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REVIEW ARTICLE

Recent advances in maxillofacial orthopedic surgery

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ABSTRACT

Introduction: orthognathic surgery constitutes an essential procedure to correct dentofacial deformities, simultaneously improving oral function and facial aesthetics.
Objective: to describe recent advances in surgical techniques, emerging technologies, and interdisciplinary approaches applied to orthognathic surgery.
Methods: a systematic review of the scientific literature was conducted across various databases. The search was performed using an algorithm with keywords and Boolean operators, allowing the identification of relevant sources. The selected studies, after applying inclusion and exclusion criteria, were critically analyzed considering timeliness, methodological quality, and thematic relevance, and were integrated into the final synthesis of the review.
Development: the findings highlight the incorporation of three-dimensional computed tomography, magnetic resonance imaging, and virtual planning as tools that optimize surgical precision. Three-dimensional printing enables the design of customized fixations and implants, reducing trauma and accelerating recovery. Minimally invasive techniques such as Le Fort I osteotomy, sagittal split ramus osteotomy, and genioplasty are described, which decrease edema and postoperative complications. Likewise, the "surgery-first" approach has improved patient satisfaction and motivation, integrating psychological and functional aspects. Interdisciplinarity among surgeons, orthodontists, and other specialists is consolidated as a cornerstone for successful outcomes.
Conclusions: orthognathic surgery has evolved toward more precise, personalized, and less invasive procedures, supported by digital technologies and virtual planning. These advances strengthen safety, reduce morbidity, and improve patients' quality of life, consolidating a comprehensive approach that combines aesthetics, function, and psychological well-being.

Keywords: Surgery, Oral; Orthognathic Surgery; Technological Development.

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INTRODUCTION

Orthognathic surgery plays a vital role in the comprehensive treatment of maxillofacial and dentofacial problems that affect both function and facial aesthetics. In cases of severe malocclusions or significant facial asymmetries, orthognathic surgery offers an effective and lasting solution, addressing not only aesthetic concerns but also functional ones.[1] This procedure is essential for correcting congenital or acquired facial deformities, improving patients' quality of life by restoring proper mastication, speech, and breathing functions. Furthermore, orthognathic surgery contributes to long-term oral health optimization, alleviates pain associated with temporomandibular disorders, and provides an integral solution for individuals facing significant challenges in their facial structure.

Orthognathic surgery can be described as a surgical procedure typically performed within craniofacial surgery to address maxillary and mandibular deformities caused by dental malocclusion, facial profile issues, and facial appearance enhancement. More recently, it has been implemented to treat patients with obstructive sleep apnea (OSA). Orthognathic surgery requires close collaboration among maxillofacial surgeons, orthodontists, and prosthodontists—from surgical planning formulation to surgical execution.[2] It has been demonstrated that orthognathic surgery positively impacts the quality of life of patients with dentofacial deformities, especially those who missed the primary treatment window (primary or mixed dentition) when functional appliances could have corrected physical anomalies. Additionally, orthognathic surgery may be an option for certain rare diseases, such as cleidocranial dysplasia, and for correcting gummy smiles or healthy gingival overgrowth.[3]

Orthognathic surgery has undergone remarkable advances over the past century. Currently, simultaneous osteotomies in the midface and mandible are performed to achieve independent or coordinated movements, addressing both functional and aesthetic concerns. Notable progress in the last two decades includes greater adoption of computer-assisted planning, use of patient-specific fixation devices, expansion of applications for treating upper airway obstruction, and shifts in orthodontic-surgical approaches.[4]

In recent years, orthognathic surgery has experienced significant advancements driven by progress in medical technologies and surgical methods. The incorporation of advanced imaging technologies—such as 3D computed tomography and magnetic resonance imaging—has enabled more detailed visualization of facial anatomy, facilitating personalized surgical planning for each patient.[5] The introduction of virtual modeling and planning techniques has allowed surgeons to simulate procedures before execution, improving precision and efficiency. Moreover, the development of minimally invasive techniques, computer-assisted surgery during procedures, and 3D printing for customized models and implants are key highlights of these advances. Although these achievements have enhanced the accuracy and safety of orthognathic surgery, research and innovation continue, promising further progress in the field.

