Clinical Oral Investigations (2024) 28:535
https://doi.org/10.1007/s00784-024-05926-6

REVIEW

Evaluating cranial landmarks for yaw orientation in natural head position: a 3D study

Sümer Münevveroğlu[1] · Gökhan Gürler[1] · Abdullah Özel[1]

Received: 8 June 2024 / Accepted: 14 September 2024 / Published online: 20 September 2024

Abstract

Objectives To assess the symmetry of various cranial anthropometric points used as references for yaw orientation in the natural head position (NHP), relative to the mid-sagittal plane.

Materials and methods A prospective analysis using tomography data from 55 patients was conducted. Radiopaque markers, placed on patients in NHP, facilitated head position recording in three planes, with subsequent digital transfer for orientation analysis. Symmetry of eight points (zygomaxillare, zygion, ectoconchion, frontozygomatic suture, stephanion, porion, mastoidale, condylion laterale) was measured against the mid-sagittal plane.

Results Significant asymmetry was observed in the stephanion, frontozygomatic suture, and ectoconchion points ($p < 0.05$). No significant differences were found in the symmetry of other points ($p > 0.05$).

Conclusions Findings suggest that stephanion, frontozygomatic suture, and ectoconchion are unreliable for yaw orientation in NHP. Other points, combined with clinical measurements, may offer better reliability.

Keywords Yaw orientation · Head orientation · Natural head position · Orthognathic surgery planning

Introduction

Orthognathic surgery plays a pivotal role in the treatment of dentofacial deformities. Critical to its success is the surgical planning phase [1]. This planning involves analyzing patient records, assessing dentofacial deformity severity, and determining the required jaw movement. Dentofacial deformities, being three-dimensional, necessitate detailed evaluation, often through computed tomography (CT) [2]. Traditionally, treatment planning focused on hard-tissue-based analyses. However, recent trends emphasize soft-tissue-based analyses, acknowledging the impact of head position on neck and head soft tissues [3]. Thus, recording patient data in the natural head position (NHP) is crucial for orthognathic surgery planning [4].

In our study, we primarily employed NHP as the standard for evaluating the patients' head posture. However, minor adjustments towards corrected head position (CHP) were made in cases where significant Angle Class II malocclusion caused hyperextension of the head. This approach was assessed by three specialists to ensure a more objective evaluation of the patients' head position. It is important to distinguish between NHP and CHP. NHP is the position a person assumes while standing or sitting upright, induced by looking at an infinite horizon or their reflection in a mirror [5]. CHP, on the other hand, considers dysfunctions and compensations in head posture caused by factors such as occlusion interferences, airway restrictions, and muscular pain [6]. We believe these occasional corrections were minimal and likely did not significantly impact the yaw orientation of the head.

A variety of methods to record NHP exist, including stereophotogrammetry, laser line marking, clinical photography, spirit level devices, gyroscopes, and laser face scanning [7]. The rise of computer-assisted surgical planning emphasizes the importance of accurately recording and transferring the NHP into a digital environment for

✉ Sümer Münevveroğlu
sumer.munevveroglu@medipol.edu.tr

Gökhan Gürler
ggurler@medipol.edu.tr

Abdullah Özel
aozel@medipol.edu.tr

[1] Department of Oral and Maxillofacial Surgery, School of Dentistry, Istanbul Medipol University, İstanbul, Türkiye

pre- and postoperative evaluation [8]. Techniques for this include placing radiopaque markers on laser-projected lines and orienting with natural position photographs [9]. Clinically, while NHP is routinely recorded on sagittal and coronal planes, recording it on the horizontal plane presents significant challenges. Consequently, horizontal plane determination often relies on presumed symmetrical anthropometric points relative to the mid-sagittal plane [10]. Despite acknowledgment in the literature of the importance of yaw assessment for orthognathic surgery planning, there remains a notable absence of studies that explicitly investigate yaw orientation within the framework of the NHP. Our study aims to address this gap by enhancing the reliability of yaw orientation through precise measurement and alignement of cranial landmarks on the horizontal plane.

This study primarily aimed to assess the symmetry of eight cranial points (Ectoconchion, Frontozygomatic suture, Stephanion, Porion, Mastoidale, Zygomaxillare, Condylion laterale, and Zygion) used to determine NHP in the horizontal plane. Additionally, it examined the alignment between the clinically determined mid-sagittal plane and specific points (crista galli and basion). Despite extensive research on NHP in sagittal and coronal planes, yaw orientation remains underexplored. This study addresses this gap by assessing the symmetry and reliability of these points for yaw orientation, critical as slight deviations in head alignment can markedly impact surgical outcomes. The findings aim to enhance the reliability of transverse plane orientation in clinical settings.

The hypothesis of this study was that none of the cranial points would exhibit symmetry when measured relative to the mid-sagittal plane on the horizontal plane, indicating the necessity of recording the horizontal plane during NHP assessment.

Material & method

Samples

Ethical approval for this prospective study was obtained from the Ethics Committee of Istanbul Medipol Universityof Istanbul Medipol University. In this prospective study, 57 patients aged 17–43 years who presented with dentofacial deformity at the Department of Oral and Maxillofacial Surgery, Istanbul Medipol University, between January 2019 and April 2020 were included. As this study involved a single group of patients undergoing orthognathic surgery, randomization and blinding were not applicable. CT images (iCT 256 Slice, Philips, Netherlands) were utilized for diagnostic assessments and treatment planning. Patients with a history of craniofacial surgery or trauma, genetic syndromes (e.g., Treacher Collins, Pierre Robin) affecting the craniofacial skeleton, or conditions (e.g., scoliosis, torticollis) affecting head and neck posture were excluded from this study.

