INTERNATIONAL SEVEN JOURNAL
OF MULTIDISCIPLINARY
ISSN: 2764-9547

RECONSTRUCTION OF THE ZYGOMATIC-ORBITAL COMPLEX GUIDED BY ORBITAL VOLUME: A NEW PARADIGM IN THE TREATMENT OF FACIAL FRACTURES

RECONSTRUÇÃO DO COMPLEXO ZIGOMÁTICO-ORBITÁRIO GUIADA POR VOLUME ORBITAL: UM NOVO PARADIGMA NO TRATAMENTO DAS FRATURAS FACIAIS

RECONSTRUCCIÓN DEL COMPLEJO CIGOMÁTICO-ORBITARIO GUIADA POR EL VOLUMEN ORBITAL: UN NUEVO PARADIGMA EN EL TRATAMIENTO DE LAS FRACTURAS FACIALES

https://doi.org/10.56238/isevmjv5n2-011

Receipt of originals: 03/11/2026 **Acceptance for publication:** 03/11/2026

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ABSTRACT

Fractures of the zygomatic-orbital complex (ZOC) represent a significant challenge in oral and maxillofacial surgery due to the anatomical complexity of the orbit and the need for precise functional and aesthetic restoration. Recent evidence demonstrates that alterations in orbital volume are directly associated with postoperative complications, such as enophthalmos and diplopia, making volumetric restoration a critical factor for therapeutic success. In this context, reconstruction guided by orbital volume, based on

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three-dimensional virtual planning, volumetric measurement using computed tomography, and the use of customized implants, emerges as a new paradigm in the treatment of these fractures. This review critically analyzes recent literature on ZOC reconstruction techniques guided by orbital volume, highlighting their foundations, measurement methods, clinical applications, and impact on functional and aesthetic outcomes. The analyzed studies demonstrate greater anatomical precision, improved orbital symmetry, and a significant reduction in ocular sequelae when compared with conventional approaches, consolidating this strategy as an evolution in the management of complex facial fractures.

Keywords: Facial Fractures. Orbital Volume. Virtual Planning. Orbital Reconstruction.

RESUMO

As fraturas do complexo zigomático-orbitário (CZO) constituem um desafio relevante na cirurgia Bucomaxilofacial devido à complexidade anatômica da órbita e à necessidade de restauração funcional e estética precisa. Evidências recentes demonstram que a alteração do volume orbital está diretamente associada a complicações pós-operatórias, como enoftalmia e diplopia, tornando a restauração volumétrica um fator crítico no sucesso terapêutico. Nesse contexto, a reconstrução guiada por volume orbital, baseada em planejamento virtual tridimensional, mensuração volumétrica por tomografia computadorizada e utilização de implantes personalizados, surge como um novo paradigma no tratamento dessas fraturas. Esta revisão analisa criticamente a literatura dos últimos anos acerca das técnicas de reconstrução do CZO guiadas por volume orbital, destacando seus fundamentos, métodos de mensuração, aplicações clínicas e impacto nos desfechos funcionais e estéticos. Os estudos analisados demonstram maior precisão anatômica, melhor simetria orbital e redução significativa de sequelas oculares quando comparados às abordagens convencionais, consolidando essa estratégia como uma evolução no manejo das fraturas faciais complexas.

Palavras-chave: Fraturas Faciais. Volume Orbital. Planejamento Virtual. Reconstrução Orbital.

RESUMEN

Las fracturas del complejo cigomático-orbitario (CCO) constituyen un desafío relevante en la cirugía bucomaxilofacial debido a la complejidad anatómica de la órbita y a la necesidad de una restauración funcional y estética precisa. Evidencias recientes demuestran que la alteración del volumen orbital está directamente asociada con complicaciones postoperatorias, como enoftalmos y diplopía, lo que convierte la restauración volumétrica en un factor crítico para el éxito terapéutico. En este contexto, la reconstrucción guiada por el volumen orbital, basada en planificación virtual tridimensional, medición volumétrica mediante tomografía computarizada y el uso de implantes personalizados, surge como un nuevo paradigma en el tratamiento de estas fracturas. Esta revisión analiza críticamente la literatura reciente sobre las técnicas de reconstrucción del CCO guiadas por volumen orbital, destacando sus fundamentos, métodos de medición, aplicaciones clínicas e impacto en los resultados funcionales y estéticos. Los estudios analizados demuestran una mayor precisión anatómica, mejor simetría orbital y una reducción significativa de secuelas oculares en comparación con los enfoques convencionales, consolidando esta estrategia como una evolución en el manejo de las fracturas faciales complejas.

Palabras clave: Fracturas Faciales. Volumen Orbital. Planificación Virtual. Reconstrucción Orbitaria.

