A systematic literature review and narrative synthesis on the use of autologous cartilage in the repair of orbital fractures

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Introduction: Fractures of the orbit are common injuries within the maxillofacial skeleton, and can often result in restrictions to ocular movement, diplopia, and enophthalmous if herniation of globe content occurs. Various studies have demonstrated the use of autologous cartilage grafts in the reconstruction of orbital fractures.

Methods: A systematic review protocol was registered with PROSPERO, and reported in accordance with the Preferred Reporting for Items for Systematic Reviews and Meta-Analyses. Comprehensive electronic search strategies of four databases were developed. Studies were screened according to the inclusion and exclusion criteria by two independent reviewers.

Results: Seven thousand one hundred seventy-one articles were identified following a comprehensive literature search. These articles were filtered for relevance and duplication, which reduced the number of articles to 16. A total of 259 patients underwent orbital reconstruction with the use of autologous cartilage. Conchal cartilage was harvested in 148 patients, auricular cartilage in 22 patients, nasoseptal cartilage in 72 patients, and costal cartilage in 17 patients. Thirty, seven, twelve, and four complications were observed in patients where cartilage was harvested from the concha, auricle, nasoseptum and rib, respectively. Most common complications included diplopia ($n = 23$), infra-orbital para/anaesthesia ($n = 27$), and enophthalmos ($n = 7$). No failure of graft or donor site morbidity were observed in the studies.

Conclusion: Autogenous materials such as cartilage can be used as an alternative for orbital reconstruction. Cartilage was considered by the authors to provide adequate structural support to the orbital contents, and that it was easy to harvest, shape, and position.

Keywords: Autologous cartilage, orbital fractures, trauma, oral and maxillofacial

Introduction

The orbit is a pyramidal structure, consisting of four boundaries made from the following seven bones: frontal, sphenoid, maxillary, zygomatic, palatine, ethmoid, and lacrimal bones. Fractures of the orbit are common injuries within the maxillofacial skeleton, most commonly as a result of road traffic accidents and assault in adults[1,2].

Orbital fractures may occur in isolation involving the orbital walls, floor or roof, or in combination with other non-orbital

HIGHLIGHTS

- The timing to undertake surgery is crucial in order to ensure optimum results and reduce the risk of complications arising.
- Cartilage can be harvested from various sites for orbital reconstruction, such as the concha, auricle, and the nasal septum.
- Cartilage harvest from the nasal septum was reported to be easy to manipulate and contour.
- Cartilage from the concha was reported to be easier to harvest due to its natural curve, and therefore required less modelling.
- In patients with an enophthalmos of less than 5 mm, the addition of 1.37–1.5 ml of cartilage graft material corresponded to 1 mm correction of enophthalmos.
- Cartilage grafts larger than 2.5×2.5 cm should not be taken to reduce the risk of donor site morbidity.

injuries. Orbital floor fractures are further sub-divided into pure blow-out fractures, and impure blow-out fractures in which the orbital floor fracture occurs with an infra-orbital rim fracture. Signs and symptoms which may develop as a result of this injury include diplopia, blurred vision, subconjunctival haemorrhage, periorbital ecchymosis, and eyelid oedema[3–8]. In cases where the orbital floor is depressed inferiorly, hypoglobus may occur as a result. An increase of more than 5% in globe volume or

herniation of 0.9 mm or more of orbital tissue, or an increase of 0.7 cm^3 in total orbital volume are all enough to result in clinically significant enophthalmos[8–10]. Furthermore, restriction to ocular movement may occur in cases where the inferior oblique and rectus muscles become entrapped along the fracture line.

