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Evolving simulation-based education in trauma care: a user-perspective on implementation requirements

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Abstract

This study explores the integration of simulation-based augmented reality (AR) education in trauma care, focusing on digital twins and computer simulations for interactive learning. Traditional case discussions in fracture treatment rely on retrospective analysis. In contrast, this approach allows participants to experiment with treatment strategies and analyze their effects using predictive analytics, enhancing surgical outcomes.

The OSORA educational platform was deployed in trauma courses, utilizing the Ulm fracture healing model to simulate the bone tissue differentiation process. Participants could modify fracture management strategies and assess healing metrics such as interfragmentary movement and bone tissue formation. Interactive visualizations facilitated understanding of complex mechanobiological relationships, fostering a transition from passive to active learning.

Feedback from 109 participants and faculty members indicated positive reception of the concept. Course participants appreciated the clarity of learning objectives and the engaging nature of digital twins in case discussions. Faculty highlighted the potential of the platform to reduce preparation workload through improved usability and asynchronous formats. However, challenges such as technical requirements for 3D visualizations and the need for faculty onboarding were noted.

Future directions include extending the tool's applications to cover the entire skeletal system, incorporating clinical planning software, and enhancing quality management through rigorous validation. Simulation-based education holds promises for improving trauma training, offering a risk-free environment to explore surgical outcomes and postoperative scenarios, ultimately bridging the gap between education and clinical practice.

1 Introduction

Understanding fracture healing is crucial for healthcare professionals involved in the treatment of fractures. Presentation-based case discussions are a tried and tested method, where experienced instructors present a surgical procedure to the course participants in a mostly linear, narrated form.

Instead of being limited to discussing the actual outcome of cases retrospectively, virtual case discussions based on digital twins (Katsoulakis, et al. 2024) and computer simulations allow for exploring the effect of different treatment strategies interactively by modifying the osteosynthesis and analysing the predicted healing outcome.

Advances in technology and increasing accessibility of virtual simulation models are opening opportunities for a wide range of user groups to gain hands-on experience by combining computer simulation methods with other (digital) learning methods (Sun, et al. 2024). The question remains, which requirements are crucial for value generation for the user groups and how the necessary training effort can be optimized (Ugwoke, et al. 2023).

2 The role of simulation-based medical education

Course participants benefit from scenario analysis based on real clinical cases. Interactive visualizations and graphical representations of important healing indicators present the complex mechano-biological relationships in an intuitive way. The transition from frontal teaching to active learning through visualization and interaction helps to better understand the impact of a selected osteosynthesis on the surgeries and post-op treatments.

Several research groups and companies are taking up the idea of providing simulation-based AR/VR environments for education and training, focusing on biomechanical principles (OSapp©), anatomy (PrecisionOS), procedure videos (Osgenic) or as a sales tool for medical devices (OSSO VR)[*].

For this study we deployed the educational software of OSORA in two trauma courses. The web-based application uses a modified variant of the Ulm fracture healing model for simulating the tissue differentiation process (Simon, Augat und Claes 2010, Niemeyer, et al. 2018, Engelhardt, et al. 2021). By utilizing digital twins of clinical example cases, course participants can vary the fracture management and use the built-in visualization and quantification tools for case discussions. Healing metrics such as interfragmentary movement, bone tissue formation over time and longitudinal fracture stiffness for configurable treatment approaches can be analysed and compared to experimental findings (see Figure 1).

To drive technology adoption, educational added value for both participants and faculty needs to be generated. The research questions for this project are straight forward:

1. Are the learning objectives within the concept clear?
2. Are digital twins perceived as a useful and valid educational tool in trauma?
3. How can the concept be further developed in the future?

[*] More information to the mentioned solutions can be found on the websites: https://osapp.aofoundation.org, https://www.precisionostech.com/, https://osgenic.com/, https://www.ossovr.com/