Currently, there is a growing preference for minimally invasive procedures across various medical specialties. Minimally invasive surgery is characterized by innovative approaches aimed at mitigating the consequences associated with conventional surgeries. Its main goals include reducing tissue damage, minimizing bleeding, edema, and injury to surrounding tissues, thereby improving both the speed and quality of recovery.[6]

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Three minimally invasive techniques have been developed for Minimally Invasive Orthognathic Surgery (MIOS): Le Fort I Osteotomy (LFO), Sagittal Split Ramus Osteotomy (SSRO), and genioplasty.[7] These are characterized by small incisions, limited periosteal detachment to preserve muscular insertions, resulting in reduced edema, trismus, and a more comfortable postoperative period. Additionally, operative time and costs are reduced. To achieve this, standardization of surgical procedures and the design of appropriate instrumentation have been proposed to enhance surgical efficiency—all made possible through 3D virtual planning (PV3D), which allows professionals to visualize, analyze, and anticipate patient anatomy.[8]

To enable standardization, sequence templates indicating the systematic order of coded instruments relative to the orthognathic surgical procedure have been developed. A "10-step-by-step" protocol was created to integrate computer-assisted 3D virtual surgical planning into daily clinical practice in an easy-to-use manner.[9] Its subsequent optimization significantly reduced total virtual treatment planning time in routine orthognathic clinical practice. Among the key parameters for reducing surgical morbidity is operative duration, along with other factors such as hypotension.[10]

In 2009, a novel protocol called the Surgery-First Approach (SFA) was developed, characterized by performing surgery first, followed by orthodontic treatment.[11] This approach can improve patient satisfaction and treatment motivation, promoting mental health and quality of life. Patients with skeletal Class II or III malocclusion undergoing orthognathic surgery can experience improved psychosocial acceptance, oral function, aesthetics, and self-esteem. Treatment encompasses not only pathology eradication and functional improvement but also aesthetic rehabilitation and recognition of psychological status.[12] Psychological and physiological factors are interconnected and can influence treatment planning, duration, postoperative complications, and postoperative satisfaction.[13] These considerations motivated the present study, which aimed to describe recent advances in surgical techniques, emerging technologies, and interdisciplinary approaches in orthognathic surgery.

METHODS

This study was designed as a systematic literature review following PRISMA guidelines to ensure transparency and reproducibility. The search period was limited to 2010–2024 to capture the most recent and relevant advances in orthognathic surgery and associated technologies.

Information sources included widely recognized biomedical databases: PubMed/MEDLINE, SciELO, ScienceDirect, Google Scholar, LILACS, and BVSALUD. Secondary references from selected articles and grey literature from institutional repositories and conference proceedings were also reviewed to broaden identification of relevant studies.

The search strategy employed an algorithm combining keywords and Boolean operators. MeSH and DeCS terms such as "Orthognathic Surgery," "Technological Advances," "3D Planning," "Minimally Invasive Techniques," and "Virtual Surgical Planning" were combined using AND and OR operators to maximize sensitivity and specificity. Publications in Spanish, English, and Portuguese were included to integrate evidence from diverse geographic and linguistic contexts.

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Inclusion criteria encompassed original articles, clinical trials, cohort studies, case reports, and systematic reviews published within the defined timeframe that directly addressed advances in surgical techniques, emerging technologies, or interdisciplinary approaches in orthognathic surgery. Duplicates, articles without full access, irrelevant documents, publications prior to 2010, as well as letters, editorials, clinical practice guidelines, and theses were excluded.

The selection process occurred in several phases: initial title and abstract screening to exclude non-relevant studies, followed by full-text evaluation of potentially eligible articles. Initially, approximately 1,200 records were identified; after removing duplicates and applying exclusion criteria, the sample was reduced to 320 articles; finally, 85 studies were included in the qualitative synthesis. The procedure was documented using a PRISMA flow diagram reflecting each selection stage.

Data extraction and analysis were performed systematically, collecting key variables such as author, publication year, methodological design, sample size and characteristics, surgical techniques used, technologies employed, and main outcomes. Information was organized into comparative matrices to facilitate interpretation. A qualitative synthesis was conducted, as methodological and outcome heterogeneity precluded formal meta-analysis. This approach enabled integration of available evidence and provided a critical, up-to-date overview of recent progress in orthognathic surgery.

