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Short Communication

Virtual 3D tooth creation for personized haptic simulation training in access cavity preparation

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Personalized medicine is a new medical concept to achieve patient-centered care. In dentistry, it is recognized for the customization of operative strategies and managements for oral diseases. Access cavity preparation in endodontic treatment is an irreversible procedure. Endodontic training will be more realistic by the implementation of clinical relevant 3D virtual reality technology. In this article, the authors first presented a personized case from a real patient to provide assess cavity preparation in haptic virtual reality dental simulator Simodont® (Nissin Dental Products Inc., Nieuw-Vennep, Netherlands). The practical framework to generate STL from cone beam computed tomography was demonstrated. A case of virtual tooth #26 access cavity preparation in Simodont® was established for trainee unlimited practices before performing the clinical procedure on a real patient. Taken together, access cavity preparation in a virtual environment using a 3D personized tooth may minimize procedural errors and facilitate clinical treatment outcome.

Introduction

The definition of personalized medicine or newly so-called precision medicine is broadly. It is recognized to use the diagnostic tools for preventions or treatments which are customized for individuals' disease process or symptoms.[1] In dentistry, it could be applied for the detection and prevention of caries, periodontal disease, and oral cancer.

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Patient-centered oral care is required for precise hand manipulation skills to minimize the malpractices and errors for patient safety.[2] Haptic 3D virtual reality simulator Simodont® (Nissin Dental Products Inc., Nieuw-Vennep, Netherlands) is one of the useful devices for pre-clinical skills learning including cavity preparation, crown preparation, and access cavity preparation.[3] Recently, the authors have reported the successful conduction of Simodont® learning and training in tooth preparation for the achievement of personized dentistry.[4]

Clinically, deep caries and serve periodontitis may cause periapical lesions. Access cavity preparation in endodontic treatment is an irreversible procedure. It needs highly coordinate hand-eye skills during operative procedure to prevent perforation, especially for interns and novice dentists. By the implementation of 3D virtual reality technology, endodontic learning and training will be more realistic and interactive. Previously, micro-computed tomography assembled extracted human tooth incorporated in haptic devices has been reported for endodontic access preparation.[5] Virtual pre-surgical practice by haptic devices and cadaveric porcine 3D computerized model generated from cone beam computed tomography (CBCT) were also demonstrated in endodontic periapical surgery.[6] However, each patient has its own unique oral situation. The more clinical relevant haptic simulation training in endodontic treatment is worth to be emphasized and improved.

The advantages of Simodont® can provide repeated practice without any waste disposal and additional instruments.[2] Simodont® has been reported to customize real patients in the virtual reality environment for tooth and inlay preparation.[4,7] However, little is known about the clinical relevant haptic simulation in access cavity preparation. In this article, the authors presented a personized case from a real patient to establish an assess cavity preparation module in Simodont®. The detailed procedures from patient's CBCT images transferred into Simodont® for customized access cavity preparation were described and discussed as following.

Materials and methods

Patient data

A 56-years-old male patient came to Department of Dentistry, Chung Shan Medical University Hospital for upper left posterior teeth spontaneous pain. After carefully clinical examination, periapical (MX-60 N, Ashiroentgen Ind. Co. Ltd., Kyoto, Japan) and CBCT (AZ3000CT, Ashiroentgen Ind. Co. Ltd.) radiographic exanimations, radiolucency lesion over tooth #26 palatal root apex was noted. Then, #26 was planned for endodontic treatment. Due to the complicated anatomic structure of maxillary molar root canal system, the CBCT images were extracted to create 3D virtual tooth #26 for learning and training before clinical treatment.

The creation of 3D virtual tooth #26

3DSlicer (https://www.slicer.org/) is a free, open resource, highly extensible module function, and multi-platform software for visualization as well as analysis of medical image data sets. It is widely used for medical, biomedical, and related image research. In this report, 3DSlicer was used to segment #26 with root canals from CBCT by a Digital Imaging and Communications in Medicine (DICOM) file (Fig. 1A). The flowchart of 4 main procedures for exporting STL file was illustrated in Fig. 1B. Finally, the STL file was transferred to Simodont®. Then, the trainee can unlimited practice access cavity preparation before treat this male patient.

