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Review

Natural position of the head: review of two-dimensional and three-dimensional methods of recording

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Abstract

Both the correct position of the patient's head and a standard system for the acquisition of images are essential for objective evaluation of the facial profile and the skull, and for longitudinal superimposition. The natural position of the head was introduced into orthodontics in the late 1950s, and is used as a postural basis for craniocervical and craniofacial morphological analysis. It can also have a role in the planning of the surgical correction of craniomaxillofacial deformities. The relatively recent transition in orthodontics from 2-dimensional to 3-dimensional imaging, and from analogue to digital technology, has renewed attention in finding a versatile method for the establishment of an accurate and reliable head position during the acquisition of serial records. In this review we discuss definition, clinical applications, and procedures to establish the natural head position and their reproducibility. We also consider methods to reproduce and record the position in two and three planes.

Keywords: Head posture; Cephalometry; Orthognathic surgery; Three-dimensional imaging

Introduction

The natural position of the head is the most balanced, natural position of the head when someone views an object at eye level.[1] It is an individual, functional, physiological position that indicates a person's true appearance.[2]

Since its introduction into orthodontics in the late 1950s it has been used as a reference position for the assessment of craniofacial morphology,[3–5] and has been advocated as a better option than intracranial reference lines because it allegedly varies less. The concept is not new: Leonardo da Vinci (1452- 1519) and Albrecht Durer (1471- 1528) used scaffolds of horizontal and vertical lines on drawings of models positioned in a "natural pose" to permit more accurate artistic and scientific replication of the human head. Artists, anatomists, and anthropologists have used it to study the human face throughout the ages, and it has been used routinely for clinical examination in medicine and dentistry by plastic and maxillofacial surgeons, and orthodontists.

Measurement of the natural head position is relevant in orthodontics for cephalometric analysis of dentofacial anomalies, orthognathic surgical planning, and evaluation of the relation between the head and the cervical column (craniocervical angulation).

In this review we have focused on techniques to establish it, and how to transfer it to the cephalostat, together with an

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Table 1
Different definitions describing head position.

Head position	Definition
Natural head position	Position of the head when the subject looks at a distant point at eye level and their visual axis is parallel to the ground.[6]
Natural head posture	The standing or seated patient feels that his or her head is in balance.[7]
Estimated natural head position or natural head orientation	Position of the patient's head while they are looking towards a distant point at eye level, reorientated by the operator; it is considered a better option for research purposes.[2]

overview of the 3-dimensional recording methods recently introduced into clinical practice.

Methods

We searched the databases PubMed and Scopus for all relevant publications, with no limitations of language or time. We used the terms "head posture", "cephalometric analysis", "natural head position", "lateral cephalometric radiographs", "cephalostat", "3-dimensional imaging", "self balance position", and "mirror position". Only original papers (randomised and non-randomised clinical trials, cohort studies, case-control studies, case reports, and reviews) were selected. References were also derived from the lists of those retrieved.

Definition and terminology

Even if all the terms reported in Table 1 describe the spatial relations of the head, they are not synonymous. In particular, the terms "natural head position" and "natural head posture" are not interchangeable: the first indicates a standard procedure applied to all subjects for the analysis of dentofacial morphology, and the second is an individual characteristic physiological posture of the head used to study the relation between posture and morphological features.[6,7]

The concept of "estimated natural head position" or "natural head orientation" was introduced because patients can have a habit of flexing or extending their heads.[2] Natural head orientation is defined as the orientation estimated by a trained clinician while the subject stands with a relaxed body and head, and looks at a distant point at eye-level.[2,8] Because patients with skeletal malocclusions such as mandibular prognathism or retrognathism may assume altered head positions to mask their skeletal patterns, it is better for an experienced clinician to modify it.[9,10]

Reproducibility of the natural head position

Reproducibility refers to how consistently a subject can reproduce the same position of the head on separate occasions. This should not be confused with reliability, which refers to how well one can locate a landmark on a lateral cephalograph.

