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Both the Observer's Expertise and the Subject's Facial Symmetry Can Affect Anatomical Position of the Head

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Abstract

Purpose: It is easier for us to judge facial deformity when the patient's head is in anatomic position. The purposes of this study were to determine: 1) if a group of expert observers agree more than a group of non-experts on what is the correct anatomical position of the head, 2) whether there is more variation in the alignment of an asymmetrical face compared with a symmetrical one, and 3) whether the alignments of experts are more repeatable than those of non-experts.

Subjects and Methods: Thirty-one orthodontists (experts) and 31 dental students (nonexperts) were recruited in this mixed-model study. They were shown randomly oriented three-dimensional head photographs of a symmetrical adult and an asymmetrical adolescent. In a viewing software,

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the observers oriented the images into anatomical position. They repeated the orientations 4 weeks later. The data was analyzed using a Generalized Linear Model and Bland-Altman plots. The primary predictor variables were *experience* and *symmetry status*. The outcome variable was *anatomical position* of the head. The other variables of interest included *time*, and *orientational direction*.

Results: There was a statistically significant difference between the measurements completed by experts and non-experts [$F(1,60)=14.83$, $P<0.01$]. The interaction between *expertise* and *symmetrical status* showed that there was a statistically significant difference between symmetrical and asymmetrical faces in both expert and non-expert groups [$F(1,60)=9.93$, $P=0.003$]. The interaction between expertise and time showed a statistically significant difference in measurement over time in both the expert and non-expert groups [$F(1,60)=4.66$, $P=0.03$].

Conclusions: The study shows that experts can set a head into anatomical position better than non-experts. Besides, facial asymmetry has a profound effect on the ability of an observer to align a head in the correct anatomical position. Finally, observer-guided alignment is not reproducible.

INTRODUCTION

Faces are easier to judge when they are oriented in *anatomical position*. A person is in anatomic position when his body is erect, his feet are flat and directed forward, his arms are on the sides with the hands palms facial forwards, and his head is in neutral posture (i.e., the head it is not flexed, it is not rotated, and is not tilted).¹⁻³

A patient's head can be placed in anatomical position using two different methods: natural head posture, and observer-guided alignment. In natural head posture, anatomical position is *automatically* attained by standing a patient and by asking him to look forward towards the horizon.⁴⁻⁷ Alternatively, one can place the patient squarely in front of a mirror and ask him to stare at the reflection of his own eyes.⁵ In observer-guided alignment, an *observer directs* the patient to rotate her head until it gets to where it is perceived to be anatomical position.^{8, 9}

While many patients can automatically place their heads into anatomical position when they stand in the natural posture, some cannot. The natural head posture is particularly problematic in children, as well as in patients with torticollis, neuromuscular disorders, deformities of the axial skeleton, or eye-muscle imbalances.^{10, 11} Moreover, the success of the natural head posture method is always judged by the observer's perception of correct alignment.¹²⁻¹⁵ For example, a patient will be considered not to be in anatomical position if his sagittal plane (plane of symmetry) is tilted, even when in natural head posture.

In a previous study, the authors asked a group of observers to align a symmetrical face into the standard anatomical position, on 2 different occasions.¹⁶ The observers were inexperienced dental students. The face they aligned was a three-dimensional (3D) photograph of a symmetrical person. The study showed that different observers disagree on the correct anatomical position and that observer-guided anatomical position is not repeatable.

However, research questions remained unanswered. We do not know if the results of the previous study would have been different if the observers were experts (rather than inexperienced dental students), or if the face that was aligned was asymmetrical (rather than symmetrical). To answer these questions, we conducted the present study based on the hypothesis that both the observer's expertise and the subject's facial asymmetry can affect anatomical position of the head. The specific aims of the study were to determine whether: 1) a group of expert observers will agree more than a group of non-experts on what is the correct anatomical position, 2) there will be more variation in the alignment of an asymmetrical face compared with a symmetrical one, and 3) the alignments of experts will be more repeatable.

SUBJECTS AND METHODS

STUDY DESIGN AND SUBJECTS

To answer the research questions, we designed a mixed-model study. The study took place at The University of Texas School of Dentistry at Houston, between August 2015 and June 2017. The study population was composed of all the board-certified orthodontists in the Department of Orthodontics and randomly-selected dental school students to match the number of orthodontists. The dental students involved in our previous study¹⁶ were excluded. Thirty-one orthodontists (experts, 18 male and 13 female, mean age 42 years) and 31 dental students (non-experts, 16 male and 15 female, mean age 24 years) participated the study as observers. The observers were selected without age, gender, or race predilection. The study was exempted by the Institutional Review Board of the University (HSC-DB-16-0212).

