Adapting a Haptic Motor-Skill Simulator to Include 3D Histology and Supporting Information Architecture (IA)

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Introduction

Many areas of medicine and public health are looking towards advancements in simulation for doctor and clinician training as it offers deliberate manual practice with the option to explore, make mistakes, and self-correct without the patient risk factor. Though the benefits of simulator training are well-documented (i.e., Cartier et al., 2016; Johnston et al., 2016, Michael et al., 2014; Teteris et al., 2012), the rapid rise has also generated criticism that the dazzle of the technology has led to a disconnect with instructional design concepts and the broader context of healthcare (Kneebone, 2005). Satava (2009) stresses that simulators are a tool to enhance curriculum and not a goal unto themselves. In this work, it was sought to reconcile technology with learning outcomes by including additional approaches to the periodontal curriculum supplementary to procedural training as a basis for contextual and exploratory learning. Integrating relevant, but sometimes neglected aspects of medical curriculum into clinical training is found to be an efficient way to reinforce learning and facilitate the transfer of knowledge for both areas of study (Rafai et al, 2016; Sheikh, Barry, Gutierrez, Cryan, and O-Keeffe, 2016).

Hypothesis

Visually representing the anatomy of the gingival tissue will allow students to appreciate the structures affected during probing procedure as well as reinforce histological understanding of the health and the disease process, in turn supporting the proper diagnosis of gingivitis or periodontitis. Merging multiple disciplines—clinical practice, applied anatomy, and histology—within a single learning module is intended to provide practical, cognitively efficient delivery of the curriculum.

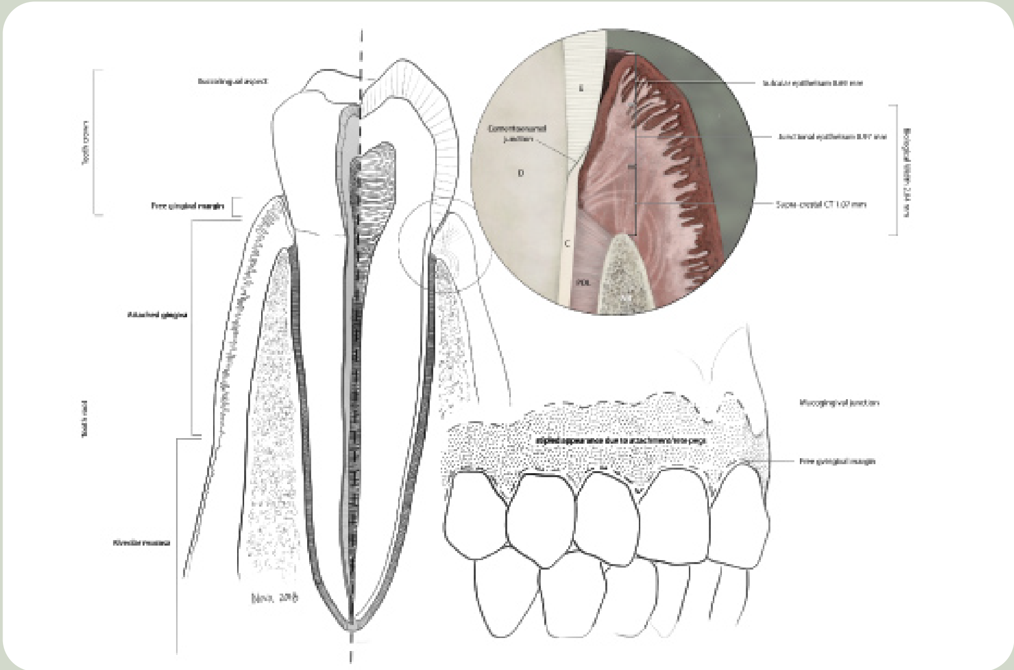


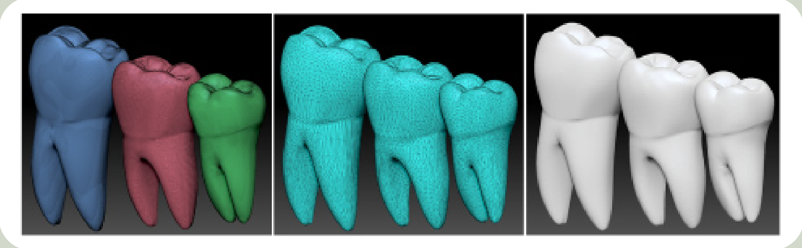
Figure 1: Learning goals illustrated in 2D

Materials & Methods

Required physical features were identified based on their importance to periodontal disease identification available at both gross- and histological-level examination. Other features identified as essential for visualization in the model were: tooth enamel, cementum, dentin, collagen fiber direction, biological width, cementoenamel junction, and mucogingival junction (Figure 1). The second premolar was cut on the buccolingual plane, so a distal-aspect cross section is ever present for student reference. Similarly, one-quarter of the gingiva surrounding the third molar was cut to view the histology of the periodontium in relationship with the tooth surface. Each model was created as a separate subtool so that appropriate tactile force feedback could be programmed for each distinct structure.