Numerous studies have successfully measured the reproducibility and stability of the natural head position, both in short and long time-lapses.[11–14] In the longitudinal serial studies by Cooke et al, the long-term stability was investigated 3-6 months, 5 years, and 15 years after the initial radiography.[11,13,15] In the last study particularly, 20 of the 618 adolescents went through 15 sequential years of observation from the ages of 12-27 years, which showed that the natural head position is a stable reference line. Its reproducibility is commonly reported as a mean square error (ranging from 1.1° -3.2°) or Dahlberg value.[11,13–21]

Dahlberg's coefficient is commonly used to assess the reproducibility of a given method or the agreement between two methods.[18] A coefficient with a value below the cut-off point of roughly 1.5°-2° indicates good reproducibility. However, Bister et al[14] suggested that it has a tendency to camouflage the true variability of the results, and they concluded that reproducibility could be assessed more accurately with a reproducibility coefficient and its corresponding graphical representation.

Although natural head position has less variability than intracranial reference lines, 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, so it depends on the subject's neuromuscular condition. In addition, it is not a single angular measurement, but a small range of angles oscillating around a mean posture,[16] so is a dynamic concept which should be recorded both dynamically and continuously.[22–24]

According to some authors the protocol for obtaining the natural head position seems to influence reproducibility, and fairly minor changes in the procedure may have appreciable effects on possible discrepancies.[14] There is also some evidence that the success of a certain protocol depends on the operator.[14]

Clinical application: natural head position compared with intracranial reference lines

Natural head position may be a more valid craniofacial reference system than anatomical craniofacial planes. According to some authors the inherent variability of intracranial cephalometric reference structures makes analysis based on them potentially misleading, with serious implications for planning orthodontic and orthognathic treatment.[2] Studies that have evaluated the relation between position of the head and selected cephalometric planes have shown wide variability in the inclination of intracranial reference lines.[16,25] In particular, Madsen et al showed that intersubject variability of the craniofacial reference planes is greater than the intrasubject reproducibility of the natural head position, which supports the use of a true vertical or horizontal reference

plane established from recording the natural head position in preference to other planes.[25] However, these findings are expected given the overall variation in craniofacial morphology in an unbiased sample. To compare the variability of intracranial reference lines of different patients to the true horizontal we use cross-sectional data, while the reproducibility of the natural head position depends on longitudinal data.[14]

Additional features that validate the use of natural head position in cephalometric analysis include the fact that it is a true-life appearance, and head positioning can substantially influence the profile and perception of the mandibular and maxillary positions in relation to the calvaria, which influences the objectives of treatment.[26] The common cephalometric landmarks and planes for the surgical correction of craniomaxillofacial deformities cannot be used to orientate the composite skull model of patients with asymmetries of the upper face and skull base, [27] but natural head position obviates the need for internal landmarks by providing a reproducible reference framework.

The execution of radiographs in natural head positioning is also related to the evaluation of posture. The analysis of craniocervical angulation has been a concern for many years because of the supposed relation that exists between the head and cervical posture, and temporomandibular disorders or neck pain and headache.[28–30] The biomechanical relation between the position of the head and cervical spine and dentofacial morphology has been investigated.[31]

The most accurate way to measure the head and cervical posture is to use teleradiographs and cephalometric analysis. To take teleradiographs in clinical practice the subject is positioned in the cephalostat with the Frankfurt plane (line from porion to orbitale) parallel to the floor. The technique is reproducible and provides a clear view of the teleradiographs with few projection errors, but it can modify the natural posture of the subject. On the other hand, lateral cephalograms of the natural head position would reproduce the subject's own postural pattern and allow the exact posture of the head and cervical spine to be evaluated accurately in the sagittal plane. Some authors have questioned whether the teleradiographs using the Frankfurt method and those obtained through the natural head position give different information about craniocervical variables,[32] and found that the head position according to the Frankfurt method has a slight tendency to back-rotation and a diminution of cervical lordosis compared with the natural head position method, even if the results did not differ significantly. Only values of the craniocervical angles differed, but not enough to be clinically relevant.[32]

Ways to obtain natural head position: "self-balance" and "mirror" positions

Most studies use the technique described by Solow and Tallgren.[16] As the position of the head is part of the total posture of the body, they first defined a reproducible and physiologically relevant body posture. Among the standing positions (such as "attention" or "relaxed") the "orthoposition" was selected, which was defined as the "intention position from standing to walking" and this was achieved clinically by letting the subject walk lightly on the spot. It was considered a habitual symmetrical standing position and was reproducible in postural investigations.

