intraosseous (IO) vascular access and dynamic hip screw (DHS) fixation. The objective was to explore whether the models were realistic, usable, and educationally valuable for medical student procedural teaching.

Materials and Methods

This was an educational simulation evaluation of two low-cost procedural training systems: A 3D-printed IO access model and a DHS fixation simulation model.

The IO model was developed to provide an inexpensive and easily accessible training aid for medical communities in resource-limited settings and has been used for training in Haiti. The model was designed to accommodate a 20 mL syringe with a nominal diameter of 20.5 mm, enabling learners to practice needle insertion and fluid aspiration or injection through a simulated bone cavity.

For the DHS training session, 12 sawbone models, two demonstration kits, and two power tools were supplied by DePuy Synthes. Five medical students attended each teaching session. Before practical training, students received introductory teaching. Baseline understanding was explored through verbal questioning by the session lead, delivered by a consultant anesthetist for the IO session and a senior registrar for the DHS session.

Students then undertook supervised hands-on practice with guidance from registrars throughout the session. After using the models, students were interviewed informally and asked to provide qualitative feedback on ease of use, realism, comparison with standard models, and perceived impact on learning.

Institutional Ethics Committee approval

This project evaluated anonymized educational feedback from medical students and did not include patient data, patient images, or an intervention on patients. The authors should retain confirmation of local educational governance approval, Institutional Ethics Committee approval, or a formal waiver before submission.

Results

Students reported that combining short didactic teaching with practical procedural training was an effective approach to learning.

Feedback from the IO session suggested that the 3D-printed model was easier to use and more realistic than the standard training model. One student commented: "The 3D-printed models were much better to use compared to the standard model because the standard models felt very soft and overused, which made it difficult to feel the resistance when the needle went in."

The DHS session was also positively received. Students described it as "extremely impactful" and reported that it "increased appreciation for this specialty." Students were able to compare the model with standard training models by considering design, functionality, usability, and realism. Overall feedback suggested that the model was straightforward to use and provided a realistic procedural learning experience.

The estimated production cost of the 3D-printed models for procedural training was approximately £2 per model.

Discussion

This project demonstrates the potential value of low-cost 3D-printed and model-based simulation for procedural training in medical education. Although simulation is routinely used for clinical and technical skill development, 3D-printed models remain underused in many teaching environments despite their ability to provide repeatable, inexpensive, and anatomically relevant practice opportunities.

The IO model appeared to address a practical limitation of some standard part-task trainers: Repeated use can reduce tactile fidelity, making it difficult for learners to appreciate the change in resistance as a needle enters the medullary cavity. By permitting aspiration and injection, the model allowed learners to rehearse the IO procedure from start to finish rather than practicing needle placement alone.

The DHS model provided early exposure to an orthopedic trauma procedure that medical students would otherwise rarely perform. Procedural simulation can improve understanding of anatomy, implant positioning, theater workflow, and the importance of controlled technical steps. It may also stimulate interest in orthopedics by making operative principles more accessible to undergraduate learners.

Cost is a major advantage. Commercial procedural trainers can range from inexpensive basic replicas to more advanced systems costing hundreds of pounds, particularly where simulated blood flow or replaceable components are included. In contrast, the approximate cost of the 3D-printed models described here was £2 per unit, suggesting that in-house 3D printing could make procedural simulation more scalable across hospitals, universities, and lower-resource training environments.

The main limitation of this evaluation is that feedback was qualitative and informal. The project did not use a validated questionnaire, objective skill assessment, pre- and post-session score comparison, or follow-up assessment to determine skill retention. The number of participants was small, and the feedback may be subject to selection and response bias. The DHS element also requires clearer technical description in future work, including whether all components were 3D printed or whether the teaching model combined sawbones, supplied demonstration kits, and 3D-printed elements.

Future evaluation should include multi-center delivery across different trusts, larger participant numbers, structured Likert-scale feedback, objective procedural checklists, and assessment of learner confidence and skill acquisition before and after training. This would allow stronger conclusions about educational effectiveness and model validity.

Conclusion

Low-cost 3D-printed and model-based simulation can provide realistic and accessible procedural training for IO vascular access and DHS fixation. The preliminary feedback in this project suggests that these models may improve learner engagement, tactile understanding, and appreciation of orthopedic procedures. Further structured validation is required before broader implementation.

Clinical Message

Affordable 3D-printed procedural models may widen access to hands-on orthopedic and emergency skills training, particularly in undergraduate and resource-limited settings, where commercial simulation equipment may be unavailable or prohibitively expensive.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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Conflict of Interest: Nil
Source of Support: Nil

Consent: The authors confirm that informed consent was obtained from the patient for publication of this article

How to Cite this Article

Borumand M, Heidari A, Stephen C, Menon S, Chohan H, Simmons M. Application of 3D-printed models in procedural training for dynamic hip screw fixation and intraosseous vascular access: An original article. Journal of Orthopaedic Case Reports 2026 September;16(09): 497-500.