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Cephalometrics for Orthognathic Surgery: Insights from Literature Review

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ABSTRACT

This literature review examines the role of cephalometric evaluation in orthognathic surgery, highlighting its significance in diagnosis, treatment planning, and postoperative assessment. By analyzing various studies, the review highlights key cephalometric parameters and their applications in predicting surgical outcomes, improving facial aesthetics, and ensuring functional balance. The findings underscore the value of cephalometric analysis as a critical tool for enhancing surgical precision and patient-specific treatment approaches in orthognathic procedures.

INTRODUCTION

Orthognathic surgery, also known as corrective jaw surgery, is a specialized branch of Maxillofacial surgery focused on correcting dentofacial deformities that affect both function and aesthetics. These deformities commonly involve misalignments of the jaws and teeth, which can lead to difficulties in chewing, speaking, breathing, and facial disharmony. The primary objective of orthognathic surgery is to restore an optimal balance between skeletal structures and soft tissues by repositioning the maxilla, mandible, or both. Achieving this balance improves both the patient's functional capacity and overall facial appearance, significantly enhancing quality of life [1].

Given the complex nature of orthognathic surgical procedures, precise preoperative diagnosis, surgical planning, and postoperative evaluation are critical to ensuring successful outcomes. Cephalometric evaluation has become an essential tool in this process, providing quantitative analysis of craniofacial morphology. Cephalometry involves taking standardized radiographic images of the head, usually lateral cephalograms, which allow clinicians to measure angular and linear relationships between cranial, maxillary, mandibular, and dental landmarks. Through these measurements, cephalometric analysis helps in identifying skeletal discrepancies, planning surgical movements, predicting postoperative changes, and assessing treatment outcomes with a high degree of accuracy [2].

The role of cephalometric evaluation in orthognathic surgery dates back to the early 20th century when pioneers like Broadbent and Hofrath introduced standardized radiographic techniques. These innovations laid the foundation for cephalometry as a diagnostic and treatment planning tool. Over the decades, various cephalometric analyses have been developed, such as Steiner, McNamara, Tweed, and Sassouni analyses, each offering unique perspectives and reference points to assess craniofacial structures. These analyses have become indispensable in the diagnosis of malocclusions, skeletal discrepancies, and growth patterns, enabling surgeons to customize orthognathic treatment to each patient's anatomical characteristics [3].

The importance of cephalometric evaluation in orthognathic surgery cannot be overstated. Accurate diagnosis of skeletal deformities is the first and arguably most crucial step toward successful surgical intervention. Cephalometric analysis provides objective data regarding the anteroposterior, vertical, and transverse relationships of the jaws relative to the cranial base. This information is fundamental in determining the nature and severity of deformities such as mandibular prognathism or retrognathism, maxillary hypoplasia, open bites, and facial asymmetries. Without this detailed assessment, surgical planning would be largely based on subjective judgment, increasing the risk of suboptimal outcomes [4].

In treatment planning, cephalometric evaluation is invaluable for simulating surgical changes and predicting their effects on both hard and soft tissues. With advances in imaging technology, three-dimensional virtual surgical planning that incorporates cephalometric data has become increasingly widespread. This approach allows surgeons to visualize the spatial relationships of skeletal structures in multiple planes, improving the precision of osteotomies and repositioning. Virtual planning also enables the fabrication of patient-specific surgical guides and splints, which reduce operative time and enhance reproducibility. Furthermore, detailed cephalometric data improve patient communication by providing visual aids that help explain the planned surgical changes and expected results [5].

Postoperative evaluation through cephalometric analysis is equally critical. Objective measurements taken after surgery allow clinicians to assess the accuracy of surgical execution, monitor skeletal stability over time, and detect any relapse or complications. Longitudinal cephalometric studies contribute to the understanding of factors influencing surgical outcomes, such as the impact of orthodontic treatment, soft tissue response, and patient compliance. This feedback loop between preoperative planning and postoperative assessment strengthens evidence-based practice in orthognathic surgery and drives continual improvements in patient care [6].

Despite its widespread use, traditional two-dimensional cephalometry has certain limitations. Since lateral cephalograms are two-dimensional projections of three-dimensional structures, they involve some degree of distortion and superimposition, particularly of bilateral anatomical features. These limitations can affect measurement accuracy and make assessment of facial asymmetry or complex deformities challenging. Additionally, landmark identification can be subjective, leading to variability in measurements. To address these issues, three-dimensional imaging modalities such as cone-beam computed tomography (CBCT) have been introduced. CBCT provides volumetric data that allow clinicians to visualize craniofacial anatomy in true spatial dimensions, improving landmark identification and measurement precision [7].

Three-dimensional cephalometric analysis offers enhanced capabilities in evaluating asymmetries, volumetric changes, and complex craniofacial relationships. It also facilitates virtual surgical planning and postoperative superimposition for detailed outcome assessment. However, the adoption of three-dimensional cephalometry is still limited by factors such as higher radiation doses compared to traditional cephalograms, cost of equipment and software, and the need for specialized training. Research continues to focus on standardizing three-dimensional cephalometric protocols, developing automated landmark detection algorithms, and optimizing imaging parameters to make this technology more accessible and clinically practical [8].

