Treatment of Orbital Fractures: The Case for Reconstruction With Autogenous Bone

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Because of the complex structure of the orbital walls, the fracture patterns vary considerably in their location as well as in their degree of severity.1 Multiple portions of the orbit can be fractured and several internal orbital walls therefore injured simultaneously.

The ideal reconstruction material for orbital floor or wall reconstruction should be easy to mold, easy to anchor, biocompatible, strong, and readily available. It should restore orbital form and support function. But is that enough?

Orbital wall fracture implies a situation where disruptions of the walls or floor have occurred. It is a defect fracture where bone fragments with torn periosteum are pushed outside of the original bony orbit. There is no intact bone even near the defect area except the thin bone rim surrounding the defect fracture. The purpose of defect repair is to support orbital contents, free entrapped tissue, and, especially, restore the original orbital volume. If the volume cannot be restored, enophthalmos will inevitably occur.2 Even a 5% change in volume leads to clinically detectable changes in soft tissue position, resulting in enophthalmos.3

The treatment of choice to restore absent bone segments in facial skeleton is to replace the defect with autogenous bone. Alloplastic materials have been used with caution, because they increase the risk of infection and have the potential for extrusion. Why should the treatment of orbital wall defect fractures differ from this general opinion?

Osteogenesis, Osteoinduction, and Osteoconduction

New bone formation occurs via 3 biologic mechanisms: osteogenesis, osteoinduction, and osteoconduction.

The bone defect filled or bridged with bone graft heals through osteogenesis. The endosteal osteoblasts will survive as long as 5 days posttransplantation due to their ability to absorb nutrients from the surrounding tissues.4 Entrapped platelets inside the graft degranulate, releasing potent growth factors,5 while endothelial cells initiate capillary in-growth. By the end of the second week, the graft will demonstrate complete revascularization. Endosteal osteoblasts from the transplanted bone will begin laying down osteoid. Stem cells will begin differentiating into osteoblasts. Islands of bone formation are then developing within the graft. Finally, the resultant lamellar bone will enter into a remodelling phase.4

Osteoinduction is the formation of bone by connective tissue cells transformed into osteocompetent cells by inductive agents, usually proteins, such as bone morphogenetic protein. Urist6 was the first to describe the osteoinduction mechanism. Since then, a wide variety of entities with different effects on bone have been discovered. They are classified as osteoinducers, osteopromoters, or bioactive peptides.

Osteoconduction describes bone formation by the process of in-growth of capillaries and osteoprogenitor cells from the recipient bed into, around, and through a graft or bioimplant that acts as a scaffold for new bone formation. Unlike osteoinduction, this process occurs in an environment already containing bone.

Guided Bone Regeneration (GBR)

Guided bone regeneration (GBR) refers to a procedure where a barrier membrane is placed over a bony defect and closely adapted to the surrounding bone surface, creating a secluded space between the bone and membrane. The close adaptation is necessary to achieve a sealing effect to prevent the in-growth of

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0278-2391/04/6207-0017$30.00/0
doi:10.1016/j.joms.2004.03.003
soft tissue cells because these cells are able to compete with bone-forming cells in the bone defect underneath the membrane. Several studies have shown that predictable and successful bone regeneration can be achieved by using this osteopromotive membrane method.

Large defects should be filled with autologous bone graft and/or a suitable bone substitute. Alternatively, GBR technique with osteopromotive membrane covering the defect can be used to restore the structure and geometry of the bone. A healing period of 9 months has been proposed for GBR technique in large bone defects. However, an osteopromotive membrane alone is not enough to restore bone volume in a critical-size defect, where autogenous bone grafting is mandatory.

**Orbital Wall Reconstruction, Guided Bone Regeneration, or Placebo**

**NONRESORBABLE IMPLANTS**

**Titanium**

Reconstruction with titanium plates and screws is considered to be a reliable method of treatment resulting in good fracture healing. The titanium mesh seems to be a valuable material for orbital wall reconstruction, especially in the orbital floor and medial wall area.

When titanium plates were introduced, it was generally believed that they need not be removed, because titanium is a highly biocompatible material. However, it has been shown that aluminum is released from titanium implants into the adjacent structures and even to regional lymph nodes. The clinical relevance of this release is not yet known.

There are some further disadvantages with titanium implants in orbital wall reconstruction. The implant is difficult to remove, because of the mesh structure. Furthermore, titanium implant placed in the orbital floor may be traumatically driven back to the orbital apex causing injury to the optic nerve.

Titanium has its place in orbital wall reconstruction. It is highly biocompatible and should be used when operation time is strictly limited and extensive reconstruction is needed.

