Aalborg Universitet

Evaluation of Head Position in Static and Dynamic Three-Dimensional Imaging

a review of the Literature

Kjærgaard Larsen, Marie; Thygesen, Torben Henrik

[Link to publication from Aalborg University](#)

Marie Kjærgaard Larsen* and Torben H. Thygesen

Department of Oral and Maxillofacial Surgery, Odense University Hospital (OUH), Odense, Denmark

Dates: Received: 21 August, 2017; **Accepted:** 29 August, 2017; **Published:** 30 August, 2017

*Corresponding author: Marie Kjærgaard Larsen, Department of Oral and Maxillofacial Surgery, Odense University Hospital (OUH), Odense, Denmark. Department of Oral and Maxillofacial Surgery, Aalborg University Hospital (AAUH), Aalborg, Denmark. Tel: +45 65 41 34 75; Fax: +45 65 41 34 77; E-mail: mkjaergaard@me.com

Keywords: Orthognathic surgery; Three-dimensional Imaging; Photogrammetry

https://www.peertechz.com

Review Article

Evaluation of Head Position in Static and Dynamic Three-Dimensional Imaging: a review of the Literature

Abstract

Background: The interest in three-dimensional imaging in orthognathic treatment planning has been growing, especially for evaluation of the natural head position. Several three-dimensional devices are available on the market. Three-dimensional evaluation of the patient will probably soon be a standard tool/method in orthognathic treatment planning.

Purpose: The purpose of the study was a clarification of the literature for studies regarding the natural head position in three-dimensional imaging.

Materials and methods: A systematic search of the literature was conducted through PubMed to identify studies that evaluate head positions in three-dimensional imaging. Following search syntax was used: "3d imaging", "three-dimensional", "natural head position", and "imaging head position".

Results: Only four studies have investigated the reproducibility and accuracy of head positions in three-dimensional imaging. The studies show that the natural head position is reproducible with the use of three-dimensional photography.

Conclusion: Three-dimensional imaging to register the natural head position in orthognathic treatment planning shows promising results. Only four studies have evaluated its reproducibility. Future studies regarding its accuracy and reproducibility are essential.

Abbrevations

OS: Orthognathic Surgery; NHP: Natural Head Position; 3D: Three-Dimensional

Introduction

The use of virtual planning and computer-aided surgery is increasing in orthognathic surgery (OS). One of the latest innovations in the virtual planning is three-dimensional (3D) imaging.

A full 3D virtual patient/model is composed of a 3D cone beam computer tomography (CBCT) of the maxillofacial skeleton, a 3D scan of the dental arch, and a 3D stereophotography of the soft tissue [1].

Natural head position is essential for proper planning of OS and may be regarded as the foundation of the clinical examination. Furthermore, head position has a huge influence on the analysis of the CBCT in orthognathic treatment planning [2]. The most standardized and reproducible relaxed head position is natural head position (NHP) [3], something long known by artists and anatomists. The concept of NHP was first introduced into the orthodontic literature in 1956 [4]. It has since become an important concept for head orientation in orthognathic treatment procedures. Studies show a remarkable reproducibility of NHP in two dimensions [5–7]. The registration of NHP has previously been carried out in standing or sitting subjects, through estimated NHP, and in combinations. Only minor differences are found when NHP is estimated using photographic registration [5]. Until recently, two-dimensional cephalometric analysis of the head has been the gold standard in orthognathic treatment planning [8]. Several different landmarks, lines, and angles have been used for analysis. The shift to virtual planning in 3D requires other, new methods/tools for analysis.

New methods in orthognathic treatment with use of new technology are being implemented, and these need to be evaluated in regard to their use in the treatment of orthognathic patients. The newest device in 3D imaging is dynamic recording, but to date, no studies have been published that have used this technique to investigate NHP.

The primary aim of this review was to systematically assess the existing literature regarding 3D photography in OS to identify methods that can be used to test the reproducibility and accuracy of NHP. A further aim was to clarify aspects that needed further investigation.

