Review Article

# ORTHOGNATHIC SURGERY EFFECT EVALUATION ON FACIAL SYMMETRY USING ARTIFICIAL INTELLIGENCE - SYSTEMATIC REVIEW

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**ABSTRACT**

Artificial intelligence (AI) is getting more popular in the public and healthcare sectors, specifically in dentistry. Therefore, this systematic review seeks to determine the impact of orthognathic surgery on facial symmetry and explore how AI can be employed in evaluating the changes in a human face. The systematic review was carried out adhering to PRISMA guidelines. This systematic review included three studies (two retrospective studies and one proof-of-concept study) that state that AI is an important tool for assessing facial symmetry after surgeries. Deep learning models have great potential to predict, evaluate, and analyse outcomes because subjective factors do not constrain them. It is established that orthognathic surgery improves facial symmetry, and AI is used to plan, predict, and analyze the outcomes of surgeries. Consequently, there is a wide range of applications for AI and this systematic review focused on a narrower area: facial symmetry. Besides, AI needs some control nowadays because there are different AI software, which could have varied capabilities, algorithms, and biases.

**Key words:** Artificial intelligence, Orthognathic surgery, Facial symmetry, Systematic.

## Introduction

Artificial intelligence (AI) is getting more popular in the public and healthcare sectors, specifically dentistry [1]. Dentistry includes various fields like health, function, beauty, and facial symmetry, which could be evaluated by AI [2].

Beauty is subjective, meaning it can be understood and appreciated differently beyond physical appearance. Often, beauty is linked to facial attractiveness [2]. However, these standards are not universally agreed upon. The majority states that the human face is more attractive when symmetrical. Artificial intelligence has been specifically trained to recognize and analyze patterns in human facial features, enabling it to assess and measure facial symmetry with remarkable precision. By leveraging advanced algorithms, AI systems can identify subtle discrepancies and variations that might be challenging for the human eye to detect. This capability allows for a rapid and objective evaluation process, bypassing the subjectivity inherent in human judgment. The integration of AI in facial analysis not only ensures consistency in symmetry assessments but also provides a standardized approach that can be applied across diverse populations and clinical scenarios. These qualities make AI a valuable tool in fields like maxillofacial surgery and aesthetic evaluations, where precise measurements of facial symmetry are essential for achieving desired outcomes. Moreover, the speed and accuracy of AI-driven assessments streamline workflows, saving clinicians time while enhancing the results' overall reliability [3].

The advancement of AI systems offers significant enhancements in evaluating procedural quality and surgical planning. In complex interventions such as orthognathic surgery, precise planning is critical to ensure surgical accuracy, meticulous attention to detail, and reliable prediction of intraoperative processes and outcomes [4]. Preparing for these procedures is inherently time-intensive and requires a high level of focus and expertise from maxillofacial surgeons, which can be challenging under demanding and extended work schedules [5]. AI, as a rapidly evolving technology, has the potential to streamline these preparatory efforts by providing precise, data-driven insights into surgical planning and execution. Additionally, it enables objective assessment of procedural outcomes, thereby improving efficiency and supporting better patient care [6].

Another key benefit of AI is enhancing communication between doctors and patients [3]. AI can provide patients with clear, personalized explanations of upcoming procedures, including step-by-step breakdowns of the process, potential risks, and expected outcomes. By visualising the procedure and its results through simulations or interactive models, patients can assess whether the anticipated outcomes align with their expectations. This empowers them to make informed decisions about proceeding with the treatment and helps ensure they are fully prepared and confident in their choice [7].

Surgical dentistry contains many different and difficult procedures, one of which is orthognathic surgery [8]. A simple classification of this surgery is three types: mandible jaw, maxillae jaw, maxillomandibular, or chin [9]. Furthermore, orthognathic procedures contain statements like Le Fort surgery, which is classified into three groups by fracture place [10].

