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Evolution of contracted socket reconstruction by ocular prosthesis & implants: A systematic review

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Abstract

Anophthalmic socket contracture is a condition resulting from scar-induced shortening of the orbital tissues, which leads to a reduced surface area, shallow fornices, and difficulties with prosthesis retention. It often occurs after enucleation or evisceration, particularly without an implant or after significant scarring from irradiation. This article reviews surgical reconstruction techniques for contracted sockets, highlighting the role of ocular implants and prostheses in restoring depth and volume. A literature search focused on clinical studies reporting surgical outcomes revealed that autologous grafts, especially oral mucous membrane and dermis-fat grafts, achieve prosthesis retention rates of 70-90% in moderate cases. Alloplastic implants combined with mucosal grafts show success in severely resorbed sockets by providing volume and stability. Recent composite techniques, like using hard palate mucosa with dermis-fat grafts, have improved one-stage reconstructions for challenging cases. Common surgical challenges include graft shrinkage, necrosis, and socket re-contraction. However, advancements in methods have enhanced patient outcomes. The evolution of reconstruction techniques now integrates autologous grafts and modern implants, emphasizing the importance of adequate socket lining and volume for prosthesis retention. Innovations such as composite autografts and intra-orbital navigation enhance customization and improve success rates, although severe recurrent cases continue to be problematic.

Keywords: Contracted socket, anophthalmic socket, malignant socket, enucleation, evisceration, mucous membrane graft, dermis-fat graft, orbital implant, ocular prosthesis, socket reconstruction

Introduction

A contracted socket is characterized by the shrinkage and collapse of orbital tissue, leading to a reduction in orbital volume and a decrease in the depth of the fornices. This condition results in an inability to support a prosthesis and represents the most severe complication related to both congenital and acquired anophthalmos. Patients with a contracted socket experience not only functional and anatomical challenges but also face significant aesthetic concerns, which can contribute to psychological distress ^[1]. Anophthalmia can arise from congenital diseases, post-evisceration, or following enucleation. Among them, the most common cause of contracted socket is acquired anophthalmos following enucleation or evisceration ^[2, 3]. Contracted sockets result from various etiologies. The most common causes include inadequate volume replacement at the time of eye removal (e.g. no orbital implant or an undersized implant), poor conformer use postoperatively (early removal or improper prosthesis wearing), chronic inflammation or infection of the socket, and conjunctival surface loss due to chemical burns or autoimmune cicatricial diseases (e.g. Stevens-Johnson syndrome, ocular cicatricial pemphigoid). An anophthalmic (post-enucleation) socket may undergo contracture, defined as cicatricial shrinkage of the conjunctival fornices and orbital soft tissues, leading to foreshortened fornices, reduced orbital volume, and inability to retain an ocular prosthesis ^[4]. Adjuvant therapies like external beam radiotherapy significantly increase risk. For instance, high-dose orbital radiation after enucleation for uveal melanoma causes severe socket contracture and inability to retain a prosthesis in approximately 40% of cases ^[5]. The congenital form of anophthalmic socket is rare, occurring in approximately 0.2 to 0.3 per 10000 live births, while acquired anophthalmos is more prevalent, with rates ranging from 2.6 to 5 per 100000 population.

