ORIGINAL RESEARCH

Comparison of Reproducibility of Natural Head Position using Two Methods

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ABSTRACT

Lateral cephalometric radiographs have become virtually indispensable to orthodontists in the treatment of patients. They are important in orthodontic growth analysis, diagnosis, treatment planning, monitoring of therapy and evaluation of final treatment outcome.

Aim: The purpose of this study was to evaluate and compare the maximum reproducibility with minimum variation of natural head position using two methods, i.e. the mirror method and the fluid level device method.

Materials and methods: The study included two sets of 40 lateral cephalograms taken using two methods of obtaining natural head position: (1) The mirror method and (2) fluid level device method, with a time interval of 2 months.

Inclusion criteria
- Subjects were randomly selected aged between 18 to 26 years

Exclusion criteria
- History of orthodontic treatment
- Any history of respiratory tract problem or chronic mouth breathing
- Any congenital deformity
- History of traumatically-induced deformity
- History of myofacial pain syndrome
- Any previous history of head and neck surgery.

Results: The result showed that both the methods for obtaining natural head position—the mirror method and fluid level device method were comparable, but maximum reproducibility was more with the fluid level device as shown by the Dahlberg's coefficient and Bland-Altman plot. The minimum variance was seen with the fluid level device method as shown by Precision and Pearson correlation.

Conclusion: The mirror method and the fluid level device method used for obtaining natural head position were comparable without any significance, and the fluid level device method was more reproducible and showed less variance when compared to mirror method for obtaining natural head position.

Clinical significance: Fluid level device method was more reproducible and shows less variance when compared to mirror method for obtaining natural head position.

INTRODUCTION

Cephalometrics has given us a different perceptive of interpreting skeletal problems in the dentofacial complex. Lateral cephalometric radiographs have become virtually indispensable to orthodontists in the treatment of patients.[1] They are important in orthodontic growth analysis, diagnosis, treatment planning, monitoring of therapy and evaluation of final treatment outcome.

Although it has been known for sometime that use of intracranial reference lines for assessment of anteroposterior skeletal relationships is inherently unreliable, they are still widely used for diagnosis and treatment planning.[2] The variability of planes, such as sella-nasion and Frankfort horizontal to each other as well as to the true horizontal is such that measurements based on these planes are likely to give misleading information (Houston, 1991; Moorrees, 1995). As pointed out by Profit and White (1991), such measurements when used on orthognathic patients are likely to be even more misleading, so use of the true horizontal and or vertical planes as alternatives would appear to be essential.[38-41,45] In cephalometric analysis, natural head position (NHP) should be preferred for profile evaluation as it reflects the everyday true-life appearance of people. The concept of natural head position is not new, which dates back to Leonardo da Vinci (1452-1519) and Albrecht Durer (1471-1528).[3] Natural head position was developed by

Molhave, a Danish orthopedic surgeon for studying the biodynamics of the human body.[4] Natural head posture is defined as a physiologic position and it is relatively constant over time. NHP has been shown to be correlated to craniofacial morphology, future growth trends and to respiratory needs.[3] It was shown that the postural control of the head is influenced by resistance to gravity, respiration, deglutition, occlusion, pressure from oral structures, masticatory muscle function, sight (visual axis), vestibular balance mechanism, hearing and position of hyoid bone.[5] Several authors using different methods have conducted NHP studies, and their data agree on the consistency of individual's head posture over time.[6] Indeed critical assessment of NHP reproducibility are rare. There might be several reasons why NHP has not found common acclaim, it could be confusion over both terminology and methodology in achieving NHP, lack of reliable reference data, and the fact that taking radiographs in NHP may be more time-consuming than simply positioning Frankfort horizontal parallel to the horizontal. However, there is certainly no contraindication to ensuring the patients, heads are oriented in NHP before lateral cephalograms are taken.[2] NHP is under the influence of chin position; however, this influence is not clinically significant.[43] Various techniques have been used to establish and transfer head orientation to radiographs. To mention a few, Schmidth made use of a frame that encircled the skull, a plumb line and a protractor. Archer and Vig used a leveling device consisting of a fluid-filled plastic ring mounted on a protractor. Murphy et al uses a contactless precision potentiometer to continuously measure changes in inclination around a single axis of rotation. Moorrees and Kean projected the image of a plumb line of a stainless steel ligature wire onto cephalometric radiographs. Showfety et al used the fluid level device to record the patient's head posture prior to exposure of the head film.[7] The regularly used method in day-to-day clinic in the orientation of natural head position is the mirror method. Since various methods for obtaining NHP exist, a need arises to determine the most accurate method of reproducibility of the NHP. The reliability in terms of reproducibility of NHP was assessed in relation to two commonly used simple and practical methods for obtaining NHP. Hence, this study encompasses mirror method and the fluid level device method, which are used to evaluate and compare the maximum reproducibility with minimum variation of NHP.[8-14]

The aim of the present study is to evaluate and compare the maximum reproducibility with minimum variation of NHP using two methods, i.e. the mirror method and the fluid level device method.