Patient records

Models and centric relation record

Models and centric relation records were obtained after removing arch wires to reduce CT scatter. Impressions of both jaws were taken using condensation-type silicone (Zetaplus, Zhermack, Italy), and models were made in type-4 dental stone (Elite Rock, Zhermack, Italy). Models was digitized using an extraoral scanner (D850, 3Shape, Denmark). Centric relation was established using the chin point guidance technique and modeled wax (Set Up Wax, Cavex, Netherlands), with excess wax removed to avoid soft tissue distortion.

Determining and recording natural head position

NHP was determined and recorded using cross-line lasers (Pcl-20, Bosch GmbH, Germany) and skin markers (VF-10, Suremark, USA) in a room specially equipped with mirrors (Fig. 1). The procedure involves guiding patients into comfortable head positions and marking reference points on the three anatomical planes, using the glabella as the midline reference of the face.

Sagittal plane (frontal view)

Patients were instructed to perform upward and downward head rotations and to halt at a position where they felt most comfortable while viewing their own reflection in the mirror. A cross-line laser, positioned on a tripod directly opposite the patient, was activated. The vertical laser line was aligned with the glabella midline point, which is also considered the clinical midline reference of the face, and a new marker was placed on the chin. This procedure was repeated twice, and a second skin marker was placed at the marked point (Fig. 2A), thereby recording the head position in the sagittal plane.

Coronal plane (lateral view)

To assess the head position in the coronal plane, a point above the zygomatic arch was marked. Patients were then asked to turn to their left, observe their reflection in a mirror positioned on their left side, and repeat the upward and downward head movements. The cross-line laser, placed on a tripod, was aligned with the point above the zygomatic arch, and an additional marker was placed near the angulus.

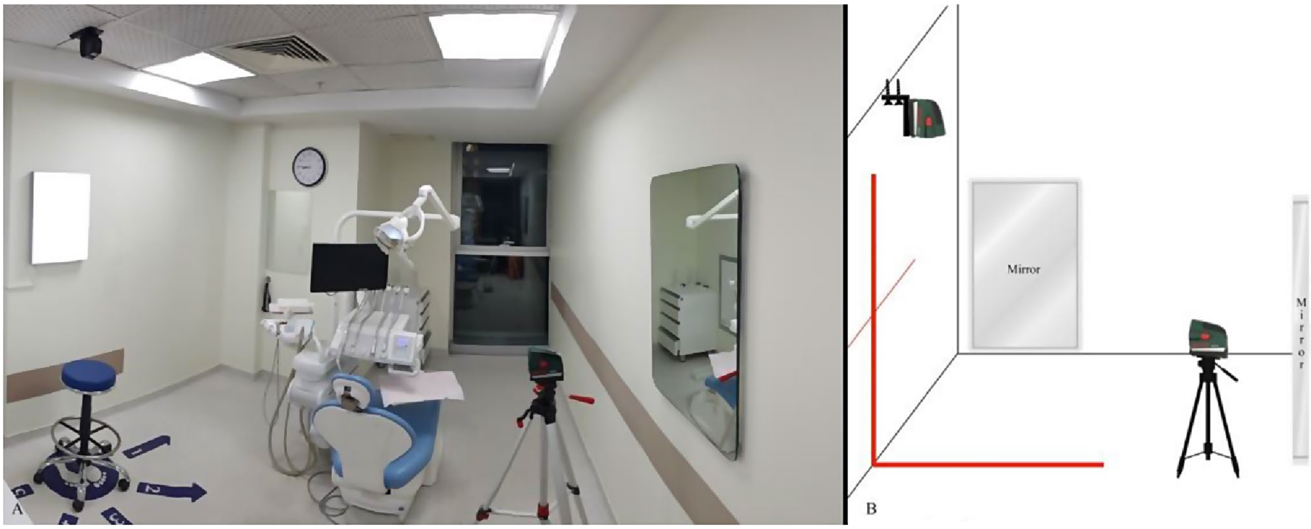

Fig. 1 Illustration of the setup for natural head position documentation. (**A**) - Photograph of the room specifically arranged for the study. (**B**) - Schematic drawing of the same room

