Reproducibility of natural head position in normal Chinese people

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Introduction: In this study, we evaluated the reproducibility of natural head position for pitch and roll acquired using 3 methods. **Methods:** The participants were 30 Chinese adults (ages, 23-28 years) who had normal occlusion with no history of orthodontic therapy, maxillofacial trauma, or surgery. The natural head position was acquired using the self-balanced, mirror, and estimated positions, which were performed in duplicate and repeated after 1 week. Three-dimensional photographs were recorded with a horizontal laser line projected onto the face. The laser lines were observed by registering the repeated 3-dimensional photographs. The roll and pitch of the head orientation were measured with a digital ruler. Reproducibility was calculated using Dahlberg's formula and the Bland–Altman method. **Results:** The reproducibility values calculated with Dahlberg's formula were 1.51°, 1.2°, and 0.99° for pitch, and 0.78°, 0.76°, and 0.41° for roll in the self-balanced, mirror, and estimated positions, respectively. **Conclusions:** The 3 methods are reproducible for both pitch and roll, and the estimated position showed the best reproducibility among these methods. This indicates that the estimated position could be used for acquiring the reference plane in preoperative planning for orthognathic surgery. (Am J Orthod Dentofacial Orthop 2015;148:503-10)

Orthognathic surgery is a main treatment method for problems with occlusion. With the development of computer-based technologies, more medical centers are beginning to use computer-aided surgical simulations for preoperative planning. Since the reference plane plays a crucial role in the preoperative design, the choice of reference plane has received much attention, particularly the Frankfort horizontal plane (FH plane)[1] and the true horizontal plane, which is based on the natural head position (NHP).[2]

The FH plane has become the most important reference plane since it was introduced in an orthodontic study in the 1880s.[3] It is considered that the FH plane in most people is parallel to the horizontal plane when the head is in the natural position. However, research has indicated that an obvious deviation of the FH plane from the horizontal is common, with the deviations of the angle formed by the FH plane and the true vertical plane ranging from 76.3° to 120.7° (mean, 89.27°; standard deviation [SD], 5.02°).[4] This deviation must be considered if the FH plane is selected as the reference plane when planning treatment. In addition, it is difficult to locate the left and right orbitales and porions on the same plane, so it would be difficult to choose the 3 points to define the FH plane. An alternative method is to use the midpoint of the 2 points, but it is also difficult to choose these 2 points.[5]

Because of these shortcomings of the FH plane, the true horizontal plane based on the NHP is becoming more popular.[6,7] Only when the NHP is acquired can the true horizontal plane be used as the reference plane.[6,8] Two methods have been widely used to acquire the NHP: the self-balanced position and the mirror position.[9-11] It has also been reported that the head position could be reproduced with less variation when corrections are made by the doctor,[3] especially for patients with a Class II or Class III malocclusion[12]; this position is referred to as the estimated position in this article. Some authors have compared the reproducibility of the 3 methods of NHP in the sagittal plane (pitch),[3,9,11] but no studies have compared the

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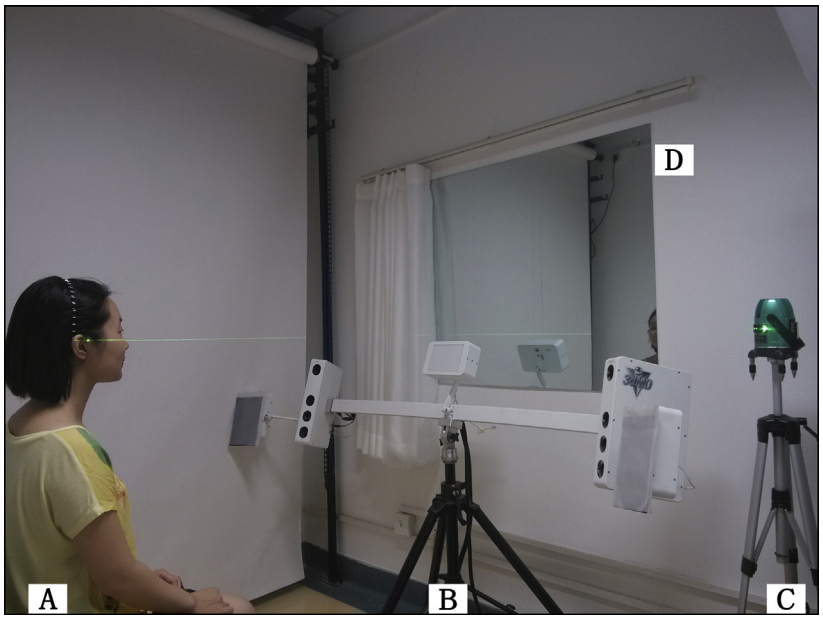

