Chapter XVIII

Virtual Dental Patient: A 3D Oral Cavity Model and its Use in Haptics-Based Virtual Reality Cavity Preparation in Endodontics

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ABSTRACT

The availability of datasets comprising of digitized images of human body cross sections (as well as images acquired with other modalities such as CT and MRI) along with the recent advances in fields like graphics, 3D visualization, virtual reality, 2D and 3D image processing and analysis (segmentation, registration, filtering, etc.) have given rise to a broad range of educational, diagnostic and treatment planning applications, such as virtual anatomy and digital atlases, virtual endoscopy, intervention planning etc. This chapter describes efforts towards the creation of the Virtual Dental Patient (VDP) i.e. a 3D face and oral cavity model constructed using human anatomical data that is accompanied by detailed teeth models obtained from digitized cross sections of extracted teeth. VDP can be animated and adapted to the characteristics of a specific patient. Numerous dentistry-related applications can be
envisioned for the created VDP model. Here we focus on its use in a virtual tooth drilling system whose aim is to aid dentists, dental students and researchers in getting acquainted with the handling of drilling instruments and the skills and challenges associated with cavity preparation procedures in endodontic therapy. Virtual drilling can be performed within the VDP oral cavity, on 3D volumetric and surface models (meshes) of virtual teeth. The drilling procedure is controlled by the Phantom Desktop (Sensible Technologies Inc., Woburn, MA) force feedback haptic device. The application is a very promising educational and research tool that allows the user to practice in a realistic manner virtual tooth drilling for endodontic treatment cavity preparation and other related tasks.

INTRODUCTION

Creation of datasets comprising of digitized images of cross sections of the entire human body (as well as images acquired with other imaging modalities such as CT and MRI) has been a major breakthrough in biomedical imaging and related fields. The first such dataset was created as a result of the National Institute of Health (NIH) Visible Human Project (Ackerman, 1998; Banvard, 2002). Within this project, a male (1994) and a female (1995) cadaver were embedded in blue gelatin, frozen and sliced at 1 mm (0.33mm for the female cadaver) cryosections, thus producing two sets of transversal body slices. Each layer of the body was photographed at a resolution of 2048 x 1216 pixels and 24 bits color depth to create the Visible Human Male (VHM) and Visible Human Female (VHF) datasets. Axial MRI images of the head and neck, and longitudinal sections of the rest of the body as well as axial CT scans of the entire body were also produced. Recently, a Chinese project (Zhang et al., 2006) resulted in the creation of five Chinese Visible Human datasets, whose creators claim that consist of images of greater integrity and have better blood vessel identification than their US counterparts. Korean scientists have also completed the Visible Korean Human (VKH) project (Park et al., 2005). These Visible Human datasets (especially VHM, VHF) have given rise to a wide range of educational, diagnostic, treatment planning and virtual reality applications such as virtual anatomy and digital atlases, virtual endoscopy, surgery planning etc. Some characteristic examples are described in Robb and Hanson (2006).

Apart from medicine, digitized anatomical head images are also a valuable asset for dentistry. Such images can be used for the construction of 3D models for the anatomical education of dentistry students. In addition, such models can be incorporated in virtual reality applications that aim at familiarizing students with (virtual) dental instruments and their use in a number of dental procedures. Especially in the field of endodontics, the success of an endodontic therapy depends on many factors, two of them being the thorough knowledge of the internal tooth anatomy and the appropriate pulp cavity access. Indeed, the knowledge of tooth anatomy and good practice in dental drilling for cavity preparation are important parts of a dental student training that can help him/her learn how to achieve correct access of the root canal system during the endodontic therapy. Usually, dental students learn how to obtain root canal access on artificial teeth and jaws that are sometimes placed within a manikin head, using dental instruments and burs before, they perform this procedure on real patients.

Thus, novel educational tools that would help students in obtaining solid knowledge of the tooth anatomy and practicing pulp cavity