Material and Methods

A web-based search was conducted using the National Center for Biotechnology Information (NCBI) to search Medline (PubMed). The following search terms were used: "3d imaging", "three-dimensional", "natural head position", and "imaging head position". Inclusion criteria were following (1) language, English; and (2) use of 3D apparatus. Exclusion criteria were (1) 3D evaluation of patients with dentofacial deformities, trauma, cancer, syndromes, or cleft lip and palate; (2) in vitro studies. In addition, a thorough bibliographic hand search identified further publications. The hand search included retrieving important publications mentioned in the reference lists of identified articles. The screening was carried out according to the inclusion and exclusion criteria. The retrieved papers were screened based on a three-stage selection process. First, titles that did not refer to 3D imaging were excluded. Second, the abstracts were screened for exclusion and inclusion criteria. Finally, full-text articles were verified according to the criteria.

The data retrieved from the selected studies included author, country, year of publication, sample size, study design, methods/measurements, conclusion.

Results

The search created a database of 674 articles. Of these, 644 were found not to be relevant with regard to 3D imaging and orthognathic treatment and were excluded. The 31 abstracts of the remaining 31 articles were assessed, and 19 articles were excluded due to the inclusion and exclusion criteria. Twelve articles were selected for full-text assessment. Only four articles met the inclusion and exclusion criteria. An additional hand search identified one additional article that met the inclusion and exclusion criteria. The four articles were published between 2011 and 2015. Figure 1, Tables 1,2.

In all included studies, the devise used for 3D imaging was 3dMDface imaging system (3dMD, Atlanta, GA, USA). All four studies investigated different aspects of NHP in
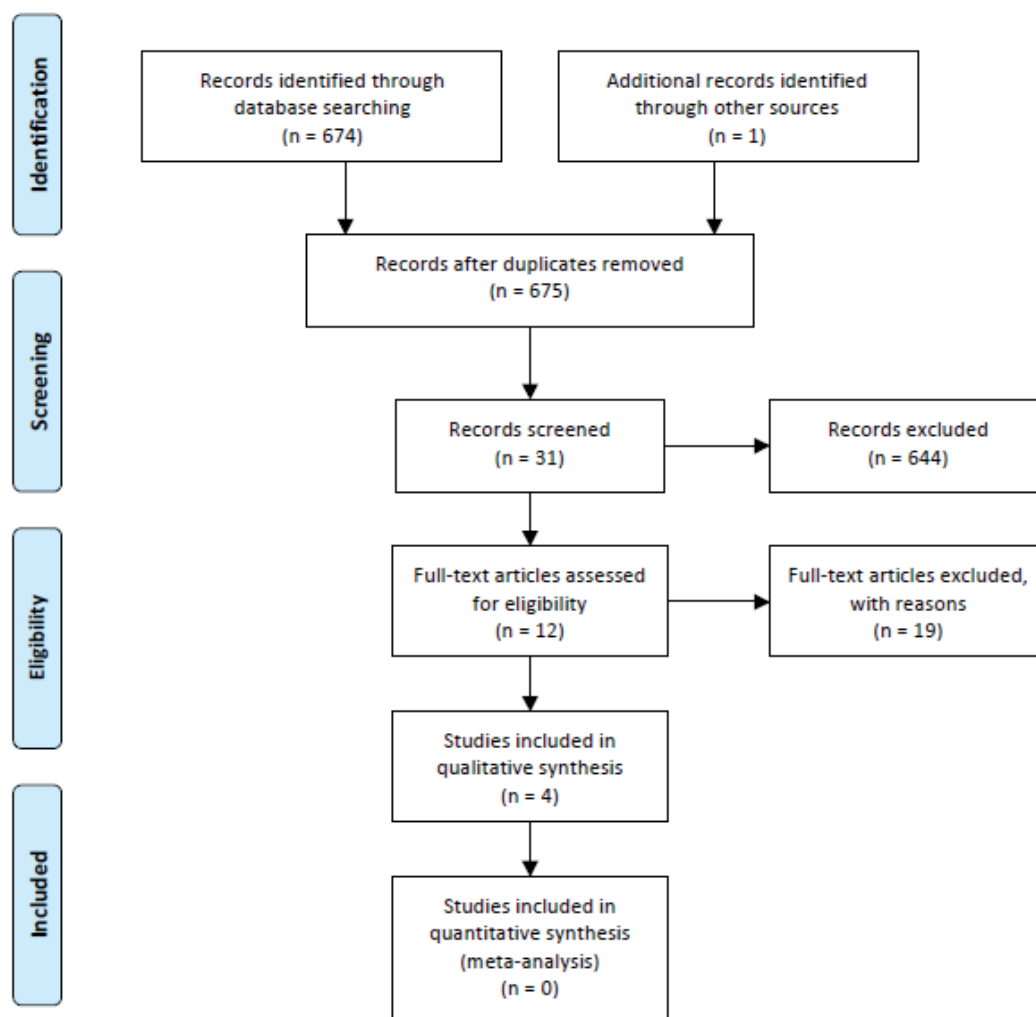