Fig 1. The setting and instruments used to record the natural head position: **A**: the subject was asked to sit upright; **B,** the 3dMDface imaging system, with the center flashlight turned off, and the right and left flashlights covered with translucent paper to reduce the intensity of the light; **C,** the laser level was set up beside the 3dMDface imaging system, and a harmless horizontal laser line was projected onto the subject's face; **D,** the mirror was mounted on the wall behind the 3dMDface imaging system (85 × 120 cm), in front of which a curtain was placed to cover the mirror during acquisition of the self-balanced position.

reproducibility of the 3 NHP methods in the coronal plane (roll).

In this study, we aimed to compare the reproducibility of NHP for pitch and roll acquired in the self-balanced, mirror, and estimated positions to identify a practical, reproducible position for preoperative digital design in orthognathic surgery.

MATERIAL AND METHODS

Thirty Chinese adults (15 women, 15 men) with normal occlusion were included in this study. Their ages ranged from 23 to 28 years (mean, 25.2 years; SD, 1.56 years). Those with a history of orthodontic therapy, maxillofacial trauma or surgery, or any disease of the motor system or vision system were excluded. If the subject had a cold with nasal obstruction at the NHP recording, it was delayed until the subject recovered.

This study was approved by the institutional review board of the Peking University School of Stomatology, Beijing, China (number PKUSSIRB-201413039). Informed consent was obtained from all participants before the study.

NHP was obtained in 3 ways: self-balanced position (position 1), mirror position (position 2), and estimated position (position 3). In the self-balanced position, each subject was first asked to sit upright with both hands on the thighs. Then, the subject tilted his or her head and decreased the amplitude until he or she was in a comfortable position, which was considered as the self-balanced position. In the mirror position, the subjects were asked to sit upright, tilt the head and decrease the amplitude, and then look at their eyes in a mirror (85 × 120 cm) located 150 cm in front of them. For acquiring the estimated position, the mirror position was adjusted by the same researcher (K.T.) for all participants. The standard criteria for the estimated position were that neither flexion nor extension of the head was observed in pitch and no obvious tilt of the head to the left or right was observed in roll.

The laser level SW902 (Saiwei, Shanghai, China) and the 3dMDface imaging system (3dMD, Atlanta, Ga) were used to record the NHP (Fig 1). According to the manufacturer's handbook, the wavelength of the laser was 635 nm, with a horizontal accuracy of 0.2 mm per 1 m. The recording procedure was as follows.