Natural head position can be calculated in two ways, the first of which uses the subject's own feeling of a natural head balance without external reference. The head position is the result of proprioceptive information from muscles and ligaments and possibly from the utricular and semicircular canals, and the position is termed the "self-balance" position. The second method is based on visual cues from some external reference, as the subject positions the head so that they can observe either their eyes in the mirror ("mirror" position) or some device placed at a distance, horizontally, in front of the eyes. Positioning according to external reference (for example mirror position) should be done only after the head has been placed in the self-balanced position.[17]

This can be summarised as: the self-balanced position is when the subject is asked to tilt the head forwards and backwards with decreasing amplitude until the natural head balance is reached, and the mirror position is when the subject is asked to look straight in into the eyes reflected on a mirror in front. Both recordings are made with the teeth in occlusion. In adults the head is kept about 3° higher in the mirror position than in the self–balance position.

Two-dimensional recording: procedure to record and transfer the natural head position to the cephalostat

Once the natural head position has been achieved it can be recorded radiographically or photographically, the latter being preferred as it allows most freedom in producing a natural position.[4,5,33]

There are two ways to record the natural head position: first, the head of the patient is orientated to it and then a marker or a plumb line is used as a true vertical reference before radiographs or photographs are taken. This is called the "registered natural head position" and it is pointed out by the marker or the plumb line. Secondly, the patient's conventional cephalograms or lateral facial photographs are taken and then rotated to their natural head position (reorientating).

Cephalometric radiographs taken in the natural head position

The procedures for recording and transferring the natural head position to the cephalostat vary.

Positioning involves instructing and rehearsing the patient outside the cephalometer before actual positioning in it.[17] The cephalostat is adjusted vertically and the head is supported with the ear rods, which should not be inserted into the acoustic meatus - they have to be reversed to support the head from both sides by lightly touching the ears.

Table 2
Description of different methods to reorientate lateral radiographs to the natural head position according to standard photographs made of the natural head position.

First author, year, and reference	Method
Lundstrom, 1992[19]	Natural head position is photographed. A vertical axis is recorded on the photographs with a plumb line and transferred to the patients' lateral head radiographs.
Ferrario, 1994[12]	The angle between the soft tissue nasion-pogonion line and the true vertical is calculated on the photograph of natural head position, and this is used to rotate the standard radiograph around the Bolton point.
Dvorstin, 2011[40]	Three superimposing protocols (the soft tissue N/subnasale line [V-line], the aesthetic line [E-line], and a proposed nasal "best fit" line [N-line]) were compared for the reorientation of the cephalogram according to the photographs made of the natural head position.

Some measuring devices will record the natural head position and transfer it to the cephalostat: a fluid level device, an inclinometer, and a bubble air device.[20,34–38] These should make it possible to measure and reproduce the head position accurately, transfer a prearranged head position to the cephalostat, and take lateral films of the head. Even though some devices could measure both pitch and roll of the head by transferring the natural head position in two planes of the space in lateral cephalometrics, a transverse adjustment is always required. The conventional use of two ear rods to stabilise the head in radiographic cephalometry (lateral or frontal radiographic projections) is therefore based on the assumption that the transmeatal axis of humans is perpendicular to the midsagittal plane. In cases where the relation of the left and right ears in their vertical and horizontal relation to each other is asymmetrical, the insertion of ear rods results in vertical or horizontal rotation of the head, or both, and produces an altered and misleading image.[39] However, the capture of a natural head position while taking a radiograph without the use of a cephalostat will give unsatisfactory pictures. Taking cephalograms of the natural head position is challenging and takes more time than the conventional method.

Reorientating techniques

Reorientation of the cephalogram according to the photographs at the natural head position: the natural head position is captured on a photograph with a plumb line and then transferred or superimposed on to a conventional cephalogram (photographic superimposition) (Table 2).[40]

Placement of markers on subject's face: a wire shadow or red laser level beam projects a true vertical line on to the subject's profile, and two points are marked on the vertical line on the face with a radiopaque material and the cephalometric radiograph is taken in the usual way.[41,42] The metal beads give radiopaque shadows that are connected as a natural vertical axis, and they permit orientation of the cephalogram in the natural head position.