Figure 1: PRISMA flow diagram.

Table 1: Studies regarding the recording of natural head position during three-dimensional photography.

	Tian et al. Reproducibility of natural head position in normal Chinese people.[9]	Weber et al. Threedimensional reproducibility of natural head position.[11]	Tian et al. Recording and transferring head positions to the virtual head using a multicamera system and laser level.[10]	De Paula et al. Digital livetracking 3-dimensional minisensors for recording head orientation during image acquisition.[12]
Activity/inte rvention	Evaluation of NHP for pitch and roll. NHP obtained in selfbalanced position, mirror position, and estimated position.	Evaluation of reproducibility of NHP over time (one week). Vertical and horizontal laser lines with four dots.	Evaluation of reliability and accuracy of recording NHP in pitch and roll with 3D imaging and a horizontal laser line.	Evaluation of minisensors for recording unrestrained natural head position during 3D stereophotogrammetry.
Control intervention	NHP obtained in estimated position.	Baseline photo (initial).	Digital gyroscope to record head position. CBCT data with gyroscope coordinates. (?)	Head position without minisensors-
Outcome measure	Angles measured between a laser line and a horizontal line.	Angles measured between two lines.	Rotation angles in pitch and roll measured when laser line was parallel to x-axis.	Distances between landmarks (8 different landmarks).
Reference	Extracranial laser line.	Extracranial laser line.	Extracranial laser line.	Intracranial landmarks.
Setting and year of study	China, 2015	USA, 2012	China, 2015	Brazil, 2011
Study subjects	Chinese adults with normal occlusion	Active-duty military personnel	A healthy Chinese adult	Adults with no dentofacial deformities, facial hair, orthodontic appliances, lip incompetence.
Number of participants	30 (15 men/15 women)	28 (15 observations per participant)	1 (woman)	20 (13 men/7 women)
Assessor(s)	One researcher for registrations. Two researchers for measurements.	One researcher.	Three researchers.	One researcher.
Threedimensional device	3dMDface imaging system (3dMD, Atlanta, GA, USA)	3dMDface imaging system (3dMD, Atlanta, GA, USA)	3dMDface imaging system (3dMD, Atlanta, GA, USA)	3dMDface imaging system (3dMD, Atlanta, GA, USA)
Conclusion	Reproducibility was best for estimated NHP, and then mirror position and selfbalanced position. Reproducibility values of head position for pitch were 1.51°, 1.2°, and 0.99°. Reproducibility values of head position for roll were 0.78°, 0.76°, and 0.41°.	NHP was reproducible in pitch, roll, and yaw over time. The degree of variation differs between the planes: coronal >axial>sagittal.	3D imaging and a horizontal laser line to record NHP were accurate and reliable.	Distances between landmarks with and without minisensors were significantly different. The use of minisensors improves the repeatability for the NHP taken in 3D photography.

Table 2: Objective parameters of the studies.

