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REVIEW ARTICLE

A Review of Biomaterials for Post Traumatic Internal Orbital Reconstruction

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ABSTRACT:
Orbital floor injuries, alone or in combination with other facial fractures, are one of the most commonly encountered midfacial fractures. Significant complications can occur as a result of these injuries, including enophthalmos, persistent diplopia, vertical dystopia and restriction of gaze. Appropriate repair is therefore critical. There is currently a greater understanding of the complex anatomy of the orbit and changes that occur within the orbit from disruption of its contents caused by trauma. Although many biomaterials are available to reconstruct these deformities but the choice of material to be used remains controversial. This review aims to give a comprehensive review of the advantages and disadvantages of biomaterials used in post-traumatic internal orbital reconstruction, with the goal of assisting surgeons to make a better choice
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INTRODUCTION

The globe and orbit constitute a very small portion of the body but trauma to this region assumes critical importance due to high value we place on vision. The orbit may be injured directly or indirectly, with both blunt and penetrating trauma. Reconstruction of the internal orbit, with a few exceptions, is treated very differently than the other facial fractures because of thinness of the bony orbital walls. The bone usually shatters when injured, therefore instead of using bone plates to hold the bone fragments into a particular position, sheets of bone or other biomaterials are required to replace the bony walls and restore pre-trauma anatomy[1].

Fractures of orbit are one of the most challenging injuries the maxillofacial surgeons deal on a daily basis. Hence, a comprehensive understanding of these fractures is necessary for treatment due to functional and aesthetic deformities that often result. Additionally, damage to the globe, optic nerve and extraocular muscles are always a concern. Isolated orbital fractures account for 4% to 16% of all facial fractures. If zygomatico-maxillarty complex (ZMC) and naso-orbito-ethmoid fractures are included, then this accounts for 30% to 55% of all facial fractures.[2,3,4] Orbital trauma may also cause blindness, so the first priority for these injuries is the health of the globe. There is also a high association with the cerebral and ocular injuries.[1] the maxillofacial surgeon should be able to conduct a thorough and expedient assessment of the eye after blunt or sharp midfacial trauma and perioperatively for the many surgical procedures that involve the orbit and surrounding soft tissues. Recognition of potentially sight-threatening disorders is of the highest priority, and prevention of secondary injury is equally important.

Optimal treatment is to restore normal bony architecture and reduce the herniated orbital tissues. Despite advances made in understanding of the injury, wide variation still exists in the method of reconstruction. Of all the considerations in orbital reconstruction, probably no topic has more differing opinions than the selection of biomaterial with which to reconstruct the orbital walls. No single material till date has been universally successful in meeting all the criterias needed for reconstruction of orbit. However, as material sciences continue to advance, materials come to possess increasingly more of these qualities. This review aims to give a comprehensive review of the advantages and disadvantages of biomaterials used in post-traumatic internal orbital reconstruction, with the goal of assisting surgeons to make a better choice.

BIOMATERIALS

Orbital reconstructions have migrated away from autogenous bone grafts to well-tolerated alloplasts, such as titanium and Medpor. The ideal technique is influenced by many factors, including specific characteristics of the injury and the experience of the surgeon. Material for reconstructing the orbit can then be selected based on requirements of the defect matched to the mechanical properties of the material. The ideal properties required for biomaterial include: (1) Chemically inert; (2) Biocompatible; (3) Nonallergenic; (4) Non carcinogenic; (5) Cost-effective; (6) Sterilizable; (7) Radioopaque; (8) Stability; and (9) Ease of handling.

