

Does the Time of Day Affect Natural Head Position or Its Reproducibility?

HR. Fattahi¹, S. Torkan^{2✉}, HR. Pakshir³, L. Darabi⁴

¹Associate professor, Shiraz Orthodontic Research Center, Orthodontic Department, Shiraz University of Medical Sciences, Shiraz, Iran

²Assistant Professor, Lorestan University of Medical Sciences and Shiraz Orthodontic Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

³Professor, Shiraz orthodontic Research Center, Orthodontic Department, Shiraz University of Medical Sciences, Shiraz, Iran

⁴Dentist, Private Practice, student Research Committee

Abstract

Objective: The aim of this study was to investigate the reproducibility of natural head position (NHP) at different times of the day and to compare the reproducibility of the initial photographs with 6-month repeat photographs.

Materials and Methods: The participants in this prospective study were seventy 14 to 50-year-old individuals. Each participant was photographed with a digital camera twice, at three different times of the day (in the morning, at noon and in the evening) and after a 6-month interval. The reproducibility of head posture was assessed by comparing the angle between the true horizontal and the ala-tragus plane. Student's paired *t*-test and repeated measure analysis were used to analyze the results. To evaluate the differences between the first and second sets of photographs, Dahlberg's coefficient (method error) was also used.

Results: Repeated measure analysis did not reveal any statistically significant differences in NHP orientation at different times of the day in the initial measurements ($p=0.15$) or after a 6-month period ($p=0.56$). Dahlberg's coefficient for all the participants during the 6-month period was 3.14° . Paired *t* test showed significant differences in NHP orientation only in the morning.

Conclusion: The time of the day during which the photograph is taken does not affect the reproducibility of NHP. However, this orientation was more stable in the evening and at noon than in the morning. No differences were found between genders. In conclusion, measurements of NHP with the ala-tragus plane were more stable than measurements based on intracranial reference planes.

Key Words: Cephalometry; Radiography; Photography

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✉ Corresponding author:

S. Torkan, Department of Orthodontic and Research Center of Lorestan University of Medical Science, Lorestan, Iran
sepideh.torkan@yahoo.com

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INTRODUCTION

Intracranial reference lines are an inherently unreliable method for assessing skeletal relationships [1,2]. The natural head position

(NHP) has been proposed as a postural basis for analyzing craniofacial morphology in both the orthodontic and anthropologic literature [3-6]. The concept of NHP was first introduced in

the 1950s by Downs [2], Bjerin [7] and Moorrees and Kean [8]. It was defined by Cole as “the relationship of the head to the true vertical”; whereas, the natural head *posture* has been defined as “the relationship of the head to the cervical column” [9, 10].

The first publication on NHP appeared in Europe in the mid-19th century [11, 12], when NHP was defined as the head position when a standing man’s visual axis is horizontal [4], determined with the help of a mirror. Luthy et al. located NHP by using a mirror and found a mean difference of 5° between the true horizontal and the Frankfurt horizontal plane [13]. Later, orthoposition was introduced as a highly reproducible position; it was defined by Mohalve et al. as the intended position for walking [14]. The advantages of using NHP as the reference to evaluate craniofacial morphology are twofold: the true horizontal reference plane is less variable than conventional cephalometric reference planes [15-17] and variables based on NHP better describe the individual’s true life appearance [18, 19].

The reproducibility of NHP has been debated [1, 6, 10, 18-22]. Although most authors have found it to be a stable orientation [1, 6, 18, 19], others such as Frankel et al. and Ferrario et al. did not reach the same conclusion [20, 21]. In a study conducted by Frankel, changes in muscle activity and respiration caused by the functional appliance might have distorted the results.

The long-term stability of NHP has been investigated 3-6 months [3], 5 years [23] and 15 years after the initial radiograph [10]. Reproducibility seemed to deteriorate over time but to stabilize after 1 to 1.5 years.

Although NHP has been postulated to have less variance than intracranial reference lines [13], it is also influenced by balance (the vestibular canals of the middle ear), vision (the need to maintain a horizontal visual axis) and proprioception from joints and muscles involved in maintaining erect posture [10].

To assess the reproducibility of a given method or the agreement between two methods, Dahlberg’s coefficient is commonly used [17]. A coefficient with a value below the cut-off point of approximately 1.5-2° is considered to indicate good reproducibility or agreement [1]. However, Bister et al. concluded that reproducibility can be more accurately assessed with a reproducibility coefficient and its corresponding graphical representation [1].

Although the short-term reproducibility of NHP has been evaluated after 4-10 minutes [6], to our knowledge no studies have evaluated the reproducibility of NHP at different times of the day. Since it has been proposed that the individual’s neuromuscular condition can affect NHP orientation [24, 25], the time of day during which the photograph is taken might affect the reproducibility of the results.

This study was designed to 1) investigate the reproducibility of NHP orientation at different times of the day and to determine whether muscle fatigue during the day affects NHP orientation and 2) to determine whether NHP reproducibility at different times of the day changes after a 6-month-period.