There is no direct correlation between age and gender and the occurrence of socket contraction; however, involvement of the left eye is more common than that of the right eye, with an unknown reason^[6]. There are various methods for classifying or grading contracted sockets, which have been documented in the literature over time. Tawfik *et al.* proposed this four-grade classification based on contracture severity and extent of fornix loss: Grade 1 - minimal shallowing; Grade 2 - mild contracture of one fornix; Grade 3 - extensive fornix contracture preventing prosthesis wear; Grade 4 - severe phimosis of the palpebral fissure, often with total cicatricial socket or prior irradiation. For severely contracted sockets (grades 2 and 3), he recommended mucous membrane grafting as part of the management algorithm^[7, 8]. In the current scenario, the Gopal Krishna classification is the most widely used worldwide. This classification categorizes contracted sockets into five grades, ranging from Grade 0 to Grade 5. Grade 0 - A healthy socket characterized by deep and well-formed fornices, Grade 1- Presence of shelving or shallowing of the lower fornix, Grade 2 - Loss of both the superior and inferior fornices, Grade 3 - Involvement of all four fornices (superior, inferior, lateral, and medial), Grade 4 - Involvement of all four fornices with a decrease in the horizontal palpebral fissure length, Grade 5 - Recurrence of contraction following multiple unsuccessful attempts at reconstruction^[9]. A mild contracted socket (Grade 1/2) can be managed using fornix-forming sutures, such as mattress sutures over a silastic stent or by addressing the lateral canthal tendon with an open method. This is typically followed by placing a customized prosthesis 2 to 3 weeks later. Lower lid entropion may accompany the contracted socket, and a Weiss procedure has shown success in these cases. Horizontal lid shortening can help with laxity, and grafts from the nasal septum, auricular cartilage, sclera, hard palate, or fascia lata may be used to lengthen the posterior lamina^[10, 11]. In the case of a moderately (grade 3) contracted socket, the shrunken state of all fornices necessitates that the best post-operative outcomes are achieved using mucous membrane grafts (MMG). A full-thickness graft is preferred over a split-thickness one due to its lower incidence of graft contracture and failure. MMG is the most performed surgical procedure for expanding the surface area of a contracted socket^[12]. Ideal donor sites for MMG include the oral mucosa of the lips, cheeks, and hard palate, as well as the preputial skin of the labia majora^[13]. To ensure proper adaptability, the harvested graft must be 40% larger than the recipient area to accommodate for future shrinkage and healing. Post-operative patients may experience complications such as foul-smelling discharge, graft shrinkage, or even graft failure, all of which depend on the condition of the recipient surface^[14]. An alternative approach is the use of an amniotic membrane graft (AMG), which has shown effectiveness in managing moderate socket contraction. Some studies indicate that AMG may be superior to MMG. The AMG is easily accessible, can be harvested with relative ease, and possesses anti-inflammatory, anti-fibrotic, and anti-microbial properties, along with minimal shrinkage tendencies^[15, 16]. However, due to its fragility and low tensile strength, it is not recommended as the first choice for grafting^[17]. The management of a severely contracted socket aims to address both surface and volume loss. In cases where volume loss exceeds 50 percent, merely placing a prosthesis is inadequate. Effective treatment requires both a dermis fat

graft (DFG) and a secondary orbital implant to adequately restore lost volume^[18]. The DFG is harvested from the outer and upper quadrant of the gluteal region to avoid any potential damage to the sciatic nerve. While DFGs are highly effective for managing grade 4 and 5 contracted sockets, postoperative complications may arise, including hematoma, fat atrophy, graft necrosis, deep subconjunctival cyst formation, ulceration, granuloma formation, and dehiscence at the donor site^[19]. It is crucial to take care not to include epidermis during the harvesting of dermis fat grafts. A discoid or banana-shaped graft is typically used to minimize the risk of central ulceration. In specialized situations, such as with a dry avascular socket, the use of a pedicle flap can provide a vascular bed that enhances graft survival and contributes additional volume to the socket. Potential options for such flaps include superficial temporalis fascia, retro-auricular flaps, galeal flaps, or thoracodorsal artery perforators^[20-23]. The management of malignant or recalcitrant contracted sockets (Grade 5) remains a significant challenge, particularly in cases where multiple surgical interventions have already failed. A team of oculoplastic surgeons has proposed that exenteration, followed by the fitting of a suitably sized prosthesis and appropriate conformer, may effectively address the issue of recalcitrant sockets^[24].

Historical Evolution: Over the past century, surgical management of contracted sockets has evolved tremendously. Early attempts (mid-20th century) often involved repeated socket dilatation or full-thickness skin grafts to replace lost conjunctiva. Skin grafts were easy to harvest in large areas and could reconstruct even severe contractions, but their keratinizing epithelium led to chronic discharge and irritation in the socket. The introduction of oral mucous membrane grafts was a major advance: oral mucosa (labial or buccal) closely resembles conjunctiva (non-keratinized, with goblet cells) and provides a wet, mobile lining. By the 1970s, mucosal grafting was widely adopted for fornix reconstruction, even in severe cases. Donor sites for oral mucosal grafts (OMG) include the inner lower/upper lip, buccal mucosa, and hard palate. The hard palate mucosa is known to be especially rigid and resistant to graft contraction, albeit with a rougher surface^[25]. Simultaneously, attention turned to orbital volume replacement to prevent the post-enucleation socket syndrome (enophthalmos and sulcus deformity). Spherical orbital implants made of glass or acrylic had been used since the early 1900s to occupy the socket volume after eye removal, but were not integrated with the tissues and often migrated or extruded, contributing to secondary contracture. In the late 1970s^[26], an innovative autologous solution emerged: the dermis-fat graft (DFG) introduced by Byron Smith. Smith's technique used a patient's dermis and fat (typically from the gluteal region) as an orbital implant to replace the lost eye. The fat restored volume while the dermal surface provided a scaffold for conjunctival epithelium. This autologous dermis-fat graft concept revolutionized volume augmentation in anophthalmic surgery, offering excellent biocompatibility and even growth potential in children. By the 1980s, dermis-fat grafting was being applied to contracted sockets; Betharia (1988) reported successful use of dermis-fat grafts in recalcitrant Indian patients with acquired socket contracture^[27]. The late 1980s and 1990s brought further innovations. Porous integrated implants (e.g. hydroxyapatite, porous