Three-dimensional recording

Since the recent increase in interest in 3-dimensional imaging for orthodontic evaluation, several studies have been published that describe different ways to record natural head position.[43–48]

Assessment of craniofacial morphology is influenced by the experience and perceptions of the examiner, [49] so the standard positioning of the patient and system for acquisition of the measurements are crucial for objective assessment. An accurate 3-dimensional coordinate system is required and Swennen et al describe how to set up a Cartesian, anatomical, 3-dimensional, cephalometric reference system.[49]

Current 3-dimensional imaging software contains tools for rotation and translation of 3-dimensional rendering, volumes, and surfaces, as well as recordings of different acquisitions with methods based on landmarks, volumes, or surfaces. However, to our knowledge there is still no external reference for head positioning, and there seems to be no stable reference structure in 3-dimensional facial photographs for soft-tissue assessments in longitudinal studies.

Positioning of the head in cone-beam computed tomography (CT) is difficult because the scanning time is relatively long (20–40 seconds), which requires the patient's head to be fixed to avoid movement. Because the images derived from cone-beam CT are 3-dimensional, the position of the head must be recorded in all three planes of space, as the pitch, roll, and yaw of the head accurately orientate the 3-dimensional image.[50]

Many studies have dealt with the issue of recording the head position when it is unrestrained, as it is during 3-dimensional photography or cone-beam CT. As for 2-dimensional imaging, there are two approaches: 3-dimensional recording with the patient in the natural head position, and acquisition of the 3-dimensional image and subsequent reorientation of the volume according to the previously chosen natural head position (Fig. 1). The first method is limited to acquisition of 3-dimensional photographs.

Some authors evaluated the use of minisensors for recording unrestrained head position during 3-dimensional stereophotogrammetry by testing a device composed of three orientation sensors with six degrees of freedom placed on a headset during acquisition of a 3-dimensional photograph. They suggested that a digital 3-dimensional tracking system can be promising for reproducibility of the head position, even though several improvements are required before they can be incorporated practically for research or clinical use.[45]

Hsung et al. recently developed a technique to capture information about natural head position using stereophotogrammetry and defined it as "stereophotogrammetric

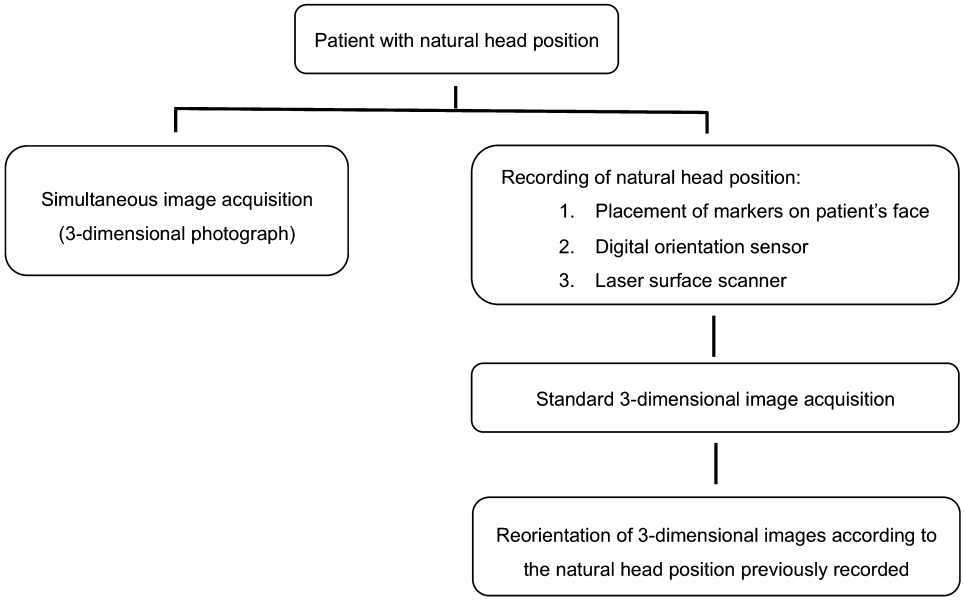

Fig. 1. Flowchart of 3-dimensional methods for recording the natural head position.