MATERIALS AND METHODS

In this longitudinal descriptive study, a total of 70 patients (37 men and 33 women) ranging in age from 14 to 50 years (mean age, 29.5 years) participated. None of the patients had undergone orthodontic or orthognathic treatment, had any type of syndrome or head and neck injury, and none wore eyeglasses to correct vision. All the photographs were taken with a digital camera (Canon IXU 860 IS) with the participant standing in profile.

The camera was mounted at a distance of 2.5 meters on an adjustable tripod, leveled with the optical horizontal axis of the lens.

The participants were asked to remove their footwear and look straight into a mirror mounted at eye level at a distance of 150 cm from the individual’s head.

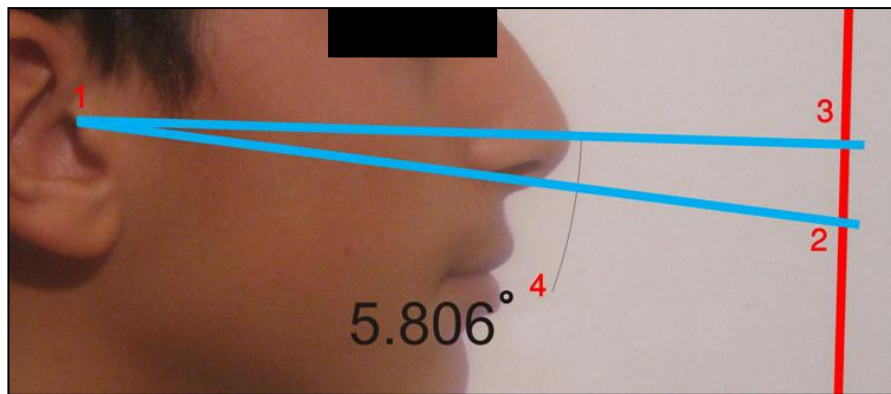


Fig 1. To measure the NHP, the ala-tragus and true horizontal plane are drawn in the software environment

They were asked to keep their head and shoulders erect with both arms hanging free at their sides, so that by looking straight into the mirror, they would reflect their self-balanced natural head position as defined by Broca [11]. A plumbline chain was photographed together with the individual to represent the true vertical. Each participant was photographed at three different times of the day: 1) in the morning (7:00-11:00), 2) around noon (12:00-15:00) and 3) in the evening (19:00-22:00). The same method was repeated 6 months later with the same participants. Photographs were measured and analyzed with Corel Draw X4 software.

All the photos were imported into the software environment and scaled to ensure identical magnification.

In the software environment, a line was drawn tangential to the plumbline to represent the true vertical and another line was then drawn from the superior border of the tragus, perpendicular to the true vertical to represent the true horizontal. A third line was drawn running through the ala-tragus plane (Figure 1).

Rahn and Heartwell [26] described this as a line running along the inferior border of the ala to the superior border of the tragus.

Once all three lines were drawn, the angle between the true horizontal and the ala-tragus plane was measured to assess the reproducibility of head posture.

Statistical analysis

To determine method error in landmark location and measurement, a method error study was performed for 20 randomly chosen photographs using double determinations.

At least 1 month after the initial measurement, angular analysis was repeated in each photograph by the same observer. Systematic errors were assessed with a paired *t*-test.

Dahlberg's formula (method error) was used to assess the differences between the first and second determinations for each subject according to the formula:

$$D (\text{method error}) = \sqrt{\frac{\sum d^2}{2N}}$$

where $\sum d^2$ is the sum of the square of the differences between the first and second determinations in all participants.

To assess the reproducibility of NHP after 6 months, Student's paired *t*-test was used. Differences in angular measurements at different times of the day were assessed with repeated measure analysis. Angular measurements between genders were compared with an independent *t*-test.

RESULT

No Seventy individuals (33 women, 47.1% and 37 men, 52.8%) comprised the sample group. The mean age of the participants was

29.5 years with a standard deviation of 9.66. Student's *t*-test revealed no significant systematic bias between the first and second landmark locations and plane readings. Table 1 shows the mean values and other descriptive statistics for the angle formed between the true vertical and the ala-tragus plane in the initial and 6-month determinations. Repeated measure analysis was used to compare NHP orientation at three different times of the day in the initial ($P=0.15$) and 6-month determinations ($P= 0.56$). No statistically significant differences were found between the three daily measurements for either period.

No statistically significant differences were detected between the results in the initial measurements and 6-month measurements for any of the three times of the day ($P= 0.54$). The mean change in the morning measurements between the first and second determination was 1.37 ($P= 0.01$), which was statistically significant. The noon and evening measurements did not change significantly after 6 months. According to Dahlberg's formula, the method error was 3.14° for morning, 3.01° for noon and 3.29° for evening photographs.

The mean method error for all participants in both initial and 6-month photographs was 3.14°. The mean change between morning and noon was 3.37° and the mean change between noon and evening was 3.12° in the initial measurements. In the 6-month measurements, the mean changes between morning and noon and between noon and evening were 2.66° and 2.44°, respectively. No significant differences were found between genders.