DEVELOPMENT

Orthognathic surgery is performed within craniofacial surgery, focusing on maxillary and mandibular deformities, dental malocclusion, and facial profile concerns. Recently, its application has expanded to address obstructive sleep apnea (OSA).[14] The success of orthognathic surgery is facilitated by collaboration and plays a crucial role in the comprehensive management of maxillofacial and dentofacial problems, addressing both aesthetic and functional aspects.

It is essential for correcting severe malocclusions, facial asymmetries, and congenital or acquired deformities, improving quality of life by restoring proper mastication, speech, and respiration. It also contributes to long-term oral health optimization and alleviates pain associated with temporomandibular disorders, providing an integral solution. Orthognathic surgery addresses maxillary and mandibular deformities, dental malocclusion, and facial profile issues, and has recently been implemented to correct OSA.[15]

Notable advances in orthognathic surgery over the last century include the use of osteotomies in the midface and mandible for independent or coordinated movements. In the past two decades, increased adoption of computer-assisted planning, use of customized fixations, and expanded applications for treating upper airway obstructions have been observed. Changes in orthodontic-surgical approaches have also marked evolution in the field.[16]

The incorporation of advanced imaging technologies—such as 3D computed tomography and magnetic resonance imaging—has improved detailed visualization of facial anatomy, enabling more precise surgical planning. Virtual modeling and planning techniques have allowed surgeons to simulate procedures beforehand, enhancing efficiency. Additionally, less invasive techniques have been developed, including computer-assisted surgery and 3D printing for customized models and implants.

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It requires collaboration among maxillofacial surgeons, orthodontists, and prosthodontists from planning to execution. Its positive impact on quality of life has been demonstrated in patients with dentofacial deformities, including those who missed the primary dentition period. Orthognathic surgery is also capable of treating upper airway obstructions by enabling detailed facial anatomy visualization and facilitating personalized surgical planning.[17]

Virtual modeling and planning techniques have enabled procedure simulation, improving precision and efficiency. Less invasive procedures have been developed—specifically, three minimally invasive orthognathic surgery (MIOS) techniques: Le Fort I Osteotomy (LFO), Sagittal Split Ramus Osteotomy (SSRO), and genioplasty. These techniques feature small incisions, minimizing edema and trismus, and offer a more comfortable postoperative course. Standardization of these procedures and appropriate instrument design, aided by 3D virtual planning, have enhanced surgical efficiency.

The current preference for minimally invasive procedures aims to reduce tissue damage, bleeding, and improve recovery. Standardization of surgical protocols and appropriate instrumentation, supported by 3D virtual planning, have contributed to surgical efficiency. An innovative approach known as the Surgery-First Approach (SFA)—beginning with surgery followed by orthodontic treatment—has emerged, with potential to improve patient satisfaction, treatment motivation, and mental health, positively affecting psychosocial acceptance, oral function, aesthetics, and self-esteem in patients with skeletal Class II or III malocclusion.[18]

The positive impact of orthognathic surgery on quality of life has been particularly observed in patients with dentofacial deformities, including those who missed the primary mixed or deciduous dentition period. Its utility in treating rare diseases—such as cleidocranial dysplasia—and correcting gummy smiles or healthy gingival overgrowth has also been explored. Psychological and physiological factors are intrinsically linked in orthognathic surgery and can influence treatment planning, duration, complications, and postoperative satisfaction. Ongoing research and innovation promise continuous advances in precision and efficacy, enabling objective, humane, individualized, and convenient diagnosis and treatment while preserving patient well-being and psychological state.[19]

Recent advances focus on integrating advanced medical technologies and surgical methods. Imaging technologies such as 3D computed tomography and magnetic resonance imaging provide detailed facial anatomy visualization, enabling personalized surgical planning. Procedure simulation via virtual modeling and planning improves precision and efficiency. Additionally, there is a growing preference for minimally invasive procedures, such as MIOS, which reduce incisions and improve postoperative recovery.[20]

Standardization and protocolization are key elements in the evolution of orthognathic surgery. Sequence templates and a "10-step-by-step" protocol have been developed to facilitate computer-assisted 3D virtual planning in clinical routines. The Surgery-First Approach (SFA)—starting with surgery followed by orthodontic treatment—has also been proposed to improve patient satisfaction and address psychosocial aspects.