Despite advances in simulator development and research performed in this field, clear guidelines are lacking on 3D modeling for a haptic interface in which polygon and surface material constraints exist. In this case, each model was duplicated and decimated to the lowest number of triangle polygons possible while still maintaining basic form. The decimated models were then subdivided up to the needed resolution for polypaint and texture. At the highest subdivision level, the mesh was projected onto the original high-poly quad mesh to regain detail. Each subtool was taken to the lowest subdivision level and cloned for UV unwrapping. The UV maps (jpg) were opened in Adobe Photoshop and the diffuse layer painted with schematic histological features. All assets were then brought into Autodesk 3DS Max, checked, and exported as a .3DS file (file type compatible with the Quick Haptics platform). The models were uploaded to Sketchfab using the Sketchfab-Zbrush plug-in.

The methodology used for the information architecture was patterned after one formulated by Kahol et al. (2009) which suggests three multithreaded components: "Sensory," "Simulation," and "Feedback" (Figure 3). The course modules were created in Articulate Storyline using web-object embedding for 3D model interaction and evaluation. Due to the scope of this project, the haptics module and feedback/replay portions of the course remain in mockup/prototype phase for conceptual overview.



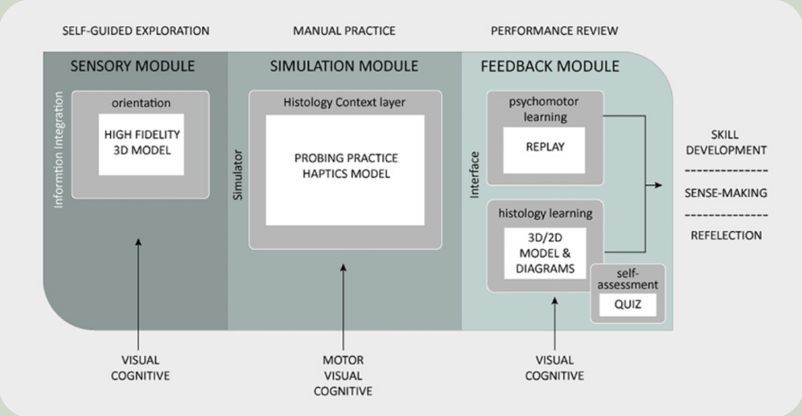


Figure 2: Polygon mesh resolution

Figure 3: Methodology for multi-modal simulator design

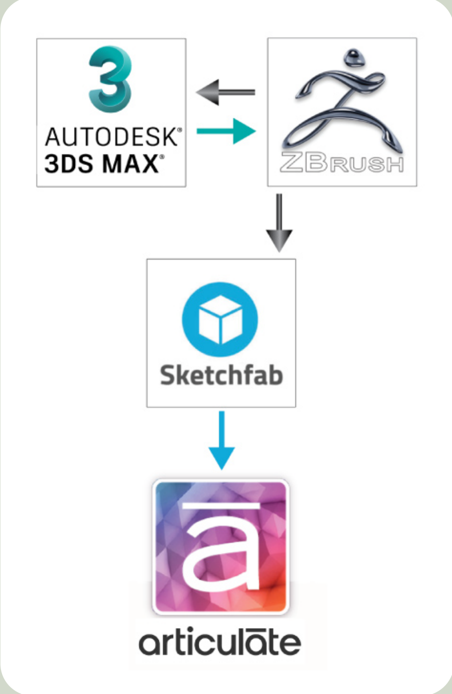


Figure 4: Production: Software workflow

Results

Seven anatomical models and ten instruments were created. The lowpoly version of each model component and UV maps were brought into 3D Systems Inc. OpenHaptics, QuickHaptics™ software version to test mesh/map system rendering and compatibility. A web- and LMS-based version of the learning module was made with a quiz section, glossary, and resources developed under the advisory of Dr. Ashrafi, director of the pre-doctoral periodontics department. Comprehensive committee satisfaction was reached through assessment of the models via the prototype learning module hosted online at: nbarto3.people.uic.edu/research/story_html5.html

Figure 5: Final model render

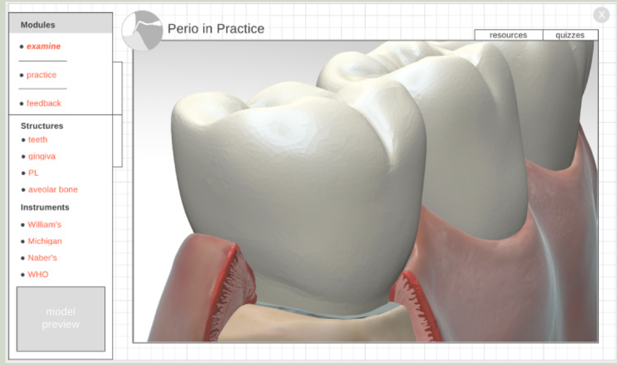


Figure 6: Learning module interface design

Discussion & Conclusions

Although simulator-based education has become prominent in research and development, technological advances do not necessarily add up to better learning outcomes. Incorporating visually-amplified models and utilizing instructional design concepts in the creation of medical simulator experiences may inspire new levels of expectation in the educational reach of simulators. In this case, the ability to explore and interact with histological features non-observable in the clinical procedure provides the opportunity for in-depth learning of the etiology of the disease. This project intends to demonstrate that a medical illustrator's contribution is equally important to that of the engineer when developing a medical simulator platform.

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