STUDY VARIABLES

The primary predictor variables were *experience* (experts and non-experts) and *symmetry status* (symmetry and asymmetry). The outcome variable was *anatomical position of the head*. The other variables of interest included *time* (1st and 2nd time), and *head orientation* (pitch, roll and yaw).

DATA COLLECTION

The data was collected in the same fashion as we did in our previous study.¹⁶ To measure how close different viewers agreed on the correct anatomical alignment, we asked each observer to orient, into anatomical alignment, 2 different 3D color head photographs: a male adult with a face that appeared symmetrical (Fig. 1) and a female adolescent with facial asymmetry (Fig. 2). The photographed subjects volunteered for the study. Both photographs were acquired using a 3dMDhead system (3dMD, LLC, Atlanta, GA).

The 3D photographs were then individually loaded into 3ds Max Design 2012 (Autodesk, San Rafael, CA), a software in which the image could be viewed from any direction and could be freely rotated. To measure the orientation of the 3D head image, we added a local (Cartesian) coordinate system and centered the image at Nasion. We intentionally misaligned this coordinate system so the bounding-box of the 3D image could not be used to place the head into a standard posture (Fig. 3a). We also misaligned the photographs of the

heads to a random initial orientation. Furthermore, the software's screen grid was hidden during the head alignments (Fig. 3b). These steps were done to avoid any possible observer bias.

The manipulation of the computer image was done by a single investigator (P.H.S.) at the verbal commands of the observers, who sat in front of the computer monitor. The observers were able to view the images from any angle, but they completed the alignment in order of pitch, roll and yaw on sagittal, coronal and axial views, respectively. Several iterations of rotations were completed from different orthogonal viewpoints. When the observers were satisfied with the head alignment, but before confirming it, they were shown the final position from the front, side, top, and bottom. The symmetrical head was aligned first, followed by the asymmetrical head. Each observer was blinded to the results of the others.

To assess if anatomical alignment changes over time, we repeated the experiment at least a month later. During the second assessment, the previous results were hidden from the observers. Finally, the orientations of the 3D photographs in anatomical alignment, in pitch, roll and yaw, were recorded in a Microsoft Excel spreadsheet. They were grouped by the level of expertise of the observers and paired with the 2 repeated measurements.

DATA ANALYSIS

To test our hypotheses, we use a Generalized Linear Model (GLM). The outcome variable was *anatomical position*. The between-factor was *the level of expertise* (expert and non-expert). The within-factors were *symmetry status* (symmetry and asymmetry), *time* (1st and 2nd time), and *direction* (pitch, roll and yaw). When the results demonstrated a statistical significant difference ($P < 0.05$), within-subject contrasts were further computed. The NCSS software package (NCSS, LLC, Kaysville, UT) was used for statistical analysis. In addition, we used Bland-Altman plots^{17, 18} to present the data.

RESULTS

Specific Aim 1:

To determine whether a group of expert observers will agree more than a group of non-experts on what is the correct anatomic position.

The results of GLM analysis show that there is a statistical significant difference between the head alignments completed by experts and non-experts [$F(1,60)=14.83$, $P < 0.01$], indicating that a group of expert observers agrees more than a group of nonexperts on what is correct anatomical position of the head.

The Bland-Altman plots (Figs. 4 and 5) demonstrate Fig. 4: Bland-Altman plots for the symmetrical face that experts do a better job than non-experts. In these plots, the variation between the 1st and 2nd head alignments is the distance between the upper and lower limits (the red and blue lines). By comparing these distances in the *non-expert* column to the *expert* column, one can see that the distances are clearly smaller in the expert group. This is true for symmetrical and asymmetrical faces and in pitch, roll, and yaw. In conclusion, the experts afford less variation.

Specific Aim 2:

To determine whether there will be more variation in the alignment of an asymmetrical face compared with a symmetrical face.

The interaction of *expertise* and *symmetrical-status* in the GLM show that there was a statistical significant difference [$F(1,60)=9.93$, $P=0.003$] between symmetrical and asymmetrical faces in both expert and non-expert groups, indicating that there is more variation in the anatomical position of an asymmetrical face, compared with a symmetrical face.

The Bland-Altman plots show significantly more variation in the anatomical position of the head when the face was asymmetrical. This is true for experienced and inexperienced observers and for all cardinal orientations: pitch, roll, and yaw. By comparing the results of the *symmetrical* face (Fig. 4) to the *asymmetrical* face (Fig. 5), one can see that the distances between the red and blue lines in symmetrical faces are smaller.