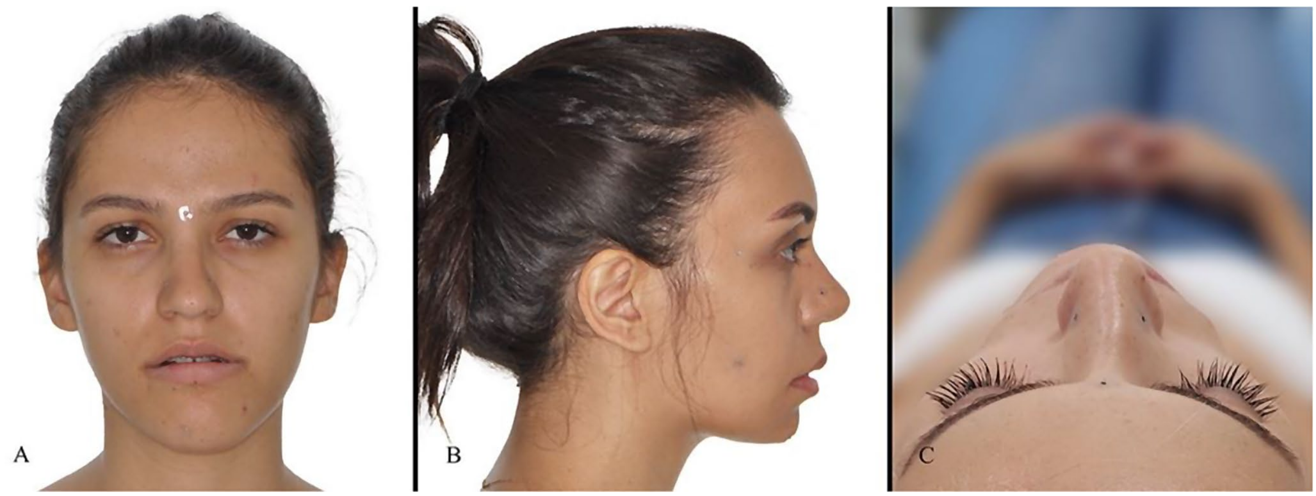

Fig. 2 Demonstration of patient positioning and reference point marking. (**A**) - Frontal view of a patient, illustrating the marking of the glabella and a point on the chin. (**B**) - Lateral view, showcasing the alignment and marking of reference points in the sagittal plane. (**C**) - Top view, depicting the technique for head alignment and placement of markers on the nose in the horizontal plane

This procedure was repeated, and the third and fourth skin markers were positioned on the patient's right profile (Fig. 2B).

Horizontal plane (top view)

To capture the head position in the horizontal plane, a point was marked on one side of the nose. A cross-line laser mounted on the ceiling was activated after the patient performed the same upward and downward head rotations and stopped at a comfortable position. The horizontal laser line was aligned with the nasal point, and a second marker was placed on the opposite side of the nose. This procedure was repeated twice, resulting in the placement of the fifth and sixth skin markers on the nose (Fig. 2C).

It should be noted that the NHP recordings for each of the three planes were not captured simultaneously but sequentially within the same session. The potential variation in head position between these recordings was considered negligible, as NHP is well-documented in the literature to be highly reproducible with minimal short- and long-term deviations.

The primary observer identified the points for determining the NHP and clinical midline. These points were subsequently verified by two additional independent observers. In case of disagreement, the points were re-evaluated and re-marked by the primary observer until consensus was reached. As the two additional observers only confirmed the points identified by the primary observer and did not perform independent measurements, method error values were not calculated.

CT scanning procedure

The patient was positioned supine, and the centric relation wax was placed and adjusted to ensure proper positioning. The patient was then instructed to gently close their teeth without clenching and to keep their lips relaxed. The skin markers were aligned with the laser lines on the CT device, and images were obtained with a slice thickness of 0.25 mm.

Measurements of anthropometric points

CT and STL data were aligned using digital planning software (NemoFAB, Nemotec, Spain) (Fig. 3). Anthropometric points were identified for symmetry evaluations, and the alignment of crista galli and basion with the mid-sagittal plane was assessed. Measurements of mid-sagittal distances on horizontal plane at ectoconchion, frontozygomatic suture, stephanion, porion, mastoidale, zygomaxillare, condylion laterale, and zygion were conducted on both sides by the same researcher using the digital planning software to assess symmetry (Fig. 4). The mid-sagittal plane was defined as the vertical line passing through the skin markers placed on the glabella and chin after 3D NHP orientation. In the orientation module, the software inherently allowed each plane to be oriented independently, ensuring that adjustments made in one plane did not affect the others. This independent orientation was facilitated through the software's interface, as depicted in Fig. 3. In this figure, the orientation module is shown with four quadrants: the top two quadrants for adjusting the sagittal plane, the bottom left quadrant for the horizontal plane, and the bottom right quadrant for the coronal plane.

The analysis was centered on the horizontal plane, as it provides sufficient information for yaw orientation. The symmetry of these landmarks on other planes was not evaluated, as the primary concern was yaw orientation (Fig. 5).

Intra-observer reliability was assessed by repeating measurements of all anthropometric points on 22 randomly selected patients.

Statistical analysis

Data were analyzed using IBM SPSS Statistics (Version 22.0, SPSS Inc., Chicago, IL, USA), employing t-tests, Mann-Whitney U tests, Chi-square tests, and Pearson correlation analysis. Intra-class correlation and Kappa coefficients were used to assess method error. A power analysis was initially conducted based on a pilot study of 15 patients using G*Power 3.1 (Düsseldorf, Germany), targeting an effect size of 0.538 with an SD of 2.8 to determine a minimum sample size of 30 for a power of 0.80 and an alpha of 0.05. Post-study power analysis was also performed with the complete set of 55 patients.