	Tian et al. Reproducibility of natural head position in normal Chinese people.[9]	Weber et al. Threedimensional reproducibility of natural head position.[11]	Tian et al. Recording and transferring head positions to the virtual head using a multicamera system and laser level.[10]	De Paula et al. Digital live-tracking 3dimensional minisensors for recording head orientation during image acquisition.[12]
Equipment calibrated	Not stated	Yes	Not stated	Not stated
Number of assessors	Two	One	One	One
Blind assessment	No	No	No	No
Competent assessor	Yes	Yes	Yes	Yes
Procedure well described	Yes	Yes	Yes	Yes

threedimensions. In spite of this, a meta-analysis of the reproducibility and accuracy of NHP in 3D imaging could not be performed. Different methods for registration of NHP were used. In three studies, laser lines were used as external references. Internal references (head landmarks) were used for evaluation in one study.

One study evaluated the technique used to determine NHP in the self-balanced position, mirror position, and estimated position (in pitch and roll). The reproducibility was best for the estimated position followed by the mirror position and the self-balanced position [9]. The same authors evaluated the reliability and accuracy of recording the NHP in pitch and roll with the use of a horizontal laser. A digital gyroscope to record the head position was used as the control intervention [10].

The reproducibility of the NHP in the three planes (coronal (pitch), axial (yaw), and sagittal (roll)) has also been evaluated. Weber et al. showed that the reproducibility of the head position was best for pitch, whereas another study found that the NHP was most reproducible in roll [9,11].

De Paula et al. evaluated NHP with internal landmarks. Their result showed highly significant differences in the distances between the landmarks between four 3D imaging of patients in NHP. In two of their 3D images, they used a sensor to orient the head in NHP. Distances between the landmarks were smaller when sensors were used to orient patients in NHP compared to NHP without sensors. In conclusion, the use of sensors improved the reproducibility of the 3D imaging [12].

Discussion

Downs was the first to introduce NHP in orthodontics in 1956 [4]. Its reproducibility and influence in cephalometric analysis has been intensively investigated since. Various physiological, psychological, and pathological components determine NHP. NHP is established physiologically by internal mechanisms, which makes extracranial reference lines more reliable and stable as a base for cephalometric analysis than intracranial references [9,10]. The ideal method to determine NHP should avoid the use of any apparatus attached to the head. The shift from two dimensions to three dimensions in diagnostic and treatment planning in OS increases the importance of accuracy for a successful outcome. In addition, new methods for analysis need to be established/developed and investigated. Today, only four studies have evaluated different methods for recording NHP in 3D photography.

3D imaging offers many advantages including fast capture speeds and minimal invasiveness. With the use of 3D imaging and a laser to establish the NHP in orthognathic treatment procedures a number of benefits are provided: no radiation; no need for markers/sensors; easy set-up; few appliances which minimize the risk for bias; etc. Different electronic software give opportunities to use the 3D imaging as references for i.e. CT scans (3dMD vultus, 3dMD, United States).

Only a few studies have investigated the changes in NHP following OS. Whether the relationship between the head posture and morphology changes after OS is of interest. The changes in NHP can perhaps have an influence on post-operative stability. Phillips et al. investigated the relationship between the orthognathic surgical procedure and the head posture. Immediately after OS, maxillary intrusion resulted in the most extended head posture, while mandibular setback resulted in the most flexed head posture. Within the first year following OS the head posture changed toward the pre-operative position [7]. Previously published data have confirmed the same change in NHP during the first post-operative year [13,14].

Tian et al. showed that the 3dMDface System and a laser level method of recording head positions were accurate and reliable [9,10]. No studies have evaluated NHP in relation to dynamic 3D records. Regarding unconscious compensatory mechanism for NHP in patients with Class II and III malocclusion, dynamic records can probably be a helpful tool in the registration of true NHP. Future studies regarding static 3D photography and NHP are, however, still essential before future studies in dynamic records are done.

Conclusions

The ideal method for achieving NHP should avoid the use of any device attached to the head. Furthermore, the method should be easy, simple, reproducible, and accurate. The use of 3D photography shows promising results.