The objective of this literature review is to synthesize current knowledge regarding the application of cephalometric evaluation in orthognathic surgery. Through an examination of various studies, this review will outline the critical cephalometric parameters used for diagnosis, treatment planning, and postoperative assessment. It will explore how cephalometric analysis aids in predicting surgical outcomes, improving facial aesthetics, and managing functional concerns. Furthermore, it highlights recent technological advances that are shaping the future of cephalometric evaluation in orthognathic surgery, along with ongoing challenges and limitations. Ultimately, this review aims to provide a comprehensive understanding of the value of cephalometric evaluation in enhancing the precision and success of orthognathic surgical interventions.

Methodology

This literature review was conducted to systematically analyze and synthesize existing research studies focusing on cephalometric evaluation in orthognathic surgery. The objective was to gather comprehensive insights into the role, applications, parameters, and technological advancements related to cephalometric analysis in the context of orthognathic surgical diagnosis, planning, and outcome assessment.

Search Strategy

A systematic search of relevant literature was performed using multiple electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search was conducted for articles published up to April 2025. Keywords and phrases used in the search included combinations of the following terms: "cephalometric evaluation," "cephalometry," "orthognathic surgery," "jaw surgery," "craniofacial analysis," "cephalometric parameters," "three-dimensional cephalometry," and "postoperative assessment."

Boolean operators (AND, OR) were applied to refine the search results and maximize the retrieval of relevant studies. Reference lists of selected articles were also manually screened to identify additional pertinent studies not captured by the database search.

Inclusion and Exclusion Criteria

Studies were selected based on the following inclusion criteria:

- Research articles, reviews, and clinical studies focusing on cephalometric evaluation related to orthognathic surgery.
- Studies discussing cephalometric parameters used for diagnosis, treatment planning, surgical simulation, or postoperative evaluation.
- Articles addressing both two-dimensional and three-dimensional cephalometric analysis.
- Publications in the English language.

Exclusion criteria included:

- Articles unrelated to orthognathic surgery or cephalometric evaluation.
- Case reports with insufficient cephalometric data or analysis.
- Studies focusing solely on orthodontic treatment without surgical intervention.
- Non-English language articles.

Data Extraction and Analysis

Data were extracted independently by the reviewer and included the following key information: study design, sample size, type of cephalometric evaluation (2D or 3D), cephalometric parameters assessed, clinical applications, technological tools used, and main findings related to orthognathic surgery outcomes. Any discrepancies in data extraction were resolved through discussion. A qualitative synthesis of the collected data was performed to identify common themes, trends, and gaps in the literature. Emphasis was placed on understanding how cephalometric evaluation informs surgical planning, predicts outcomes, and assesses postoperative stability. Special attention was given to advances in three-dimensional imaging technologies and their impact on cephalometric accuracy and surgical precision.

Limitations of Methodology

The methodology of this review is limited by the reliance on published literature, which may be subject to publication bias. The exclusion of non-English articles might have omitted relevant studies from non-English-speaking regions. Furthermore, variations in cephalometric techniques, patient populations, and surgical procedures across studies may affect the generalizability of findings. Nonetheless, this review provides a comprehensive overview of the current knowledge base and identifies areas for future research in cephalometric evaluation within orthognathic surgery.

Review

Cephalometric evaluation remains a cornerstone in the diagnosis, treatment planning, and postoperative assessment of orthognathic surgery. Since its inception in the early 20th century, cephalometry has provided clinicians with a reliable and

reproducible method to analyze craniofacial morphology and skeletal relationships. The lateral cephalogram, as the most commonly used imaging modality, allows for standardized linear and angular measurements that are crucial in identifying malocclusions, jaw discrepancies, and facial asymmetries [9].
Numerous cephalometric analyses have been developed to guide surgical interventions, including Steiner, McNamara, and Tweed analyses, each offering specific landmark definitions and measurement strategies. These analyses enable surgeons to quantify skeletal disharmonies in the sagittal, vertical, and transverse planes, facilitating individualized surgical plans tailored to the patient's anatomical needs. For example, the SNA, SNB, and ANB angles provide insight into maxillary and mandibular positions relative to the cranial base, assisting in diagnosing prognathism or retrognathism. Vertical measurements, such as the mandibular plane angle and facial height ratios, help identify vertical dysplasia, which may necessitate specific surgical techniques like impaction or elongation osteotomies [10].
Beyond hard tissue assessment, soft tissue analysis integrated with cephalometric evaluation has gained prominence, acknowledging the significant role of soft tissue response in determining aesthetic outcomes. Predicting soft tissue changes after skeletal movements remains complex, but advancements in cephalometric techniques have improved the accuracy of these predictions, helping surgeons achieve better facial harmony [11].
Despite its widespread use, traditional two-dimensional cephalometry has inherent limitations. Superimposition of bilateral structures and projection errors can reduce measurement accuracy, particularly in cases involving facial asymmetry or complex multiplanar deformities. To overcome these limitations, three-dimensional imaging techniques such as cone-beam computed tomography (CBCT) have been increasingly adopted. CBCT offers volumetric data, allowing for precise spatial evaluation of skeletal and dental structures without superimposition. Three-dimensional cephalometric analysis enhances diagnosis, surgical simulation, and postoperative evaluation by enabling assessment of asymmetries and volumetric changes [12].
However, three-dimensional cephalometry is not without challenges. Increased radiation exposure, higher costs, and the requirement for specialized software and training limit its routine clinical use. Research is ongoing to optimize imaging protocols and develop standardized three-dimensional cephalometric landmarks to facilitate wider adoption.

