Int. J. Oral Maxillofac. Surg. 2017; xxx: xxx–xxx
http://dx.doi.org/10.1016/j.ijom.2017.07.016, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Research Paper
Imaging

The difference between registered natural head position and estimated natural head position in three dimensions

S. Zhu[1], A. Keeling[2], T. C. Hsung[1], Y. Yang[1], B. Khambay[1,2,3]
[1]Faculty of Dentistry, The University of Hong Kong, Hong Kong; [2]School of Dentistry, University of Leeds, Leeds, UK; [3]Institute of Clinical Sciences, College of Medical and Dental Sciences, The School of Dentistry, University of Birmingham, Birmingham, UK

S. Zhu, A. Keeling, T.C. Hsung, Y. Yang, B. Khambay: The difference between registered natural head position and estimated natural head position in three dimensions. Int. J. Oral Maxillofac. Surg. 2017; xxx: xxx–xxx.

Abstract. This study determined the intra-rater and inter-rater reliability of re-orientating three-dimensional (3D) facial images into the estimated natural head position. Three-dimensional facial images of 15 pre-surgical class III orthognathic patients were obtained and automatically re-orientated into natural head position (RNHP) using a 3D stereophotogrammetry system and in-house software. Six clinicians were asked to estimate the NHP of these patients (ENHP); they re-estimated five randomly selected 3D images after a 2-week interval. The differences in yaw, roll, pitch, and chin position between RNHP and ENHP were measured. For intra-rater reliability, the intra-class correlation coefficient (ICC) values ranged from 0.55 to 0.77, representing moderate reliability for roll, yaw, pitch, and chin position, while for inter-rater reliability, the ICC values ranged from 0.38 to 0.58, indicating poor to moderate reliability. The median difference between ENHP and RNHP was small for roll and yaw, but larger for pitch. There was a tendency for the clinicians to estimate NHP with the chin tipped more posteriorly (6.3 ± 5.2 mm) compared to RNHP, reducing the severity of the skeletal deformity in the anterior–posterior direction.

Key words: estimated natural head position; registered natural head position; natural head position; class III; orthognathic surgery.

Accepted for publication 21 July 2017

Head orientation influences the anterior–posterior perception of the maxillomandibular complex and may result in incorrect diagnosis[1,2]. Currently, intracranial reference lines such as the Frankfort horizontal (FH) and sella–nasion (SN) are widely used in standardizing lateral head film orientation[3,4]. Natural head position (NHP) is more reproducible and is an alternative method of recording head orientation[5–7]. As a consequence, NHP has gained popularity with both orthodontists and oral and maxillofacial surgeons[8]. NHP is readily retrievable from a profile photograph or lateral cephalogram by using a true vertical reference line and is referred to as 'registered natural head position'[9].

Three-dimensional (3D) surface imaging has become a routine method of capturing pre-treatment facial images. The

0901-5027/000001+07

Please cite this article in press as: Zhu S, et al. The difference between registered natural head position and estimated natural head position in three dimensions, *Int J Oral Maxillofac Surg* (2017), http://dx.doi.org/10.1016/j.ijom.2017.07.016

calibration of the device does not usually consider any physical reference lines or planes and only the patient's surface topography, irrespective of orientation, is captured[10]. Even though the patient's facial image is captured in NHP, the resulting 3D facial image when re-loaded into viewing software will be displayed in an orientation dictated by the calibration and will no longer be in the correct orientation (Figs 1 and 2). To overcome this problem, the concept of registered natural head position (RNHP) was suggested[9]. RNHP uses devices that record and transfer NHP. These include registration jigs[11], digital orientation sensors[12], and a laser level beam[13–15]. However the devices themselves may influence the accuracy of RNHP and in some cases cause soft tissue distortion. Hsung et al. proposed the use of a physical reference system based on a secondary reference target to re-orientate the captured images to the pose in which the individual was originally captured, e.g. NHP. This technique was accurate and could be regarded as a method (gold standard) of re-orientating 3D facial images into NHP[10].

In situations where lateral cephalograms or lateral profile photographs are not taken in NHP, it is possible for clinicians to re-orientate the profile image (up and down) into the 'estimated natural head position' (ENHP)[16,17]. For 3D images, the complexity increases as the images can be manipulated with six degrees of freedom, three for changes in position (translation) along the *x*, *y*, and *z* axes, in addition to rotation around each of the three axes. The majority of 3D virtual orthognathic planning software packages require the user to load and re-orientate the 3D image into the correct pre-planning position, i.e. NHP. The assumption is that this can be performed correctly based on subjective clinical estimation or the use of some form of positioning device.