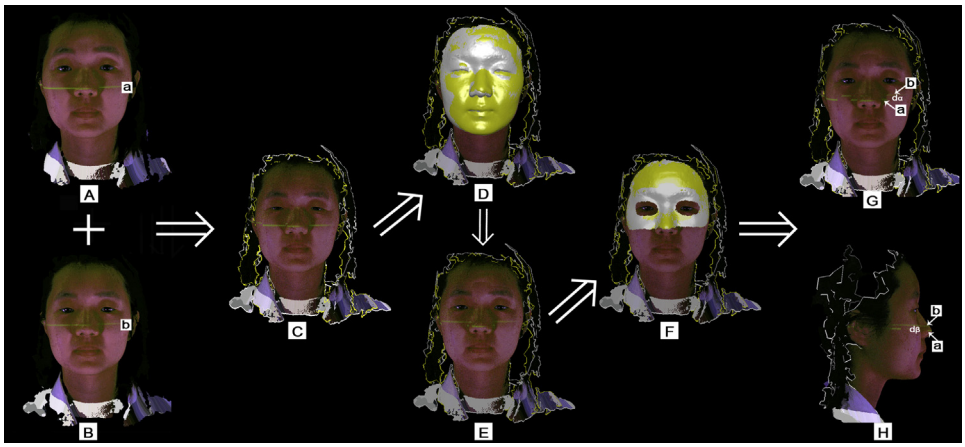

Fig 2. Procedure for evaluating the difference between the initial and repeated photographs: **A,** the initial photograph (T1) with the laser line (*line a*); **B,** the repeated photograph (T2) with the laser line (*line b*); **C,** the photographs show the registration result based on the whole surfaces; **D,** the second registration based on the selected face region; **E,** the photographs show the second registration result; **F,** the last fine registration based on the relatively stable region; **G** and **H,** after registering the 3D photographs together, the difference between the laser lines could be seen; $d\alpha$ and $d\beta$ refer to the difference in angles between T1 and T2 for roll and pitch, respectively.

First, with the subject sitting straight, the height of the laser level was adjusted so that it could project a horizontal laser line onto the participant's face within the area from the nasal apex to the infraorbital margin. Then, the center flashlight of the 3dMDface imaging system was turned off so that the laser line appeared more clearly on the obtained images. After these settings, the subject was asked to position the head in the NHP, and then the laser level was turned on to project the horizontal laser line, and the shutter of the 3dMDface imaging system was pressed to record the 3-dimensional (3D) photograph of the face.

To reduce any error that might be caused by a slight shaking of the subject's head, all 3 positions were acquired in duplicate for all subjects (in the order of self-balanced, mirror, and estimated positions [T1]). The subjects were asked to rest and walk around for about 5 minutes between the recording of positions 1 and 2, and between the recording of positions 2 and 3. This procedure was repeated after 1 week (T2). Eventually, a total of 12 photographs were taken of each subject.

To evaluate the changes in head position, the 3D photographs of the same subjects were registered by the same researcher (K.T.) in the 3dMDpatient software (3dMD; Fig 2). The self-balanced position is shown here to illustrate the registration procedure. There were 4 photographs of the self-balanced position for each subject. These photographs were registered together in 3 steps. First, the 3D photographs were registered by surface registration based on the whole surfaces (Fig 2, *C*). Second, the whole face region was selected, and surface registration based on the selected region was performed (Fig 2, *D* and *E*). Although all subjects were asked to relax their faces, there might have been some differences around the mouth and eyes between the photographs. Therefore, in the third step we cleared the selected whole face region, reselected a relatively stable region, and finally performed another fine registration based on that region (Fig 2, *F*). Subsequently, the differences between the laser lines could be observed (Fig 2, *G* and *H*). The same registration procedure was performed for the mirror and the estimated positions.

For the measurement of NHP, the DWRule (version 1.0; Dowell, Beijing, China) was used to measure the angles, with an accuracy of 0.01°. When the ruler was rotated away from the horizontal, the rotation angle could be displayed automatically (Fig 3). The self-balanced position is shown here to illustrate the measuring procedure.

The registered 3D photographs were locked together and rotated to display the frontal view, and the inner canthus line was made horizontal to the axial plane in the 3dMDpatient software (Fig 2, *G*). Then, we displayed the 3D photographs one by one and took a screenshot of each photograph in the frontal view. During this screenshot procedure, the 3D photographs could not be rotated. After all the screenshots of the frontal views had been taken, the right lateral view of the 3D photographs was displayed (Fig 2, *H*). Then, all 3D

