

SURGICAL MANAGEMENT OF BLOW-OUT FRACTURES: PROTOCOLS AND RECONSTRUCTIVE TECHNIQUES

MANEJO CIRÚRGICO DAS FRATURAS BLOW-OUT: PROTOCOLOS E TÉCNICAS RECONSTRUTIVA

MANEJO QUIRÚRGICO DE LAS FRACTURAS POR ESTALLIDO: PROTOCOLOS Y TÉCNICAS RECONSTRUCTIVAS



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ABSTRACT

The surgical management of blow-out fractures represents a constant challenge in maxillofacial and ophthalmologic surgery due to the anatomical complexity of the orbit and the need for simultaneous restoration of both function and facial aesthetics. This study aimed to review and critically analyze the scientific evidence published between 2015 and 2025 regarding surgical protocols and reconstructive techniques employed in the treatment of these fractures. It is an integrative narrative review of the literature, conducted in the PubMed, SciELO, and ScienceDirect databases, using combined descriptors in Portuguese and English related to “orbital floor fracture,” “blow-out fracture,” “reconstruction,” and “surgical management.” Fourteen articles meeting the eligibility criteria were included, encompassing clinical studies, reviews, and case reports. The results were organized into five thematic axes: surgical indication criteria, reconstructive approaches, materials used, clinical-functional outcomes, and technological innovations. A consensus was observed regarding the surgical indications—enophthalmos greater than 2 mm, persistent diplopia, and muscle entrapment—as well as a tendency toward minimally invasive approaches, particularly the transconjunctival and endoscopic endonasal accesses. Regarding materials, titanium meshes remain the gold standard due to their strength and biocompatibility; however, alternative materials such as porous polyethylene, PMMA, and PEEK have shown favorable results, especially when combined with virtual planning and CAD/CAM technology. It is concluded that the surgical management of blow-out fractures has evolved significantly over the past decade, driven by advances in biomaterials and digital technologies applied to orbital reconstruction. Nevertheless, there is still no consensus on universal protocols, highlighting the need for multicenter studies and systematic reviews to establish clinical guidelines based on robust scientific evidence.

Keywords: Orbital Fracture. Surgical Reconstruction. Biocompatible Materials. Three-Dimensional Planning. CAD/CAM.

RESUMO

O manejo cirúrgico das fraturas blow-out representa um desafio constante na cirurgia bucomaxilofacial e oftalmológica, devido à complexidade anatômica da órbita e à necessidade de restauração simultânea da função e da estética facial. Este estudo teve como objetivo revisar e analisar criticamente as evidências científicas publicadas entre 2015 e 2025 acerca dos protocolos cirúrgicos e das técnicas reconstrutivas empregadas no tratamento dessas fraturas. Trata-se de uma revisão narrativa integrativa da literatura, realizada nas bases de dados PubMed, SciELO e ScienceDirect, utilizando descritores combinados em português e inglês relacionados a “orbital floor fracture”, “blow-out fracture”,

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“reconstruction” e “surgical management”. Foram incluídos 14 artigos que atenderam aos critérios de elegibilidade, abrangendo estudos clínicos, revisões e relatos de caso. Os resultados foram organizados em cinco eixos temáticos: critérios de indicação cirúrgica, abordagens reconstrutivas, materiais empregados, resultados clínico-funcionais e inovações tecnológicas. Observou-se consenso quanto às indicações cirúrgicas, enoftalmia superior a 2 mm, diplopia persistente e aprisionamento muscular, bem como tendência ao uso de abordagens minimamente invasivas, especialmente o acesso transconjuntival e o endoscópico endonasal. Em relação aos materiais, as malhas de titânio permanecem como padrão ouro, mas materiais alternativos, como o polietileno poroso, o PMMA e o PEEK, têm mostrado bons resultados, sobretudo quando associados ao planejamento virtual e à tecnologia CAD/CAM. Conclui-se que o manejo cirúrgico das fraturas blow-out evoluiu significativamente na última década, impulsionado pelo avanço dos biomateriais e das tecnologias digitais aplicadas à reconstrução orbitária. No entanto, ainda não há consenso sobre protocolos universais, sendo necessária a realização de estudos multicêntricos e revisões sistemáticas que consolidem diretrizes clínicas baseadas em evidências robustas.

Palavras-chave: Fratura Orbitária. Reconstrução Cirúrgica. Materiais Biocompatíveis. Planejamento Tridimensional. CAD/CAM.