A search of the current literature showed that only four studies regarding the NHP in 3D photography have been published. These studies show that NHP is reproducible when it is recorded with external laser lines. The reproducibility is best for estimated NHP compared to the mirror position and the self-balanced position. The four studies reviewed do not agree regarding in which plane the NHP is most reproducible. Further studies regarding the planes and reproducibility are required.

Additional research on the use of 3D photography in recording head positions and evaluating NHP following OS are necessary to further improve outcomes in OS. Furthermore, the influence of NHP obtained with 3D photography on the treatment plan and outcome in OS still need to be more thoroughly investigated.

References

1. Plooij JM, Maal TJJ, Haers P, Borstlap WA, Kuijpers-Jagtman AM et al. (2011) Digital three-dimensional image fusion processes for planning and evaluating orthodontics and orthognathic surgery. A systematic review. Int J Oral Maxillofac Surg 40: 341-352. **Link:** https://goo.gl/Cv9Xj6

2. Swennen GRJ, Mollemans W, Schutyser F (2009) Three-dimensional treatment planning of orthognathic surgery in the era of virtual imaging. J Oral Maxillofac Surg 67: 2080-2092. **Link:** https://goo.gl/txkbgb

3. Moorrees CF (1994) Natural head position--a revival. Am J Orthod Dentofacial Orthop 105: 512-513. **Link:** https://goo.gl/HBgkKb

4. Downs WB (1956) Analysis of the dentofacial profile. Angle Orthod 26: 191-212. **Link:** https://goo.gl/Uw5evL

5. Lundström A, Forsberg CM, Westergren H, Lundström F (1991) A comparison between estimated and registered natural head posture. Eur J Orthod 13: 59-64. **Link:** https://goo.gl/zFDfsM

6. Showfety KJ, Vig PS, Matteson S (1983) A simple method for taking natural-head-position cephalograms. Am J Orthod 83: 495-500. **Link:** https://goo.gl/rYyMtk

7. Phillips C, Snow MD, Turvey TA, Proffit WR (1991) The effect of orthognathic surgery on head posture. Eur J Orthod 13: 397-403. **Link:** https://goo.gl/7zJWjE

8. Ferrario VF, Sforza C, German D, Dalloca LL, Miani A (1994) Head posture and cephalometric analyses: an integrated photographic/radiographic technique. Am J Orthod Dentofacial Orthop 106: 257-264. **Link:** https://goo.gl/ohv8Ri

9. posture and cephalometric analyses: an integrated photographic/radiographic technique. Am J Orthod Dentofacial Orthop 106: 257-264. **Link:** https://goo.gl/ohv8Ri

10. Tian K, Li Q, Wang X, Liu X, Wang X et al. (2015) Reproducibility of natural head position in normal Chinese people. Am J Orthod Dentofacial Orthop 148: 503-510. **Link:** https://goo.gl/mHL5tw

11. Tian K, Xue Z, Liu X, Wang X, Li Z (2015) Recording and transferring head positions to the virtual head using a multicamera system and laser level. J Oral Maxillofac Surg 73: 2039.e1-2039.e13. **Link:** https://goo.gl/6VRHpp

12. Weber DW, Fallis DW, Packer MD (2013) Three-dimensional reproducibility of natural head position. Am J Orthod Dentofac Orthop 143: 738-744. **Link:** https://goo.gl/XNvp6q

13. De Paula LK, Ackerman JL, Carvalho FDAR, Eidson L, Soares Cevidanes LH (2012) Digital live-tracking 3-dimensional minisensors for recording head orientation during image acquisition. Am J Orthod Dentofac Orthop 141: 116-123. **Link:** https://goo.gl/oGhAkt

14. Proffit WR, Phillips C, Turvey TA (1987) Stability following superior repositioning of the maxilla by LeFort I osteotomy. Am J Orthod Dentofac Orthop 92: 151-161. **Link:** https://goo.gl/mVyPDY

15. Watzke IM, Turvey TA, Phillips C, Proffit WR (1990) Stability of mandibular advancement after sagittal osteotomy with screw or wire fixation: a comparative study. J Oral Maxillofac Surg 48: 108-121. **Link:** https://goo.gl/LwTcLs