MATERIALS AND METHODS

The study included two sets of 40 lateral cephalograms taken using two methods of obtaining NHP (1) the mirror method and (2) fluid level device method, with a time interval of 2 months.

Inclusion Criteria

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Materials

The materials used for this study are:
1. Panoramic and cephalometric machine (Gendex Orthoralix 9200) with 60 to 84 kV, 15 mA and 0.16 to 2.5 seconds exposure time.
2. A face mirror (30 × 40 cm) with holders mounted for vertical adjustments (Fig. 1).
3. Fluid level device comprises of (Fig. 2):
   a. Double-stick adhesive tape
   b. A glass capsule
   c. Radiopaque dye (urografin-sodium meglumine diatrizoate)

Fig. 1: Mirror mounted on the wall

d. An air bubble
e. Stainless steel wire, to coincide the edges of the air bubble.
4. Lateral cephalogram films (8 × 10 inches)—it is placed vertically in the cephalostat cassette holder.
5. Acetate matte tracing paper (0.003 inches thick, 8 × 10 inches) (Fig. 3).
6. 0.3 mm pencil (Steadier).
7. A view box.
8. Masking tape for securing the tracing sheet on the radiograph.
9. A protractor and a set-square for drawing the reference lines and measuring the angle.

Methods

In this study, reproducibility of the natural head position is done by using two methods—the mirror method and the fluid level device method. The study was done on 40 subjects who were volunteers from RV Dental College and Hospital. Lateral cephalograms were taken for the above 40 subjects using the mirror method. They were made to stand in front of the mirror with all possible precautions to avoid any radiation hazards, such as lead aprons and thyroid

Fig. 2: Fluid level device

collar to obtain the NHP. They had their feet slightly apart and divergent anteriorly. They were asked to look into the mirror of their own eyes, after tilting their head up and down with decreasing amplitude until they felt they are relaxed. The size of the mirror is 30 × 40 cm (Fig. 1), and it is positioned 120 cm in front of the subject. The subject is placed in the cephalometric head holder and the ear rods are placed in the patient's ears. When the NHP is achieved, lateral cephalogram was obtained for all the above subjects. The same subjects are taken for lateral cephalogram with a fluid level device attached to the subject's temple, using the following steps:[6]

Step 1: The fluid level device is fixed to the subject's temple with a double-stick adhesive tape. The ideal location is the area between the eyebrows and the hairline behind the prominent temporal crest of the frontal bone (Fig. 4). This crest is easily palpable clinically and places the radiopaque image of the device as an area on the head film, which does not obscure any diagnostically useful structures.

Step 2: The subject is instructed to stand upright, and arms at his or her sides and look into a far distance. This part of the procedure represents an attempt to control the general body posture and visual target. A practical and easily obtained body position is the standing position that is commonly used throughout the day and not totally artificially. This position is sometimes referred to as the 'intentional position'.[6]

Step 3: The subject is instructed to take a step forward.

Step 4: The fluid level is positioned until the bubble is aligned with the ends of the wire.

Step 5: The reproducibility of NHP is checked by repeating steps 3 and 4. The method is verified by observing whether the ends of the bubble return to align with the wire.

Step 6: The subject is placed in the cephalometric head holder and the ear rods are placed in the patient's ears.
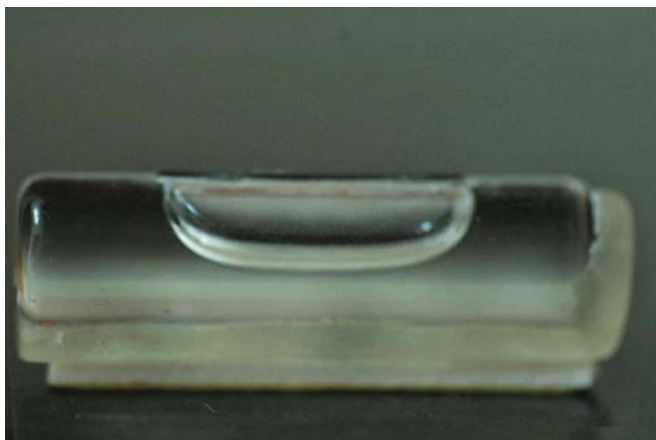