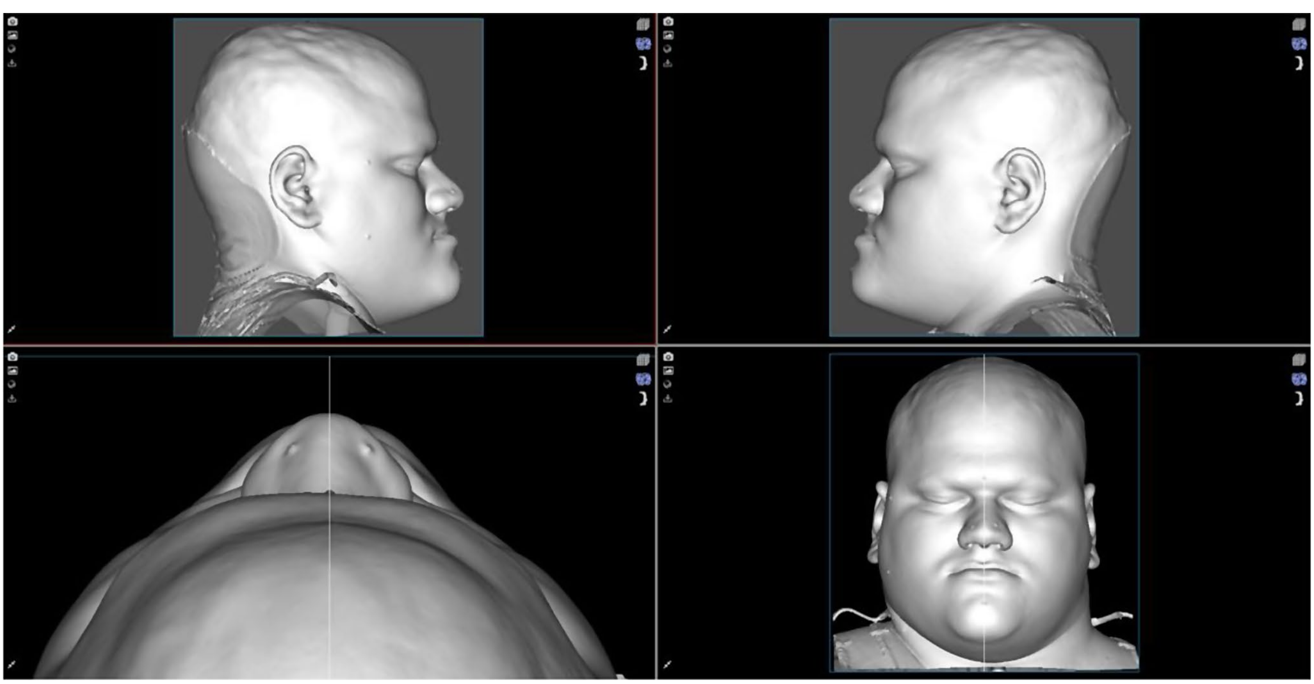

Fig. 3 Screenshot of the orientation process in digital planning software

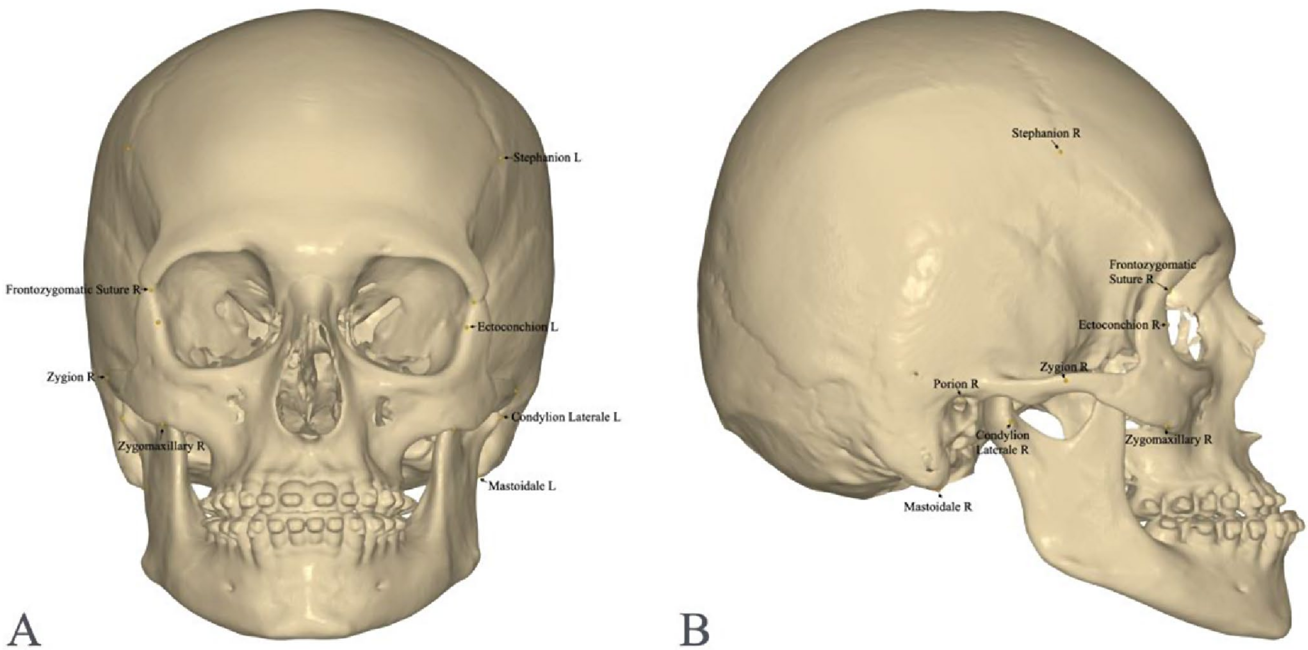

Fig. 4 Visual representation of the eight anthropometric points. (**A**) - Frontal view: Seven of the eight anthropometric points are illustrated, with the Porion not visible due to the angle. (**B**) - Profile view: All eight anthropometric points, including the Porion, are clearly visible