Furthermore, the procedural steps involved in orthognathic surgery are fundamentally consistent. The maxillofacial surgeon performs osteotomies to reposition the bone structures accurately, stabilising them with fixation devices such as bone plates, screws, and wires [11]. However, the complexity of these operations necessitates exceptional precision and meticulous preoperative planning [12]. Advanced imaging modalities, including X-rays, computed tomography, intraoral scans, and standardised protocol photographs, are integral to this planning process. Consequently, AI plays a pivotal role in enhancing diagnostic accuracy and planning efficiency for orthognathic surgery. Its growing adoption reflects its significant contributions to improving surgical outcomes and streamlining workflows [5, 13].

Orthognathic surgeries are often scheduled by at least two specialists - a maxillofacial surgeon and an orthodontist [10, 11]. Today, two popular opinions exist about which treatment variant – conventional or surgery-first – has more benefits and fewer drawbacks [14]. The traditional opinion contains an understanding that orthodontic treatment is needed before and after orthognathic surgery [10]. This type of treatment is not short, so it is difficult for patients to choose this path, especially when it is hard to foresee prelaminar results [10, 15]. There is a solution to this problem—AI—which offers the capability to predict treatment outcomes and assess facial attractiveness with a high degree of precision after undergoing the extended process of traditional orthodontic and orthognathic interventions [15]. By leveraging advanced algorithms and data-driven models, AI can simulate post-treatment results, providing patients with a visual representation of potential changes in facial symmetry and aesthetics. This predictive capability not only addresses the uncertainty associated with lengthy treatment plans but also empowers patients to make informed decisions with greater confidence. Additionally, AI facilitates personalised treatment planning by integrating individual anatomical data, thereby enhancing both patient satisfaction and clinical efficiency.

This systematic review seeks to determine the impact of orthognathic surgery on facial symmetry and explore how AI could be used to evaluate the changes in a human face [16, 17].

## Materials and Methods

The protocol for this systematic review was registered as PROSPERO CRD42024593688.

*Search strategy*

An electronic search of articles published between 2019 and 2024 was first undertaken in September 2024 in the following databases: PubMed, Google Scholar, and ResearchGate. The search strategies used the terms “orthognathic surgery”, “artificial intelligence”, and “facial symmetry”. The literature search was restricted to articles written in English and did not apply any limitation concerning publication country or status.

The titles of all reports identified through the electronic searches were reviewed independently by two authors. The selection of the publications was carried out in two stages. In the first one, was read only titles and which publications were not relevant to the topic were excluded. In the second stage, selected publications were read fully, analysed, and assigned to the literature review or excluded. If two independent researchers disagreed on including an article, a third researcher had the final judgment [18, 19].

*Selection criteria*

The inclusion criteria included:

- Prospective and retrospective studies;
- Studies include any AI that assessed facial symmetry after orthognathic surgery;
- Studies contain AI together with face symmetry;
- Studies under five years old.

*Exclusion criteria*

The exclusion criteria included:

- Reviews;
- Meta-analyses;
- Case reports;
- Case series;
- Publications older than 5 years;
- Studies that did not assess facial symmetry.

*Risk of bias assessment*

The Cochrane Collaboration tool for assessing the risk of bias was used to evaluate the quality of the selected studies [20]. Seven domains, random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other potential threats to validity, were analysed and classified as low risk of bias, some concerns, and high risk of bias **(Figure 2)**.

*Quality assessment*

The studies' quality was assessed using the National Institutes of Health's Quality Assessment Tool [21]. Studies of “good” quality were judged to have at least 7 points, “fair” quality from 4 to 6 points, and “poor” quality from 0 to 3 points **(Table 2)**.

*Definitions*

- Artificial intelligence – the development of computer systems capable of performing tasks that typically require human intelligence [22].

- Orthognathic surgery – the procedure performed to correct dentofacial deformities and malocclusion for adult patients [23].
- Facial symmetry – one of the facial attractiveness traits, refers to a full match in size, position, form, and arrangement of each face component about the sagittal plane [21].

**Results and Discussion**

*Study selection*

The electronic literature search yielded 45 articles, of which 16 were duplicates and were excluded. A total of 29 articles were included in the title and abstract screening. After the eligibility process, 11 articles were obtained, and the full text of the related studies was read. Finally, three articles fulfilled all necessary inclusion criteria in this systematic review **(Figure 1)**.