RESUMEN

El manejo quirúrgico de las fracturas por estallido representa un desafío constante en la cirugía maxilofacial y oftalmológica, debido a la complejidad anatómica de la órbita y a la necesidad de restaurar simultáneamente la función y la estética facial. Este estudio tuvo como objetivo revisar y analizar críticamente la evidencia científica publicada entre 2015 y 2025 sobre los protocolos quirúrgicos y las técnicas reconstructivas utilizadas en el tratamiento de estas fracturas. Se trata de una revisión narrativa integradora de la literatura, realizada en las bases de datos PubMed, SciELO y ScienceDirect, utilizando descriptores combinados en portugués e inglés relacionados con "fractura del suelo orbitario", "fractura por estallido", "reconstrucción" y "manejo quirúrgico". Se incluyeron catorce artículos que cumplieron con los criterios de elegibilidad, incluyendo estudios clínicos, revisiones e informes de casos. Los resultados se organizaron en cinco ejes temáticos: criterios de indicación quirúrgica, abordajes reconstructivos, materiales utilizados, resultados clínico-funcionales e innovaciones tecnológicas. Se observó consenso respecto a las indicaciones quirúrgicas: enoftalmos mayor de 2 mm, diplopía persistente y atrapamiento muscular, así como una tendencia hacia el uso de abordajes mínimamente invasivos, especialmente los abordajes transconjuntivales y endoscópicos endonasaes. En cuanto a los materiales, las mallas de titanio siguen siendo el estándar de oro, pero materiales alternativos como el polietileno poroso, el PMMA y el PEEK han mostrado buenos resultados, especialmente al combinarse con planificación virtual y tecnología CAD/CAM. Se concluye que el manejo quirúrgico de las fracturas por estallido ha evolucionado significativamente en la última década, impulsado por los avances en biomateriales y tecnologías digitales aplicadas a la reconstrucción orbitaria. Sin embargo, aún no existe consenso sobre protocolos universales, y se necesitan estudios multicéntricos y revisiones sistemáticas para consolidar guías clínicas basadas en evidencia sólida.

Palabras clave: Fractura Orbitaria. Reconstrucción Quirúrgica. Materiales Biocompatibles. Planificación Tridimensional. CAD/CAM.

1 INTRODUCTION

Orbital floor fractures, known as *blow-out fractures*, constitute one of the most prevalent types of facial trauma, representing about 10% to 25% of all facial fractures, with a direct impact on orbital contour and function (FERNANDES et al., 2020). These lesions result from blunt trauma to the periorbital region, which may cause soft tissue herniation, enophthalmos, diplopia, and restriction of eye movements. Such alterations require a precise surgical approach, aimed at anatomical and functional restoration of the orbit. Due to the anatomical complexity of the region and the variability of fracture patterns, the management of these injuries requires well-defined and standardized surgical protocols (VIEIRA; SOUSA; SOUZA, 2021).

In view of this complexity, the definition of the moment and the appropriate surgical technique has become one of the main challenges in the management of orbital fractures. Treatment is indicated in cases of enophthalmos greater than 2 mm, persistent diplopia, muscle entrapment, and involvement of more than 50% of the orbital floor, according to widely accepted clinical and radiographic criteria (FERNANDES et al., 2020). In recent decades, reconstructive approaches have evolved significantly, with emphasis on transconjunctival access and the use of endoscopic techniques, which provide better aesthetics, lower morbidity, and satisfactory functional results (TISSOT et al., 2024).

The materials used in orbital reconstruction play a decisive role in surgical success. Titanium meshes and plates remain the gold standard due to their strength and biocompatibility, while alternative materials such as porous polyethylene, polymethylmethacrylate (PMMA) and polyetheretherketone (PEEK) have been widely studied for their adaptability and lower cost (SANTOS; GONTIJO; LEITE, 2024). At the same time, the incorporation of biotechnology and three-dimensional (3D) virtual planning has revolutionized the reconstructive field, allowing accurate preoperative simulations, reduced surgical time, and better predictability of results, especially in complex cases of orbital trauma (HELGER et al., 2025).

In addition to technological advances, recent literature shows efforts to standardize surgical protocols with a focus on reducing postoperative complications and improving aesthetic outcomes (FERNANDES et al., 2020; TISSOT et al., 2024). Among the emerging techniques, the use of the cheek fat pad stands out, an effective biological alternative for filling and sustaining the orbital content, with a low complication rate and positive functional results (FERNANDES et al., 2020). These innovations demonstrate the importance of surgeons constantly updating new approaches, materials, and guidelines that optimize aesthetic and functional rehabilitation.