**Silicone, Polyethylene, and Teflon**

The main applications of these materials are craniofacial augmentation, defect filling, and silicone in addition to joint rehabilitation. They have all been used for orbital wall reconstruction even though they are neither osteogenic nor osteoconductive or osteoinductive. They evoke a mild fibroblastic or inflammatory reaction, but they have been reported to cause severe complications, including extrusion or migration of the implant and infection. In orbital wall reconstruction with silicone inferior eyelid swelling, pain, ocular dystopia, and maxillary sinusitis have been reported.

Silicone, polyethylene, and Teflon will remain in the tissue permanently, are known to evoke adverse tissue reactions, and are alone too weak for GBR, and have absolutely no bone repair properties.

**ALLOGENIC DURA IMPLANTS**

Dura mater has been used for different clinical purposes with good results. Allogenic dura mater has been used in the repair of orbital defects for several decades. Dura is biocompatible and flexible and can be individually contoured. The clinical evidence about dura suggests that the material is strong enough to support the orbital contents. Lyophilized dura may have osteoconductive properties. The complication rate is low, 7% to 8%, and there is no need for secondary surgery to remove the implant. No major graft migration or extrusions have been reported after orbital wall reconstruction with dura implants. However, a few cases of Creutzfeldt-Jakob disease patients have been reported, which has probably been transmitted via cadaveric dura. This emphasizes that instead of allogenic implants, autologous tissue should be considered whenever possible.

**RESORBABLE IMPLANTS**

**Polydioxanone**

Biodegradable materials have been used for biomedical applications for many years. These materials do not need to be removed.

Polydioxanone (PDS) is a biodegradable material, which loses 50% of its strength in the first postoperative month. It has been widely used in the treatment of orbital wall defect fractures even though it has not been reported to possess osteoconductive properties. This lack of osteogenic properties was documented in our own study as well as other studies on reconstruction of orbital wall with PDS. Computed tomography scanning showed no bone growth along the resorbing PDS but occurred along the torn peristeum. Both experimental and clinical studies suggest that the newly formed bone tissue does not follow the original anatomic bone geometry but instead follows the dislocated bone fragments leading to increased orbital volume.

PDS plates have other disadvantages such as rapid resorption, which leads to inflammatory reactions, like sinus formation and excessive scar formation. Also some doubts of inferior mechanical properties of PDS have been raised.

PDS material has no osteogenic, osteoconductive, or osteoinductive properties. PDS may mimic GBR
membrane, which explains why clinical results in the reconstructions of small orbital wall defects are fairly good but not of large defects (Figs 1, 2).

Polylactides

Polylactide implants have been used for orbital floor reconstruction since 1972, when Cutright and Hunsuck published an experimental study on rhesus monkeys.

Although clinical and experimental studies conclude that biodegradable polylactide (PLLA) implants are well tolerated in the orbital region, it seems that during the degradation fluid accumulates at the implantation site, resulting in edema. Histologic studies have revealed a nonspecific foreign body–type reaction around remnants of degrading PLLA crystals. The main drawback of PLLA implants are the low degradation rate and slow resorption in clinical use.

Poly-LD-lactide (PLDLA) stereocopolymers have been developed to shorten the degradation time. The degree of crystallinity can be moderated by changing the optic isomer (L/LD) ratio. The degradation time of the PLDLA stereocopolymer is shorter than of pure PLLA in vitro, yet strength properties are comparable to those of pure PLLA. In an experimental study by Kontio et al., PLDLA 85/15 plate–shaped implants proved to be mechanically inadequate. They were already broken in vivo after 4 weeks. Immunohistochemical verification of tenascin and cellular fibronectin suggested a prolonged wound healing and inflammatory reaction around degrading implants.

In a study on sheep orbital floor fractures, reconstruction was carried out with low monomeric SR-PLDLA 96/4 stereocopolymer implants. The material seemed to be well tolerated in immunohistochemical studies, where only low inflammatory reaction was detected. Unfortunately, the implants became coiled after 12 weeks. The differences in healing between the reconstructed and control (nonreconstructed) orbital floors were not statistically significant. The orbital floors did ossify during the follow-up. However, the new bone ossified in a too caudal position, resulting in increase of orbital volume. PLDLA96 were deformed and fractured far beyond the ideal GBR period.

The resorption of the most PLDLA implants may occur too fast compared with bone healing. The plate cannot tolerate the pressure caused by the orbital content and, hence, gives no support to GBR.

Bone Grafts

Autogenous bone grafting has been the gold standard to provide framework for facial skeleton and orbital walls.