natural head position".[48] Stereophotogrammetry machines provide non-invasive, photographic-quality, 3-dimensional, accurate, capture of objects, and because calibration does not usually need any physical reference, the stereophotogrammetry system can capture only the surface morphology irrespective of its anatomical orientation. The resulting facial image is tilted to an unknown orientation, so the authors proposed additional calibration to correct the orientation by using some physical references such as true vertical and mirror orientation.[48]

Their first step is to record a digital mesh model of a hanging reference board placed at the capturing position of the stereophotogrammetry machine. The board is aligned to the true vertical using a plumb bob, and to a laser plane parallel to a hanging mirror located at the centre of the machine. The measurements derived from the digital mesh model of the board are used to adjust the roll, pitch, and yaw of the subsequent facial images, and the physical reference information is valid until the next time that the machine is calibrated. This approach allows the patient to achieve the natural head position without the use of any devices or troublesome markings on the face. More importantly, it is extremely repeatable and accurate, because the placement of the board showed a SD of less than 0.1° for pitch and yaw angles and less than 0.15° for roll angles. Alternatively, the 3-dimensional image can be reorientated according to the position previously recorded.

Methods of recording to orientate 3-dimensional images into the natural head position

Laser-assisted surface marking followed by acquisition of the image: laser lines are used as reference lines to place soft tissue reference markers. Some authors place six glass spheres on the patient's face as soft-tissue reference markers. They then take a cone-beam CT and the image is orientated in the three planes of space by aligning the reference marks to the horizontal references lines.[43] In another study an iCAT™ device was used as a reference to place four ink points on the faces for orientation by using the machine laser-light beams projected to record true horizontal and vertical lines. The placement of dots to record natural head position is followed by facial imaging with the stereophotographic imaging system.[46] However, putting marks on a patient's face could introduce problems of reproducibility and variability, and it also lengthens the operating time for making each of the 3-dimensional or CT scans.

Laser surface scanning: a 3-dimensional laser scanner records the surface geometry and absolute orientation of soft facial tissues while the patient is in the natural head position, and the CT model is orientated to the natural head position based on these results.[27] Although recording the position by laser scanner is accurate, the method is impractical for routine use, because the device is bulky and expensive.[44]

Natural head position recording device: this uses a small and inexpensive device that consists of a digital orientation sensor attached to the patient by a bite jig and a facebow, which is capable of digitally recording natural head position in three dimensions and transferring it precisely to a 3-dimensional model.[44,51] Although the orientation sensor method is inexpensive compared with the laser scanner, it requires the construction of a patient-specific bite jig, and severely displaces the upper and lower lips during the CT imaging. Because the position of the upper lip is the most important landmark for predicting soft tissue in the simulation of 3-dimensional surgery, an undeformed resting lip position is essential in computer-assisted orthognathic surgery.

Table 3
Recent studies on recording head position during 3-dimensional image capture (cone-beam computed tomography (CT) and 3-dimensional photograph).

First author, year, reference	Method	3-dimensional image
Damstra 2010[43]	Laser lines used to place six soft-tissue markers (glass spheres); cone-beam CT taken and patient's image orientated in the three planes of space by aligning the reference marks to the horizontal lines.	Cone-beam CT
Xia 2011[44]	Digital orientation scanner attached to patient by an bite jig and facebow permits recording of natural head position in 3 dimensions and transfers it precisely to a 3-dimensional model.	CT
De Paula 2012[45]	Three-dimensiosnal picture taken of patient with unrestrained head position wearing headset with 3-dimensional live tracking sensors, each of which records six degrees of freedom in head position.	Photograph
Weber 2013[46]	iCAT™ device used as reference to place four orientation ink spots on face using the machine's laser beams projected to record true horizontal and vertical to record natural head position. This is followed by facial imaging with stereophotographic imaging system.	Photograph
Kim 2014[47]	Spherical ceramic markers attached with transparent tape to the face as feature points. Frontal photograph of natural head position taken using ordinary digital camera parallel to the horizon, followed by CT. Positions of ceramic markers calculated on 2-dimensisonal image and correspond to points on the 3-dimensional model through POSIT.	CT
Hsung 2014[48]	Digital mesh model of reference board recorded and superimposed on model of patient's face. Facial images are corrected to natural head position according to pitch, yaw, and roll angle of the reference board model.	Photograph

iCAT™ = cone-beam CT scanner.
POSIT = pose from orthography and scaling with iterations.

