Int. J. Oral Maxillofac. Surg. 2016; xxx: xxx–xxx
http://dx.doi.org/10.1016/j.ijom.2016.11.011, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Research Paper
Imaging

A study to evaluate the reliability of using two-dimensional photographs, three-dimensional images, and stereoscopic projected three-dimensional images for patient assessment

S. Zhu[1], Y. Yang[1], B. Khambay[1,2]
[1]Paediatric Dentistry and Orthodontics, Faculty of Dentistry, The University of Hong Kong, Hong Kong; [2]School of Dentistry, University of Leeds, Leeds, UK

S. Zhu, Y. Yang, B. Khambay: A study to evaluate the reliability of using two-dimensional photographs, three-dimensional images, and stereoscopic projected three-dimensional images for patient assessment. Int. J. Oral Maxillofac. Surg. 2016; xxx: xxx–xxx.

Abstract. Clinicians are accustomed to viewing conventional two-dimensional (2D) photographs and assume that viewing three-dimensional (3D) images is similar. Facial images captured in 3D are not viewed in true 3D; this may alter clinical judgement. The aim of this study was to evaluate the reliability of using conventional photographs, 3D images, and stereoscopic projected 3D images to rate the severity of the deformity in pre-surgical class III patients. Forty adult patients were recruited. Eight raters assessed facial height, symmetry, and profile using the three different viewing media and a 100-mm visual analogue scale (VAS), and appraised the most informative viewing medium. Inter-rater consistency was above good for all three media. Intra-rater reliability was not significantly different for rating facial height using 2D ($P = 0.704$), symmetry using 3D ($P = 0.056$), and profile using projected 3D ($P = 0.749$). Using projected 3D for rating profile and symmetry resulted in significantly lower median VAS scores than either 3D or 2D images (all $P < 0.05$). For 75% of the raters, stereoscopic 3D projection was the preferred method for rating. The reliability of assessing specific characteristics was dependent on the viewing medium. Clinicians should be aware that the visual information provided when viewing 3D images is not the same as when viewing 2D photographs, especially for facial depth, and this may change the clinical impression.

Key words: stereoscopic; photographs; projected; three-dimensional; facial deformity; orthognathic; class III.

Accepted for publication 18 November 2016

0901-5027/000001+07

Following the clinical assessment of patients with dentofacial deformities, additional records including pre-treatment extraoral photographs, radiographs, and study models are recommended.[1] These are used to document the initial presentation, for diagnosis and treatment planning, as well as providing evidence of treatment. The records also have a role in patient communication, education, audit, and research.[2] Pre-treatment records should therefore be valid, accurate, complete, and contemporaneous.[3] Given the longitudinal nature of orthognathic surgery, the pre-treatment records should enable the different members of the orthognathic team to re-identify the key features of the clinical assessment, in the absence of the patient. One of the assumptions of present clinical practice is that the extraoral photographs are valid in this context.

Using stereophotogrammetry or laser scanning it is possible to capture the photorealistic three-dimensional (3D) facial soft tissue appearance.[4,5] Clinicians are accustomed to viewing conventional two-dimensional (2D) photographs and assume that working with and viewing 3D images will be similar. However, even though the individual's facial images are captured in 3D, they are currently not viewed in 'true 3D'. This may result in underutilization of the additional information acquired during 3D capture and may be clinically important.

Currently the 3D facial images are viewed after they have been reconstructed (rendered) onto a 2D plane, i.e. the screen of an LCD computer monitor. Image depth perception is created using monocular cues, such as the size differential generated by perspective projection and the texture gradient by lighting and shading. These perspective techniques are not able to provide a true perception of depth as experienced by the human visual system, i.e. binocular vision. This can only be recreated using 'stereoscopic viewers', such as active or passive 3D projection systems.[6] Passive 3D projection systems project two different images with a spatial disparity onto a screen; each eye views each image at the same time using polarized glasses. The differences between these two images (known as stereo-pairs of images) are recovered by the human visual system as depth.[7] In a medical context, stereoscopic displays offer significant clinical improvements, especially in the areas of diagnostic applications including ophthalmic imaging, mammography, vascular imaging, and orthopaedic imaging.[7]