Computed tomographic (CT) scans of the orbit and facial skeleton are required in the preoperative planning stage of management as they will provide an accurate description on the size of the fracture, the degree of displacement of the bony fragments, the degree of herniation, and the presence of other facial fractures. Surgical management will then involve accurate anatomical reduction of the fractured segment, and the restoration of globe volume and herniated globe contents into their normal anatomical position. Inadequate treatment may result in the development or persistence of the aforementioned symptoms and signs. Both alloplastic and autogenous materials are utilised for orbital floor reconstruction. The choice of the material however will depend on the operating surgeon, and the characteristics of the material utilised[11,12]. Examples of autograft tissue include bone and cartilage. The choice of autograft will depend on the availability of tissue for harvest, and the ability to shape the tissue to the dimensions required to repair the defect. Autologous tissue has the advantages of low risk of infection, of reduced host-immune reactions, and of not resulting in significant additional costs. However, disadvantages of autologous tissue include donor site morbidity and resorption of tissue over time[13]. Various studies have demonstrated the use of autologous cartilage grafts in the reconstruction of orbital floor fractures[13,14]. Cartilage is considered easier to harvest and shape, further contributing to long-term support without resorption[15,16]. Examples of autologous cartilage include nasoseptal cartilage, conchal cartilage and costal cartilage. The primary aim of this systematic review is to report the type and frequency of complications which may arise in the use of autologous cartilage in the repair of orbital fractures.

Methods

Literature search

A systematic review protocol was registered with PROSPERO (CRD42022300402). This review is reported in accordance with the Preferred Reporting for Items for Systematic Reviews and Meta-Analyses (PRISMA)[17]. Comprehensive electronic search strategies were developed for each database using a combination of relevant keywords and index headings. A total of four bibliographic databases were searched (Embase, MEDLINE, CINAHL Plus and Cochrane Central Register of Controlled Trials). The search strategy was modified so that the index headings relevant to each specific database were selected. The search strategy was peer-reviewed by an information specialist. Forward and backward citation searches were conducted on articles identified as eligible for full-text review. Full search strategies and results are contained in Supplement 1.

Duplicate papers were identified and removed in Endnote 20 before being uploaded to Rayyan for screening. Two independent reviewers screened titles and abstracts according to the inclusion and exclusion criteria (Table 1). The remaining articles were downloaded in full-text format and re-screened. Discussion with a senior author to achieve consensus resolved any conflicts between the two reviewers.

Data extraction

The following information was extracted from full-text articles onto a customised Microsoft Excel spreadsheet: (1) Study characteristics, including author, year of publication, sample size, country, and study timeframe; (2) Patient demographics; (3) procedure performed ; (4) cartilage graft location; and 4) Outcome data, including the complication types and rates, and satisfaction rates.

Synthesis

A meta-analysis was not considered for this review due to the heterogeneous nature of the results. However, a narrative synthesis was performed to synthesise the findings of the different studies. The results of the studies were discussed and structured into themes, depending on the site of cartilage harvest. This formed the framework for our narrative synthesis. All articles in this review were published before. The quality and risk of bias of the studies eligible for inclusion were evaluated using the Newcastle-Ottawa Scale (NOS)[18]. Studies with NOS scores 0–3, 4–6 and 7–8 were considered as low, moderate and high quality, respectively.

The methodological quality of this systematic review was evaluated by our team by utilising A Measurement Tool to Assess Systematic Reviews 2 (AMSTAR-2)[19]. This tool is comprised of 16 items, with 7 critical items, and 9 non-critical items. For non-critical items, we assigned 1 point for 'Yes', 0.5 for 'Partial Yes', and 0 for 'No'. For critical items, the score was double. The total AMSTAR-2 score was 23 points[20,21]. The AMSTAR-2 score for this systematic review was 13. This study was registered with the Research Registry, unique identifying number: reviewregistry1683[22].

Results

Seven thousand one hundred seventy-one articles were identified following a comprehensive literature search. These articles were filtered for relevance and duplication, resulting in 46 articles. A full-text assessment was then performed, which reduced the number of articles to 16 articles[13,14,23–36]. With regards to quality of evidence, all of the studies which were eligible for inclusion were considered to be of moderate quality. Table 2 summarises the patient demographics, and Table 3 summarises the NOS score, cartilage donor site, and follow-up period for each study. The PRISMA flow diagram is summarised in Figure 1.