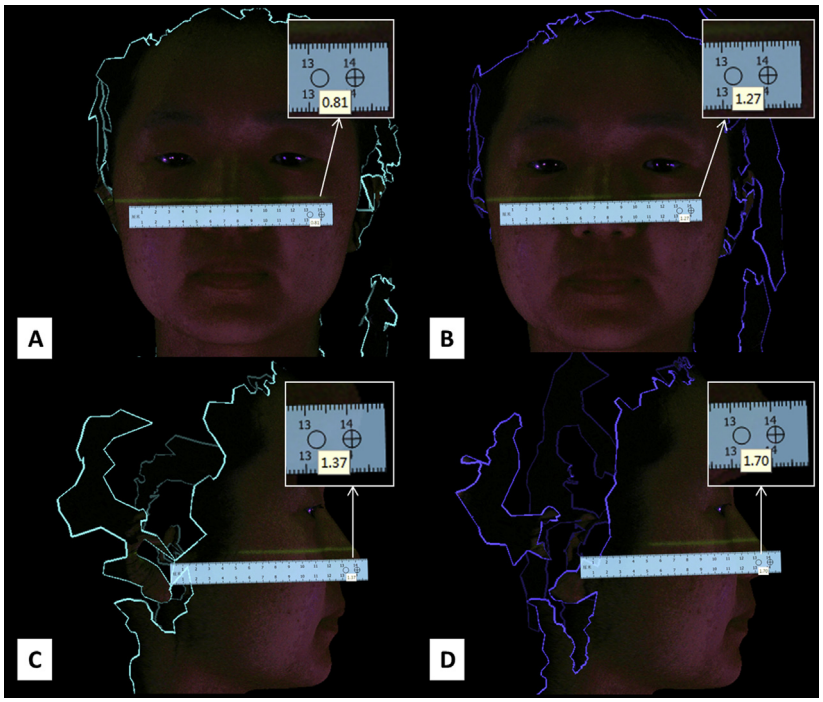

Fig 3. Angle measurement with the DWRuler: **A-D,** the *arrows* indicate the measurement results. The DWRuler could be rotated so that it was parallel to the laser line, and the inclination of the DWRuler to the horizontal line is shown as the result.

photographs were hidden again. This time, screenshots of each 3D photograph were taken in the right lateral view after displaying them one by one. During this procedure, no rotation of the 3D photographs could occur. All screenshots were saved as .jpg files. After this procedure, the frontal and right lateral views of all 3D photographs in 1 coordinate system could be recorded. Thus, the angle measured by the DWRuler between the laser line and the horizontal line of the screen represented the roll of the head orientation (in the frontal view, Fig 3, *A* and *B*) and the pitch of the head orientation (in the right lateral view, Fig 3, *C* and *D*).

All angles were measured 3 times at an interval of at least 3 days to reduce measurement error. All measurements were made by the same researcher (K.T). With regard to each position at each time (T1 or T2), 2 photographs were taken; a total of 6 measurements were obtained for both roll and pitch. The mean value of these 6 angles was calculated as the final angle to represent the roll or pitch angle for each position at each time.

The 3D photographs of 15 subjects (8 men, 7 women) were selected randomly to test the reliability of the measurements. The angles mentioned above were measured by 2 researchers (K.T. and another). Each researcher repeated the measurements 3 times at an interval of at least 3 days. The SPSS statistical package (version 13.0; SPSS, Chicago, Ill) was used to calculate the intraclass correlation coefficient (ICC) to estimate the reliability of the measurements.

The reproducibility of NHP was evaluated for pitch and roll separately. The reproducibility was calculated for each method separately using Dahlberg's formula[13] (method error$=\sqrt{\sum d_i^2/2n}$).[14] In the formula, d_i (d_α for roll and d_β for pitch; Fig 2, *G* and *H*) was the difference between the initial and repeated photographs (T1 and T2) for the same position, and n was the sample size. Excel (version 2010; Microsoft, Redmond, Wash) was used for this calculation.

To make it more intuitive, the method of Bland and Altman[15] was also used to evaluate the reproducibility. The 1-sample Kolmogorov-Smirnov test was used to test normality, and the assumption of normal distribution could not be rejected. Software (version 15.2.2; MedCalc, Ostend, Belgium) was used to perform the Bland-Altman analysis.

RESULTS

Eventually, 180 photographs were used for the reliability test. They were obtained from 15 randomly selected subjects, with 12 photographs from each subject (4 photographs for each of the 3 positions).

Table I. Reliability of the measurement (N = 180)

	ICC (95% CI)		
	Estimator 1	*Estimator 2*	*Between estimators*
Pitch	0.984 (0.980, 0.988)	0.976 (0.970, 0.982)	0.934 (0.919, 0.948)
Roll	0.990 (0.987, 0.992)	0.991 (0.988, 0.993)	0.989 (0.986, 0.991)