There appears to have been no study investigating the reliability of using 2D photographs and 3D images (both relying on monocular cues) or stereoscopic projected 3D images (binocular cues) to assess specific features of a facial deformity. Therefore the aim of this study was to evaluate the reliability of using these three different viewing media to rate specific facial characteristics in a group of pre-surgical class III patients: facial height, symmetry, and profile. The null hypothesis was that there are no differences in ratings of the facial height, symmetry, and profile (as assessed using a visual analogue scale (VAS) score) using the three different viewing media ($P < 0.05$). In addition, the raters were asked supplementary questions to appraise which viewing medium provided the most information during the assessment.

Materials and methods

Subjects

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of Hong Kong University and Hospital Authority Hong Kong West Cluster. Forty pre-surgical orthognathic patients attending the Department of Orthodontics or the Department of Oral and Maxillofacial Surgery of Prince Philip Dental Hospital, Hong Kong, were recruited. All patients had previously been diagnosed with a skeletal class III deformity by the orthognathic team and required surgical correction. Patients with craniofacial syndromes or anomalies, including cleft lip and palate, were excluded. Written informed consent was obtained from all patients included in the study. The average age of the patients was 22.9 ± 3.2 years; 22 were female and 18 were male.

Image acquisition

Each patient was imaged using a conventional digital camera (2D images) and a 3D stereophotogrammetry system (3D images). To standardize the images, hair was kept away from the face, the lips were kept in repose, and the head was maintained in the natural head position (NHP).[8]

2D images

Seven standardized 2D photographs of each patient (frontal view, right and left profiles, right and left three-quarter profiles, bird's eye view, and worm's eye view) were captured using a Canon EOS 700D camera (Canon, Tokyo, Japan) with Canon Macro Ring Lite MR-14EX II and Canon Macro Lens EF-S 60 mm 1:2.8 USM (Canon). All photographs were taken using the same camera settings, illumination, background, and distance. A vertical plumb line was used as the true vertical reference. Using Adobe Photoshop CS (Adobe Systems Inc., San Jose, CA, USA), each facial image was cropped to remove the headband, ears, neck, and shoulders, producing a standardized image. The photographs for each patient were organized onto one PowerPoint slide (Microsoft, Redmond, WA, USA) and saved (Fig. 1). This was repeated for each patient using the same template PowerPoint slide.

3D images

Immediately following 2D photographs, 3D facial images were taken using the Di3D system (Dimensional Imaging Ltd, Glasgow, UK) based on the standardized capture protocol and saved as Wavefront files (OBJ). Using MeshLab software (STI-CNR, Rome, Italy; http://meshlab.sourceforge.net/), each facial image was cropped to remove the headband, ears, neck, and shoulders, producing a standardized image. The 3D facial image was then reoriented to NHP according to a previously published technique[9] and saved in OBJ format (Fig. 2).

Viewing method

2D images and 3D images

The 2D photographs were viewed as PowerPoint slides and the 3D facial images in NHP were viewed using Di3DView (Dimensional Imaging Ltd). Both were projected onto a smart board (SMART Technologies, Calgary, Canada) by a projection system (EB-480; Epson, Suwa, Nagano, Japan) during the rating sessions.

Stereoscopic projected 3D images

The 3D facial images in NHP were imported into 3D-Hub software (WSP^{av}, Colchester, Essex, UK; Instant Effects, Santa Barbara, CA, USA), and projected onto a large projector screen (Da-Lite Versatol Tripod Screen 99 in. (70 × 70) Silver Lite 2.5; Da-Lite, Warsaw, IN, USA) using a passive 3D projection system (EB-W16SK; Epson) (Fig. 3). The stereoscopic projected 3D facial images were viewed using a pair of polarized 3D glasses.

Raters

Eight raters (with a Membership in Orthodontics diploma (MOrth) or equivalent) from the Department of Orthodontics at

Please cite this article in press as: Zhu S, et al. A study to evaluate the reliability of using two-dimensional photographs, three-dimensional images, and stereoscopic projected three-dimensional images for patient assessment, *Int J Oral Maxillofac Surg* (2016), http://dx.doi.org/10.1016/j.ijom.2016.11.011