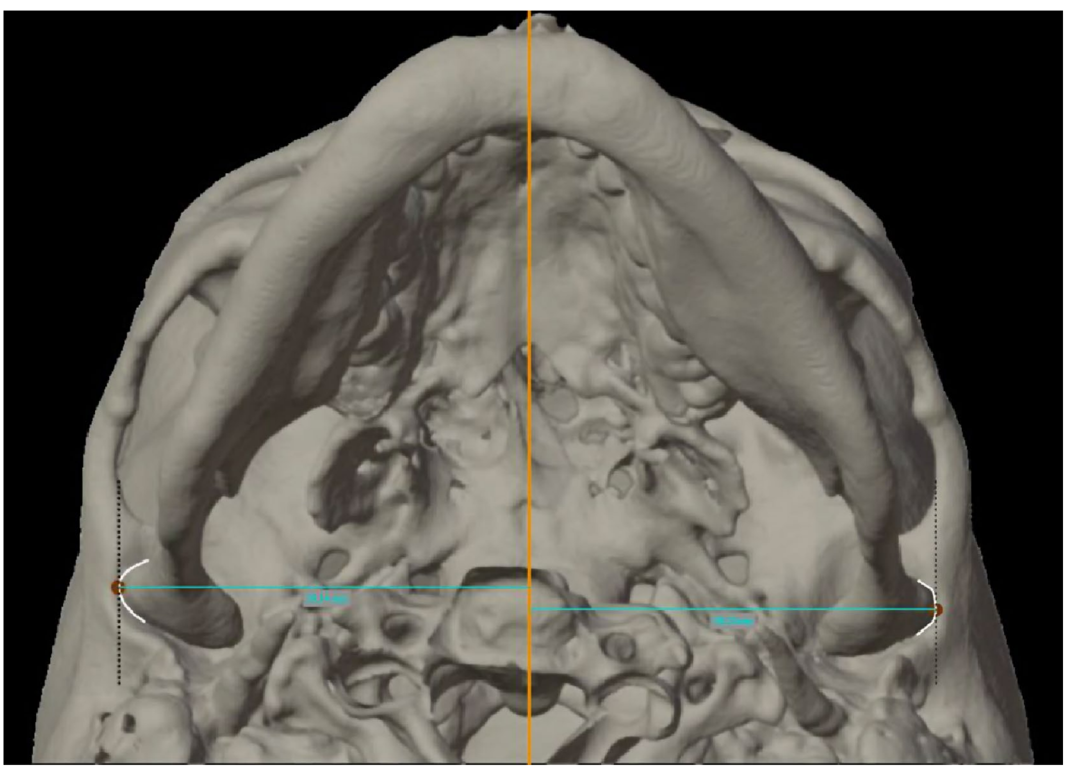

Fig. 5 Demonstration of the measurement process for the condylion laterale landmark, showing the distances to the mid-sagittal plane on the horizontal plane for both the right and left sides using digital planning software. The orange line represents the mid-sagittal plane, the brown points indicate the condylion laterale points, and the turquoise lines represent the measurements from the anthropometric points to the mid-sagittal plane

Results

The study included 55 patients (35 females, 20 males) with a mean age of 24.85 ± 5.8 years (females: 24.49 ± 5.05 years, males: 25.5 ± 7.05 years), aged between 17 and 43 years. Two were excluded: one for prior maxillofacial surgery and another for ethnicity-based considerations. Symmetry of eight anthropometric points was assessed in these patients. Significant asymmetries were found in ectoconchion, frontozygomatic suture, and stephanion points ($p < 0.05$) (Table 1).

A significant correlation was found between the mid-sagittal plane and both crista galli (85.5% overlap, $p < 0.001$) and basion points (63.6% overlap, $p = 0.043$), indicating a reliable alignment with the mid-sagittal plane. Additionally, intra-observer reliability, assessed via intra-class correlation coefficients (ICC), showed high agreement levels for measurements on both sides (98.8-100%, $p = 0.000$), demonstrating consistent measurement accuracy by the evaluator.

To further validate the symmetry of anthropometric points, Bland-Altman analyses were conducted for each of the cranial landmarks. The Bland-Altman plots revealed that while certain landmarks, such as Zygion and Porion, exhibit high symmetry and close agreement, other landmarks like Ectoconchion, Stephanion, and Frontozygomatic Suture demonstrate more significant variability (Fig. 6).

Discussion

Clinical and radiological analyses are crucial for planning orthognathic surgery to treat dentofacial deformities. These analyses provide insights into potential changes in soft and skeletal tissues, guiding treatment predictions. While traditional planning used two-dimensional techniques, advancements in computer software now enable three-dimensional procedural execution.

The goal of orthognathic surgery is to achieve ideal occlusion and enhance facial aesthetics. Predicting soft tissue changes consequent to skeletal modifications is a pivotal aspect of orthognathic surgery. Recent studies have focused on the jaw bones' movements and their impact on soft tissues, leading to the frequent use of digital simulations in clinical practice [11].