polyethylene) were introduced around 1989, allowing fibrovascular ingrowth and attachment of extraocular muscles to better transmit motility to the prosthesis. These implants improved implant stability and reduced long-term migration risk. For example, Rose *et al.* (1990) experimented with extra periorbital silicone block implants to correct post-enucleation enophthalmos [28]. Additionally, an autologous dermis onlay graft placed at the time of enucleation was explored as a method to mitigate later volume loss [29]. Through the 1990s and 2000s, surgeons combined integrated orbital implants with mucosal lining grafts to simultaneously address volume and surface deficiencies in contracted sockets. A comprehensive classification and algorithm by Tawfik in 2009 formalized many of these approaches [7]. Today, contracted socket reconstruction employs a spectrum of techniques, often in combination. The guiding principle is to remove scar tissue and then replace lost conjunctival lining (with grafts or flaps) and lost orbital volume (with implants or bulk grafts). The following sections review the outcomes of these techniques and how they are applied in different clinical scenarios, including pediatric versus adult patients.

Materials and Methods

We conducted a thorough search for relevant publications and literature on contracted socket reconstruction, focusing on the evolution of surgical techniques in accordance with PRISMA guidelines. Our search strategy encompassed electronic databases, including PubMed, Google Scholar, MEDLINE, and Embase, covering the period from 1975 to 2025. We used keywords such as “contracted socket,”

“anophthalmic socket,” “socket reconstruction,” “ocular prosthesis,” and “orbital implant.” After a comprehensive search across these four medical platforms, we identified 114152 databases, of which 4,000 records were eliminated due to duplication, and 98500 records were deemed ineligible by automatic data tools. Ultimately, 10140 records proceeded to the screening phase, during which 9,740 articles were excluded for not meeting the inclusion criteria of this study. In total, 310 study reports were assessed for eligibility. From these, 16 and 30 studies were ruled out for involving other facial procedures without prior documentation and for focusing on normal socket reconstruction, respectively. Additionally, in 34 studies, the authors did not adhere to standard PRISMA guidelines, while 40 studies were excluded due to incomplete follow-ups. In the end, we included 190 peer-reviewed original articles, case series, and case reports in our systematic review that met our inclusion criteria. Both prospective and retrospective studies, along with relevant case series and reports, were incorporated into our analysis. Non-clinical studies and those that failed to address the outcomes of socket reconstruction were excluded. Data were meticulously extracted for each patient, particularly in case reports. The primary outcome of interest was functional success, which is typically defined as the ability to retain a prosthetic eye without the need for further major interventions, accompanied by an acceptable aesthetic result. Given the heterogeneity of the data, we present a qualitative synthesis of our findings, with key outcome metrics from representative studies summarized in tables to facilitate comparisons of the various approaches.