Despite the technical advances and available materials, there is still no consensus in the literature regarding the ideal criteria for surgical indication, the choice of biomaterials, and the standardization of reconstructive protocols. This gap highlights the need for reviews that gather and critically analyze recent knowledge on the subject. Thus, the present study aims to review and discuss, in light of the evidence published between 2015 and 2025, the main protocols and reconstructive techniques applied to the surgical management of *blow-out* fractures, highlighting materials used, surgical approaches, and technological innovations (FERNANDES et al., 2020; SANTOS; GONTIJO; LEITE, 2024; TISSOT et al., 2024).

2 METHODOLOGY

This study is an **integrative narrative review of the literature**, whose objective was to gather, analyze and critically discuss the scientific evidence on the surgical management of *blow-out fractures*, with emphasis on the **reconstructive protocols and techniques** used in the last ten years. This type of review was chosen because it allows the integration of research results with different methodological designs, enabling a broad, up-to-date, and critical view of the theme (MENDES; SILVEIRA; GALVÃO, 2019).

The **bibliographic search** was carried out between **November 2025 and January 2026**, in the following electronic databases: **PubMed (US National Library of Medicine)**, **SciELO (Scientific Electronic Library Online)** and **ScienceDirect (Elsevier)**. These databases were selected for their wide coverage of national and international scientific journals in the area of **oral and maxillofacial surgery, ophthalmology and facial traumatology**, ensuring the scope and quality of the sources consulted.

The **descriptors** used were selected from the **Health Sciences Descriptors (DeCS)** and the **Medical Subject Headings (MeSH)**, in Portuguese and English, combined by the Boolean operators **AND** and **OR**, in order to optimize the sensitivity and specificity of the search. The combinations applied were:

- "orbital floor fracture" **AND** "surgical management";
- "blow-out fracture" **AND** "reconstruction";
- "orbital reconstruction" **AND** "titanium mesh" **OR** "polyethylene";
- "orbital fracture" **AND** "surgical approach" **AND** "transconjunctival".

The following **inclusion criteria were adopted**: a) original scientific articles, narrative, integrative or systematic reviews; b) studies published between **2015 and 2025**; c) texts available in **Portuguese, English or Spanish**; d) publications that addressed, directly or

indirectly, surgical management, reconstructive materials or treatment protocols for *blow-out fractures*.

The following were **excluded**: duplicate papers, simple conference abstracts, letters to the editor, *in vitro experimental studies*, and articles that did not have a direct relationship with orbital reconstruction.

The initial search resulted in a total of **138 scientific articles**. After reading the titles and abstracts, **84 were excluded** because they did not meet the inclusion criteria. Of the **54 eligible articles**, **26** were read in full, and **14 studies** fully met the criteria and made up the final sample analyzed. The article selection process followed four stages: (1) initial search in the databases; (2) removal of duplicates; (3) screening of titles and abstracts; and (4) full reading for final inclusion. This selection flow was adapted from the **PRISMA 2020 model**, ensuring transparency and reproducibility of the process.

Data **extraction** was performed independently by two reviewers, with the objective of reducing biases and ensuring the reliability of the information. In case of divergence, consensus was reached by discussion among the researchers. The information of each selected article was systematized in a **spreadsheet prepared in Microsoft Excel®**, containing the following fields: author, year, country of publication, type of study, surgical approach, reconstructive material used, complications observed, and main clinical results reported.

Data **analysis** was conducted in a **qualitative, descriptive and thematic** way, identifying emerging categories from the full reading of the texts. The main categories defined were: (1) criteria for surgical indication; (2) reconstructive approaches; (3) materials used; (4) clinical-functional results; and (5) applied technological innovations. This categorization made it possible to organize the findings according to the frequency and relevance of the topics addressed in the studies.

The **levels of scientific evidence** of the included articles were evaluated according to the classification proposed by **the Oxford Centre for Evidence-Based Medicine (OCEBM, 2011)**, ranging from levels 1 to 4, corresponding to systematic reviews, observational studies, and case series.

Finally, the results of this review were organized and presented in a **descriptive** manner, following the defined thematic axes, in order to allow a critical synthesis of the advances, protocols, and reconstructive techniques applied to the surgical management of *blow-out fractures*.