Table II. Reproducibility of NHP in pitch and roll acquired by the 3 methods

			Paired T1 and T2 samples					*Reproducibility (°)*		
	Position	*Sex*	*Mean (°)*	*SD (°)*	*SE (°)*	*t value*	P *Value*	*One sex*	*Combined sexes*	P *Value*
Pitch	1	M	1.10	2.46	0.63	1.737	0.104	1.85	1.51	0.122
		F	−0.10	1.56	0.40	−0.237	0.816	1.06		
	2	M	−0.04	1.66	0.43	−0.092	0.928	1.13	1.20	0.881
		F	0.06	1.84	0.48	0.121	0.905	1.26		
	3	M	−0.45	1.27	0.33	−1.362	0.195	0.92	0.99	0.351
		F	0.04	1.53	0.39	0.102	0.920	1.05		
Roll	1	M	0.25	1.41	0.36	0.687	0.503	0.98	0.78	0.446
		F	−0.07	0.76	0.20	−0.357	0.727	0.52		
	2	M	−0.15	1.39	0.36	−0.429	0.675	0.95	0.76	0.445
		F	0.16	0.72	0.19	0.854	0.407	0.50		
	3	M	−0.18	0.64	0.17	−1.055	0.309	0.46	0.41	0.383
		F	0.01	0.52	0.14	0.108	0.916	0.36		

Position 1, Self-balanced; *position 2*, mirror; *position 3*, estimated; *T1*, NHP recorded in the first series; *T2*, NHP recorded after a 1-week interval; *M*, male; *F*, female.

The reliability values of the measurements as calculated from independent repeated measurements are summarized in Table I. It was found that the ICC values between estimators for pitch and roll were 0.934 (0.919, 0.948) and 0.989 (0.986, 0.991) respectively, and that the intraobserver ICC values were even higher. These findings indicated that this method of measurement was quite stable and reliable for evaluating the reproducibility of the head position.

The statistical analysis results of the paired samples and the reproducibility results of Dahlberg's formula[13] are summarized in Table II. Method errors (reproducibility) ranged from 0.36° to 1.85°. The *t* test results showed no significant intersex differences in d_i, so the data for both sexes were combined to analyze the reproducibility.

The Bland-Altman method[15] showed that the means were almost within 0.5° for pitch and 0.1° for roll, and the 95% limits of agreement were all within 4.7° for pitch and 2.5° for roll (Table III).

DISCUSSION

In this study, we investigated the reproducibility of the NHP in pitch and roll. Three methods for acquiring the NHP were compared. Dahlberg's formula[13] and the Bland-Altman method[15] showed similar results. Moreover, we found that for both pitch and roll, the reproducibility of the estimated position was the best, followed by the mirror position and then the self-balanced position. This result agrees with the results of other studies[3,9,11,16] and, to some degree, proved the correcting function of the subjects' visual system when they looked in the mirror, which is involved in the control of NHP.[17]

To record the NHP in 3 dimensions, several scholars have developed new methods in recent years. Schatz et al[18] and Xia et al[19] developed a new method using a digital gyroscope to record the NHP in 3 dimensions, and their method was shown to have high accuracy. However, the weight of the device might affect the head position.[18] Kim et al[20] developed a novel method using 1 frontal facial photograph based on the pose from orthography and scaling with iterations to record the NHP in 3 dimensions. Their method was time-effective and needed no extra instruments, and it might be convenient for orthognathic surgery. However, we could not use their method in our study because setting the camera in front of the subject when acquiring the NHP could have obstructed his or her line of view, and we needed to avoid computed tomography scans as much as possible for this volunteer study.

Weber et al[21] also used the 3dMDface imaging system to record the sitting NHP. They marked 4 ink dots

Table III. Summary of the Bland-Altman analysis for the reproducibility of NHP (°)

	Position	*Mean*	*SD*	*95% CI of bias*	*Lower limit of agreement (95% CI)*	*Upper limit of agreement (95% CI)*
Pitch	1	0.50	2.11	−0.28 to 1.29	−3.63 (−4.99 to −2.27)	4.64 (3.28 to 6.00)
	2	0.01	1.72	−0.63 to 0.65	−3.37 (−4.48 to −2.26)	3.39 (2.28 to 4.50)
	3	−0.20	1.40	0.73 to 0.32	−2.96 (−3.86 to −2.05)	2.55 (1.64 to 3.45)
Roll	1	0.09	1.12	−0.33 to 0.51	−2.11 (−2.84 to −1.39)	2.29 (1.57 to 3.02)
	2	0.00	1.10	−0.41 to 0.41	−2.15 (−2.85 to −1.44)	2.15 (1.44 to 2.86)
	3	−0.08	0.58	−0.30 to 0.14	−1.23 (−1.60 to −0.85)	1.07 (0.69 to 1.44)