1 INTRODUCTION

Fractures of the zygomatic-orbital complex represent a significant portion of traumas of the middle third of the face and are frequently associated with high-energy mechanisms, such as car accidents, physical aggression, and falls. Due to the anatomical complexity of the zygomatic region and the intimate relationship with the orbital cavity, these fractures are a relevant challenge in craniomaxillofacial surgery, and can simultaneously compromise facial aesthetics and ocular function (LEHTINEN et al., 2022; EBRAHIMI et al., 2019).

Changes in the position of the zygoma and orbital walls can result in important functional sequelae, including enophthalmos, diplopia, limitation of ocular motility, and persistent facial asymmetry. Studies have shown that anatomical reduction of bone fragments alone is not always sufficient to prevent these complications, especially when there is an increase in orbital volume, even in reconstructions considered satisfactory under conventional radiographic evaluation (TAHERNIA et al., 2009; EBRAHIMI et al., 2019).

The literature shows a direct correlation between the increase in orbital volume and the posterior displacement of the eyeball, with enophthalmos being one of the most frequently observed late complications after fractures of the zygomatic-orbital complex. Small volumetric variations are already capable of producing noticeable clinical changes, reinforcing the importance of precise volumetric restoration of the orbit in surgical planning (WI et al., 2017; CHEPURNYI et al., 2020).

Three-dimensional computed tomography has established itself as the method of choice for the evaluation of orbital fractures, allowing not only the detailed analysis of bone structures, but also the objective measurement of orbital volume by means of digital segmentation techniques. The comparison with the unaffected contralateral orbit provides a reliable parameter for surgical planning and for the evaluation of postoperative outcomes (CHEPURNYI et al., 2020; WALKER et al., 2022).

With the advances in digital technologies applied to craniomaxillofacial surgery, tools such as three-dimensional virtual planning, mirroring of the contralateral orbit, and the use of personalized implants have become part of the management of complex orbital fractures. Recent evidence indicates that these approaches provide greater precision in the restoration of orbital volume, better facial symmetry, and significant reduction of ocular

sequelae when compared to conventional techniques (NOVELLI et al., 2014; LEHTINEN et al., 2022; KHALIFA et al., 2025).

Thus, orbital volume-guided reconstruction of the zygomatic-orbital complex emerges as a new paradigm in the treatment of facial fractures, by incorporating objective quantitative parameters and advanced digital technologies into surgical planning. This approach shifts the focus from simple anatomical replacement to functional restoration based on orbital volume normalization, promoting better clinical and aesthetic outcomes and greater therapeutic predictability (SOLIMAN et al., 2025; MENVILLE et al., 2025).

2 METHODOLOGY

The present study is characterized as a narrative review of the literature, of a qualitative and descriptive nature, with the objective of critically analyzing the scientific evidence related to the reconstruction of the zygomatic-orbital complex guided by orbital volume in the treatment of facial fractures.

The bibliographic search was carried out in the PubMed (National Library of Medicine) and SciELO (Scientific Electronic Library Online) databases, as they are recognized as reliable and widely used sources in the health area. Controlled and uncontrolled descriptors were used, combined using the Boolean operators AND and OR, including the terms: *orbital fractures*, *zygomaticomaxillary complex fractures*, *orbital volume*, *orbital reconstruction*, *three-dimensional planning* and *patient-specific implants*, as well as their counterparts in Portuguese.

As inclusion criteria, original articles, observational studies, reviews, and clinical research that addressed the relationship between fractures of the zygomatic-orbital complex, changes in orbital volume, and reconstruction techniques guided by volumetric planning were selected. Priority was given to studies published in the last ten years, in English or Portuguese, with full-text availability and direct clinical relevance to craniomaxillofacial surgery.

Experimental studies in animal models, isolated case reports without volumetric analysis, duplicate publications, articles with unclear methodology or that did not directly address orbital reconstruction associated with fractures of the zygomatic-orbital complex were excluded.

After the search stage, the titles and abstracts were analyzed independently, and studies that met the previously established criteria were selected. Next, the eligible

articles were read in full, with the extraction of relevant information related to the methods of measuring the orbital volume, surgical techniques employed, use of three-dimensional virtual planning, personalized implants, and functional and aesthetic results.

The data obtained were organized in a descriptive and comparative way, allowing the critical analysis of the different therapeutic approaches and the identification of the main evidences that support orbital volume-guided reconstruction as a new paradigm in the treatment of fractures of the zygomatic-orbital complex.

3 RESULTS

The analysis of the selected studies showed consensus regarding the importance of orbital volumetric restoration in the treatment of fractures of the zygomatic-orbital complex. The reviewed studies demonstrate that changes in orbital volume are directly associated with the development of enophthalmos and ocular motility disorders, with volumetric measurement being a determining factor for adequate surgical planning (EBRAHIMI et al., 2019; WI et al., 2017).

Volumetric evaluation methods based on computed tomography with three-dimensional segmentation showed high reproducibility and reliability, especially when compared to the intact contralateral orbit as an anatomical reference (CHEPURNYI et al., 2020; WALKER et al., 2022). Studies indicate that volumetric differences greater than approximately 1.5–2.0 cm^3 are associated with noticeable clinical manifestations, reinforcing the need for a quantitative approach in the management of these fractures (TAHERNIA et al., 2009; EBRAHIMI et al., 2019).