A total number of 259 patients underwent orbital reconstruction with the use of autologous cartilage. Within this patient cohort, there were 247 cases of orbital floor fracture, 16 cases of medial wall fracture, 5 cases of lateral wall fractures, and 2 cases of orbital roof fractures. Preoperatively, enophthalmos was reported in 101 cases, diplopia in 65 cases, paraesthesia within the infra-orbital nerve distribution in 70 cases, dystopia in 23 cases, tissue entrapment in 31 cases, limitations in ocular movement in 35 cases, and concomitant ocular injury in 5 patients.

Of the 259 patients included in this review, conchal cartilage was harvested in 148 patients, auricular cartilage in 22 patients, nasoseptal cartilage in 72 patients, and costal cartilage in 17 patients. No donor site morbidity was reported in the studies included in this review. Table 4 summarises the number of patients and postoperative findings depending on cartilage donor site.

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Table 1

Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Primary research paper investigating orbital floor reconstruction with autologous cartilage graft	Systematic/narrative reviews, case reports, book chapters, abstracts, comments or notes
English language studies only	Animal or cadaveric studies
	Non-English language papers
	Primary research papers investigating orbital floor reconstruction with autologous cartilage graft which did not report on postoperative findings/complications
	Studies unrelated to orbital reconstruction using autologous cartilage

In the group reconstructed with conchal cartilage, two patients developed scleral show, 10 cases of diplopia persisted, of which 5 resolved at 6-month follow-up. Limitation in upward gaze persisted in one patient, and enophthalmos persisted in two patients. Seven patients reported anaesthesia, and 17 reported paraesthesia in the distribution area of the infra-orbital nerve, of which 9 cases resolved after 6 months. Entropion was reported in one case, and palpebral oedema another case. Displacement of conchal graft occurred in two patients, and two patients exhibited palpable grafts at the orbital margin postoperatively. One patient developed retro-orbital haematoma with orbital compartment detected prior to anaesthetic awakening, requiring haematoma evacuation, and orbital decompression, without the need for a canthotomy.

In the group reconstructed with auricular cartilage, palpebral oedema developed in the immediate postoperative setting in one patient, however this resolved. Infra-orbital paraesthesia persisted in 2 patients at the 6-month follow-up. Diplopia persisted in three patients and enophthalmous in one patient.

In the group reconstructed with nasoseptal cartilage, infra-orbital nerve parasthesia persisted in one patient, and diplopia

Table 2

Patient demographics.

Author	Total no. patients	Male	Female	Mean age (range)[a]
Ozyazgan et al.[13]	10	7	3	30 (6–48)
Castellani et al.[14]	14	10	4	NA
Penna et al.[23]	24	18	6	40 (6–87)
Kim et al.[24]	12	7	5	34 (20–60)
Li[25]	5	4	1	25 (18-34)
Kraus et al.[26]	20	15	5	29 (8–65)
Lai et al.[27]	13	12	1	26 (12–51)
Seven et al.[28]	55	42	13	30 (17–54)
Kinnunen et al.[29]	14	11	3	NA
Lee[30]	5	4	1	36 (28–54)
Kraus et al.[31]	3	-	3	9 (8–12)
Kruschewsky et al.[32]	8	6	2	54
Talesh et al.[33]	20	N/A	N/A	32 (22–48)
Düzgün et al.[34]	19	N/A	N/A	NA
Bayat et al.[35]	22	N/A	N/A	NA
Mohamed et al.[36]	15	N/A	N/A	NA

[a]Mean age and age range reported in years.
NA, not available.

persisted in 6 patients. Enophthalmous persisted in three patients, and developed in one case. One case scleral show developed postoperatively.

