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Research Paper
Virtual Reality

An innovative virtual reality training tool for orthognathic surgery

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Abstract. Virtual reality (VR) surgery using Oculus Rift and Leap Motion devices is a multi-sensory, holistic surgical training experience. A multimedia combination including 360° videos, three-dimensional interaction, and stereoscopic videos in VR has been developed to enable trainees to experience a realistic surgery environment. The innovation allows trainees to interact with the individual components of the maxillofacial anatomy and apply surgical instruments while watching close-up stereoscopic three-dimensional videos of the surgery. In this study, a novel training tool for Le Fort I osteotomy based on immersive virtual reality (iVR) was developed and validated. Seven consultant oral and maxillofacial surgeons evaluated the application for face and content validity. Using a structured assessment process, the surgeons commented on the content of the developed training tool, its realism and usability, and the applicability of VR surgery for orthognathic surgical training. The results confirmed the clinical applicability of VR for delivering training in orthognathic surgery. Modifications were suggested to improve the user experience and interactions with the surgical instruments. This training tool is ready for testing with surgical trainees.

Key words: 3D; virtual reality; Oculus Rift; Leap Motion; surgery.

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There has been an upsurge in advancements in surgical training methods and tools in the last century[1]. Training in surgery requires broad clinical exposure and adequate supervision[2–7]. A lack of training facilities may compromise the quality of care delivered to patients[8,9].

This article reports on innovative research in which a virtual reality (VR) and immersive virtual reality (iVR) experience in the field of orthognathic surgery (mainly Le Fort I maxillary osteotomy) was designed, validated, and evaluated. The objective of this study was to test the validity and usefulness of VR surgery for surgical training. The primary objective was to explore the validity of VR as a valid training tool for Le Fort I osteotomy. The secondary objective was to test the usability of VR surgery, with regard to its possible inclusion in the current surgical training curriculum, using a panel of expert surgeons.

Materials and methods

Development of VR surgery

VR surgery is a holistic learning application that provides an uninterrupted close-up surgical training experience[10]. The Oculus Rift Development Kit 2 (DK2) VR headset and a Leap Motion controller were used in the application. The three essential elements used to develop the VR surgery experience were a 360° recording of an operating room, close-up stereoscopic vi-

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Fig. 1. 360° video of the operating room.

sualization of surgery, and three-dimensional (3D) interaction.

To create a 360° operating room, spherical videos and computer-generated 3D models of an operating room were used. Six GoPro Hero cameras recorded the operating room from all angles. By 'stitching' the individual videos from each of these cameras together[11], a spherical video was created, as shown in Fig. 1. The 360° video creates a sense of presence in the operating room when watched on a head-mounted display, such as an Oculus Rift headset. It can also be viewed on a desktop with a 360° video viewer[12].

The Le Fort I osteotomy display was subdivided into four sections: soft tissue reflection, osteotomy of the maxilla, bone fixation, and suturing. Each section showed a sequence of stereoscopic 3D videos representing different steps of surgery. These videos were recorded using a Sony 3D camera (HXR-NX3D1E; Sony, London, UK) and arranged in a sequence following the human factors methodology of the cognitive task analysis technique[13]. Further, 3D models of the head and neck anatomy and 3D surgical instruments were achieved using modelling software and 3D photogrammetry techniques. The users were able to choose the surgical instruments and manipulate the tool for the applications at various anatomical sites in order to achieve the desired surgical movements.

A Leap Motion sensor, which tracks the movements of the hands to provide a multi-sensory interactive learning experience, was included in the application[14]. Natural user interfaces were designed to show a menu that allows the user to select different parts of the application. A facility that allows the user to zoom the size of the content using specific gestures, pause a specific part of the surgery, and interact with the anatomy and surgical instruments, was added, as shown in Fig. 2. Additionally, a computer-generated model of the operating room was included to allow the trainees to navigate and interact with 3D models of the patient's data. Data from cone beam computed tomography (CBCT) scans, stereophotogrammetry, and the soft tissue prediction planning were used in the application, as shown in Fig. 3. A quiz scene was also added to test user knowledge on the subject. The developed application was designed to lend itself to the inclusion of other surgical procedures.

Evaluation of the developed VR surgery

Expert oral and maxillofacial surgeons in various National Health Service (NHS) authorities across the UK tested the validity of the VR surgery for its content and functionality, and the usability of the application. This study was designed based on previous research on face and content validity for VR surgical simulators[15]. Ethics approval was obtained for this study from the School of Art, Design and Architecture Ethics and Integrity Committee, Huddersfield University.

Nine consultant surgeons volunteered to participate in the validation process. Following instructions on safety measures before use of the Oculus Rift headset, all participants were asked if they suffered from any psychiatric disorders (including attention deficit hyperactivity disorder or epilepsy), or if they were on any antipsychotic drugs. Any previous history of motion sickness or seizures was considered an exclusion criterion. The implementation of the study followed the sequence as shown in Fig. 4.

Two separate questionnaires were used to check the validity of VR surgery: a pre-intervention questionnaire to understand the training needs and a post-intervention feedback questionnaire to comment on the efficacy, usability, and acceptability of the

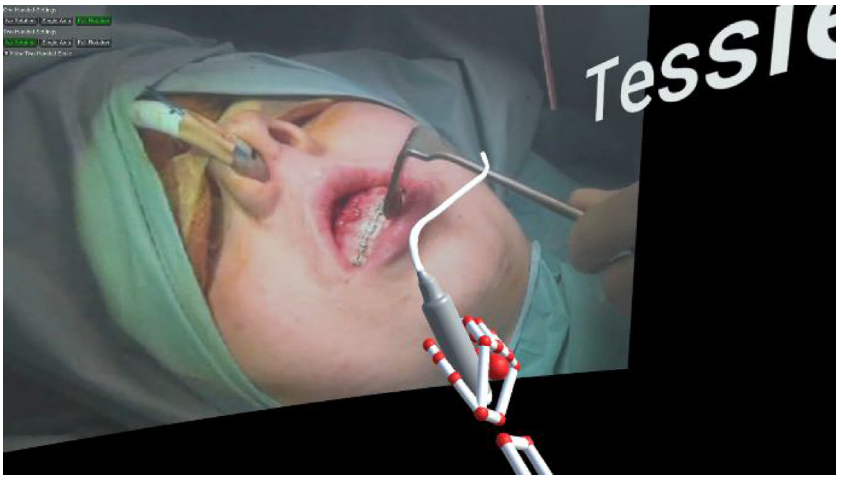

Fig. 2. Interaction with the instruments while watching the stereoscopic 3D videos of surgery.

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