Aulologous bone has persisted as a reliable, safe and lifelong material for reconstruction of the orbit. Its use seems to depend on the experience of the surgeon. A wide variety of specialities, and therefore training backgrounds, are involved in the primary treatment of traumatic orbital injuries, which has significant impact on the selection of biomaterials for orbital reconstruction. In appropriate hands, harvesting autologous tissue results in minimal added morbidity to the patient, especially when it may be obtained within the same operative field, and is reasonably easy to mould and adapt for use within the orbit. No alloplastic material to date has been shown to be superior to fresh autogenous bone grafts. Autologous bone still remains the gold standard for reconstructing the bony defects characteristic of orbital injuries. Resorbable materials may evolve into reliable materials for reconstruction of the orbit. However, biodegradable materials used in the orbital floor currently manifest an 8.3% incidence of inflammatory reactions, and therefore these materials should be used with appropriate caution.[5]

AUTOGENOUS MATERIALS

Autogenous tissues were the the first material used to reconstruct the internal orbit and are still frequently used.[6] they require a second operative site, which increases patient morbidity; require increased operative time to harvest; are limited in quantity; and are plagued by variable amounts of resorption over time. The variable resorption and potential for late onset enophthalmos are the most critical arguments against autogenous materials. Souces for autogenous bone includes calvarium, Iliac crest, rib, anterior maxillary wall, mandibular symphysis, ramus, lingual cortex, and coronoid process. Autogenous cartilage grafts are the most frequently used material for nasal augmentation[7] but their use for reconstructing orbital fractures is not as prevalent. However autogenous cartilage provides an easily harvested autogenous material for smaller defects in appropriately selected patients. Sources for autogenous cartilage grafts include cartilaginous nasal septum and conchal cartilage.

ALLOGENEIC MATERIALS

Allogeneic materials (allografts, homografts) contain no living cells but, may possess osteoinductive and/or osteoconductive properties, depending on the material. These materials become incorporated into host tissues and provide a structural framework for ingrowth of host tissues. They do not require a second operativ site, therefore require less operative time, and are generally abundant in supply. Waite and Clantons reported that allografts seem to give equally successful results as autografts for reconstruction of the orbital floor. Use of allogeneic materials, however, is marked by concern for antigenicity of the materials and transmission of infectious disease.[8] The two most common allografts used for orbital reconstruction are homologous bone and cartilage.

ALLOPLASTIC MATERIALS

Alloplasts have been gaining popularity for reconstruction of the internal orbit because of their ease of use and reduction in surgical mobility. Other benefits of alloplasts include decreased operative time, multitude of sizes and shapes available and seemingly endless supply. The disadvantages of alloplasts stem from the fact that they are foreign bodies and elicit some degree of host reaction to the material. Alloplasts may be classified as nonresorbable or resorbable. Nonresorbable materials are immune to many of the late-occuring complications; however, the literature reports several cases of inflammatory reactions to some of these products.

Metallic mesh

Titanium mesh has been approved by the Food and Drug Administration since 1984, and now is accepted throughout the world, especially in larger defects. They have unique ability to compensate for volume when properly contoured, without the potential for resorption. Titanium has further advantage of producing fewer artifacts on CT than other metals. However, it is costly and may have irregular edges that may impinge on soft tissue. Furthermore, fibrous tissue will incorporate the mesh-holes, which can make implant replacement technically difficult.[9]

Medpor

High density porous polyethylene (Medpor) has been widely used in smaller orbital floor defects. It is non-absorbable and easily malleable into shapes. The smooth surface of medpor allows tissues within the orbit to move around freely.[10] Connective tissue and vascular components can grow into the pores which provide great biocompatibility. Medpor is reported to be able to achieve similar outcomes and lower infection rates than autologous bone.[11]

Medpor Titan

It is a sheet of titanium mesh embedded in porous polyethylene and has gained much attention in the literature recently. It has the strength, memory and radioopacity of titanium and the potential for fibrous ingrowth of polyethylene. The medpor titan implant allows the surgeon to avoid the considerable tissue ingrowth through the holes that is seen with titanium mesh, preventing the tissue from adhering to the surface of implant. Medpor Titan possesses improved handling characteristics compared with traditional Medpor, allowing the surgeon to bend and contour thin implant material to the desired shape while providing the strength usually associated with a much thicker traditional Medpor implant.