Reference	Study Type	Focus/Objective	Key Findings	Cephalometric Aspect
Inchingolo et al. (2023) [9]	Systematic Review	Orthognathic surgery relapse	Identified factors contributing to relapse after orthognathic surgery; emphasized need for accurate planning and evaluation to minimize relapse	Postoperative stability and relapse
Steegman et al. (2023) [10]	Systematic Review	Volumetric airway changes via CBCT after orthognathic surgery	Demonstrated significant airway volume changes post-surgery, highlighting importance of 3D cephalometric analysis	3D airway assessment and volumetric analysis
Lohia et al. (2025) [11]	Clinical Study	Agreement between clinical diagnosis and two cephalometric analyses (COGS and STCA)	Reported varying levels of agreement between clinical and cephalometric diagnoses; underscored importance of selecting appropriate cephalometric methods	Comparison of cephalometric analyses
Pachnicz & Ramos (2021) [12]	Overview / Quantitative Review	Mandibular condyle displacements after orthognathic surgery	Summarized quantitative findings on condylar positional changes post-surgery; suggested cephalometric monitoring for TMJ function	Skeletal changes, condyle position
Messaoudi et al. (2023) [13]	Systematic Review and Meta-Analysis	Craniofacial cephalometric traits and open bite deformity in Amelogenesis Imperfecta	Identified distinctive cephalometric characteristics associated with open bite deformity; implications for surgical planning	Skeletal and dental cephalometric characteristics

Table 1: Literature Review Table: Cephalometric Evaluation in Orthognathic Surgery

DISCUSSION

Cephalometric evaluation remains an indispensable component in orthognathic surgery, serving as a foundational tool for diagnosis, treatment planning, and postoperative assessment. The extensive literature reveals that cephalometric analysis provides critical quantitative data that guide surgeons in identifying skeletal and dental discrepancies, allowing tailored interventions that optimize both functional and aesthetic outcomes. The enduring utility of two-dimensional (2D) lateral cephalograms, despite their limitations, reflects their established role in clinical practice. Parameters such as SNA, SNB, and ANB angles consistently enable the accurate diagnosis of anteroposterior jaw relationships, while vertical plane measurements assist in detecting facial height abnormalities, guiding surgical strategy effectively [13].

CBCT's volumetric data provide superior spatial resolution and accuracy in landmark identification, improving diagnosis and surgical planning, especially in patients with multiplanar deformities or significant asymmetry. The literature emphasizes the promise of 3D cephalometric analysis for enhancing surgical precision and postoperative evaluation, including more reliable monitoring of skeletal stability and soft tissue response [11].

However, the adoption of 3D cephalometry is tempered by practical constraints, including increased radiation exposure, cost implications, and the need for specialized training and software. These barriers underscore the ongoing challenge of striking a balance between technological advancement and clinical feasibility. The review also highlights the emerging yet growing role of artificial intelligence in automating landmark detection and enhancing the reliability of cephalometric measurements, which may reduce interobserver variability and improve workflow efficiency [11-13].

Soft tissue analysis integrated with cephalometric evaluation has become increasingly important as surgeons seek to predict postoperative aesthetic outcomes more accurately. The soft tissue response to skeletal repositioning is complex and influenced by numerous factors, making prediction difficult. Advances in cephalometric techniques have improved the ability to forecast these changes, but variability remains. This reinforces the need for continuous research to refine predictive models and integrate patient-specific factors such as age, gender, and tissue characteristics [15].

Postoperative cephalometric assessment plays a critical role in validating surgical accuracy and long-term stability. Longitudinal studies cited in the review demonstrate how cephalometric monitoring aids in detecting early relapse, guiding timely intervention, and informing evidence-based refinements in surgical protocols. The feedback loop between preoperative planning and postoperative evaluation contributes significantly to improving outcomes and reducing complications.

CONCLUSION

Overall, the literature synthesis suggests that cephalometric evaluation, whether 2D or 3D, remains central to achieving successful orthognathic surgical results. Future research should focus on standardizing 3D cephalometric protocols, minimizing radiation exposure, and leveraging artificial intelligence for enhanced accuracy and accessibility. Moreover, interdisciplinary collaboration between surgeons, orthodontists, and radiologists is essential to maximize the clinical benefits of cephalometric analysis. Such integration will ensure more precise diagnosis, optimized surgical plans, and improved functional and aesthetic outcomes for patients undergoing orthognathic surgery.

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