Results

As shown in Fig. 2, a case for virtual 3D tooth #26 access cavity preparation was installed in Simodont® to enable the further treatment outcome of a real patient. The parameters of virtual environment like instruments, mirror view, and angle limitation were set for corresponding to clinical situation. In this pilot project, only 5 dental interns and the dentists in the two-year postgraduate year training program for dentists got the opportunity to practice this new module. They found that it was a good method for practicing access cavity preparation from their perceptions.

Discussion

Processing CBCT image to generate STL model has been reported in combination with 3D printing to assist endodontic treatment and education.[8] However, the additional time, materials, and specific instruments are required for the manufacture of 3D printing teeth. Modern dentistry is not only to facilitate the equitable quality education, but also to enhance environmental sustainability.[9] Hence, directly input STL models into simulation training take advantages in terms of time efficiency and environmental protection.

According to the module of Simodont®, 3D tooth morphology could be obtained from surface scanning by oral scanner.[4,7] The creation of virtual tooth has been documented from an extracted tooth with CBCT by specially designed software program ColorMapEditor (Sensegraphics, Stockholm, Sweden).[10] Although, this software could add the hardness, color, or pathology in virtual tooth. However, it is not open for use, only for extracted tooth, and the procedures were relative complicated and time-consuming. In this study, 3D tooth inside with root canal from CBCT was first successfully established for assess cavity preparation by 3DSlicer software. The advantages of 3DSlicer includes easy to use, create, and edit 3D virtual tooth from clinical CBCT images. In addition, 3D model form extracted tooth and cadaveric porcine[4,5] were set up for reducing operative errors during endodontic treatments. Our study further transferred the real patient's tooth model for a pre-operation training. It is believed to have more predictable benefit and clinical relevance. Taken together, it seems as a new method in endodontic education.

To the best of our knowledge, this is the first report about the clinical relevant haptic simulation learning and training in access cavity preparation. However, there are some limitations need to be addressed. First, the distinct occlusal anatomy on segmented model from CBCT is not so

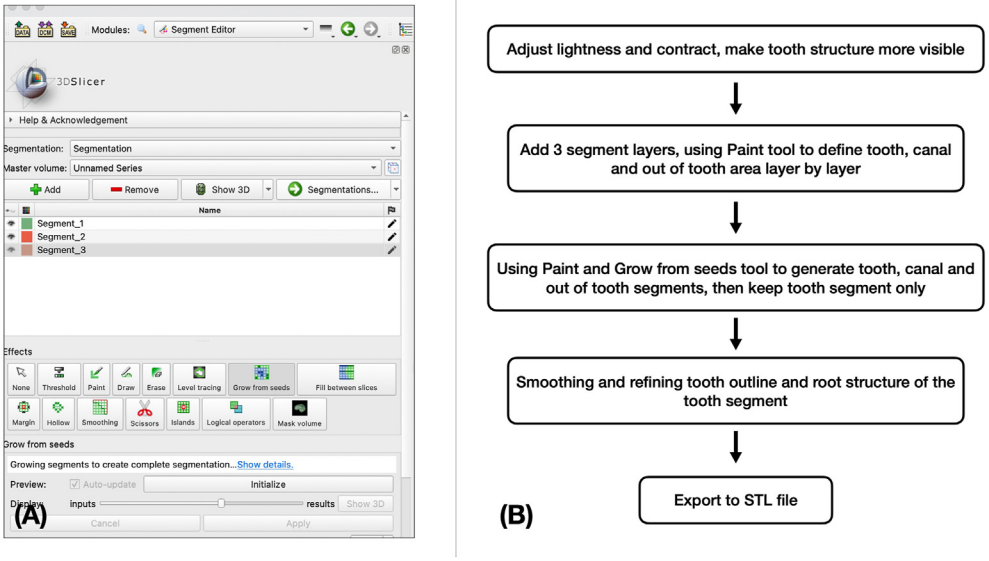

Figure 1 How to create of a virtual 3D tooth in 3DSlicer. (A) Main segment editor module panel of 3DSlicer. (B) A flowchart of STL exported from CBCT DICOM file.