Recording the horizontal plane orientation poses challenges, often requiring the use of bilateral anthropometric points or midline references [10, 12]. Ma et al. highlighted the significance of 'yaw' over 'pitch' in treatment mechanics, underscoring its importance in surgical planning [13]. Ackerman et al. observed that 'yaw' is frequently overlooked in standard analyses, despite its prevalence in cases with significant midline discrepancies. They emphasized the criticality of 'yaw' evaluation in managing treatment mechanics and surgical planning [4].

Despite the common use of the Frankfort Horizontal Plane as a reference for head position, concerns have been raised about its reliability due to soft tissue influences [14]. Nevertheless, one of the significant advantages of the NHP is its long-term repeatability. Studies by Weber et al. and Üşümez and Orhan support its stability over time, highlighting its reliability in various planes [15].

In our study, we primarily employed NHP as the standard for evaluating the patients' head posture. However, minor adjustments towards CHP were made in a few cases, particularly where significant Angle Class II malocclusion caused hyperextension of the head. This approach, although subjective, was assessed by three specialists to minimize bias, ensuring a more objective evaluation of the patients' head position. It is important to distinguish between NHP and CHP. NHP is the position a person assumes while standing or sitting upright, induced by looking at an infinite horizon or their reflection in a mirror [5]. CHP, however, considers the dysfunctions and compensations in head posture caused by factors such as occlusion interferences, airway restrictions, and muscular pain [16]. We believe these occasional corrections did not affect the yaw orientation of the head. Despite our efforts to minimize bias by involving three specialists, the subjectivity inherent in manual adjustments may still introduce measurement variability. Additionally, the relatively small sample size of 55 patients, along with potential demographic limitations, may affect the generalizability of our findings.

Chen et al.'s study on using a cross-line laser level for head position determination highlighted the practicality and cost-effectiveness of combining skin markers with laser beams for digital transfer [17]. We adopted this approach in our study, aligning with current best practices for clinical convenience and accuracy.

The use of radiopaque skin markers is essential for visualization in radiographic images [18]. Damstra et al.'s recommendation of ceramic-based precision skin markers over

Table 1 Assessment of asymmetry in anthropometric points: differences between right and left side

	Differences between right-left sides Mean ± SD	p
Ectoconchion	0,83 ± 1,98	0,003*
Frontozygomatic Suture	0,93 ± 2,12	0,002*
Stephanion	1,66 ± 4,18	0,005*
Porion	0,23 ± 3,56	0,629
Mastoidale	0,52 ± 5,02	0,449
Zygomaxillare	0,67 ± 2,57	0,059
Condylion Laterale	0,51 ± 3,55	0,288
Zygion	0,21 ± 2,77	0,567