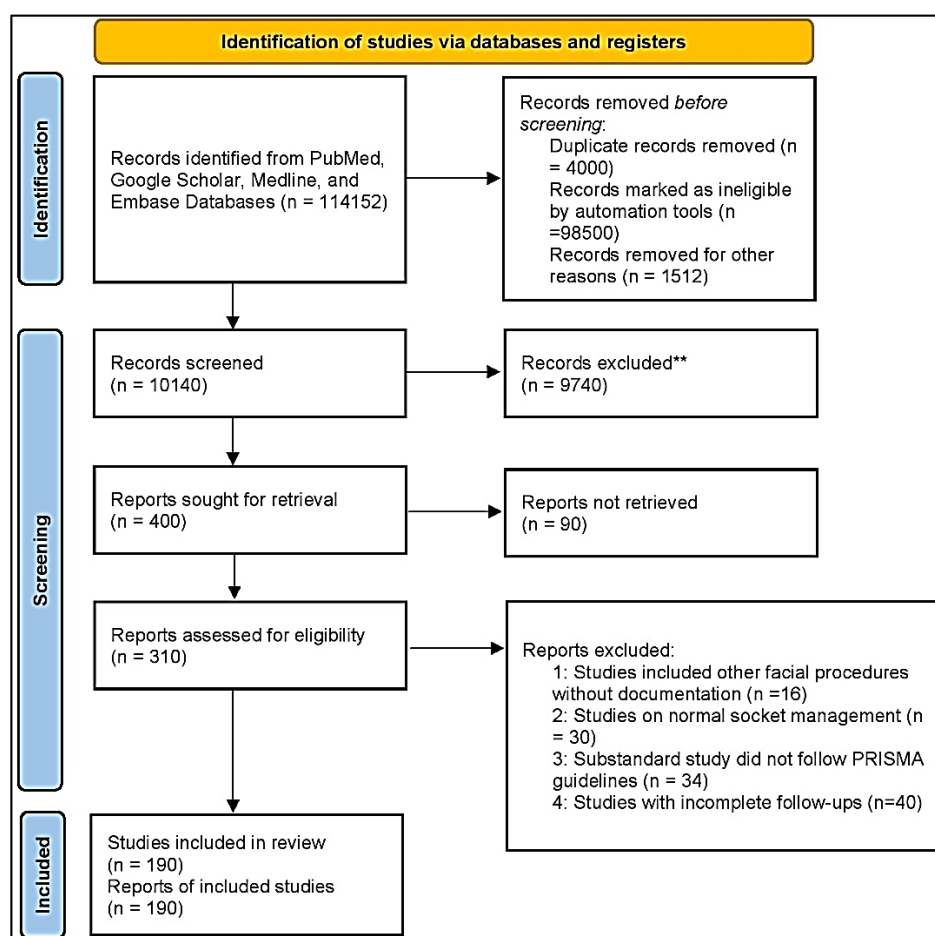


Fig 1: PRISMA flow diagram illustrating the search strategy and study selection process for the systematic review

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses^[30].

Search Strategy

The population, intervention/condition, control/comparison, and outcome (PICO) criteria were utilized to conduct a thorough literature review. The search was conducted on databases such as PUBMED, Google Scholar, MEDLINE,

and EMBASE using the following keywords such as contracted socket, Anophthalmic socket, Socket reconstruction, Orbital implant, and Ocular prosthesis. The medical subject heading (MeSH) approach for PubMed (including Medline) and Google Scholar, as detailed in Table 1, was employed to develop a comprehensive search strategy.

Table 1: showing the search strategy, search engines used, and the number of results displayed.

S. No.	Databae	Search Strategy	Search results
1.	PubMed	Contracted socket, Anophthalmic socket, Socket reconstruction, Orbital implant, Ocular prosthesis	22880
2.	Google Scholar	Contracted socket, Anophthalmic socket, Socket reconstruction, Orbital implant, Ocular prosthesis	86980
3.	Medline	Contracted socket, Anophthalmic socket, Socket reconstruction, Orbital implant, Ocular prosthesis	4212
4.	Embase	Contracted socket, Anophthalmic socket, Socket reconstruction, Orbital implant, Ocular prosthesis	80

Data Extraction

Standardized data extraction forms were used to record key information, including author(s), year, study type, country, sample size, patient demographics (age, gender), etiology of socket contracture, surgical technique, implant, or graft material used, and duration of follow-up. Outcomes assessed included prosthetic retention, implant integration, aesthetic satisfaction, complication rates, recurrence of contracture, and revision procedures.

Quality Assessment

Studies were evaluated using the Oxford Centre for Evidence-Based Medicine levels of evidence and the Newcastle-Ottawa Scale (for non-randomized studies). The risk of bias was assessed at both the study and outcome levels.

Data Synthesis

Given the heterogeneity in study designs, surgical interventions, and outcome measures, a meta-analysis was not feasible. A qualitative synthesis was conducted by categorizing studies chronologically and thematically.