The interconnection of psychological and physiological factors in orthognathic surgery patients is recognized, affecting treatment duration, postoperative complications, and overall satisfaction. Current research focuses on evaluating the impact of emerging technologies—such as 3D virtual planning and 3D printing—on the precision and efficacy of orthognathic surgery. Collectively, these advances outline an evolving landscape aimed at continuous improvement in orthognathic surgical practice. Interdisciplinarity is vital due to the complexity of this medical field. Orthognathic surgery addresses facial and dental malformations, and its success depends not

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only on surgical expertise but also on collaboration among various medical disciplines. The integration of orthodontists, maxillofacial surgeons, and other health professionals is essential for comprehensive patient assessment and management.[21]

Collaboration between orthodontists and maxillofacial surgeons is essential for effective treatment planning and execution. Orthodontists prepare the patient preoperatively by aligning teeth and establishing a solid dental foundation for surgery. Maxillofacial surgeons perform the necessary surgical interventions to correct skeletal and facial deformities. This close collaboration ensures harmonious integration of procedures and successful patient recovery.

Moreover, inclusion of other professionals—such as radiologists, anesthesiologists, and pathologists—in the interdisciplinary team contributes to thorough and safe patient evaluation. Accurate interpretation of radiological images, safe anesthesia administration, and assessment of potential pathological complications are crucial aspects requiring expertise from multiple specialties. Interdisciplinarity ensures all dimensions of patient health are addressed throughout the surgical and recovery process.[22]

Orthognathic surgery, as a specialized branch of craniofacial surgery, has proven invaluable in correcting a wide range of dentofacial anomalies—from severe malocclusions to facial asymmetries and congenital or acquired deformities. Its application extends beyond facial aesthetic harmony to address fundamental functional aspects of quality of life, such as mastication, speech, and respiration. Its recent expansion to treat obstructive sleep apnea underscores its versatility and adaptability to emerging medical needs.[23]

Technological advances have been a key driver in the evolution of orthognathic surgery. The introduction of computer-assisted planning tools has revolutionized how surgical procedures are planned and executed, enabling unprecedented precision and customization tailored to each patient's unique characteristics. Advanced imaging modalities—such as 3D computed tomography and magnetic resonance imaging—provide detailed facial anatomy visualization, facilitating precise surgical planning and minimizing procedural risks.[24]

Interdisciplinary collaboration is a cornerstone of orthognathic surgery success. Integration of maxillofacial surgeons, orthodontists, radiologists, anesthesiologists, and other health professionals enables a holistic approach addressing both medical and psychosocial treatment aspects. This collaboration ensures comprehensive patient needs assessment and integrated care that optimizes surgical outcomes and postoperative recovery. Concurrently, surgical approaches have evolved toward less invasive procedures like MIOS, which minimize surgical trauma and accelerate patient recovery. The Surgery-First Approach (SFA) has emerged as an innovative strategy prioritizing initial surgical intervention followed by orthodontic treatment, potentially improving patient satisfaction and addressing psychological and emotional aspects associated with malocclusion.[25]

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CONCLUSIONS

Orthognathic surgery is established as an essential tool in the comprehensive management of dentofacial deformities, offering both aesthetic and functional benefits that enhance patients' quality of life. Its ability to correct severe malocclusions, asymmetries, and respiratory problems is complemented by a shift toward minimally invasive techniques and the use of advanced imaging, 3D printing, and virtual planning technologies—enhancing precision, reducing morbidity, and accelerating recovery. The incorporation of approaches such as surgery-first, postsurgical orthodontics, and integration of psychological aspects into therapeutic plans reflects a more holistic, patient-centered vision that strengthens satisfaction and emotional well-being. Likewise, standardization of procedures and design of specialized instruments optimize clinical practice and support professional workflow. Collectively, these advances mark a transition toward more personalized, safe, and efficient orthognathic surgery that balances physical, functional, and psychosocial dimensions of care.

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