Specific Aim 3:

To determine whether the alignments of experts will be more repeatable.

The interaction between *expertise* and *time* show a statistically significant difference [$F(1,60)=4.66$, $P=0.03$] in measurement over time in both expert and non-expert groups, indicating that the head alignment is not repeatable.

The Bland-Altman plots show that when the face is symmetrical (Fig. 4), the repeatability of experts and non-expert is relatively good for roll and yaw, but not for pitch. When the face is asymmetrical (Fig. 5), the repeatability is poor for all observers (experts and non-experts).

DISCUSSION

The key results of the present study are: 1) that experts can set heads in anatomical position better than non-experts, 2) that facial asymmetry hurts the ability of an observer to align heads into anatomic position, and 3) that the observer-guided anatomical position is not reproducible. Also, the current study confirms the previous findings: 1) that the perception of correct anatomical position changes with time, 2) that different observers disagree on the correct head alignment, and 3) that estimation of pitch varies more than the judgment of roll and yaw.¹⁶

The present study has potential limitations, however. First, the observers aligned three-dimensional photographs rather than human subjects. One might wonder if the results would have been better if the study were done on actual subjects. We do not think so. The 3D photographs used in the study were accurate representations of the subjects. Also, if real subjects were used, each model would have had to pose 124 times. Not only would a large number of poses be taxing to the volunteers, but over time, they would have learned how to stand in the correct anatomical position. Besides, the head orientations of real human subjects would have had to be recorded. Instead, the virtual heads gave us direct measurements of head orientation, avoiding any measurement error.

Another potential limitation is that the age and gender of the subjects that volunteer for the face photographs was different. One was male, the other female. One was young, the other older. The study design could have been more robust if the only difference between the 2 photos was symmetry. That being said, we have no reason to believe that either the gender or the age of the subjects could have influence the head orientations established by the observers. We based this statement on the current understanding of how our brain perceives the orientation of the objects in our environment.^{19, 20}

How should we interpret the current findings? The present study shows that facial asymmetry hurts the ability of an observer to set heads in anatomic position, especially in roll and yaw. Why? When estimating the correct roll or yaw on a symmetric patient, an observer can use the clues of facial symmetry. One can look from the front, at the internal facial features (e.g., eyes, ears, nose, and mouth), and rotate the head until these features are symmetrical.^{16, 21} One can also look at the external facial contour and rotate the head until the outline is symmetrical. For yaw, an observer can look at the head, from above or below, and be guided by the ears and by the contour of the head. As before, one can rotate the head until these features are symmetrical. The clues from symmetry help us agree, within narrow margins, as to the correct alignment.¹⁶ In an asymmetric patient, these clues are absent.

How should we generalize the findings of this study? In clinical practice, we record the anatomical position of the head to reorient medical images, e.g., computed tomography scans. The images are used to assess facial deformity and to plan correction. We may seek anatomical position by asking the patients to stand tall and to gaze at the horizon; we call this maneuver the natural head posture. Unfortunately, we all know that this technique fails frequently. We recognize that natural head posture method has failed when we perceive the patient's head to be flexed, extended, rotated, or tilted, even when the patient is standing tall and looking straight forward. What do we do when this happens? We ask the patient to rotate his/her head, one way or another until we are satisfied with the posture. We call this observer-guided alignment. Until recently, we considered the observer-guided correction reliable. However, the results of our studies call this approach into question. It appears that better methods of calculating the reference frame of the face are needed. Our group has been developing mathematical algorithms that can calculate the anatomical frame of the face, even when the face is asymmetrical. Initial results have been promising.^{22, 23} Currently, we are collecting data to validate this algorithm.

In conclusion, the study shows that experts can align a head into anatomical position better than non-experts. Besides, facial asymmetry has a profound effect on the ability of an observer to correctly align a head in the correct anatomical position. Finally, observer-guided alignment is not reproducible.

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Fig. 1:
3D photograph of a symmetrical subject at the initial orientation prior to the test. A: right view. B: frontal view. C: bottom view.

Fig. 2:
3D photograph of an asymmetrical subject at the initial orientation prior to the test. A: right view. B: frontal view. C: bottom view.

Fig 3:

Coordinate systems used during the evaluation. A: The head image intentionally misaligned to both local and world coordinate systems. B: Only the 3D image and the center of rotation were seen during the evaluation.

Fig. 4:
Bland-Altman plots for the symmetrical face.

Fig. 5:
Bland-Altman plots for the asymmetrical face.