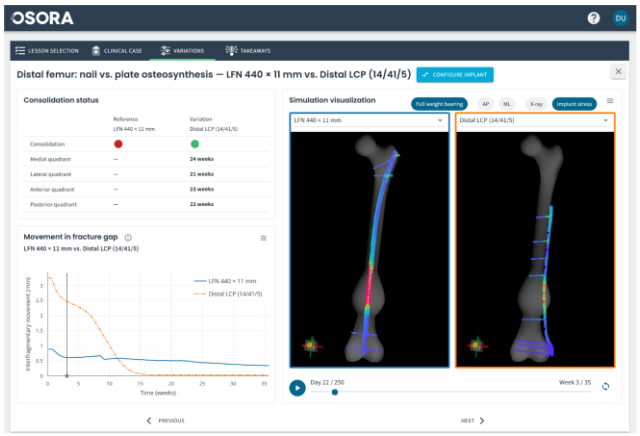

Figure 1: OSORA software platform exemplary showing choice of implants and prediction of bony consolidation, interfragmentary movement curve and visualization of implant stresses

3 Methodology

First time course participants of osteosynthesis courses with basic knowledge of fracture treatment and no prior contact with the OSORA educational software were asked to evaluate the course content. Answers were prepared on a 5-level Likert scale. After data cleansing, a sample size of $n = 109$ was available for analysis.

The feedback of the faculty was gathered in the form of structured interviews with a focus on indications, technical concept and level of achievement of teaching objectives. The qualitative approach was necessary due to different levels of involvement during course preparation, individual focus topics in the course sessions and debriefing availability.

4 Results

The results of the participant survey are shown in Figure 2, with course participants reacting generally positively to the introduction of the new concept.

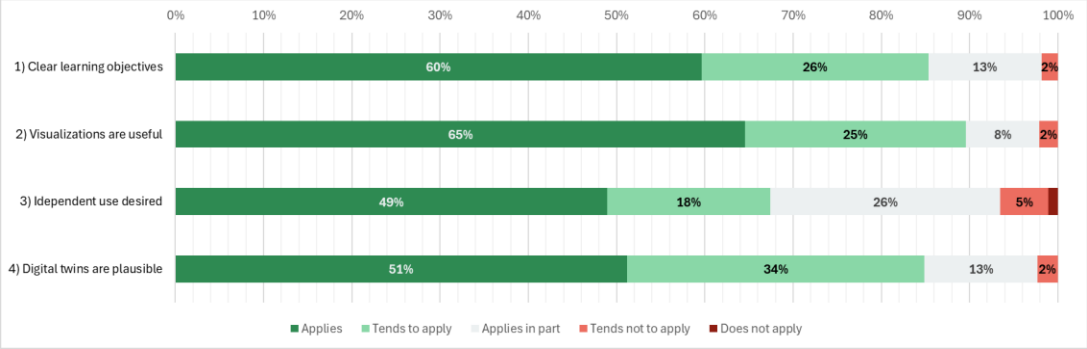

Figure 2: Feedback of course participants (n=109)

Faculty feedback was documented, transcribed and analyzed according to the course process.

5 Discussion & Limitations

The clear and structured learning objectives perceived by the participants are due to the established course format in which the digital twin sessions were embedded. The data analysis showed that digital twins were a useful and engaging addition to the case discussion sessions. The demand for course-independent use in the form of a mobile application can enable the further transition into hybrid, asynchronous course formats, which would decrease faculty workload and increase user engagement (Awada, Florea and Scafa-Udriste 2024, 7(2)).

For faculty the non-linear approach to the case discussions requires preparation time. This poses a disadvantage compared to the existing case discussions with well-known presentation software. A remedy could be the further development of the usability of the software solution up to the complete abandonment of the now necessary faculty onboarding. Storytelling on cases helps to convey content, so instructors still want to import own cases, instead of solely relying on prefabricated content.

The browser-based web app increases the technical requirements for internet availability and bandwidth as well as the available performant computers with graphics acceleration to handle complex, interactive 3D visualizations.

In a next step, the effectiveness of the simulation-based teaching modules in comparison to existing course formats needs to be analyzed, to reach the goal of moving education closer to clinical reality (Ramani and Leinster 2008). Participants expressed their need to incorporate simulation-based case assessments within their existing clinical planning software.

6 Conclusion

With the first deployments of the simulation-based AR teaching tool it could be shown that the concept adds value to both participants as well as faculty in delivering trauma education. The digital twins offer a playground for risk-free training without artificial bones and off-the-patient. Visualization helps with understanding the interactions of stability and bone healing.

Future extensions should target more indications to finally include the whole human skeleton, a selection of load scenarios for aftercare, bone quality assessments and analysis of implant failure.

All users trust the simulation results. The need for continuous quality management through verification and validation may ensure credibility of the visualizations and derived therapy recommendations.

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