In the group reconstructed with costal cartilage, diplopia developed in 3 patients, but had resolved within 4-months. In one case, diplopia persisted postoperatively, but to a minor degree when compared to the patient's preoperative state.

Discussion

Orbital fractures were first described by MacKenzie and Lang in 1844[37]. Since then, there have been numerous studies performed which have investigated the timing and surgical approach of this presentation, however the criteria for the surgical management of orbital fractures still remains a controversial topic[36]. Currently, three general guidelines are agreed upon that if present, may be an indication to early surgical intervention. Firstly, the presence of enophthalmos which is greater than 2 mm 14 days after trauma. Enophthalmos of this size or greater often results in a cosmetic defect that is only corrected through surgical intervention[38]. Secondly, the presence of diplopia with restricted ocular movement. The rationale for surgery in this presentation is that there is likely rectus muscle or perimuscular entrapment within the fractured segment. Without surgical intervention, the entrapped segment will likely undergo atrophy within the 2–3 weeks following the traumatic event, and will subsequently result in an enophthalmos[14]. Finally, fractures involving one half or more of the orbital floor, and the medial wall, may require surgical intervention as these fractures likely result in a cosmetic and/or functional defect in the form of enophthalmos and diplopia[38].

The material utilised in reconstruction is an important factor in the management of orbital fractures. Many reconstruction materials have been described within the literature, such as autologous bone grafts, autologous cartilage grafts, allogenic material (such as human dura matter, lyophilised cartilage, fascia lata), and alloplastic material (such as stainless steel, titanium, polyethelene, Teflon)[39,40]. The choice of implant material is largely dependent upon the surgeon's preference; however, the success of the material is also dependent on other factors such as appropriate patient selection and timing of surgery. Alloplastic materials have gained popularity over the recent years due to their ease of use, availability, and due to this approach not introducing the risk of donor site morbidity to the patient. The current gold standard for complex orbital fractures with large wall defects are prefabricated orbital plates or titanium mesh plates, as they are both rigid and highly malleable, allowing for easier positioning[41]. However, depending on the alloplastic material utilised, there remains a risk of extrusion, displacement and adhesion formation[42,43]. To reduce the risk of extrusion and displacement, it is important to meticulously contour the edges to the minimum required size intra-operatively.

Autogenous cartilage can be used as an alternative for orbital reconstruction. Evidence within the literature suggests that autogenous cartilage is rapidly incorporated by the host tissue, and that the graft retains most of its volume and integrity years after the procedure[44]. Within this review, cartilage was harvested from various sites, such as the concha, auricle, and the septum. Nasoseptal cartilage was considered advantageous by Li and colleagues as it was easy to access through a standard submucous resection technique, and that no visible scar or palpable

Table 3

NOS score, cartilage donor site, and follow-up period for each study.

Author	NOS score	Cartilage donor site	Length of time from injury to repair (range)	Follow-up period
Ozyazgan et al.[13]	5	Concha	Cases which presented immediately after trauma = 7 Cases that presented late (45 days to 1 year) = 3	Range: 2–40 months
Castellan et al.	5	Concha	NA	3 months and 6 months
Penna et al.[23]	5	Concha	Range = 4–18 days	Seven and 14 days and later 1, 3, and 6 months
Kim et al.[24]	5	Costal	NA	Range: 10–17 months (mean 13 months)
Li[25]	5	Nasoseptal	NA	Range: 3–5 months (mean 4 months)
Kraus et al.[26]	5	Nasoseptal	Mean = 3 days Range = 12 h–12 days	Range: 1 week–6 months (mean follow-up 12.3 weeks)
Lai et al.[27]	5	Nasoseptal	Mean = 7 days Range = 4–14 days	3 months–4 years
Seven et al.[28]	5	Concha	1 week	Mean follow-up time was 31 months
Kinnunen et al.[29]	6	Auricular	Range = 3–10 days	2–5 years
Lee[30]	5	Costal	NA	8 months–3 years
Kraus et al.[31]	5	Nasoseptal	NA	12–24 months
Kruschewsky et al.[32]	6	Auricular	NA	3 months and 6 months
Talesh et al.[33]	5	Nasoseptal	NA	Mean = 19 months Range = 5–39 months
Düzgün et al.[34]	6	Conchal	Median = 8 days Range = 2–60 days	6–31 months
Bayat et al.[35]	6	Conchal & nasoseptal	NA	10 days, 1 month, and 3–6 months
Mohmed et al.[36]	6	Conchal	NA	30, 90 and 180 days