Fig. 3: Armamentarium in the study

Step 7: The subject's head is tilted up or down until the bubble is once again aligned with the wire (Fig. 4).[6]

If all steps are correctly executed then the piece of wire in the fluid level device will be aligned at 90 degree to the true vertical line, which is taken from the edge of the film.[1,4]

This image of the bubble will come very close to being centered on the ends of the wire on the radiographs. Failure to see these features on inspection indicates the technical, error. Place the radiopaque image of the device as an area on the head film, which does not obscure any diagnostically useful structures (Fig. 5).

Forty subjects were taken and following the above steps lateral cephalograms were repeated after 2 months and then both the sets of cephalograms were traced.

CEPHALOGRAM TRACING

After obtaining the lateral cephalograms, four planes are taken into consideration as follows (Fig. 6):

1. True horizontal plane (perpendicular to the true vertical plane as represented by the edge of the film).
2. Horizontal plane through fluid level device (line drawn through the edges of the bubble).
3. A true vertical is dropped from the nasion (N) (parallel to the edge of the film).
4. *S-N plane:* The sella-nasion plane is drawn from point sella, located at the center of sella turcica, and point nasion, located at the suture junction of the frontal bone with nasal bone.

The lateral cephalograms were traced accordingly: First, a true vertical line is drawn at the edge of the film.[1,4] A true horizontal is drawn perpendicular to true vertical line. A line is dropped from nasion parallel to true vertical. The S-N plane is drawn and angle between S-N plane and true vertical at nasion is measured. Then, comparative evaluation was done to assess which method is better to reproduce the NHP.

STATISTICAL METHODS

J Dahlberg's reproducibility coefficient has been used to find the reproducibility of natural head postures, bias and precision in terms of SD of bias were calculated to find the consistency of observations between different readings, Pearson correlation coefficient has been used to find the correlation of initial and after 2 months readings for each method. Student t-test has been used to find the significance of readings between initial and after 2 months. Bland and Altaian plot were presented to know the reproducibility of the methods.

1. t-test for two population means (method of paired comparisons)
   Objective: To investigate the significance of the difference between two population means. No assumption is made about the population variances
2. t-test of a correlation coefficient—
   Objective: To investigate whether the difference between the sample correlation coefficient and zero is statistically significant.

Fig. 4: Subject positioned with fluid level device

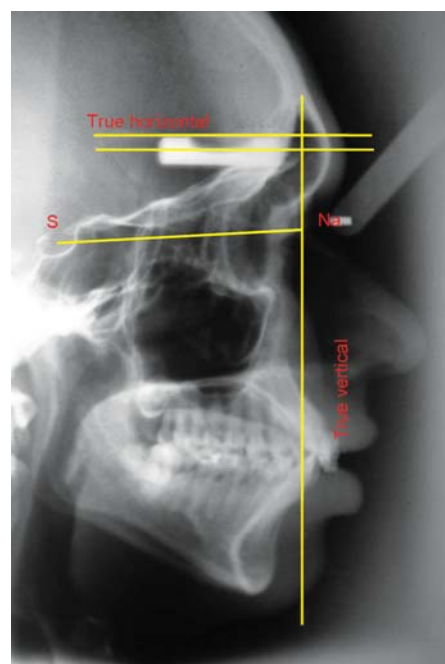**Fig. 5:** Lateral cephalogram with fluid level device

Fig. 6: Measurements on lateral cephalogram—S-N line and perpendicular line from N drawn

Limitations: It is assumed that the x and y values originate from a bivariate normal distribution and that relationship is linear. To test an assumed value of population coefficient other than zero, refer to the Z-test for a correlation coefficient.

Classification of correlation coefficient (r)

• Up to 0.1 trivial correlation
• 0.1-0.3 small correlation
• 0.3-0.5 moderate correlation
• 0.5-0.7 large correlation
• 0.7-0.9 very large correlation
• 0.9-1.0 nearly perfect correlation
• 1 perfect correlation.

3. Dahlberg's reproducibility coefficient—
  Statistical software: The statistical software namely SPSS 11.0 and Systat 8.0 were used for the analysis of the data and Microsoft Word and Excel have been used to generate graphs, tables, etc.