Basically there are 2 forms of free autogenous bone grafts: cortical and cancellous. Cancellous grafts are revascularized more rapidly and more completely than cortical grafts. Second, creeping substitution of a cancellous graft initially involves appositional bone formation followed by a resorptive phase; with cortical grafts, it is vice versa. Third, cancellous grafts tend to repair completely, whereas cortical grafts remain as an admixture of necrotic and viable bone.

Many different sources such as calvarium, mandibular and maxillary bone, ribs, and iliac crest have been used.

In his study of internal orbital wall reconstruction, Ellis and Tan compared calvarium bone with titanium mesh in 38 patients. They concluded that both titanium mesh and calvarium bone can be successfully used for reconstruction of isolated blowout fractures. However, there was significant difference in the cross-sectional area of anterior region of the orbit. This is probably due to brittleness of calvarium bone. It cannot be contoured to adapt the complex structure internal orbit. The soft tissue contents of the

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**FIGURE 1.** Number of patients (total 16) with hypophthalmos (parallelogram) and hyperophthalmos (square) during each clinical follow-up with polydioxanone floor reconstruction.

**FIGURE 2.** Number of patients (total 16) with enophthalmos (parallelogram) and proptosis (square) of more than 2 mm during each clinical follow-up with polydioxanone floor reconstruction.
orbital fracture area were successfully replaced with both reconstruction materials. The authors concluded that titanium might not prove to be the best material for orbital wall reconstruction, if the functional study will be included.

Dempf and his coworkers used calvarial and iliac crest grafts in repairing osseous orbital defects. Of 42 patients 34 were followed up at least 4 months. Seven patients were observed to have enophthalmos, and 2 patients had diplopia at the end of the follow-up. They concluded that with autogenous bone transplants, good aesthetic and functional results can be achieved, and that autogenous grafts can be broadly recommended for providing primary care.

Autogenous anterior iliac crest graft could be an ideal reconstruction material considering that enough bone is always available and bone can be harvested simultaneously to orbital exploration. However, iliac crest graft is said to be bulky without trimming and it may resorb unpredictably. Both de Visscher and van der Wal and Bartkowski and Krzystkowa used iliac crest graft for orbital floor or medial wall reconstruction in their follow-up studies. Postoperatively none of the patients had enophthalmos more than 2 mm. Six of 85 patients had diplopia after 10-month follow-up. They both concluded that autogenous corticocancellous bone like iliac crest has proved to be extremely well tolerated and is adequate material for orbital wall reconstruction.

Sullivan and his co-workers studied free iliac grafts with or without supporting titanium mesh plate in an experimental study. The result was that the resorption of the graft was similar in both groups and the magnitude of resorption after 28 weeks was one-third of the iliac bone graft thickness. Roncevic and Malinger followed 75 patients with orbital floor injury reconstructed with bone grafts. They concluded that the medial cortex of anterior iliac crest is moldable and after trimming is easily adapted to the shape.

FIGURE 3. An iliac bone graft with medial corticocancellous graft shaped for orbital reconstruction.

FIGURE 4. A, Postoperative 3-dimensional computed tomography scan showing the position and shape of iliac crest bone graft on both orbital floors. B, From a 31-year-old man who sustained a bicycle accident. Sagittal computed tomography scan shows an accurate alignment of iliac crest graft. C, Same patient as in B, 6 months after surgery. Computed tomography shows excellent bone healing at the posterior part of reconstruction and slight overall thinning of the graft.
and form of the internal orbital wall. I have come to the same conclusion in clinical practice (Figs 3, 4).

The lateral wall of maxilla has also been used for orbital floor reconstruction. In a study by Lee et al., of 41 patients, 2 had enophthalmos postoperatively. Except nerve paresthesia, no other complications were reported. No evidence of bone resorption was detected and the volume of the orbit was maintained.

For correction of posttraumatic globe malposition, the method of choice is bone grafting. This can provide statistically significant improvement in the enophthalmos between preoperative and postoperative status and diplopia. 

Disadvantages of autogenous bone graft include nerve and blood vessel injuries, chronic donor site pain, gait disturbances, and cosmetic disturbances. Although there are multiple sites for autogenous grafts, the anterior iliac crest remains the most common site. Despite a large volume of autologous iliac crest grafts used, the donor site morbidity seems to be low. A study by Banwart revealed that none of the 261 studied patients had a severe perioperative complication; none of the 225 patients with long-term follow-up had a severe late complication. The authors concluded that severe complications from iliac crest bone graft harvest can be avoided and major complications affecting functioning are uncommon, but minor complications are common. Ahlmann et al. had similar results in their study. A major complication was associated with 8% (n = 5) and minor complications were 15% (n = 10) of the 66 anterior iliac sites. Although complication rate seems to be low, the donor side complications should not be ignored.

References