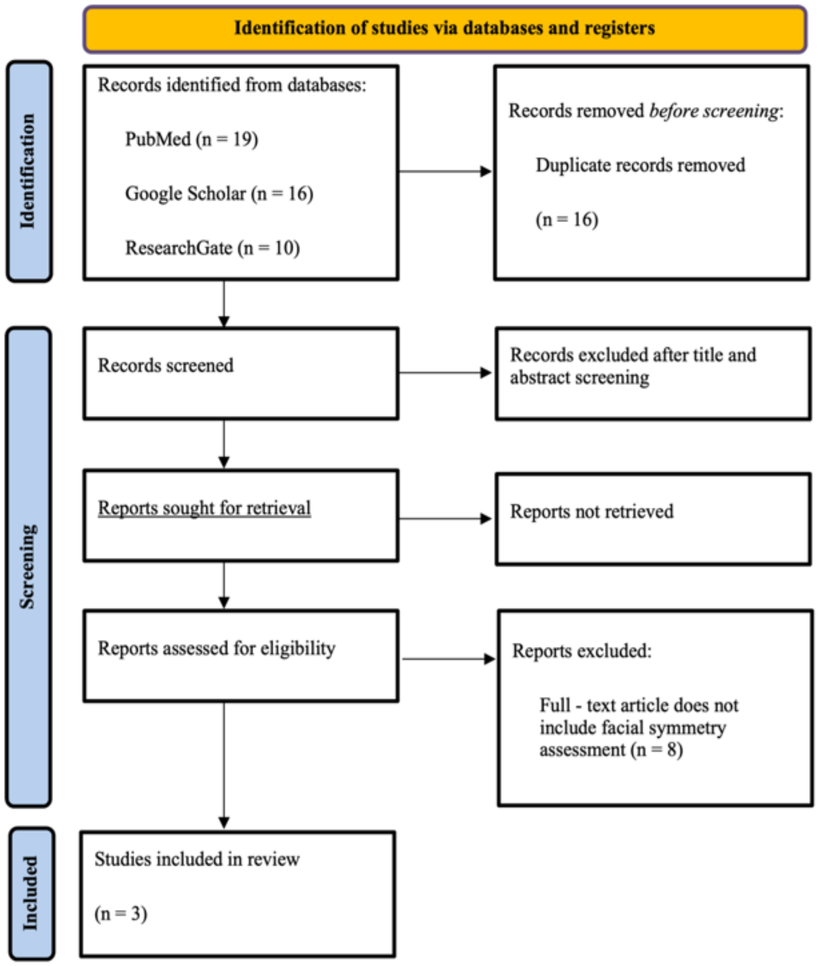



**Figure 1.** PRISMA flow chart

*Study characteristics*

This systematic review included two retrospective studies [3, 5] and one proof-of-concept study [6]. **Table 1** shows all the main characteristics of the included studies.

**Table 1.** Characteristics of included studies.

| **Authors** | **Lo *et al.*** [3] | **Peck *et al.*** [6] | **Choi *et al.*** [5] |
|---|---|---|---|
| **Year** | 2021 | 2021 | 2022 |
| **Country** | Taiwan | USA | South Korea |
| **Methods** | 3D facial photographs were captured by the 3dMD face system before and at least 6 months after surgery. 3D images were extracted and assessed of facial symmetry. | The Haystack AI was used to assess the apparent age and attractiveness. | The novel preoperative simulation process on the dental model was performed to determine the final occlusion without presurgical orthodontic treatment. |

| | | | |
|---|---|---|---|
| **Participants** | 158 patients before and after OGS | A group of 65 orthognathic surgery patients | 33 surgery-first and 26 orthodontics-first patients |
| **Software program** | 3-Matic, MATLAB | Haystack Artificial Intelligence algorithm | RetinaNet |
| **Intervention** | Single-splint 2-jaws OGS, Le Fort I, in conjunction with a bilateral sagittal split osteotomy with or without genioplasty | - | Two-jaw surgery |
| **Outcomes** | The average degree of improvement in facial symmetry after surgery was 21% | In comparison to humans, the AI algorithm provided higher overall attractiveness scores in both pre-and post-operative | The surgery-first approach yielded results like those of the traditional approach in correcting facial asymmetry |
| **Test of significance** | A paired-sample t-test was used to compare preoperative and postoperative facial symmetries. P values of <0,05 were considered to indicate statistical significance | Paired t-tests and Pearson's correlations were used to compare pre-and post-operative age and attractiveness scores across the Haystack and human rater groups. | The independent t-test and chi-square test |