RESULTS

This study included two sets of 40 lateral cephalograms taken using two methods for obtaining NHP (1) the mirror method and (2) fluid level device method, with a time interval of 2 months to assess and compare maximum reproducibility and minimum variance of the two methods. The following results obtained were tabulated accordingly.

The values obtained (angulation between SN-true vertical drawn from N) for 40 subjects with the mirror method and the fluid level device method during the initial lateral cephalograms are shown in Table 1.

The values obtained for the same 40 subjects after interval of 2 months for mirror method and fluid level device method are shown in Table 2.

The Table 3 shows the initial value for mirror method of 83.71 mean with 3.83 standard deviation and, after 2 months, the mirror method showed 83.63 mean with 4.48 standard deviation. The initial value for fluid level device method is 84.25 mean with 4.36 standard deviation and, after 2 months, the fluid level device method showed 84.45 mean with 4.44 standard deviation and the p-value for mirror method is 0.779 and the p-value for fluid level method is 0.395 showing no statistical significance.

As the p-value is not much of statistical significance, Dahlberg's reproducibility coefficient has been used to find the reproducibility of the two methods. The fluid level device method has the maximum reproducibility (Dahlberg's coefficient, 1.0368) when compared to mirror method (Dahlberg's coefficient, 1.3636) as shown by Dahlberg's coefficient. The fluid level device method has the minimum variance [precision (SD),1.45] when compared to mirror method [precision (SD), 1.95].

The results obtained in terms of mean and SD is not statistically significant between initial and after 2 months interval on the lateral cephalograms taken. The lower Dahlberg's coefficient (1.0368) and higher precision (1.45) has proved that the fluid level device method is better than the mirror method in obtaining maximum reproducibility and minimum variance.

Graph 1 shows Bland and Altman method with difference of scores against the average values for mirror method with more scattering indicating less reproducibility.

Graph 2 shows Bland and Altman method showing the difference of scores against the average values for fluid level device method which shows lesser scattering hence showing that the fluid level device method has more reproducibility than the mirror method.

Graphs 3 and 4 show Pearson correlation coefficient to find the correlation of initial and after 2 months readings

Table 1: Initial lateral cephalograms		
Sl No	*Mirror method (in degrees)*	*Fluid Level Device (in degrees)*
1	88.5	86.5
2	80.5	85.5
3	77.5	81
4	83	81
5	83.5	86
6	86	87
7	82	85
8	84.5	85
9	82	80.5
10	82	84
11	82	83
12	83.5	85
13	88	90
14	82.5	83.5
15	83.5	88
16	92	93.5
17	87	85
18	75	76
19	81	84
20	85	86
21	83	88.5
22	95.5	99
23	79	80.5
24	79.5	79.5
25	86	86
26	90	85
27	82.5	85
28	89	91
29	82	80
30	80	82
31	81	83
32	85	81.5
33	84	80
34	81	79.5
35	86	88
36	84.5	81
37	84	83
38	83	83
39	82	82
40	82.5	77

Table 2: Lateral cephalograms taken after 2 months interval

Sl No	Mirror method (2 months later) method in degrees	Fluid level device (2 months later) in degrees
1	87	83.5
2	82.5	83.5
3	78	81
4	80.5	81.5
5	87.5	88
6	85	87
7	84.5	85.5
8	85	85.5
9	80	82.5
10	84	86
11	81	81
12	81.5	85
13	93.5	92
14	81.5	82.5
15	84.5	88
16	94.5	94.5
17	85.5	83.5
18	74.5	74.5
19	80.5	84
20	86	86
21	83	88
22	96	98.5
23	80	82.5
24	79	77.5
25	85	85
26	87.5	85
27	84	86
28	91	89.5
29	82	83
30	79	81.5
31	78	84
32	83	80
33	79.5	82
34	81	82.5
35	85.5	89
36	85	82
37	84	85
38	84	84
39	81.5	81.5
40	80	76.5

Graph 1: Bland and Altman plot showing the difference of scores against the average values for mirror method
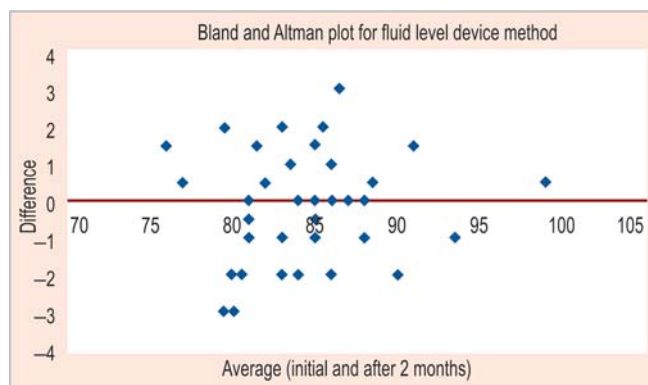
Graph 2: Bland and Altman plot showing the difference of scores against the average values for fluid level device method