3 RESULTS AND DISCUSSION

The analysis of the selected studies allowed the identification of five main thematic axes related to the surgical management of blow-out fractures: (1) criteria for surgical indication; (2) reconstructive approaches; (3) materials used; (4) clinical-functional results; and (5) applied technological innovations. In total, 14 scientific articles were included and analyzed qualitatively, covering clinical studies, case reports, systematic reviews, and narratives. Of these, five addressed criteria for surgical indication, four discussed reconstructive approaches, seven described materials used, six evaluated clinical-functional outcomes, and three emphasized technological innovations. Some studies presented thematic overlap, being classified in more than one axis of analysis.

3.1 SURGICAL INDICATION CRITERIA

The criteria for surgical indication in *blow-out* fractures remain widely discussed, but the literature converges on the need for intervention in cases of **enophthalmos greater than 2 mm, persistent diplopia, muscle entrapment, and involvement of more than 50% of the orbital floor** (FERNANDES et al., 2020; VIEIRA; SOUSA; SOUZA, 2021). Recent studies suggest that the **optimal time for surgery is up to two weeks after trauma**, reducing the risk of fibrosis and maximizing functional recovery (KIM et al., 2021).

However, there are divergences regarding the ideal surgical time. While Fernandes et al. (2020) and Vieira, Sousa and Souza (2021) advocate the early approach, **Kim et al. (2021)** demonstrate that delayed repair, performed up to 30 days after trauma, can present **comparable results**, as long as there is no muscle entrapment. In addition, **three-dimensional computed tomography** has been consolidated as a fundamental tool for diagnosis and preoperative planning, allowing better identification of fracture extension and pattern (HELGER et al., 2025).

3.2 RECONSTRUCTIVE APPROACHES

The surgical approaches employed in orbital reconstruction vary depending on the fracture pattern and the surgeon's experience. The **transconjunctival approach** is the most reported in the recent literature, as it allows wide exposure of the medial wall and the orbital floor, associated with a low rate of aesthetic complications (SANTOS; GONTIJO; LEITE, 2024). The **subciliary approach**, although effective, has been progressively replaced due to the higher incidence of eyelid retraction and visible scarring (TISSOT et al., 2024).

Endoscopic **endonasal access**, described in international publications, has been successfully applied to isolated fractures of the orbital floor, offering lower morbidity, reduced

surgical time, and faster postoperative recovery (KIM et al., 2021; CHEN et al., 2022). International reviews, such as the one by **Lee et al. (2023)**, indicate that the endoscopic approach presents results equivalent to open approaches when applied to limited fractures, but with significant aesthetic advantage.

These findings demonstrate a worldwide trend towards **less invasive and more precise techniques**, reinforcing the importance of **individualized planning** according to the morphology of the fracture and the clinical characteristics of the patient.

3.3 RECONSTRUCTIVE MATERIALS

Orbital floor reconstruction requires the use of materials that provide **structural stability, biocompatibility, and precise restoration of orbital volume**. Titanium **meshes and plates** continue to be widely used, due to their mechanical resistance and excellent tissue integration (TISSOT et al., 2024). However, **polymeric and biocompatible materials**, such as **porous polyethylene, polymethylmethacrylate (PMMA)** and **polyetheretherketone (PEEK)**, have gained ground because they combine good anatomical adaptation at a lower cost (SANTOS; GONTIJO; LEITE, 2024).

Comparative studies show that **PEEK** and **PMMA**, when molded by **CAD/CAM technology** and printed in **3D models**, offer reconstructions with high anatomical accuracy and aesthetic results similar to titanium (HELGER et al., 2025; LEE et al., 2023). The use of **autogenous materials**, such as the **cheek fat body (Bichat's fat pad)**, is also reported as an effective and low-cost alternative for filling and orbital support in minor fractures (FERNANDES et al., 2020).

Although synthetic biomaterials have advantages in durability and modeling, autogenous biomaterials are still preferred in contexts of greater economic limitation, especially in public reference centers.

3.4 CLINICAL-FUNCTIONAL RESULTS

Most of the studies analyzed report **significant improvement in ocular motility, resolution of diplopia, and correction of enophthalmos** after orbital reconstruction (FERNANDES et al., 2020; KIM et al., 2021). The most observed complications are **volumetric undercorrection, eye movement restriction, and eyelid asymmetry**, although in an incidence of less than 10% (VIEIRA; SOUSA; SOUZA, 2021).