Discussion

The volumes can be reorientated into the natural head position on cone-beam CT scans taken vertically or horizontally. This reorientation and the subsequent cephalometric evaluation can reliably be done only when the soft-tissue facial profile has not changed as a consequence of recording in the supine head position. Some research workers claim that the drape of the soft tissues of the face is different when a patient is supine.[52] Hoogeveen et al investigated whether the soft-tissue facial profile, as evaluated by soft-tissue cephalometric analysis, is different for a subject when in the natural or supine head position,[53] and they found significant differences depending on the head position while the recording is being made. However, these differences were not clinically relevant, except for the chin–throat angle, which is over 5° more acute when recorded supine, suggesting a more prominent chin. This can influence the planning of orthognathic surgery and compromise the result of the procedure. To avoid this, the authors advise that the picture of the chin–throat area should be accompanied by a complementary (photographic) recording in the natural head position.[53]

Kim et al developed a new way to record and reproduce the 3-dimensional natural head position from a single frontal photograph of a patient face using a "pose from orthography and scaling with iterations" (POSIT) algorithm.,[47] which was developed by DeMenthon and Davis to calculate the rotation matrix of an object (the patient's head) and to transform its coordinates into a camera coordinate system.[54] It combines two algorithms: the first, pose from orthography and scaling (POS), approximates the perspective projection using a scaled orthographic projection, and calculates the rotation matrix of an object by solving a linear system. The second, POS with iterations (POSIT), uses the approximate POS in an iteration loop to compute better orthographic projections for the featured points.[54] The authors proposed that spherical ceramic markers 4 mm in diameter should be attached with transparent tape to the patient's face as feature points. A frontal photograph of the patient's natural head position is taken with an ordinary digital camera parallel to the global horizon. A CT image is then taken of the patient with the markers. The positions of the ceramic markers are calculated on the 2-dimensional image and correspond to points in the 3-dimensional model. The 3-dimensional rotation matrix calculated from the feature points by the POSIT method is applied to the CT model to reproduce the natural head position with no additional recording or processing. The authors say that the method is easy to use, accurate, and inexpensive. In addition it does not affect the patient's lip position, and it can be applied to various CT images to diagnose and treat orthognathic patients, particularly those with facial asymmetry (Table 3).[47]

We conclude, first, that taking cephalograms of the natural head position is useful to investigate the association between craniocervical posture and dentofacial morphology. However, stabilisation of the head in the cephalostat produces rigid fixation that might prevent the patient from reaching the relaxed natural position.

Secondly, the natural head position has been proposed as a postural basis for assessment of craniofacial morphology. It has therefore been advocated as a better option than intracranial reference lines for cephalometric analyses in orthodontics and orthognathic surgery. It would therefore be appropriate to combine them in clinical decision-making. The aesthetic and anthropometric examination of the profile should be made on the patient's natural head position to provide important supplementary information for the intracranial cephalometric diagnosis.

Finally, we have described various techniques to reproduce and record the natural head position in two and three planes of space. The ideal method should avoid the use of any device attached to the head to achieve the natural head position. It should be simple and easy to do, with no troublesome

markings on the patient's face or subjective identification of specific reference points. The success of the protocol should not be operator-dependent, so that an inexperienced practitioner can follow the procedures to record and reproduce the 3-dimensional natural head position without complex training. It is therefore desirable that the method does not produce major artefacts in the CT images and does not affect the patient's lip position or deform the facial soft tissues, and lastly it should be quick and cost-effective.

Conflict of Interest

We have no conflict of interest.

Ethics statement / Confirmation of patients' permission

Not required.