Position 1, Self-balanced; *position 2*, mirror; *position 3*, estimated.

to record the NHP before taking the 3D photograph. According to our experience, the head of the subject was likely to vibrate slightly while the ink dots were being marked. To overcome this difficulty, we developed this new method to record the NHP. Thus, the time interval between acquiring and recording the NHP could be controlled to within 1 second. In our research, we used the 3dMDface imaging system and the laser level to record the head position and evaluate the reproducibility of the 3 sitting NHPs.

The reproducibility values of the head position for pitch, as determined in our study with Dahlberg's formula,[13] were 1.51°, 1.2°, and 0.99° in the self-balanced, mirror, and estimated positions, respectively. The reproducibility values in other studies ranged from 1.34° to 4.9°.[3,9,11,14,22-26] Most of these studies recorded NHP using lateral cephalometric radiographs, which might be the main reason for the low reproducibility. We think that the procedure used for positioning the subject in the cephalostat might have reduced the reproducibility. In our research, the 3dMDface imaging system does not influence or obstruct the subjects when their NHP is being acquired and recorded. Furthermore, in some studies, ear rods were inserted when acquiring the radiographs, which could also have reduced the reproducibility.[11]

The reproducibility values of the head position for roll in this study using Dahlberg's formula[13] were 0.78°, 0.76°, and 0.41° in the self-balanced, mirror, and estimated positions, respectively. Huggare[16] reported the reproducibility for the roll to be 1.15° in the self-balanced position, and Usumez and Orhan[26] reported it to be 0.9°. Usumez and Orhan[27] introduced a method for recording NHP that required the subject to wear eyeglasses to which 2 inclinometers were attached. They proved that the weight of the device had no influence on the NHP, but they did not mention whether the eyeglasses could be worn in the same position at each recording; this could have had a great impact on the accuracy.

We found that the reproducibility for roll was better than that for pitch in our study; this agrees with the results of Usumez and Orhan[26] and Weber et al.[21] This may be because the mechanism for controlling the head position in the sagittal plane is more complicated than that in the coronal plane. Wenzel et al[28] believed that psychosocial factors could impact NHP in the pitch: ie, patients were more likely to lift their heads if they were more self-confident. Vig et al[29] found that respiratory requirements could influence neuromuscular control, which could influence the head position in the sagittal plane. Salem and Preston[30] found that deprivation of visual input might result in extension of the standing NHP. Furthermore, Weber et al found that large muscle groups balanced the head in the coronal plane, and this made it more stable.

Since reproducibility was the main issue tackled in this study, the factors that might influence reproducibility were intensively considered, as discussed below.

To reduce the confounding bias, we designed this self-control study in which the 3 NHPs of each subject were acquired and compared. Because the estimation of the researcher might influence the self-balanced and mirror positions, and the mirror position might influence the self-balanced position, we designed the sequence of acquiring NHPs as mentioned previously. Moreover, we used a 5-minute washout time between the 2 positions, as suggested in the studies of Bjerin[22] and Cooke and Wei.[11]

To evaluate the reproducibility, the radiographs or photographs had to be comparable. In previous studies, registrations based on the skull base or the profile were used.[3,9,11] In more recent studies, Weber et al[21] superimposed the 3D photographs by choosing the area of the forehead, soft-tissue nasion, and nose bridge. Maal et al[31] studied the accuracy of the surface-based registration. They found that the mean registration error could be 0.42 mm if the registration was based on the selected region, and they also found an interobserver error.[32] Moreover, the precision and accuracy of this imaging system were reported to be sufficient for clinical use.[33] Thus, we followed their methods and conducted the registration procedure rigidly, as stated previously. To eliminate the interobserver error, all registrations were performed by the same author (K.T.). Moreover, during the 1-week

interval, no obvious change was observed in the face of any subject.