Recent research shows that **early surgery associated with the use of personalized implants** significantly improves functional outcome and reduces complication rates (HELGER et al., 2025). In general, the literature highlights that aesthetic and functional

rehabilitation strongly depends on precise **three-dimensional planning** and the **appropriate selection of reconstructive material**.

3.5 TECHNOLOGICAL INNOVATIONS AND FUTURE PROSPECTS

Technological advances have revolutionized the surgical management of orbital fractures. Tools such as **3D virtual planning**, the use of **custom biomodels**, and **computerized surgical navigation** provide greater predictability and accuracy (HELGER et al., 2025).

International studies reinforce that the use of **customized titanium or PEEK implants**, digitally designed, reduces surgical time, improves anatomical fit, and minimizes reconstruction failures (LEE et al., 2023; CHEN et al., 2022). However, **high costs**, **prolonged production time**, and **the need for specialized training** are still pointed out as barriers to wide application in developing countries (SANTOS; GONTIJO; LEITE, 2024).

These innovations reflect the growing integration between **reconstructive surgery and biomedical engineering**, ushering in a new era of personalized treatments for *blow-out fractures*, with **safer and more predictable results**.

3.6 INTERPRETATIVE SYNTHESIS AND LIMITATIONS OF THE STUDIES

The integrated analysis of the reviewed studies demonstrates that, despite technological advances and the variety of materials available, **there is still no universal consensus** on the best orbital reconstruction protocol. Therapeutic decisions remain highly dependent on the **surgeon's experience**, the **patient's clinical conditions**, and the **availability of technological resources**.

However, the present review identified recurrent methodological limitations in the studies analyzed, such as **small sample sizes**, **lack of standardization of functional assessment methods**, and **predominance of observational designs**. Such factors restrict the generalization of results and reinforce the need for **multicenter clinical trials and systematic reviews with meta-analysis** to define protocols based on robust evidence.

These findings meet the objective proposed in this review, by synthesizing the **main protocols, reconstructive techniques, and materials used** in the surgical management of *blow-out fractures* in the last ten years, contributing to the **consolidation of evidence-based approaches** and to the improvement of contemporary clinical practice.

Thus, the evidence gathered indicates significant advances in reconstructive precision and in the use of biomaterials, but highlights the need for **standardization of clinical**

guidelines that guide the treatment of orbital fractures based on uniform technical and functional parameters.

4 CONCLUSION

The present integrative narrative review of the literature allowed us to gather and critically analyze the scientific evidence published between 2015 and 2025 on the surgical management of *blow-out* fractures, with emphasis on the protocols, reconstructive techniques, and materials used. The findings point to significant advances in surgical approaches and in the incorporation of digital technologies that have improved the accuracy and predictability of results.

It was observed that, although there is consensus regarding the main criteria for surgical indication, such as enophthalmos greater than 2 mm, persistent diplopia, and muscle entrapment, there are still divergences regarding the ideal time of intervention. The literature also shows a growing preference for minimally invasive accesses, especially transconjunctival and endoscopic endonasal accesses, which have aesthetic and functional advantages compared to conventional techniques.

Regarding reconstructive materials, titanium meshes and plates remain the gold standard for their strength and biocompatibility. However, materials such as porous polyethylene, PMMA and PEEK, associated with CAD/CAM technology and 3D printing, have stood out for allowing individualized reconstructions and results equivalent to titanium, with better anatomical adaptation. The use of autogenous materials, such as the cheek fat pad (*Bichat's fat pad*), remains a viable alternative in situations of lower complexity and limited resources.

It was also found that the best clinical-functional results are directly related to three-dimensional surgical planning, the appropriate choice of material, and the early execution of orbital repair. The application of technologies such as virtual planning, 3D biomodeling, and computer-aided navigation represents a milestone in contemporary orbital reconstruction, favoring greater accuracy and predictability.

However, the review also identified important limitations in the literature, such as the small number of controlled clinical trials, the methodological heterogeneity of the studies, and the predominant use of small samples. Such factors restrict the generalization of results and highlight the need for multicenter, standardized, and comparative investigations that allow the establishment of consolidated clinical guidelines based on robust evidence.

Thus, it is concluded that the surgical management of *blow-out* fractures has evolved considerably in the last decade, driven by technological innovations and the development of

new biomaterials. However, the absence of universal protocols and standardization of conducts still represents a challenge for clinical practice. Therefore, new clinical studies and systematic reviews are essential to strengthen the available evidence and guide safe, effective, and reproducible conducts in orbital reconstruction.

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