All three included studies met the 7-point limit of quality assessment and were rated as "good" **(Table 2)**.

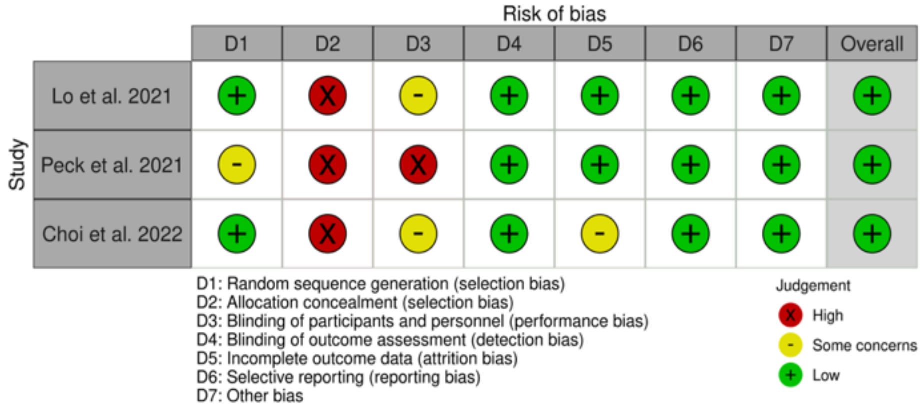
**Table 2.** Quality assessment of included studies.

| **Authors** / **Criteria** | **Lo *et al.*** [3] | **Peck *et al.*** [6] | **Choi *et al.*** [5] |
|---|---|---|---|
| **Study question** | + | + | + |
| **Eligibility criteria and study population** | + | + | + |
| **Study participants are representative of the clinical population of interest.** | + | - | - |
| **All eligible participants enrolled.** | + | + | + |
| **Sample size** | + | + | + |
| **Intervention clearly described** | - | + | + |
| **Outcomes measures are clearly described, valid, and reliable.** | + | + | + |
| **Blinding of outcome assessors** | - | - | - |
| **Follow up rate** | + | - | - |
| **Statistical analysis** | + | + | + |
| **Multiple outcome measures** | + | + | + |
| **Group-level interventions and individual-level outcome efforts** | NA | NA | NA |

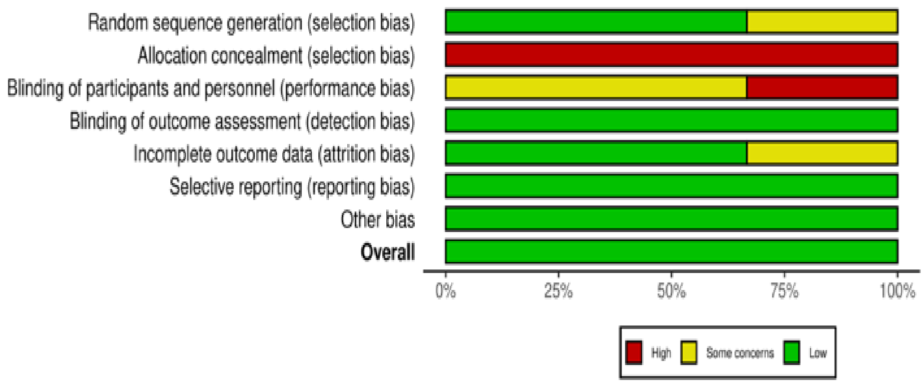
**Symbols: + - corresponds to criteria; - – does not corresponds to criteria; NA – not applicable*

*Risk of bias*

All three included studies were evaluated for the risk of bias using the tools of Cochrane Collaboration **(Figure 2)**. As shown in **Figure 2**, all three studies have some concerns and a high risk of bias in one or two domains. Meanwhile, allocation concealment and blinding of participants and personnel were noted as the highest proportion of high risk of bias. However, overall, all studies were at low risk of bias.




a)




b)

**Figure 2.** Risk of bias assessment of included studies in the review. a) Risk of bias summary; b) Risk of bias graph. Symbols: X – high risk of bias; - – some concerns; + – low risk of bias.