Nylon Suprafoil

Smooth nylon foil is a non-absorbable clear sheeting material manufactured from standard nylon suture. Formerly known as Supramid, nylon foil has been used to repair orbital fractures since 1965. In 2007, Majmundar and Hamilton examined 10 orbital floor fractures in 9 patients who were treated with smooth nylon foil from 2004 to 2006. They reported no incidences of implant extrusion, rejection, or infection, and concluded that SupraFoil was safe, easy to use, and reliable.[12]

Hydroxyapatite

Hydroxyapatite [Ca_{10} $(PO_4)_6(OH)_2$] is a calcium phosphate salt that is a major constituent of bone. Calcium phosphate ceramics can be produced through the fusion of calcium phosphate crystals. Several forms are available for reconstruction of the facial skeleton. Hydroxyapatite is highly biocompatible and causes minimal inflammatory response in the surrounding tissues. It produces a strong mechanical bond with host bone and allows ingrowth of host tissue, providing a scaffold for bone repair. It demonstrates limited resorption and obviates a second surgical site. Hydroxyapatite (all types) has a favorable infection rate of 2.7% for craniofacial reconstruction.[13] Block forms of hydroxyapatite are most commonly used within the internal orbital skeleton. Ease of use and limited mechanical qualities are the main disadvantages of hydroxyapatite.[14] Its low tensile strength and inflexibility make HA a poor bone substitute. It is brittle, and therefore challenging to contour for placement. Hydroxyapatite is extremely difficult to stabilize because overtightening a screw will lead to fracture of the implant. Because of its limited adaptability and relative incompatibility with rigid fixation, hydroxyapatite is rarely used for primary treatment of orbital fractures.

Silicones and Polytetrafluoroethylene (Teflon)

The current use of these materials is limited because of numerous reports of late complications arising as many as 20 years postoperatively.

RESORBABLE ALLOPLASTIC MATERIALS

Biodegradable fixation systems have been available for more than 20 years, and are gaining acceptance in many areas of facial reconstructive surgery. Advocates believe these systems perform comparably to metal fixation systems and that the resorbable systems possess a distinct advantage over the lifelong risk of complications characteristic of nonresorbable alloplasts. The development of a resorbable fixation system with mechanical properties similar to metal fixation systems is particularly enticing for use within the orbital skeleton.

Polylactide

Early systems consisted of high-molecular weight polymerized poly(L-lactide) (PLLA). Animal studies investigating the use of PLLA within the orbit have been performed using a 0.4-mm thick PLLA implant in a goat model.[15] Clinical and microscopic evaluation showed good healing of the orbital defects, with formation of a mature connective tissue capsule and new bone on both antral and orbital sides of the implant. On the antral side, normal sinus mucosa was present across the implant surface. No inflammatory reactions were noted at longest follow-up (78 weeks); however, the implants had not fully resorbed at this time. In a 5-year follow-up to this study,[16] no complications related to the implants were seen in the remaining goats, and the implants were still present. The authors reported that the tissue reaction around the implants had not increased substantially, but the mass-loss seemed to be limited.

Lactosorb (Walter Lorenz Surgical, Jacksonville, FL) is a biodegradable copolymer of polylactic and polyglycolic acids that has been in use clinically for more than 10 years. Studies have shown that this copolymer formulation has a more rapid rate of degradation (9–15 months) compared with PLLA and therefore might be better suited for use as an orbital implant. Clinical studies have shown good results with Lactosorb throughout the craniofacial skeleton.[17]