DISCUSSION

To achieve the best treatment results for each patient, it is important to consider and record the individual's natural posture and program the treatment plan accordingly. This study evaluated the reproducibility of NHP in photographs, which is the same method used by Ferrario et al. [20], Lundstrom [18] and Moorrees and Kean [8]. According to Bister et al. [1], photography is useful for training radiographers without unnecessary radiation exposure of the patients. However, technical differences in the preparation of photographs and radiographs might cause differences or misleading similarities in some instances.

Table 1. Mean, standard deviation and other descriptive statistics for the ala-tragus–true horizontal angle in the initial and 6-month photographs

	Timing of Day								
	Morning			Noon			Afternoon		
	Min	Max	Mean(SD)	Min	Max	Mean(SD)	Min	Max	Mean(SD)
Initial Photographs	2.7	27.8	13.5(5.2)	2.7	24.7	12.2(5.02)	-4.9	27.4	12.7(5.4)
6 month Photographs	0.58	23.1	12.3(5.2)	0.5	25.6	11.9(4.5)	2.6	28.8	11.5(5.4)
Total photographs	0.58	27.8	12.9(4.7)	0.5	25.6	12.9(4.7)	-4.9	28.8	12.1(5.02)

We investigated whether the specific time of day during which the photograph was taken had any effect on NHP orientation. According to our results, there was no significant difference in the short-term reproducibility of NHP, even though from a quantitative point of view, the ala-tragus plane formed a more acute angle with the true vertical in the morning, which suggests that in the morning, the participant's head has a tendency towards extension compared to the other times of the day. However, this morning difference was not statistically significant. Solow and Tallgren [25] and Murphy et al. [24] suggested that NHP depends on the individual's neuromuscular condition. Earlier work has suggested that the body equilibrium and posture in everyday life are a complex function involving multiple receptor organs in addition to the labyrinth of the ear. In other words, postural stability can be ensured only when visual proprioceptive and vestibular reflexes are integrated [27, 28]. We found a difference of more than 2° in the morning ala-tragus angle between the initial and 6-month measurement in 58.5% of our participants. This means that NHP orientation was more reproducible at noon and in the evening than in the early hours of the day. Based on Dahlberg's coefficient, the reproducibility of photographs taken during the early morning should be considered poor. The implication of this finding for clinical practice is that if a lateral cephalogram is ordered for an orthodontic patient, the appointment should be scheduled in the afternoon rather than in the morning. This can ensure better reproducibility of NHP measurements in future cephalograms.

The reproducibility of photographic measurements based on Dahlberg's coefficient remains controversial [1, 3, 17]. Bister et al. [1] defined a cut-off point of approximately $1.5\text{-}2^\circ$ to indicate good reproducibility or agreement. Nouri et al. [6] obtained a Dahlberg's coefficient of 2.44° in the short term and 3.23° in the long term and reported good reproducibility of NHP

in both periods. Based on Dahlberg's coefficient, in our study, the reproducibility of NHP was 3.14° after 6 months, a figure which according to Bister et al. would be considered poorly reproducible [1]. A study by Cook et al. [3] reported a 2.34° reproducibility of NHP after 3-6 months, a value significantly below that obtained with intracranial reference planes to the vertical ($25^\circ\text{-}36^\circ$) [17].

Assuming that the individual's muscle condition can affect NHP, extreme muscle fatigue (unlikely to result from normal daily activity) could lead to differences in NHP. However, our results show that individuals maintain nearly the same posture throughout the day. The suggestion was made by Conley et al. that neck muscle fatigue affects the mechanisms of postural control by producing abnormal sensory input to the CNS, which can result in a sense of instability. However, vision can overcome the disturbances in posture caused by neck muscle fatigue [29]. Schieppati and co-workers [30] proposed that the effects of neck muscle fatigue on orientation counteract those of neck proprioception. They showed that the head remains in place despite fatigue of the head extensor muscles and suggested that this effect depended on the very low level of force necessary to counteract head flexion. Because differences between morning measurements and measurements at other times of the day may be affected by diurnal changes in the individual's neuromuscular condition, additional studies are needed to investigate the possibility [29, 30]. In our study, age or gender did not affect NHP orientation, a finding consistent with the results of Peng and Cook [19] and Lin and Arlid [31]. However, the age range of the participants in the latter study was 6-9 years; whereas, in our study the age range was much higher (14-50 years). Similar studies of NHP should be carried out in larger samples with stratification for different age groups so that the effect of age on the reproducibility of NHP can be clarified.

CONCLUSION

1. NHP orientation of individuals remains almost the same throughout the day with no statistically significant changes. In the long term, NHP is more stable at noon and in the afternoon than in the morning.
2. There was no statistically significant difference in NHP between men and women.
3. Based on the results of this study, the coefficient of NHP was 2.89° in the short term and 3.14° in the long term.
4. If a lateral cephalogram is ordered for an orthodontic patient, the appointment should be scheduled in the afternoon rather than in the morning. However, the difference does not seem to be of significant value from the clinical viewpoint.

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