References

1. Broca P. On projections of the head and a new cephalometric technique (in French). *Bulletin of the Society of Anthropology of Paris* 1862;**3**:514–44.
2. Lundström A, Lundström F, Lebret LM, et al. Natural head position and natural head orientation: basic considerations in cephalometric analysis and research. *Eur J Orthod* 1995;**17**:111–20.
3. Downs WB. Analysis of the dentofacial profile. *Angle Orthodontist* 1956;**26**:191–212.
4. Bjehin R. A Comparison between the Frankfort horizontal and the sella turcica -nasion as reference planes in cephalometric analysis. *Acta Odontologica Scandinavica* 1957;**15**:1–12.
5. Moorrees CF, Kean MR. Natural head position: A basic consideration in the interpretation of cephalometric radiographs. *American Journal of Physical Anthropology* 1958;**16**:213–34.
6. Marcotte MR. Head posture and dentofacial proportions. *Angle Orthod* 1981;**51**:208–13.
7. Moorrees CF. Natural head position–a revival. *Am J Orthod Dentofacial Orthop* 1994;**105**:512–3.
8. Jiang J, Xu T, Lin J. The relationship between estimated and registered natural head position. *Angle Orthod* 2007;**77**:1019–24.
9. Halazonetis DJ. Estimated natural head position and facial morphology. *Am J Orthod Dentofacial Orthop* 2002;**121**:364–8.
10. Ahangar-Atashi M-H, Kachoei M. Effect of chin position on natural head orientation reproducibility. *Med Oral Patol Oral Cir Bucal* 2011;**16**:e317–22.
11. Cooke MS. Five-year reproducibility of natural head posture: a longitudinal study. *Am J Orthod Dentofacial Orthop* 1990;**97**:489–94.
12. Ferrario VF, Sforza C, Germanò D, et al. Head posture and cephalometric analyses: an integrated photographic/radiographic technique. *Am J Orthod Dentofacial Orthop* 1994;**106**:257–64.
13. Peng L, Cooke MS. Fifteen-year reproducibility of natural head posture: A longitudinal study. *Am J Orthod Dentofacial Orthop* 1999;**116**:82–5.
14. Bister D, Edler RJ, Tom BD, et al. Natural head posture–considerations of reproducibility. *Eur J Orthod* 2002;**24**:457–70.
15. Cooke MS, Wei SH. The reproducibility of natural head posture: a methodological study. *Am J Orthod Dentofacial Orthop* 1988;**93**:280–8.
16. Solow B, Tallgren A. Natural head position in standing subjects. *Acta Odontol Scand* 1971;**29**:591–607.
17. Siersbaek-Nielsen S, Solow B. Intra- and interexaminer variability in head posture recorded by dental auxiliaries. *Am J Orthod* 1982;**82**:50–7.
18. Sandham A. Repeatability of head posture recordings from lateral cephalometric radiographs. *Br J Orthod* 1988;**15**:157–62.
19. Lundström F, Lundström A. Natural head position as a basis for cephalometric analysis. *Am J Orthod Dentofacial Orthop* 1992;**101**:244–7.
20. Huggare JA. A natural head position technique for radiographic cephalometry. *Dentomaxillofac Radiol* 1993;**22**:74–6.
21. Uşümez S, Orhan M. Reproducibility of natural head position measured with an inclinometer. *Am J Orthod Dentofacial Orthop* 2003;**123**:451–4.
22. Murphy KE, Preston CB, Evans WG. The development of instrumentation for the dynamic measurement of changing head posture. *Am J Orthod Dentofacial Orthop* 1991;**99**:520–6.
23. Todres JI. *Static and continuous measurement of head posture: a comparative investigation*. Thesis for the degree of M Dent, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, 1993.
24. Preston CB, Evans WG, Todres JI. The relationship between ortho head posture and head posture measured during walking. *Am J Orthod Dentofacial Orthop* 1997;**111**:283–7.
25. Madsen DP, Sampson WJ, Townsend GC. Craniofacial reference plane variation and natural head position. *Eur J Orthod* 2008;**30**:532–40.
26. Barbera AL, Sampson WJ, Townsend GC. Variation in natural head position and establishing corrected head position. *Homo* 2014;**65**:187–200.
27. Xia JJ, Gateno J, Teichgraeber JF. New clinical protocol to evaluate craniomaxillofacial deformity and plan surgical correction. *J Oral Maxillofac Surg* 2009;**67**:2093–106.
28. 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.
29. Sonnesen L, Bakke M, Solow B. Temporomandibular disorders in relation to craniofacial dimensions, head posture and bite force in children selected for orthodontic treatment. *Eur J Orthod* 2001;**23**:179–92.
30. Watson DH, Trott PH. Cervical headache: an investigation of natural head posture and upper cervical flexor muscle performance. *Cephalalgia* 1993;**13**:272–84.
31. Gomes L, de C, Horta KO, et al. Systematic review: craniocervical posture and craniofacial morphology. *Eur J Orthod* 2014;**36**:55–66.
32. Armijo-Olivo S, Jara X, Castillo N, et al. A comparison of the head and cervical posture between the self-balanced position and the Frankfurt method. *J Oral Rehabil* 2006;**33**:194–201.
33. Lundström F, Lundström A. Clinical evaluation of maxillary and mandibular prognathism. *Eur J Orthod* 1989;**11**:408–13.
34. Showfety KJ, Vig PS, Matteson S. A simple method for taking natural-head-position cephalograms. *Am J Orthod* 1983;**83**:495–500.
35. Showfety KJ, Vig PS, Matteson S, et al. Associations between the postural orientation of sella-nasion and skeletodental morphology. *Angle Orthod* 1987;**57**:99–112.
36. Ozbek MM, Köklü A. Natural cervical inclination and craniofacial structure. *Am J Orthod Dentofacial Orthop* 1993;**104**:584–91.
37. Uşümez S, Orhan M. Inclinometer method for recording and transferring natural head position in cephalometrics. *Am J Orthod Dentofacial Orthop* 2001;**120**:664–70.
38. Leitao P, Nanda RS. Relationship of natural head position to craniofacial morphology. *Am J Orthod Dentofacial Orthop* 2000;**117**:406–17.
39. Verma SK, Maheshwari S, Gautam SN, et al. Natural head position: key position for radiographic and photographic analysis and research of craniofacial complex. *J Oral Biol Craniofacial Res* 2012;**2**:46–9.
40. Dvortsin DP, Ye Q, Pruim GJ, et al. Reliability of the integrated radiograph-photograph method to obtain natural head position in cephalometric diagnosis. *Angle Orthod* 2011;**81**:889–94.
41. Raju NS, Prasad KG, Jayade VP. A modified approach for obtaining cephalograms in the natural head position. *J Orthod* 2001;**28**:25–8.
42. Chen CM, Lai S, Tseng YC, et al. Simple technique to achieve a natural head position for cephalography. *Br J Oral Maxillofac Surg* 2008;**46**:677–8.
43. Damstra J, Fourie Z, Ren Y. Simple technique to achieve a natural position of the head for cone beam computed tomography. *Br J Oral Maxillofac Surg* 2010;**48**:236–8.