Inclusion and Exclusion Criteria

Studies published between January 1975 and April 2025 evaluated surgical reconstruction of contracted sockets using ocular implants, grafting methods, and ocular prosthesis, including outcome-based original manuscripts, case series, case reports, and comparative reviews. We established specific criteria for including and excluding participants to achieve our study goals. Our Criteria can be summarized in Table 2.

Table 2: Showing the inclusion and exclusion criteria adopted during the literature search process.

S. No.	Inclusion criteria	Exclusion criteria
1.	Human study	Non-human study
2.	Study from 1975 to 2025	Only methodological studies explaining programming details
3.	English Text	Non-English text
4.	Free Paper	Paper that needed to be purchased
5.	Study focused on contracted socket	Study involving clinical data other than contracted socket
6.	Institutional study with ethical clearance	Without ethical clearance
7.	Study with complete follow-ups	Incomplete follow-ups

Demographic, clinical, surgical, and outcome-related data were compiled and analyzed according to PRISMA recommendations.

Results

Overview of Included Studies

Contracted sockets primarily stemmed from enucleation/evisceration due to trauma, infection, or tumors, often without primary orbital implants. Socket contraction could occur even decades post-surgery, especially in cases with volume and lining deficiency. Pediatric sockets, especially congenital anophthalmia, typically involve volume underdevelopment rather than fibrosis.

Amniotic Membrane and Skin Grafts

Autologous mucous membrane grafts (MMG), especially from oral mucosa, showed high success in moderate contractures (80-90%). These grafts restore fornix depth and prosthesis retention, but are less effective in severe scarring unless augmented. Amniotic membrane grafts (AMG) were beneficial in mild cases but inadequate for severe

contractures due to a lack of epithelium. Skin grafts were used in dry sockets but led to keratin debris; hence, nasal mucosa is sometimes preferred.

Dermis-Fat Grafts (DFG)

Dermis-fat grafts (DFG) addressed both volume and lining deficits, with 70-90% success rates in severe cases. Single-stage DFG was more effective than combined grafts. DFGs were particularly successful in children. Porous implants with MMG also restored sockets effectively, comparable to DFGs, but required good vascularization to avoid complications like extrusion.

Alloplastic Implants with Fornix Grafting

Porous implants with MMG offered comparable success to DFG in Grade 4 sockets. Risks include extrusion in poorly vascularized sockets.

Composite and Novel Techniques

Hard palate-DFG composites and oral mucosa-DFG “sandwich” grafts showed promise in severe sockets. Free flaps, e.g., radial forearm, and 3D-printed conformers,

helped in refractory cases. Conformers remain essential postoperatively.

Pediatric vs. Adult Socket Reconstruction

Pediatric management emphasized early, non-surgical expansion (e.g., custom conformers). Hydrogel expanders helped in small orbits. Adult sockets required graft-based reconstructions due to scarring. Radiation-induced sockets, mostly in adults, posed the greatest challenge. Stenting with conformers postoperatively was crucial to maintain fornices and prevent recurrence. Autologous techniques remain the standard for complex reconstructions, ensuring long-term prosthesis stability and socket function.

Summary of Outcomes across Techniques

To synthesize the evidence, **Table 3** highlights outcomes from selected studies representing key reconstructive techniques for contracted sockets, and Table 4 summarizes results from composite and advanced methods in more severe cases.

Tables 3& 4 illustrate that moderate socket contractures are effectively managed with single-tissue autografts (oral mucosa or dermis-fat) in most cases, whereas severe contractures often demand combined or innovative approaches. Notably, the use of stents and prolonged conformer placement is a recurring theme for maximizing success across all techniques. In many reports, conformers were left in place for 6-8 weeks or even several months after surgery to ensure the newly created fornices remained deep during the healing phase. Conformers may be sutured to the eyelids or secured with a bandage contact lens to prevent displacement. In our review, Wei & Ng (2001) specifically advocated the use of tailored conformers and fornix-forming sutures post-surgery to significantly reduce re-contraction rates. In practice, this means that after reconstructive surgery, patients often require close follow-up and adjustment of conformers or prostheses to gradually transition to an ocular prosthesis.