It was necessary for the measurement method to be accurate and reliable to evaluate the reproducibility. The DWRuler used in this study was accurate to 0.01°; this made it more accurate than the traditional protractor used in the previous studies.[3] Moreover, accuracy relied heavily on accurate rotation of the DWRuler operated by the observer. This means that the DWRuler must be rotated as parallel to the laser line as possible to measure the angles accurately. Thus, we tested the repeatability and reliability of this procedure for both intraobserver and interobserver findings first. The high intraobserver and interobserver ICC values indicated that measurements with the DWRuler were reliable and repeatable to test the reproducibility.

Currently, many studies use the sitting NHP.[19,21,34-37] Therefore, we designed our study based on previous studies and clinical practicability. In the clinical environment, patients differ in height; therefore, sitting on a height-adjustable stool could provide a more stable position for taking 3D photographs and estimating their NHP. Thus, we compared the 3 sitting NHPs of the subjects in our study. Bjerin[22] evaluated the differences between the sitting and standing positions. He found that the standard deviations were 1.62° for sitting and 1.34° for standing. Hence, he concluded that accuracy did not depend on whether the standing or sitting position was used. However, he also found that the head in the sitting position was approximately 1.9° more extended than in the standing position; the probable reasons for this difference were not discussed in his research. Similarly, Cooke and Wei[11] found that the difference between the self-balanced position and the mirror position was about 2° for male subjects. Despite this, it was difficult to conclude which position would be a more "natural" one; this might need further study.

Since we evaluated the reproducibility of NHP, a larger sample size might help to strengthen the results. Because we assessed the 1-week-interval reproducibility of the 3 sitting NHPs of normal subjects, future research should be conducted on long-term interval reproducibility, especially for the estimated position, and the differences between the sitting and standing positions. Moreover, further study of the NHP of patients with malocclusion would be required for orthognathic surgery.

CONCLUSIONS

Based on our research, it can be concluded that for both pitch and roll, the 3 NHPs are reproducible. Moreover, the estimated position had the best reproducibility among the methods. This indicates that the estimated position could be a practical method for acquiring the reference plane.

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REFERENCES

1. Zinser MJ, Mischkowski RA, Sailer HF, Zoller JE. Computer-assisted orthognathic surgery: feasibility study using multiple CAD/CAM surgical splints. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;113:673-87.
2. Bell RB. Computer planning and intraoperative navigation in cranio-maxillofacial surgery. Oral Maxillofac Surg Clin North Am 2010;22:135-56.
3. Moorrees CF, Kean MR. Natural head position, a basic consideration in the interpretation of cephalometric radiographs. Am J Phys Anthropol 1958;16:213-34.
4. Leitao P, Nanda RS. Relationship of natural head position to craniofacial morphology. Am J Orthod Dentofacial Orthop 2000;117:406-17.
5. Gateno J, Xia JJ, Teichgraeber JF. New 3-dimensional cephalometric analysis for orthognathic surgery. J Oral Maxillofac Surg 2011;69:606-22.
6. Cooke MS, Wei SH. A summary five-factor cephalometric analysis based on natural head posture and the true horizontal. Am J Orthod Dentofacial Orthop 1988;93:213-23.
7. Viazis AD. A cephalometric analysis based on natural head position. J Clin Orthod 1991;25:172-81.
8. Gelesko S, Markiewicz MR, Weimer K, Bell RB. Computer-aided orthognathic surgery. Atlas Oral Maxillofac Surg Clin North Am 2012;20:107-18.
9. Solow B, Tallgren A. Natural head position in standing subjects. Acta Odontol Scand 1971;29:591-607.
10. Solow B, Tallgren A. Head posture and craniofacial morphology. Am J Phys Anthropol 1976;44:417-35.
11. Cooke MS, Wei SH. The reproducibility of natural head posture: a methodological study. Am J Orthod Dentofacial Orthop 1988;93:280-8.
12. Verma SK, Maheshwari S, Gautam SN, Prabhat KC, Kumar S. Natural head position: key position for radiographic and photographic analysis and research of craniofacial complex. J Oral Biol Craniofac Res 2012;2:46-9.
13. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience Publications; 1940.
14. Cooke MS. Five-year reproducibility of natural head posture: a longitudinal study. Am J Orthod Dentofacial Orthop 1990;97:489-94.
15. Bland JM, Altman DG. Measuring agreement in method comparison studies. Stat Methods Med Res 1999;8:135-60.
16. Huggare J. Natural head position recording on frontal skull radiographs. Acta Odontol Scand 1989;47:105-9.
17. Solow B, Sandham A. Cranio-cervical posture: a factor in the development and function of the dentofacial structures. Eur J Orthod 2002;24:447-56.