NA, not available; NOS, Newcastle-Ottawa Scale.

donor site defect is left following harvest. Furthermore, they commented that cartilage harvested from the septum was easy to manipulate and contour when compared to auricular cartilage, while also providing better structural support[25]. However, Penna and colleagues stated that harvesting from the nasoseptal cartilage carried an increased risk in morbidity when compared to harvesting cartilage from the auricle or concha. Complications which may arise within the donor area included septal haematoma, septal perforation, and saddle nose deformity[23,25]. Although no donor site morbidity was noted within the studies which utilised nasoseptal cartilage, two studies within our review argued that conchal cartilage is superior to septal as it was easier to harvest, and due to its natural curve, it required less modelling[14,23]. Chowdhury and Krause agreed that the natural curve of the conchal cartilage graft is advantageous for orbital floor repairs, as it is likely to fit easier when compared to cartilage grafts from other sites[45]. Costal cartilage grafts were utilised by Kim et al.[24] in the correction of post-traumatic enophthalmos. The team found them to be advantageous due to their consistency, flexibility, resistance to absorption and extrusion, and ease of carving and trimming. The incidence of postoperative complication depending on site of graft varied, with the highest complication rate belonging to the auricular cartilage group (31.8%), and the lowest belonging to the nasoseptal cartilage group (16.6%). Unfortunately, not all preoperative and postoperative symptoms were reported in all the included studies. Therefore, we were not able to accurately determine which cartilage group had the highest rate of symptom persistence postoperatively. A further point to highlight within the auricular cartilage group within the study by Kinnunen and colleagues was the use of lyophilised dura with their cartilage grafts. However, the authors state that no clinical difficulties were encountered with its use with the cartilage grafts during the study[29].

The timing to undertake surgery is crucial in order to ensure optimum results and reduce the risk of complications arising.

Unless contraindicated, most surgeons will wait 24–72 h until the oedema subsides before undertaking any surgical intervention. Most surgeons report optimum results if surgical intervention is performed early. The study by Bayat et al.[35] suggest that the best results are obtained when surgical intervention is performed within 4-weeks of the injury. In paediatric patients with an orbital fracture and oculomotor dysfunction, surgical management is recommended within 7 days of injury[46]. In cases of tissue herniation and muscle entrapment, delayed surgical intervention will likely result in muscle atrophy and fibrosis, ultimately resulting in enophthalmos which in these cases is difficult to treat[47,48]. In the study by Ozyazgan et al.[13] ten patients with orbital wall fractures underwent repair utilising conchal cartilage graft . Limitation in eye movement, diplopia, and enophthalmos did not occur in their patient cohort, except for one. This one patient presented 1-year following the trauma with limitation of gaze, diplopia and enophthalmos. Postoperatively, this patient had a 2-mm enophthalmos on the operative side, relative to the opposite eye. If this patient had presented earlier, operative outcomes may have been better and significant damage to periorbital tissue may have been avoided.