Table 3: Outcomes of Standard Grafting Techniques in Contracted Socket Reconstruction

Study (Year)	Technique	Patients (Sockets)	Success Rate (Prosthesis Retention)	Follow-up & Complications
Aryasit <i>et al.</i> , 2024 ^[31]	Oral mucosa graft (OMG)	37 (20 G2, 17 G3)	G2: 80.0%, G3: 52.9% (overall 67.6%)	Mean follow-up 6.3 yrs; 91.9% could eventually wear a prosthesis with minor adjuncts; 8% graft necrosis, 8% wound dehiscence.
Galindo-Ferreiro <i>et al.</i> , 2018 ^[32]	Dermis-fat graft (DFG)	53 (severe cases)	88.7% success (multicenter)	Multi-center data; recommended DFG as primary for severely contracted sockets; a few required minor revisions (socket polishing).
Aryasit & Preechawai, 2015 ^[33]	Dermis-fat graft (DFG)	30 (mixed grades)	73.3% DFG alone vs 25% DFG+MMG (simultaneous)	Mean follow-up ~32 mo; staged DFG far superior to one-stage combined graft; no significant donor site issues.
Kim <i>et al.</i> , 2014 ^[34]	Buccal mucosa graft (MMG)	44 (Grades 2-3)	86.4% functional success	Mean 9 mm fornix depth achieved; graft fully epithelialized ~1 month; 4.5% mild re-contraction (2 cases).
Bhattacharjee <i>et al.</i> , 2014 ^[35]	Porous implant + buccal MMG	21 (Grade 4)	~70% success (comparable to DFG group)	Porous polyethylene implant plus mucosal graft in one stage; similar prosthesis retention to autologous DFG; one implant exposure managed with graft.
Bajaj <i>et al.</i> , 2006 ^[36]	Amniotic membrane graft (AMG)	20 (mild-mod)	75% improved fornix depth at 1 yr	Fornix depth and volume increased significantly; no keratinization or discharge; not used in severe cases.

Table 4: Outcomes of Composite and Advanced Techniques in Refractory Contracted Sockets

Study (Year)	Advanced Technique	Patients	Outcome	Remarks
Qi <i>et al.</i> , 2022 ^[37]	“Sandwich” OMG + conjunctiva + DFG	4 (severe, infected sockets)	100% success (all wearing prosthesis)	One-stage autologous layered grafts; history of implant infections; achieved deep fornices, smooth socket with no recurrence.
Groot <i>et al.</i> , 2021 ^[38]	Custom 3D-printed conformer (long-term use)	5 (recurrent sockets)	80% success (4 of 5 regained prosthesis)	Personalized conformers worn long-term with occasional adjustments; avoided further surgeries in cases with multiple prior failures.
Choi <i>et al.</i> , 2019 ^[39]	Hard palate mucosa + dermis-fat graft (HP-DFG)	6 (severe)	100% prosthesis retention at 1 year	Combined rigid palate graft (for fornix) with DFG (volume); all fornices maintained; used 5-FU injections to reduce scarring.
Al Sultan <i>et al.</i> , 2018 ^[40]	Split skin graft-wrapped conformer (temporary stent)	47 (very severe)	Improved fornices in all (multi-year follow-up)	Skin graft sutured to conformer left in socket; used as internal stent for months; allowed eventual prosthesis fitting in cases previously considered unsalvageable.
Sterker & Frerich, 2007 ^[41]	Free radial forearm flap	3 (failed prior grafts)	3/3 functional success	Microvascular free flap bringing skin/fascia; required microsurgery; excellent lining and vascularity, but complex surgery.
Mu <i>et al.</i> , 1999 ^[42]	Temporalis muscle flap + skin graft	2 (post-radiation)	Both achieved stable socket & prosthesis	2-stage: vascularized muscle rotated into orbit, skin graft for lining; bulky but effective in irradiated beds.

Abbreviations: G2 = Grade 2, G3 = Grade 3 contracture. “Success” generally means that the patient can comfortably wear a prosthesis without requiring additional major surgery. MMG = mucous membrane graft; OMG = oral mucosa graft; DFG = dermis-fat graft.

Discussion

This systematic review underscores substantial progress in

the reconstruction of contracted anophthalmic sockets, while also identifying persisting challenges and areas of

innovation. Historically regarded as one of the most difficult problems in oculoplastic surgery, contracted sockets can now be successfully rehabilitated in most patients, thanks to improved graft materials, a better understanding of socket dynamics, and adjunct therapies.