Regarding reconstructive techniques, studies that used three-dimensional virtual planning demonstrated greater accuracy in the restoration of orbital anatomy when compared to conventional approaches. The use of contralateral orbital mirroring allowed the definition of personalized anatomical parameters for each patient, favoring postoperative facial symmetry (NOVELLI et al., 2014; LEHTINEN et al., 2022).

The application of customized titanium implants, made from virtual planning, presented superior clinical results in terms of volumetric restoration and structural stability. Patients undergoing this approach demonstrated a lower incidence of residual enophthalmos and a lower need for surgical reintervention (LEHTINEN et al., 2022; KHALIFA et al., 2025).

In addition, recent studies reinforce that the decision regarding orbital floor reconstruction should consider not only the size of the bone defect, but also the global volumetric analysis of the orbit. This change in criteria represents an evolution in the traditional therapeutic algorithm, by incorporating objective parameters in the surgical indication (SOLIMAN et al., 2025; MENVILLE et al., 2025).

In general, the results of the literature indicate that orbital volume-guided reconstruction provides greater surgical predictability, better anatomical symmetry, and better functional outcomes when compared to techniques based exclusively on visual anatomical reduction.

4 DISCUSSION

The findings of the literature analyzed reinforce that the reconstruction of the zygomatic-orbital complex should not be limited to the anatomical replacement of bone fragments, but rather consider the precise restoration of the orbital volume as a central factor for the functional and aesthetic success of the treatment. Recent studies have shown that relatively small volumetric changes are sufficient to trigger relevant clinical complications, especially post-traumatic enophthalmos, corroborating the need for a quantitative approach in surgical planning (EBRAHIMI et al., 2019; WI et al., 2017).

The direct relationship between increased orbital volume and posterior displacement of the eyeball is widely documented in the literature, and is considered one of the main determinants of late sequelae after fractures of the zygomatic-orbital complex. Volumetric measurement by three-dimensional computed tomography proved to be a reliable and reproducible method, allowing an objective evaluation of the orbital deformity and comparison with the unaffected contralateral orbit, considering the patient's individual anatomical pattern (CHEPURNYI et al., 2020; WALKER et al., 2022).

Studies that used three-dimensional virtual planning and contralateral orbit mirroring techniques demonstrated greater accuracy in orbital reconstruction when compared to conventional approaches. This strategy allows anticipating residual deformities and guiding bone replacement in a more predictable way, reducing postoperative volumetric discrepancies and improving facial symmetry (NOVELLI et al., 2014; LEHTINEN et al., 2022). These findings support the idea that virtual planning should not be seen only as an auxiliary tool, but as a central element in the management of complex orbital fractures.

Another relevant point discussed in the literature concerns the use of personalized implants, especially those made of titanium from individualized three-dimensional models. These implants have demonstrated greater adaptation to orbital walls, structural stability, and precision in restoring orbital volume, resulting in better clinical outcomes and a lower rate of surgical reinterventions (LEHTINEN et al., 2022; KHALIFA et al., 2025). In comparison, standardized implants have greater dependence on surgeon experience and greater variability in final results.

In addition, recent studies question the traditional criteria for indication of orbital floor reconstruction, which historically were based only on the extent of the bone defect. Current evidence suggests that global volumetric analysis of the orbit provides more accurate information for surgical decision-making, allowing for more targeted interventions and avoiding both undertreatment and unnecessary procedures (SOLIMAN et al., 2025; MENVILLE et al., 2025).

Thus, orbital volume-guided reconstruction represents a conceptual change in the treatment of fractures of the zygomatic-orbital complex, by integrating digital technology, objective volumetric analysis, and therapeutic personalization. This approach contributes to greater surgical predictability, reduction of late complications, and better functional and aesthetic outcomes, in line with the current principles of evidence-based surgery.

5 CONCLUSION

The reconstruction of the zygomatic-orbital complex based on the precise restoration of the orbital volume configures a paradigmatic change in the management of fractures of the middle third of the face. The incorporation of volumetric measurement by three-dimensional computed tomography, associated with virtual planning and the use of customized implants, increases surgical precision and reduces the variability of postoperative results.

Scientific evidence shows that the normalization of orbital volume is directly related to the reduction of residual enophthalmos, improvement of ocular function and greater facial symmetry, determinant aspects for the functional and aesthetic success of the treatment. In this context, volumetric evaluation is no longer complementary and becomes part of the decision-making core of surgical planning.

Although the application of these technologies requires specialized infrastructure and greater initial investment, the clinical benefits observed suggest that orbital volume-

guided reconstruction tends to consolidate itself as the approach of choice in complex orbital fractures, promoting greater therapeutic predictability and alignment with contemporary principles of evidence-based surgery.

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