Given that 3D images are not always displayed in NHP and that positioning devices are not routinely available, the purpose of this study was to determine the intra-rater and inter-rater reliability of re-orientating 3D facial images of a group of class III patients into ENHP. The primary outcome measure was the difference in chin position between the ENHP and RNHP orientation using the technique suggested by Hsung et al.[10]. The null hypothesis was that the difference in anterior–posterior chin position (z direction) between the ENHP and RNHP orientation was not different to 6 mm, as this has been found to be clinically significant[18].

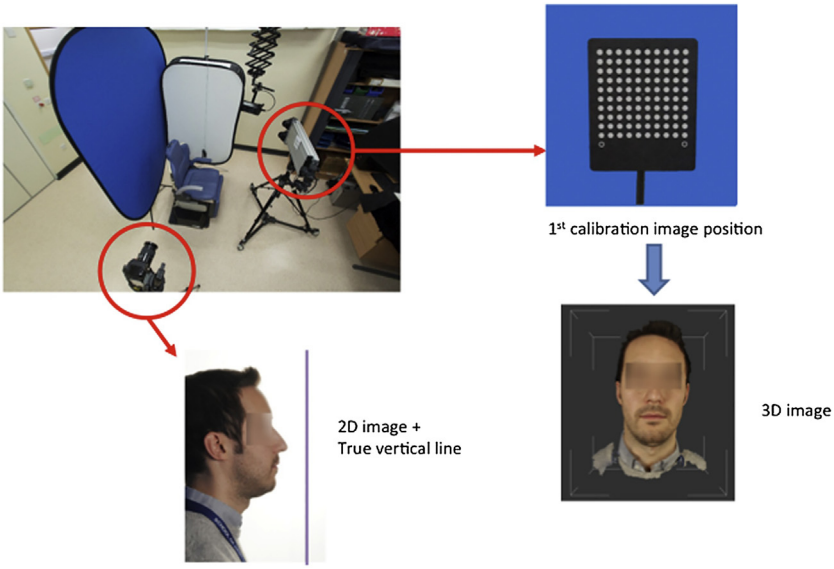

Fig. 1. Simultaneous 2D and 3D capture. Subject captured in NHP based on the true vertical line in 2D.

Materials and methods

Sample size calculation

Based on a standard deviation of 3.5° in the sella–nasion line to horizontal plane (SN/HOR) angle between RNHP and ENHP[19], an SN length of approximately 6.5 cm[20], SN–pogonion angle of approximately 80°[21], and total anterior facial height of 116 mm[20], the corresponding standard deviation at the chin (pogonion) would be expected to be approximately 5 mm. Using Minitab 17 (Minitab, State College, PA, USA) it was calculated that with 90% power, a significance level of 0.05, and a 6-mm clinical significance[18], a minimum sample size of 10 class III orthognathic surgical patients would be needed.

Patient recruitment

Following ethical approval by the Institutional Review Board (IRB) of Hong Kong

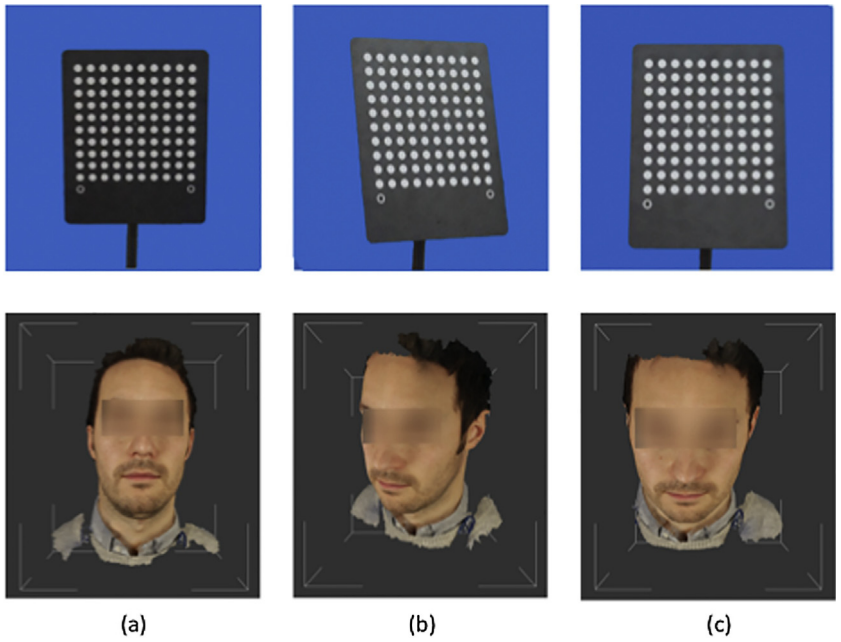

Fig. 2. Subject image captured once, but reloaded and viewed based on three different calibration target orientations. Note the change in head position.

Please cite this article in press as: Zhu S, et al. The difference between registered natural head position and estimated natural head position in three dimensions, *Int J Oral Maxillofac Surg* (2017), http://dx.doi.org/10.1016/j.ijom.2017.07.016