

Dental Simulator for Endodontic Access Cavity Preparation

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ABSTRACT

This paper presents a virtual environment to simulate the opening process of a tooth's crown. The environment tries to simulate a haptic interaction between a high-speed handpiece dental drill and a tooth during the dental material removal process. A low-cost device was created specifically for this application. The simulator is designed to train dental students, allowing the tasks to be repeated in controlled situations, while the students movements are monitored.

Keywords: Virtual Reality, Odontology, Haptic Device.

Index Terms: Virtual reality, visualization, haptic interfaces, force feedback, biomedical engineering education.

1 INTRODUCTION

The preparation of teeth is a biomechanical treatment which aims to remove tissues contaminated by decay or that have any other type of lesion that attacks the hard parts of a tooth (enamel or dentin) so that the remaining tooth structure is able to receive a filling material. Usually the removal of the tissues is made using cutting rotary tools equipped with drill bits of different formats. During the training process the odontology students usually use extracted natural teeth or artificial teeth made of resin, inserted on a mannequin or manipulated in the hands of the student. Some problems rise in the use of such teeth, for example, obtaining natural teeth comes up against with ethical problems due to the small amount of Human Teeth Banks. In case of artificial teeth, the material that composes the tooth has uniform rigidity, and then is impossible for the student to identify the layers of enamel, dentin and pulp that form the tooth through the tactile sensation to use the correct force to remove each material. Moreover, in both types of teeth it is not possible to place the student in specific situations because the available teeth may not have all important features, such as teeth with internal calcification, multiple roots or irregular shaping.

Computer-Assisted Learning (CAL) techniques have been used to support dental education, as evidenced by the work of Al-Jewair et al. [1]. Some educational institutions are already using hybrid or Virtual Reality (VR) based simulators to simulate the patient during preclinical training [2].

In this demonstration we present a VR-based simulator focused on dentistry training, that aims to increase the students skills in access cavity preparation task. The main reasons to use the simulator are the possibility of repeating the tasks and simulation of teeth problems that rarely can be treated during the conventional training.

2 SIMULATOR DESCRIPTION

The Virtual Environment has 3 types of objects. The first one represents the virtual tooth that will be treated, the second is a virtual model of the lower jaw and the last one is a rotating tool for drilling the tooth (Figure 1).

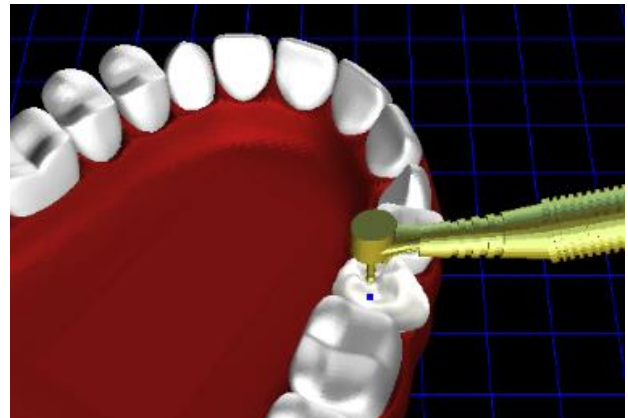


Figure 1 - Virtual Environment

The lower jaw is modeled as a set of polygons. The tooth is represented as volumetric model that describes both the external and internal structure of the tooth, identifying the stiffness of each voxel and its resistance to perforation. This makes it possible to calculate force feedback for the haptic rendering and the removal of voxels which affects the geometry of the model that is presented to the user, in the graphic render. Figure 2 shows a volumetric model of a tooth, the haptic points and the tooth view.

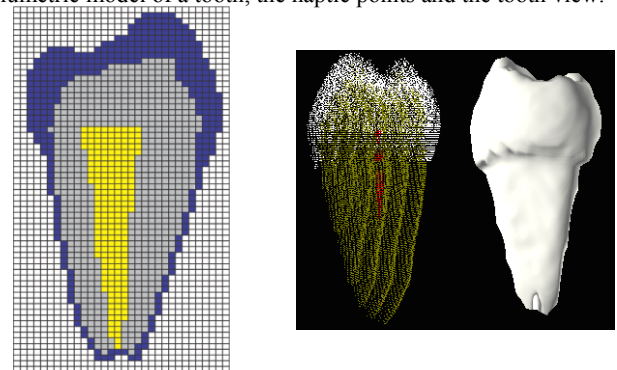


Figure 2 – Volumetric Tooth Model

The tool is modeled in a hybrid way. A geometric model is used for the handle of the tool and a volumetric model for the part used for drilling the volume (the drill bit). Figure 3 shows some possible drill bit models, but other models are possible.

In order to model the drill bits, two types of voxels are used. One in the cutting part of the drill bit, which is responsible for removing the tooth's voxels (represented in gray in Figure 3), and

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another one (in red) that represents the drill bit's handle, used only for collision detection.