Surgical Approaches: Autologous oral mucosal grafts and dermis-fat grafts emerge as the cornerstones of socket reconstruction. Oral mucosal grafting addresses the critical issue of fornix lining: it provides a non-keratinizing, lubricated surface very similar to conjunctiva. As shown by Kim *et al.* [33] and others, buccal grafts achieve excellent functional outcomes, especially in moderate contractures. The principal advantage of mucosal grafts is their biological compatibility with the socket environment - they bring their mucus-producing goblet cells and remain moist, reducing issues like dryness and keratin debris that are seen with skin grafts. The main limitation is that in extremely scarred sockets, a mucosal graft alone may not suffice due to a lack of structural support. In such cases, mucosal grafts are often combined with structural support or done in stages after volume augmentation. Dermis-fat grafts, on the other hand, provide both orbital volume and surface area. A successful DFG effectively creates a neo bulb in the socket, preserving fornices and preventing the post-enucleation volume loss that leads to deep superior sulcus deformity. Our review confirms high success rates with DFG in many scenarios: from primary implantation at enucleation (to prevent contracture) to secondary use in contracted sockets that have lost implants. Quaranta-Leoni *et al.* [4] demonstrated that even in children (who pose growth concerns), DFGs integrate and grow, making them ideal for pediatric cases where an implant might not expand with the orbit. The findings by Aryasit & Preechawai [32] that simultaneous MMG with DFG had lower success have important clinical implications: it suggests the surgeon should not attempt to “do everything at once” in a very severe socket, but rather stage the reconstruction to let each graft fully incorporate. The dermis-fat graft can serve as a platform, and a mucosal graft can be added later if needed, as also recommended by other authors.

Role of Orbital Implants: The evolution of ocular implants has had a profound impact on contracted socket management. Modern porous implants have dramatically reduced the incidence of post-enucleation socket syndrome when used at the time of eye removal. However, in established contractures, their role is more adjunctive. The review by Bhattacharjee *et al.* [34] shows that when combined with proper lining (MMG), an orbital implant can successfully rehabilitate even a Grade 4 socket. This approach is essentially recreating a proper enucleation: place an implant to fill volume and cover it with mucosa to form fornices. One advantage of using an implant is potentially better prosthesis motility (especially if extraocular muscles can be attached or if a motility peg is used later, though pegging is rare nowadays). However, implants in scarred sockets carry the risk of exposure if the graft covering them contracts or if vascularity is poor. Many surgeons are therefore cautious about using implants in sockets that have active scarring or poor vascular supply (for instance, a socket that lost an implant to infection may be safer reconstructed with a DFG). Our review suggests that outcomes of porous implant + MMG versus DFG are

comparable in experienced hands for severe sockets, so the choice may come down to surgeon preference and patient factors. Notably, Bhattacharjee *et al.* found no significant difference in success, reinforcing that a well-done implant plus graft can substitute for an autologous graft.

Adjunctive Therapies: The use of antifibrotic agents like MMC and 5-FU is an important adjunct in socket surgery. Several studies in our review employed intraoperative MMC (applied to dissected scar areas before graft placement) to reduce postoperative fibrosis, as well as postoperative 5-FU injections in the conjunctiva during the healing phase to modulate scarring [36]. Shome *et al.* (2010) reported that low-dose topical MMC can be used safely after socket reconstruction to prevent re-contracture, with good efficacy in maintaining fornices [43]. Elder *et al.* (2018) similarly found that short-term postoperative MMC eye drops helped in refractory cases without significant complications. These agents work by inhibiting fibroblast proliferation, thereby reducing scar formation. However, their use must be judicious; excessive MMC can impair healing or cause surface complications. In the context of our review, we note that, especially in Grade 4 cases or those with a history of aggressive scarring, adjunctive MMC/5-FU may tilt the outcome towards success and is increasingly reported in the literature [44]. Another adjunct is scar prophylaxis by conformers. We cannot overemphasize the importance of maintaining what we surgically create. Many failures of socket reconstruction occur due to early re-contraction when the graft or flap is not supported. Techniques like the sutures anchoring conformers to the orbital rim or eyelids (socket molders) have been described [45]. In our practice and as reflected in multiple reports, we ensure that a conformer stays in situ for at least 6-8 weeks, and in cases of very bad scarring, even 3-6 months (changed periodically for hygiene). The Al Sultan *et al.* technique [39] is an extreme example: they effectively left a conformer in place for a long duration, with a skin graft providing internal lining, to gradually achieve a stable fornix, a testament to how prolonged stenting can yield success where repeated surgeries might fail.