*Results*

A study by Lo *et al*. [3] underscores AI's significant role in enhancing clinical practices and improving patient outcomes, particularly in orthognathic surgery. The researchers developed a web-based system utilising AI to analyse 3D facial images, allowing clinicians to assess facial symmetry more precisely. The system generates detailed symmetry scores, which can be tracked over time to monitor the impact of surgical interventions. The study's findings indicate a remarkable improvement in facial symmetry, with an average enhancement of 21% following surgery (p = 0,00), providing strong statistical evidence of the procedure's effectiveness. This highlights the potential of AI-driven tools to streamline the assessment process and help surgeons make more informed decisions, ensuring more predictable and satisfactory patient outcomes. Integrating AI into surgical planning and post-operative evaluation can improve the accuracy of assessments and the overall quality of care in facial reconstruction and orthognathic surgery.

Peck *et al.* [6] explore both the potential and limitations of integrating AI into aesthetic assessments, particularly in the context of cosmetic and reconstructive surgeries. Traditional methods of evaluating aesthetic outcomes, which rely on ratings from surgeons or laypeople, often suffer from subjectivity, inconsistency, and limited statistical reliability. These human-centered assessments can vary based on individual preferences, biases, or lack of standardised criteria.

In contrast, this study demonstrates that AI can offer a more consistent and quantifiable measure of perceived attractiveness when applied to aesthetic evaluation. The AI system consistently rated patients as more attractive after surgery, pre-and post-operatively, compared to human raters (pre-operative: human raters 4,53, AI 5,42; post-operative: human raters 4,97 and AI 5,78 on a scale of 1-10; p < 0,01). Notably, the AI-generated ratings were consistently higher, indicating that the system might be more lenient or less impacted by subjective biases than human evaluators.

However, the study also reveals a significant limitation: a poor correlation between the attractiveness scores given by AI and those provided by human raters. This discrepancy raises questions about the nature of "attractiveness" and how different evaluators perceive it. While AI can offer a standardised, repeatable approach to aesthetic assessments, its subjective divergence from human perception highlights the complexity of human beauty. It suggests that AI may not fully replicate the nuanced, emotional components that influence human judgment. This finding emphasises the need for further refinement in AI algorithms to better align with human standards of attractiveness or to better understand the inherent differences in AI vs. human-based evaluations of aesthetics.

Ultimately, this study points to the promise of AI as a tool for aesthetic evaluation but also suggests that a balanced approach – where both human expertise and AI insights are integrated – might yield the most reliable and comprehensive results for assessing surgical outcomes.

Choi *et al.* [5] demonstrated a high degree of reliability between AI and plastic surgeons in the context of cephalometric analysis, a crucial component of both orthodontic and orthognathic surgeries. By integrating AI into this process, the study suggests that AI can significantly enhance the accuracy and efficiency of surgical planning, leading to improved patient outcomes. The researchers compared two common approaches for correcting facial asymmetry: the "surgery-first" approach, where surgical intervention is performed before orthodontic treatment, and the "orthodontics-first" approach, which involves correcting the alignment of the teeth before surgery. Between AI and a plastic surgeon, interrater reliability is 0,90.

Interestingly, the AI-based program was able to deliver results that closely mirrored those of the surgeons' evaluations, indicating that AI can effectively assist in planning complex surgeries involving facial skeletal corrections. The program's ability to provide consistent and precise measurements allowed for the identification of the most appropriate treatment plan based on a detailed analysis of the patient's cephalometric data. Furthermore, the AI system showed comparable results for both treatment approaches, suggesting that it can serve as a versatile tool in deciding which method may yield the best outcomes for different patients.