18. Schatz EC, Xia JJ, Gateno J, English JD, Teichgraeber JF, Garrett FA. Development of a technique for recording and transferring natural head position in 3 dimensions. J Craniofac Surg 2010;21:1452-5.
19. Xia JJ, McGrory JK, Gateno J, Teichgraeber JF, Dawson BC, Kennedy KA, et al. A new method to orient 3-dimensional computed tomography models to the natural head position: a clinical feasibility study. J Oral Maxillofac Surg 2011;69: 584-91.
20. Kim D, Yang HJ, Huh K, Lee S, Heo M, Choi S, et al. Three-dimensional natural head position reproduction using a single facial photograph based on the POSIT method. J Craniomaxillofac Surg 2014;42:1315-21.
21. Weber DW, Fallis DW, Packer MD. Three-dimensional reproducibility of natural head position. Am J Orthod Dentofacial Orthop 2013;143:738-44.
22. Bjerin R. A comparison between the Frankfort horizontal and the sella turcica-nasion as reference planes in cephalometric analysis. Acta Odontol Scand 1957;15:1-12.
23. Siersbaek-Nielsen S, Solow B. Intra- and interexaminer variability in head posture recorded by dental auxiliaries. Am J Orthod 1982; 82:50-7.
24. Luyk NH, Whitfield PH, Ward-Booth RP, Williams ED. The reproducibility of the natural head position in lateral cephalometric radiographs. Br J Oral Maxillofac Surg 1986;24:357-66.
25. Peng L, Cooke MS. Fifteen-year reproducibility of natural head posture: a longitudinal study. Am J Orthod Dentofacial Orthop 1999;116:82-5.
26. Usumez S, Orhan M. Reproducibility of natural head position measured with an inclinometer. Am J Orthod Dentofacial Orthop 2003;123:451-4.
27. Usumez S, Orhan M. Inclinometer method for recording and transferring natural head position in cephalometrics. Am J Orthod Dentofacial Orthop 2001;120:664-70.
28. Wenzel A, Williams S, Ritzau M. Changes in head posture and nasopharyngeal airway following surgical correction of mandibular prognathism. Eur J Orthod 1989;11:37-42.
29. Vig PS, Showfety KJ, Phillips C. Experimental manipulation of head posture. Am J Orthod 1980;77:258-68.
30. Salem OH, Preston CB. Head posture and deprivation of visual stimuli. Am Orthopt J 2002;52:95-103.
31. Maal TJJ, van Loon B, Plooij JM, Rangel F, Ettema AM, Borstlap WA, et al. Registration of 3-dimensional facial photographs for clinical use. J Oral Maxillofac Surg 2010;68:2391-401.
32. Maal TJ, Plooij JM, Rangel FA, Mollemans W, Schutyser FA, Berge SJ. The accuracy of matching three-dimensional photographs with skin surfaces derived from cone-beam computed tomography. Int J Oral Maxillofac Surg 2008;37:641-6.
33. Lubbers HT, Medinger L, Kruse A, Gratz KW, Matthews F. Precision and accuracy of the 3dMD photogrammetric system in craniomaxillofacial application. J Craniofac Surg 2010;21:763-7.
34. Wozniak K, Piatkowska D, Lipski M. The influence of natural head position on the assessment of facial morphology. Adv Clin Exp Med 2012;21:743-9.
35. Hsung T, Lo J, Li T, Cheung L. Recording of natural head position using stereophotogrammetry: a new technique and reliability study. J Oral Maxillofac Surg 2014;72:2256-61.
36. Cole SC. Natural head position, posture, and prognathism: the Chapman Prize Essay. Br J Orthod 1986;1988:227-39.
37. Dvortsin DP, Ye Q, Pruim GJ, Dijkstra PU, Ren Y. Reliability of the integrated radiograph-photograph method to obtain natural head position in cephalometric diagnosis. Angle Orthod 2011;81:889-94.

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