Pediatric Considerations: Pediatric socket reconstruction focuses on orbital growth. The use of early conformers and expanders, as noted by Changal *et al.* [46], is crucial for minimizing facial asymmetry. A key point is that children's orbits are malleable and respond to volumetric stimulation: hence the high success of conformer therapy initiated in infancy. Our review suggests that by 1-2 years of conformer expansion, many children can go on to simply wear prostheses, whereas without such intervention, they would require major orbital expansion surgery later. When surgery is needed in children (for example, to place a dermis-fat graft or an expander), it is often done in the toddler years once the orbit is large enough to handle a graft. Tarantini *et al.* [47] and Quaranta-Leoni *et al.* [4] provide strong evidence that primary dermis-fat grafting during childhood is safe and effective, supporting the practice of using DFG at primary enucleation in pediatric patients. In contrast, adult contracted sockets often present after years of stable anophthalmia that suddenly decompensate (for instance, after an implant extrusion or with aging changes in the socket). These require more of a reconstructive approach rather than growth stimulation.

Challenges and Future Directions: Despite the high success rates reported, some contracted sockets remain notoriously difficult. *Radiation-induced* sockets, as mentioned, are one such challenge; they often require vascularized tissue (flaps) because grafts tend to shrink or fail in the ischemic environment^[5]. *Recurrent contracture* after multiple surgeries is another each surgery adds scar tissue, making subsequent grafts less likely to take. These approaches like custom 3D conformers or free flaps, are promising but not yet widely available. The future likely holds further integration of tissue engineering - perhaps bioengineered conjunctival equivalents or stem cell-seeded scaffolds could provide a new lining without needing to harvest from patient tissue. Additionally, improvements in implant materials (e.g. newer porous materials or drug-eluting implants that reduce scarring) might reduce the incidence of contraction after enucleation in the first place. One interesting area is the management of the *entire anophthalmic socket syndrome*, which includes not only contracture but also issues like deep superior sulcus and ptosis. Some patients with volume loss but without severe scarring benefit from injectable fillers or orbital floor implants to address enophthalmos rather than full socket reconstruction. For instance, calcium hydroxyapatite fillers have been used for post-enucleation enophthalmos with good effect in select cases (avoiding a full surgery)^[48]. These adjunctive treatments can sometimes stave off a frank contracture if used early. In addition to established techniques utilizing autologous or allogeneic tissue, various tissue engineering approaches involving scaffolds and stem cell expansion techniques are currently being explored as potential alternatives for socket reconstruction^[49]. The evolution of contracted socket reconstruction represents a progression from simple grafts to more complex, targeted interventions. By harnessing autologous tissues such as mucosa, skin, and fat, along with advanced implants, surgeons are now able to reconstruct sockets that would have been deemed untreatable just a few decades ago. The integration of volumetric augmentation and fornix restoration, often achieved through innovative one-step solutions, has significantly enhanced patient outcomes. Equally crucial is the recognition that success extends beyond the operating room: diligent postoperative care, including stenting, monitoring, and adjunctive drops, is vital for achieving and maintaining a functional socket. Consequently, the prospects for patients with even advanced contracted sockets have greatly improved compared to the past, and ongoing innovations hold the promise of further enhancing these results while minimizing morbidity.

Conclusion

Contracted anophthalmic socket reconstruction has progressed from rudimentary skin grafts to sophisticated combined techniques that address both orbital volume deficiency and fornix lining. Autologous grafts, particularly oral mucous membrane and dermis-fat grafts, remain the mainstay, yielding high success in reforming the socket fornices and allowing prosthetic eye retention in most patients. In severe cases, modern approaches employ a combination of methods (e.g. mucosal grafts with orbital implants, composite hard palate-fat grafts, or staged procedures) to achieve functional results. Adjunctive measures such as anti-fibrotic medications (mitomycin-C, 5-FU) and prolonged conformer stenting have further

improved outcomes by minimizing postoperative scarring. Pediatric socket management emphasizes early intervention with conformers or grafts to promote orbital growth, whereas adult cases often involve surgical reconstruction of lost lining and volume. Although challenges persist in cases with extensive scarring (especially post-radiation or multiple failures), advances in autologous tissue engineering, integrated implants, and customized expansion devices have significantly increased the success rates and patient satisfaction. Today's reconstructive algorithms allow many patients with contracted sockets to regain a stable, prosthesis-wearing socket and an acceptable cosmetic appearance, reflecting a remarkable evolution in this field.

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