This finding highlights AI's potential to standardise and optimise treatment protocols, reduce human error, and streamline decision-making processes in facial asymmetry correction. It also emphasises the growing role of AI in personalised medicine, where treatment plans can be tailored more accurately to the individual's specific needs, helping to ensure more predictable and successful results. However, while AI shows promise, it is important to note that these tools should complement, rather than replace, the judgment and expertise of experienced clinicians, especially in complex, nuanced cases. The study paves the way for broader applications of AI in improving not only the planning phases but also the surgical execution and post-operative care of patients undergoing orthodontic and orthognathic procedures [24-26].

*Discussion*

This systematic review carried out three studies that state that AI is an important tool for assessing facial symmetry after surgeries. Deep learning models have great potential to predict, evaluate, and analyse outcomes because subjective factors do not constrain them. While all studies were held in different populations – Taiwan, the USA, and South Korea – it did not affect the results: all studies have shown that facial symmetry improved after surgeries, and AI evaluated the differences. However, studies had a different number of patients, in this way, a significant result was in the study with the most participants. This could lead to an opinion that other studies were not so accurate. Nevertheless, all authors stated that orthognathic surgery positively changes facial symmetry, and AI has great potential to evaluate it.

Our findings support the conclusions of previous studies that orthognathic surgery is a commonly accepted treatment that helps with facial symmetry [10]. However, the AI evaluation on this topic is not so common. AI is becoming more and more popular, and it will have an impact on facial symmetry assessment. Today, we only have a few studies that aim to investigate AI input after orthognathic surgery. Several studies have utilised AI to examine outcomes following sagittal split osteotomy and blepharoplasty, as well as to analyse changes in facial morphology and soft tissues after surgical procedures [4, 27-29].

Consequently, there is a wide range of applications for AI. However, this systematic review focused on a narrower area: facial symmetry. In this case, it is rejected as a subjective factor that plays an important role when humans rate facial attractiveness.

Despite its advancements, AI systems exhibit certain limitations. A significant drawback is that most AI software is designed to process images predominantly from a single perspective, such as a frontal view, which complicates the comprehensive assessment of three-dimensional (3D) visuals. While substantial progress has been made in the analysis of hard tissues, the evaluation of soft tissue alterations remains a challenge. The complexity of soft tissue dynamics, influenced by variables such as elasticity, age-related changes, and the interplay with underlying skeletal structures, further exacerbates these limitations. Overcoming these challenges is essential for achieving more precise and holistic assessments in clinical applications.

While we followed rigorous inclusion criteria, we acknowledge several limitations in our review. All studies used different software programs, which could lead to discrepancies in AI assessments. Every program could have a unique code for AI, so its evaluation can be dissimilar. Because of the new technology, there were not many studies that completely matched the inclusion criteria, so only three studies that fit had different numbers of participants. This also could raise doubts about the significance of the results of all studies.

Advancements in dental technology, particularly within the realm of surgical procedures, are continuously evolving and integrating into clinical practice. Artificial intelligence (AI) has demonstrated significant utility in various aspects of dental care, including diagnosis, surgical planning, and preoperative preparation. Moreover, AI holds considerable promise in the post-surgical assessment of facial symmetry, particularly following complex procedures such as orthognathic surgery. Given its ability to analyse intricate patterns and provide data-driven insights, AI presents substantial potential for enhancing the precision and efficiency of aesthetic surgical outcomes. Consequently, the integration of AI into aesthetic surgery is poised to play a pivotal role in shaping the future of dental and maxillofacial interventions, offering improved diagnostic capabilities and optimised treatment planning.

## Conclusion

This systematic review aimed to investigate the impact of orthognathic surgery on facial symmetry and artificial intelligence in assessing it after orthognathic treatment. It is established that orthognathic surgery improves facial symmetry, and AI is used to plan, predict, and analyse the outcomes of surgeries. Besides, it has significant potential to assess facial symmetry, although it needs some control nowadays because there are different AI software, which could have varied capabilities, algorithms, and biases.

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**Ethics statement:** None

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