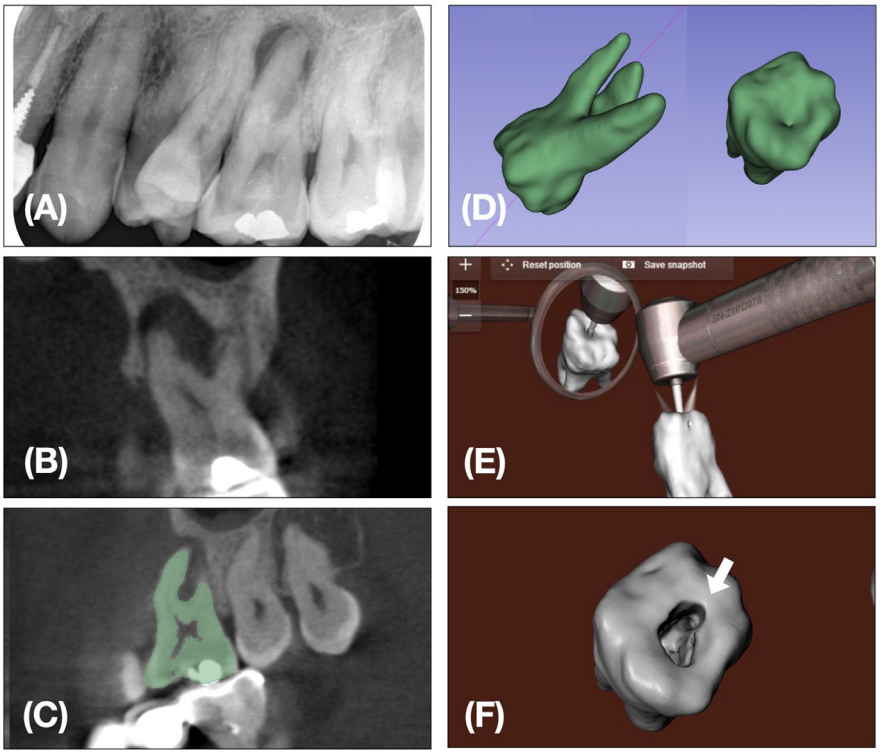

Figure 2 A case of virtual 3D tooth #26 assess cavity preparation in clinical relevant haptic simulation environment. (A) The #26 apical lesion examined by periapical radiography and (B) CBCT. (C) #26 segmented on slice window. (D) Virtual 3D tooth #26 documented in different view after smoothing the outer surface. (E) Access cavity preparation in Simodont® relevant to clinical preparation situation. (F) The arrow indicated the palatal canal entrance after access cavity preparation.

clear as compared with surface scanning. Metal artifacts on or near by the tooth can produce scatter effect and noise on CBCT image that may lead the difficulties in segmentation. Second, the production of a virtual tooth model of a patient for endodontic is required from CBCT. Compared to routine periapical film taking, the dose of radiation may be a critical issue. Third, only STL file format could be imported in Simodont® patient-centered mode that the model color is monochromatic and the hardness is homogeneous. These constraints would not simulate different layers of tooth such like enamel and soft dentin. Fourth, only access preparation step of endodontic treatment is

available in current model. The real-time statistic calculation in recognition of exact root canal location still needs to be improved.

Hand operation skill training under virtual environment is a trend in pre-clinical and clinical dental education. Customizing patient's situation in Simodont® could extend the real situation to the virtual environment, also decrease the gap between pre-clinical and clinical training. In this report, virtual tooth creation for personized haptic simulation training in access cavity preparation was successfully preliminary established. It is still necessary for further optimization and perfection.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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