The volume of cartilage utilised in the repair of orbital defects is another important aspect of the surgical procedure. In the study by Lee et al.[30], they concluded that in patients with an enophthalmos of less than 5 mm, the addition of 1.37–1.5 ml of cartilage graft material corresponded to 1 mm correction of enophthalmos. Aesthetically satisfactory results were also achieved by Kim et al.[24] in the correction of enophthalmos utilising sliced costochondral cartilage; however, replacement volume was not measured and was based on the surgeon's experience. They concluded that additional studies on quantitative assessment of enophthalmos with three-dimensional (3D)-CT are needed to calculate the needed volume preoperatively. However, the limited size and bulk of cartilage from the concha and septum places these donor sites at a disadvantage, and at an increased risk
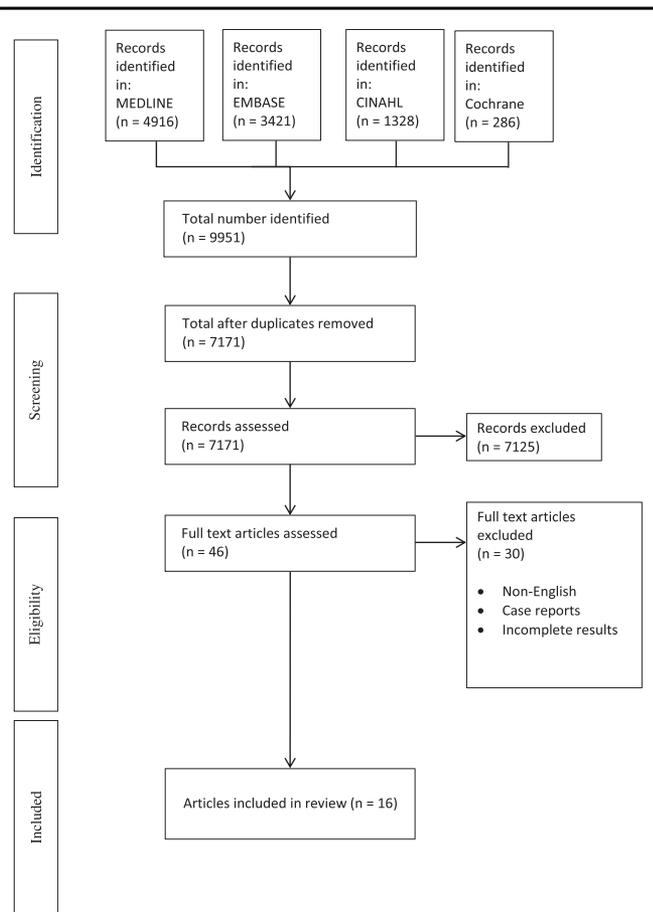
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Figure 1. Prisma flow diagram.

of donor site morbidity if a large volume of graft material is required.

The size of defect is a feature which must be taken into consideration when choosing a material for reconstruction. Nasoseptal cartilage was found to be a reliable reconstructive material by Lai et al.[27] in the repair of orbital blow-out fractures. The mean size of orbital floor defects treated within their study was 518 ± 242 mm^2. Similarly, it was also a suitable reconstructive material in the study by Li et al.[25] where it was used to repair orbital defects larger than 1×1 cm. With regards to conchal cartilage, Özyazgan et al.[13] recommended the use of conchal cartilage in the repair of defects up to 2×2 cm which do not involve the orbital rim. Similarly, Düzgün et al.[34] achieved satisfactory results when conchal cartilage graft was used to repair defects smaller than 4 cm^2. Although Castellani et al.[14] did achieve similar results in defects up to 2×2 cm, they recommended that cartilage grafts larger than 2.5×2.5 cm should not be taken to reduce the risk of donor site morbidity. In orbital defects between 1.5 and 2 cm^2, Mohamed et al.[36] found that bilateral sutured conchal cartilages helped overcome some of the problems which may arise from such large defects.