Concerning the haptic device, the simulator uses a device of the type Novint Falcon Controller (www.novint.com) that has three Degrees Of Freedom (DOF) to perform the translation of the tool in the VE. To make the most realistic simulation was necessary to adapt to the equipment a new handler with 3 DOF, which allows the user to identify the rotations made by the user, thus making the device with 6 DOF.

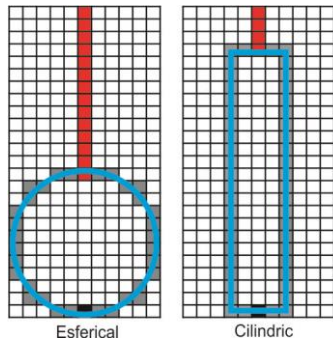


Figure 3 - Drill bit models

In addition, the handler is equipped with a dental high-speed hand piece drill, which aims to make the equipment more familiar to the users. The device captures the movements every 10 ms and sends them to the system through an Arduino prototyping platform (<http://www.arduino.cc>). The Figure 4 presents the haptic device adapted with the new handle, the adapted dental high-speed handpiece drill and the extent of the rotation movements allowed.

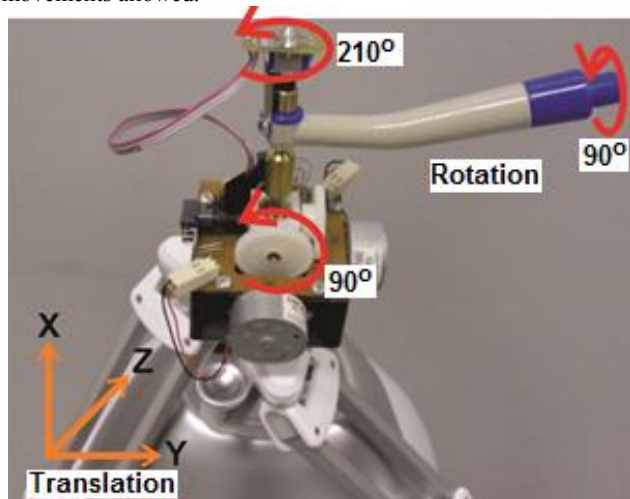


Figure 4 - Adapted Haptic Device

The teeth models used in the simulator can be obtained from simplified models or through the segmentation of Computerized Tomography or Magnetic Resonance images, allowing the layers of the tooth to be separated. In addition, it is possible to modify the internal and external structure of the models including new problems to be treated. The Figure 5 shows examples of teeth models that can be used. On the left, the original model obtained from a CT is shown, and on the right, the model modified to receive a calcification within the pulp chamber.

3 DEMONSTRATION

This demonstration simulates the cavity preparation process for endodontic treatment. For this procedure the user must start using

a spherical drill bit (Figure 6A) to make a small opening in the tooth crown. The perforation should be performed longitudinally towards the pulp chamber. When the drill bit reaches the chamber, the user will feel the sense of falling into an empty space. In other words, the user will no longer feel the tooth drilling resistance. At this time the user must be very careful because it cannot contuse the tooth roots that are just below the pulp chamber. The correct application of pressure on the instruments and the direction chosen for the opening are the aspects that determine the success of this part of the treatment. The second part of the treatment is to remove all the enamel and dentin of the roof of pulp chamber, allowing endodontic instruments to be used without interference.



Figure 5 - Tooth models

This cleaning process can be done with a cylindrical drill bit without an active tip (Figure 6B), which will prevent the tooth roots to be damaged (Figure 6C) and remove large amounts of material. The result of the treatment should be a visible pulp chamber, allowing small holes to be observed from the top of the tooth (Figure 6D) and the radiograph of the tooth after access cavity preparation (Figure 6E). A video with the simulator demonstration can be found on <https://youtu.be/PROX-PpA-HU>.

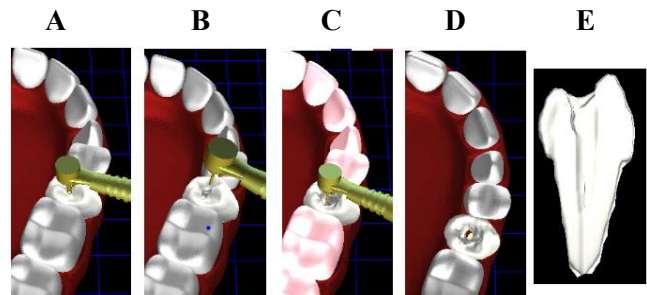


Figure 6 - Models. (A) Spherical drill bit, (B) cylindrical drill bit, (C) tooth roots damaged, (D) pulp chamber and (E) tooth radiograph

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5 REFERENCES

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