POLYGLACTIN

Polyglactin 910, most commonly known as the suture material Vicryl, is a resorbable synthetic material composed of lactide and glycolide acids. Both film and mesh forms of polyglactin 910 have been reported for repair of orbital fractures. The process of resorption may take longer in the mesh forms compared with the film forms, though the tissue reactions elicited are the same with both the forms. Vicryl mesh is currently the most commonly used form of polyglactin 910 for repair of orbital fractures. Mauriello and colleagues[18] reported that Vicryl mesh has many advantages over other implants for use in the orbit, such as the fact that it is resorbable, it is layered and may be cut to the appropriate thickness at the time of surgery, it is soft and pliable, and therefore easily fits within the orbit and presents no risk to the tissues of the orbital apex; and it does not require fixation. Vicryl mesh is too flimsy to function effectively as a material for orbital repair; this is best shown in the report by Mauriello and colleagues, in which up to 56 layers of material were required to obtain the desired result. The bulk of material necessary for successful outcome may be the underlying cause of the low-grade inflammatory reactions seen; however, no mention is made of an association between the patients who developed inflammatory reactions and the amount of material used.

POLYDIOXANONE PLATES

Polydioxanone is a resorbable aliphatic polyester polymer. Degradation reportedly occurs through hydrolysis in 10 to 12 weeks. The use of polydioxanone plates for orbital fractures has been recommended for orbital defects of 1 to 2 cm. Polydioxanone is available in preformed bowl-shaped plates that are easily cut to fit. It can be easily stabilized to adjacent host bone with screws, wires, or suture. Early reports of use of polydioxanone within the orbit seemed favorable. *Iizuka and colleagues*[19] reported the use of polydioxanone plates for orbital floor reconstruction in 20 patients and they reported the material to be well tolerated, with no clinically apparent inflammatory reactions. The most common complication was inferior migration of globe position over time, for which the authors recommend routine overcorrection of globe position at surgery. Of the 20 patients in the study, 10 (50%) showed overcorrection postoperatively, 9 of which had transitory diplopia related to the degree of overcorrection. It resolved in all but 2 cases over an average of 29 days. Other studies have shown a less favorable outcome. *Kontio and colleagues*[20] prospectively followed 16 patients treated with polydioxanone implants for internal orbital wall reconstruction. Postoperative evaluation consisted of clinical, CT, and MRI examination. Reconstructed orbital shape was unsatisfactory and proper orbital volume was not restored. MRI showed thick scar formation (37.5%). The investigators concluded that use of polydioxanone implants for internal orbital reconstruction is not advisable. *de Roche and colleagues* compared the use of polydioxanone with polylactide in a sheep model. Histologic and radiologic findings at 4 and 12 months were reported for each material. The polydioxanone membranes showed fragmentation leading to severe fibrous tissue reaction, and demonstrated a greater tissue reaction than did polylactide membranes. Tissue reactions associated with polydioxanone led to significant postoperative sequelae, including sensory disturbances (59%), restriction of globe motility (38%), and enophthalmos (24%).

CONCLUSION

Treatment of traumatic orbital injuries will continue to be a topic of considerable controversy. The ideal technique, which may involve different reconstructive materials and various surgical access sites, could be influenced by many factors, including characteristics of the maxillofacial trauma and the experience of the surgeons. Ideal materials for reconstruction of the orbital skeleton will be determined by the same factors. Comparisons of alloplastic (bioresorbable or non-bioresorbable) and autogenous materials depend on the assessment of the precision of bony defect reconstruction and the clinical assessment of graft healing aspects and distant graft resorption. It is the responsibility of the surgeon to recognize the diversity of the materials available and to apply them selectively in clinical use.

A comprehensive understanding of orbital fractures is necessary for the treating surgeon due to the functional and esthetic deformities that often result. Careful attention to a thorough pre-operative assessment, individualized surgical plan, honest appreciation of one’s own limitations, meticulous attention to surgical technique with a clear understanding of the relevant anatomy, and a thoughtful respect for the local essential structures are the pre-requisites for good outcome of post-traumatic orbital reconstruction. Above all a holistic approach and a steep learning curve is the foundation for best results.

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