Due to the limited availability of cartilage tissue and concerns regarding donor site morbidity, extensive efforts have been made to address this issue. While tissue engineering approaches involving unrelated cells and synthetic scaffolds have been explored, not all studies have demonstrated success[49–51]. Recent strides in the realm of 3D bioprinting offer a promising avenue to tackle this challenge. Although still in its early stages, 3D bioprinting holds the potential to provide an alternative to autologous tissue harvesting by fabricating intricate, native-like tissue structures while meticulously controlling their assembly at the nano-, micro-, and macroscopic scales[52]. This advancement has the potential to eliminate the need for autologous tissue procurement, thereby revolutionizing reconstructive surgery[53,54]. Nonetheless, concerns persist regarding the integration of regenerative medical approaches into clinical practice, primarily revolving around the safety of cells for therapeutic applications, as well as the cost and clinical efficacy of this treatment modality[55,56].

Limitation

The heterogenous nature of the studies included within our review reduced the generalisability of our results. Variables such as size and location of the defect, and the type and quantity of cartilage harvested did not allow for an accurate comparison to be performed between the studies. Additionally, not all preoperative and postoperative signs and symptoms were reported in the included studies, therefore a true postoperative complication rate and further statistical analysis testing for associations could not be performed. This lack of standardisation in measuring these outcomes increased the degree of clinical heterogeneity. Furthermore, the cohort of patients which underwent either auricular cartilage harvest or costal cartilage harvest were relatively small, further reducing the generalisability of our results. Finally, the majority of the studies within our review were case series. The lack of a comparator groups within these studies would likely reduce their degree of internal validity, and therefore reduce the validity of our results.

Table 4

Postoperative findings for each cartilage donor site.

Cartilage donor site	No. patients	Postoperative findings (no. patients)	Total number (incidence %), n (%)
Concha	148	Scleral show (2)	30 (20.3)
		Diplopia (10)	
		Limitation in gaze (1)	
		Enophthalmos (2)	
		Infra-orbital para/ anaesthesia (24)	
		Entropion (1)	
		Palpebral oedema (1)	
		Displacement of graft (2)	
		Retro-orbital haematoma (1)	
Auricular	22	Palpebral oedema (1)	7 (31.8)
		Infra-orbital paraesthesia (2)	
		Diplopia (3)	
		Enophthalmos (1)	
Nasoseptal	72	Infra-orbital paraesthesia (1)	12 (16.6)
		Diplopia (6)	
		Enophthalmos (4)	
		Scleral show (1)	
Costal	17	Diplopia (4)	4 (23.5)

Conclusion

Numerous alloplastic and autogenous materials may be utilised in the reconstruction and repair of orbital fractures, each with its own set of advantages and disadvantages. While prefabricated orbital plates or titanium mesh plates are currently regarded as the gold standard for managing complex orbital fractures, autologous cartilage represents a viable alternative for orbital reconstruction due to their morphological features, and their ability to provide adequate structural support to the orbital contents. Nevertheless, the use of autologous cartilage introduces the potential for donor site morbidity, which may be deemed an unnecessary risk when a suitable alloplastic material is at one's disposal. The utilisation of cartilage grafts should be considered in scenarios where implant availability is limited.

Ethical approval

No ethical approval was required for this project as it was a systematic review of the literature.

Consent

Not required as this was a systematic review of the literature. We did not have a cohort of patients we trialled treatment on. We incorporated data from other publications, where it is assumed that consent was provided by the patients for publication.

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NA.

Author contribution

M.A.: design of study, screening papers, data collection, data analysis, writing the paper. S.T.: design of study, editing paper, supervisor. E.O.: screening papers, data collection, data analysis. E.F.: screening papers, data collection, data analysis. M.R.H.: data analysis, writing the paper. R.W.: development of search strategy.

Conflicts of interest disclosure

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Research registration unique identifying number (UIN)

The systematic review protocol was registered with PROSPERO (CRD42022300402). This study was registered with the Research Registry, unique identifying number: reviewregistry1683 Hyperlink: https://www.researchregistry.com/browse-the-registry#regis tryofsystematicreviewsmetaanalyses/.

Guarantor

Munir Abukhder.

Data availability statement

Datasets generated during and/or analysed during the current study are available upon reasonable request.

Provenance and peer review

Not commissioned, externally peer-reviewed.

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