44. Xia JJ, McGrory JK, Gateno J, 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.
45. De Paula LK, Ackerman JL, Carvalho F, et al. Digital live-tracking 3-dimensional minisensors for recording head orientation during image acquisition. *Am J Orthod Dentofacial Orthop* 2012;**141**:116–23.
46. Weber DW, Fallis DW, Packer MD. Three-dimensional reproducibility of natural head position. *Am J Orthod Dentofacial Orthop* 2013;**143**:738–44.
47. Kim DS, Yang HJ, Huh KH, 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.
48. Hsung TC, Lo J, Li TS, et al. Recording of natural head position using stereophotogrammetry: a new technique and reliability study. *J Oral Maxillofac Surg* 2014;**72**:2256–61.
49. Swennen GR, Schutyser F, Hausamen JE. *Three-dimensional cephalometry. A color atlas and manual*. Berlin: Springer; 2006.
50. Ackerman JL, Proffit WR, Sarver DM, et al. Pitch, roll, and yaw: describing the spatial orientation of dentofacial traits. *Am J Orthod Dentofacial Orthop* 2007;**131**:305–10.
51. Schatz EC, Xia JJ, Gateno J, et al. Development of a technique for recording and transferring natural head position in 3 dimensions. *J Craniofac Surg* 2010;**21**:1452–5.
52. McCollum AG, Evans WG. Facial soft tissue: the alpha and omega of treatment planning in orthognathic surgery. *Semin Orthod* 2009;**15**:196–216.
53. Hoogeveen RC, Sanderink GC, Berkhout WE. Effect of head position on cephalometric evaluation of the soft-tissue facial profile. *Dentomaxillofac Radiol* 2013;**42**:20120423.
54. DeMenthon D, Davis L. Model-based object pose in 25 lines of code. *International Journal of Computer Vision* 1995;**15**:123–41.