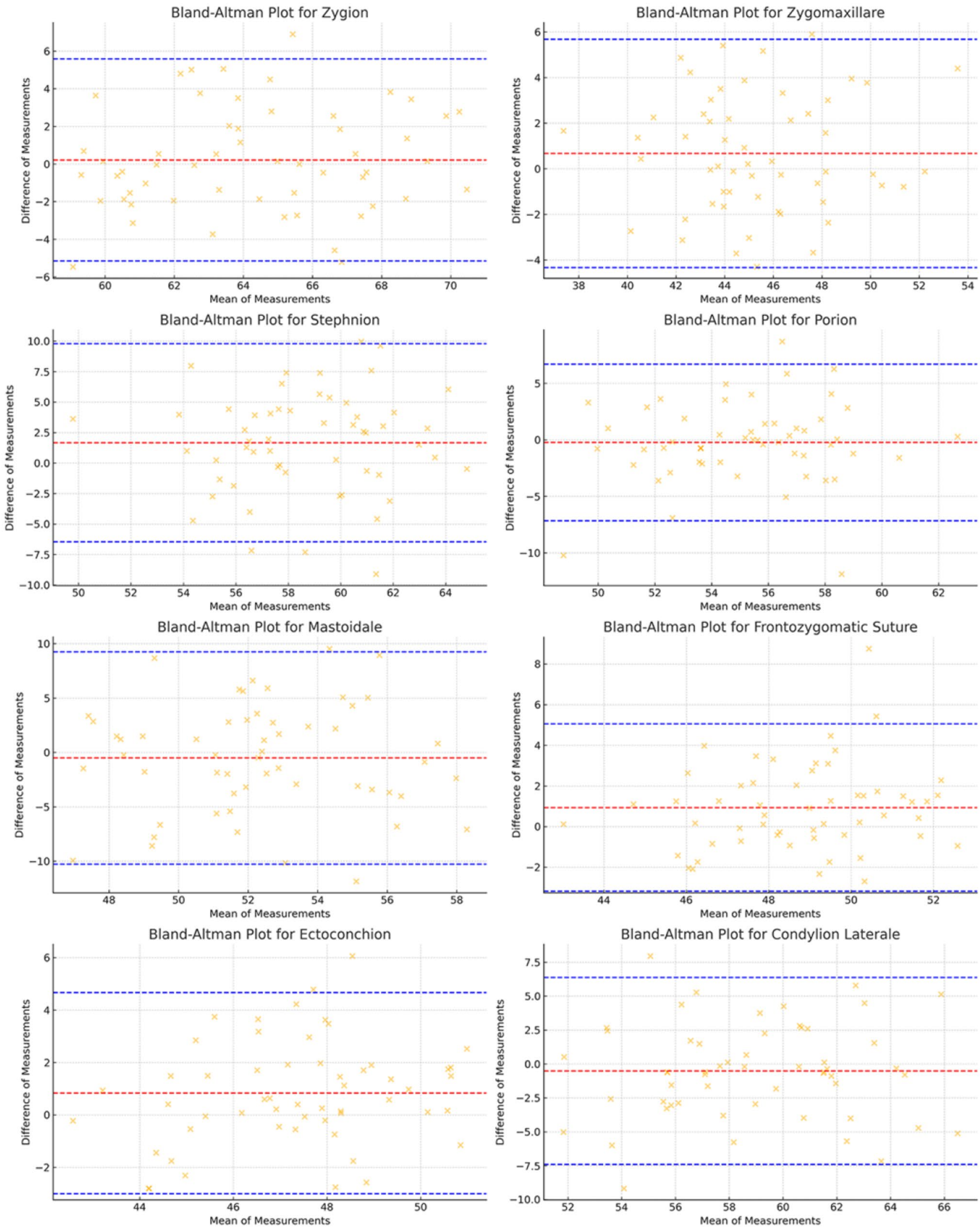

Fig. 6 Bland-Altman plots illustrating the symmetry for eight anthropometric points. The red dashed line represents the mean difference for each landmark, while the blue dashed lines represent the limits of agreement (mean difference ± 1.96 SD)

metal ones to avoid scattering was incorporated into our methodology [19].

Our study examined eight bilateral anthropometric points and two midline points, including the porion. We defined the porion based on description by Choi et al. adapting it for three-dimensional tomographic images [20].

Our patient demographics, consistent with Bortoluzzi et al., involved 55 individuals with a mean age of 24.85 ± 5.8 years, supporting the representativeness of our study population [21]. The female-to-male ratio of 3.5:2 aligns with Mayo et al.'s demographic assessment [22].

The study aimed to evaluate the symmetry of eight cranial points in the context of NHP and their reliability for yaw orientation. Our hypothesis that none of the cranial points would exhibit symmetry was partially disproved. Specifically, ectoconchion, frontozygomatic suture, and stephanion points showed significant asymmetry, confirming the need for careful assessment of these landmarks. It is important to note that a landmark's position on other planes could vary. However, our focus on the horizontal plane is based on the understanding that yaw orientation is primarily influenced by the symmetry of landmarks in this plane. We believe that the variation in the vertical or sagittal planes does not significantly impact the horizontal plane measurements used for yaw assessment.

On the other hand, zygion and porion points demonstrated higher symmetry, suggesting that these points can be considered reliable for yaw orientation despite not being statistically significant. Additionally, crista galli and basion showed a statistically significant overlap with the clinically determined mid-sagittal plane, indicating their potential as reference points in orthognathic surgery planning.

These findings highlight the importance of including horizontal plane recordings in NHP assessments to ensure accurate yaw orientation, ultimately enhancing surgical outcomes. While some anthropometric points, excluding ectoconchion, frontozygomatic suture, and stephanion, demonstrated statistically significant symmetry, the ideal approach would be to record NHP in all three planes. However, because recording the head position on the horizontal plane is clinically challenging, the relatively higher symmetry observed in zygion and porion points, despite not being statistically significant, along with the statistically significant alignment of the mid-sagittal plane with crista galli and basion, suggests that these points can serve as reliable references for yaw orientation in clinical practice when horizontal plane recordings are not feasible. However, the limited sample size of 55 patients may affect the generalizability of the findings, especially when considering the variability in cranial anatomy among different populations. Future research with larger, more diverse populations is recommended to confirm and expand upon these results. In our study, NHP was not recorded simultaneously across all planes, which is a limitation. However, literature indicates that NHP is considered stable both in the short and long term [23]. Therefore, we believe that the fact that NHP was recorded at different times for each plane in our study can be reasonably overlooked.

Conclusion

- Ectoconchion, frontozygomatic suture, and stephanion points exhibited statistically significant asymmetry and should not be used as references for yaw orientation.
- Zygion and porion points demonstrated higher symmetry. Suggesting their potential reliability for yaw orientation.
- Crista galli and basion points showed a statistically significant overlap with the clinically determined mid-sagittal plane, indicating their potential as reference points.

These findings suggest that the distances of zygion and porion to the mid-sagittal plane, along with the alignment of crista galli and basion with the mid-sagittal plane, could serve as alternatives for adjusting yaw orientation, which is clinically challenging to record. Further research with larger, more diverse populations is needed to confirm these findings.

Author contributions S.M., G.G., and A.Ö. conceived and designed the study. S.M. and G.G. collected and analyzed the data and added Figs. 4, 5 and 6. A.Ö. prepared Figs. 1, 2 and 3. S.M. and G.G. wrote the main manuscript text. All authors reviewed and approved the final manuscript.

Funding No funding was obtained for this study.

Data availability No datasets were generated or analysed during the current study.

Declarations

Ethical approval Ethics approval was obtained from the Ethics Committee of Istanbul Medipol University, approval number 10840098-604.01.01-E.1918. Informed consent was obtained in written form from all individual participants who were included in the study.