Graph 3: Pearson correlation coefficient of initial and after 2 months readings for mirror method

Table 3: Comparison of mirror method and fluid level device methods of natural head position

Natural head position in degrees	Mirror method (in degrees)	Fluid level device method (in degrees)
Initial (mean ± SD)	83.71 ± 3.83	84.25 ± 4.36
After 2 months (Mean ± SD)	83.63 ± 4.48	84.45 ± 4.44
p-value (Student t-test paired)	0.779	0.395
Dahlberg's co-efficient	1.3636	1.0368
Precision (SD)	1.85	1.45

for each method. Mirror method showed 0.901 correlation and 0.944 correlation of fluid level device method which indicates that fluid level device is better.
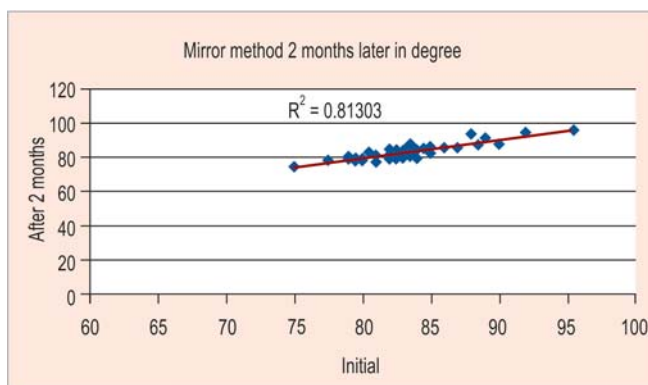
Table 4 shows initial lateral cephalograms taken for mirror method with a mean of 83.71 with 3.83 standard deviation and fluid level device method with a mean of

84.25 with 4.36 standard deviation were comparable. After 2 months, the lateral cephalograms taken for mirror method with a mean of 83.63 with 4.48 standard deviation and fluid level device method with a mean of 84.45 with 4.44 standard deviation were comparable. Dahlberg's coefficient of mirror method (1.3636) and fluid level device method (1.0368) showed that fluid level device method had maximum reproducibility coefficient. Precision (standard deviation) of mirror method (1.95) and fluid level device method (1.45) showed minimum variance for fluid level device method. Bland and Altman plot for mirror method showed more

scatter and fluid level device method showed less scattering hence showing the fluid level device method better in reproducibility. Pearson correlation showed mirror method (0.901) and fluid level device method (0.944) showing the fluid level device method was more reproducible.

DISCUSSION

A number of studies have examined the reproducibility of the NHP under controlled conditions prevailing at university, departments or hospitals and clinics. These studies have focused on the position of the head to the true vertical or true horizontal and have demonstrated that despite the apparent volatility of the concept that a particular head posture should be more 'natural' than others, a reproducible head posture can, infact, be recorded.[15] Orthodontists should consider head posture, not only in the patient's first evaluation and treatment planning but also during the entire treatment period.[23,24,26]

An easy, inexpensive and harmless evaluation of the head posture modifications during this time is of great interest.[26-36] Reorientation of radiographs according to standardized photographs made at the NHP is a reliable and objective method to standardize the radiographs at the NHP for cephalometric analysis.[42,43] NHP, a long proposed modification, yet not fully into practice, can be an 'ideal' reference for us to improve our cephalometric interpretation.

Graph 4: Pearson correlation coefficient of initial and after 2 months readings for fluid level device method

Hence, this study was done for obtaining NHP with two methods, i.e. the mirror method and the fluid level device method and evaluating their maximum reproducibility and minimum variance.

The fluid level device used in the study is a method to record standing NHP and to transfer this to the cephalometric head film based on the principle of physics which underlies that fluid levels in a nonaccelerating fluid system (hydrostatic), the surface of a liquid is horizontal. This is similar to that used by Showfety et al and[6] Huggare.[37] Previous studies of NHP indicate that an individual's head position is reproducibly recorded under such experimental conditions within 2 degree of variation around an average posture.[6]

For comparing the two methods in the present study, Dahlberg's coefficient and Bland and Altman plot were used which are most appropriate as suggested by Bister et al[2] where these similar methods were used to assess reproducibility of NHP.