Conflict of interest The authors declare that they have no financial or non-financial conflicts of interest related to this study.

Competing interests The authors declare no competing interests.

References

1. Hammoudeh JA, Howell LK, Boutros S, Scott MA, Urata MM (2015) Current status of Surgical Planning for Orthognathic surgery: traditional methods versus 3D Surgical Planning. Plast Reconstr Surg Glob Open 3:307–316. https://doi.org/10.1097/GOX.0000000000000184
2. Bamber M, Harris M, Nacher C (2001) A validation of two orthognathic model surgery techniques. J Orthodont 28:135–142
3. Hoogeveen RC, Sanderink GC, Berkhout WE (2013) Effect of head position on cephalometric evaluation of the soft-tissue facial profile. Dentomaxillofacial Radiol 42:20120423. https://doi.org/10.1259/dmfr.20120423
4. Ackerman JL, Proffit WR, Sarver DM, Ackerman MB, Kean MR (2007) Pitch, roll, and yaw: describing the spatial orientation of dentofacial traits. Am J Orthod Dentofac Orthop 131:305–310. https://doi.org/10.1016/j.ajodo.2006.05.032
5. Cooke MS, Orth D, Wei SH (1988) The reproducibility of natural head posture: a methodological study. Am J Orthod Dentofac Orthop 93:280–288
6. Gunson MJ, Arnett GW (2019) Orthognathic virtual treatment planning for functional esthetic results. Book title. Elsevier
7. Leung MY, Lo J, Leung YY (2016) Accuracy of different modalities to record natural head position in 3 dimensions: a systematic review. J Oral Maxillofac Surg 74:2261–2284. https://doi.org/10.1016/j.joms.2016.04.022
8. Liu XJ, Li QQ, Pang YJ, Tian KY, Xie Z, Li ZL (2015) Modified method of recording and reproducing natural head position with a multicamera system and a laser level. Am J Orthod Dentofac Orthop 147:781–787. https://doi.org/10.1016/j.ajodo.2015.01.016
9. Damstra J, Fourie Z, Ren Y (2010) Simple technique to achieve a natural position of the head for cone beam computed tomography. Br J Oral Maxillofac Surg 48:236–238. https://doi.org/10.1016/j.bjoms.2009.10.001
10. Lee J-K, Jung P-K, Moon C-H (2014) Three-dimensional cone beam computed tomographic image reorientation using soft tissues as reference for facial asymmetry diagnosis. Angle Orthod 84:38–47
11. Nike E, Radzins O, Pirttiniemi P, Vuollo V, Slaidina A, Abeltins A (2023) Evaluation of facial soft tissue asymmetric changes in Class III patients after orthognathic surgery using three-dimensional stereophotogrammetry. Int J Oral Maxillofac Surg 52:361–370. https://doi.org/10.1016/j.ijom.2022.06.022
12. Méndez-Manjón I, Haas OL Jr, Guijarro-Martínez R, de Oliveira RB (2019) Valls-Ontañón A and Hernández-Alfaro F Semi-Automated Three-Dimensional Condylar Reconstruction. Journal of Craniofacial Surgery 30:2555–2559
13. Ma B, Shan S, Chen X, Gao W (2008) Head Yaw estimation from asymmetry of facial appearance. IEEE Trans Syst Man Cybernetics Part B (Cybernetics) 38:1501–1512
14. Ramírez DM, Jiménez JC, Ramírez EG, Paniagua HJ, Ruidíaz VC (2013) Discrepancies in cephalometric measurements in relation to natural head position. Revista Mexicana De Ortodoncia 1:27–32
15. Weber DW, Fallis DW, Packer MD (2013) Three-dimensional reproducibility of natural head position. Am J Orthod Dentofac Orthop 143:738–744. https://doi.org/10.1016/j.ajodo.2012.11.026
16. Barbera AL (2008) Corrected head position. University of Adelaide
17. Chen CM, Lai S, Tseng YC, Lee KT (2008) Simple technique to achieve a natural head position for cephalography. Br J Oral Maxillofac Surg 46:677–678. https://doi.org/10.1016/j.bjoms.2008.03.022
18. Arnett GW, McLaughlin RP (2004) Facial and dental planning for orthodontists and oral surgeons
19. Damstra J, Fourie Z, Slater JJRH, Ren Y (2010) Accuracy of linear measurements from cone-beam computed tomography-derived surface models of different voxel sizes. Am J Orthod Dentofac Orthop 137:16 e1-16. e6%@
20. Choi JW, Jung SY, Kim H-J, Lee S-H (2015) Positional symmetry of porion and external auditory meatus in facial asymmetry. Maxillofacial Plast Reconstr Surg 37:33–41
21. Bortoluzzi MC, de Camargo Smolarek P, Claudino M, Campagnoli EB, Manfro R (2015) Impact of dentofacial deformity on quality of life: age and gender differences evaluated through OQLQ, OHIP and SF36. J Oral Maxillofacial Res 6:1–8
22. Mayo KH, Vig KD, Vig PS, Kowalski CJ (1991) Attitude variables of dentofacial deformity patients: demographic characteristics and associations. J Oral Maxillofac Surg 49:594–602
23. Peng L, Cooke MS (1999) Fifteen-year reproducibility of natural head posture: a longitudinal study. Am J Orthod Dentofac Orthop 116:82–85