The results in this present study indicate that (Table 3) Dahlberg' s coefficient of mirror method was 1.3636 and fluid level device method was 1.0368. This infers that the fluid level device method had maximum reproducibility coefficient. The precision (standard deviation) of mirror method (1.95) and fluid level device method (1.45) showed minimum variance for fluid level device method.

With the Bland and Altman plot, in the present study, the mirror method showed more scatter (Graph 1) while the fluid level device method (Graph 2) showed less scattering, hence showing that the fluid level device method is better in reproducibility of NHP.

It has been demonstrated in several studies that the NHP is reproducible with a method error of only a few degrees[16-22] which were similar to the results of the present study. In a study by Michael Cooke et al,[3] the method error for the position of the head to true vertical after 3 to 6 months by mirror method was 2.3° while in the study of Andrew Sandham,[22] the method error by plumb line method was 3.2°. In the present study, the method error after 2 months for mirror method is 1.36° while the method error for fluid level device after 2 months is 1.03°, which are quite lower and indicating more reproducibility of NHP.
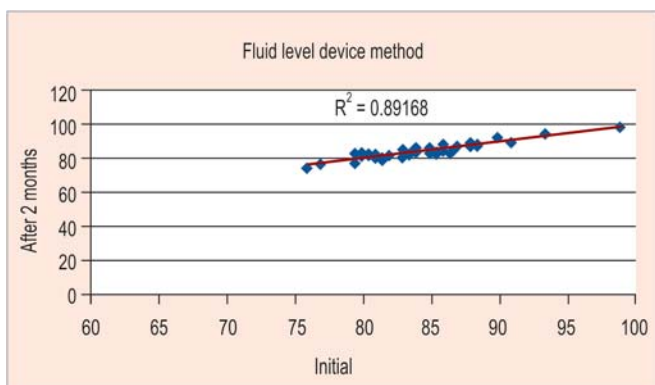
Table 4: Evaluation of methods for reproducibility of natural head position			
Natural head position in degrees	*Mirror Method*	*Fluid level device method*	*Remarks*
Initial(Mean ± SD)	83.71 ± 3.83	84.25 ± 4.36	Comparable
After 2 Months(Mean ± SD)	83.63 ± 4.48	84.45 ± 4.44	Comparable
Dahlberg's co-efficient	1.3636	1.0368	Fluid level device method has maximum reproducibility co-efficient
Precision (SD)	1.95	1.45	Minimum variance for Fluid level device
Bland and Altman Plot	More scattered	Less scattered	Fluid level device is better
Pearson Correlation	0.901	0.944	Fluid level device is better

A study by Showfety et al[6] had taken the S-N to the true vertical to assess the NHP which was similar to that used in the present study. In contrast, a study done by Lundstrom et al[25] used S-N line to the horizontal and FH plane to horizontal to assess NHP, which showed higher standard deviation. This probably might suggest that S-N to true vertical is better to assess NHP.

The protocol for NHP itself appears to have an influence on reproducibility. There is some evidence to suggest that the success of a certain protocol is operator-dependant. However, in a clinical situation it seems to be difficult to improve reproducibility beyond 1.4º, even when only one dedicated radiographer takes the cephalographs/ photographs, which meant that the limit of reproducibility is 4º.[2] In the present study with both the methods—the mirror method and fluid level device method, the reproducibility was within the above mentioned range, i.e. 4.48° and 4.44° respectively.

One of the earlier study by Huggare[37] showed no significant difference in the accuracy of the fluid level and mirror methods for registration of the individual head posture while in the current study even though there was no statistical significance between the fluid level and mirror methods, the fluid level device method was more reproducible with minimum variance as shown by Dahlberg's coefficient.

The current study showed that reproducibility of NHP was more with fluid level device in similarity to that of Showfety et al which might suggest that NHP can be reliably recorded with cephalometric radiography and a simple fluid level device used in conjunction with it.[6]

The present study shows that both the methods for obtaining NHP—the mirror method and fluid level device method were comparable, but maximum reproducibility was more with fluid level device as shown by the Dahlberg's coefficient and Bland and Altman plot. The minimum variance was seen with the fluid level device method as shown by precision and Pearson correlation.

CONCLUSION

The conclusions obtained from this study were as follows:
1. The mirror method and the fluid level device method used for obtaining NHP were comparable without any significance.
2. The fluid level device method was more reproducible and showed less variance when compared to mirror method for obtaining NHP.

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