PHILIPPINE JOURNAL OF
Ophthalmology
VOL. 29 • NO. 3 JULY - SEPTEMBER 2004

ORIGINAL ARTICLE

Ostrich eggshell as an onlay bone-graft substitute for orbital blow-out fractures

Rhoumel A. Yadao, MD[1]
Gloria D. Lim, MD[1]
Lawrence C. Pe,MD[1]
Allan M. Valdez, MD[1]
Susan Cristobal, MD[2]
Alice Tuesday C. Sunico, MD[2]
Hazel L. Romero, MD[3]

[1]*Department of Ophthalmology*
[2]*Department of Pathology*
[3]*Department of Radiology*
East Avenue Medical Center
Quezon City, Philippines

ABSTRACT

Objective

To assess the biological behavior of an ostrich eggshell implant as an onlay graft on the orbital floor.

Methods

This is an experimental study of 12 rabbits implanted with ostrich eggshell (6 rabbits with 5mm- and 6 rabbits with 10mm-diameter grafts) subperiosteally in the right orbital floor. The right orbit was harvested en bloc 1, 2, and 3 months after onlay. Radiographic studies were done one day after implantation and prior to harvest. The specimens were submitted for gross and microscopic studies.

Results

All animals showed normal wound healing. The grafts were stable and no foreign body reaction was observed 1, 2 and 3 months postimplantation. The size of the ostrich eggshell implants remained the same. There was no change in radiodensity at 3 months observation.

Conclusion

The results of this study support the potential application of ostrich eggshell as bone substitute for orbital floor fractures.

Correspondence to
Rhoumel A. Yadao
Eye Department
East Avenue Medical Center
East Avenue, Diliman
1104 Quezon City, Philippines
Telefax: +63-2-9288550

Key words: *Eggshell, Blow-out, Implant, Orbit, Graft*

The authors have no proprietary or financial interest in any product used or cited in this study.

PHILIPP J OPHTHALMOL 2004; 29(3): 127-130
© PHILIPPINE ACADEMY OF OPHTHALMOLOGY

THE MANAGEMENT of orbital floor fractures has been controversial for many years.[1, 2] Some orbital floor fractures require only observation while others require surgical reduction. When surgery is performed, the herniated, displaced orbital tissues are freed and repositioned into the orbit. To prevent reherniation, an implant is used to span the orbital floor defect.

Several forms of implants are available but none possesses the ideal characteristics; each has its own advantages and drawbacks. Autografts are preferred by most plastic and craniofacial surgeons,[3] but bone harvesting procedures are associated with increased morbidity such as bleeding, infection, and pain at the donor graft site.[4, 5] Allograft is associated with transmission of hepatitis and AIDS.[6] Alloplastic implants such as silicone, polyethylene, hydroxyapatite, and metal alloy plates are preferred by ophthalmologists, but these materials are expensive.

In an earlier study by Dupoirieux[7] on the use of chicken eggshell as bone substitute in maxillofacial surgery, he concluded that the eggshell is biocompatible and suggested its use for filling limited bone defects in nonweight-bearing areas. A 1999 follow-up study by the same author using ostrich eggshell as onlay graft on rabbit mandibles showed similar results.[8] The eggshell had the mechanical strength for load-bearing areas. Other advantages cited were:

1. Ease of trimming with a dental burr;
2. Ease of sterilization by autoclaving without altering its biological properties;
3. Conformity of the form and thickness of the implant to the curvature of the human orbit.

The ostrich *(Struthio camelus)* has the largest egg of any living bird with a mean weight of 1.5 kg and mean size of 16 cm x 12 cm. The shell is about 2 mm thick and is strong to stand a force of up to 55 kg.[8] The composition of avian eggshells differs slightly among species, but is mainly a mineral matrix (over 97%) composed of calcium carbonate (97.4%), magnesium phosphate (1.9%), and tricalcium phosphate (0.7%).

This study evaluated the clinical and histological responses to ostrich eggshell when used as onlay graft on the orbital floor in rabbits.

METHODOLOGY

Empty ostrich eggs bought from Gross Ostrich farm in San Antonio, Nueva Ecija were fragmented with a dental burr to sizes 5 mm x 2 mm (diameter x thickness) and 10 mm x 2 mm. The membranes were peeled from the inner surface with forceps and the implants were then bleached in a 10% solution of sodium hypochlorite (NaClO) for 24 hours. The implants were subsequently washed with sterile water and sterilized by autoclaving.

Twelve white rabbits weighing 2 to 2.5 kg each were equally divided into two groups. One group was implanted with ostrich eggshells measuring 5 mm in diameter, and the other group with ostrich eggshells measuring 10mm in diameter. The animals were anesthetized with ketamine 10mg/kg (Ketaject, Astrapin Pharma, Pfaffen-Schwabenheim, Germany) intramuscularly. The right eye was prepped with 10% povidone-iodine solution. A subciliary incision was done followed by division of the orbicularis oculi muscle. After elevation of muscle-skin flap, the periosteum was incised 2 mm from the inferior orbital rim and the implant was laid down on the orbital floor. The periosteal division was closed with 5-0 chromic gut suture (Ethilon, Johnson & Johnson, New Brunswick, NJ, USA) and the skin with 6-0 silk (Ethilon, Johnson & Johnson, New Brunswick, NJ, USA). Antibiotic ointment was applied over the skin incision and cefazolin 50 mg/kg (Megacef, Oboi Laboratories, Mumbai, India) was injected intramuscularly. The skin sutures were removed 5 days after the operation.

The right orbit was harvested en bloc at 1, 2, and 3 months after implantation for each group (2 per group/month). The eyeball was enucleated to facilitate gross examination. Specimens were fixed in 10% formalin, partially decalcified in dilute nitric acid and then infiltrated with paraffin for sectioning. Histologic sections of the specimens were stained with hematoxylin and eosin for examination with light microscopy.

Radiographic studies of the orbit (left and right oblique views) were obtained immediately after implantation and prior to harvesting.

Treatment of the rabbits adhered to the guidelines of the Association for Research in Vision and Ophthalmology.

RESULTS

No wound infection was encountered in all experimental animals. One rabbit belonging to the 5 mm implant group died 3 days after implantation because of unknown causes and was excluded from the study.

On gross examination (Figure 1), the implants were easily distinguished from the surrounding bone and maintained normal contour in all cases. Observing through the intact periosteum, there were no signs of graft extrusion and none was mobile. The diameter and thickness of the ostrich eggshell grafts did not change 1, 2, and 3 months after implantation.

On radiological examination (Figure 2), no signs of extrusion, new bone formation, or resorption were seen.

Histological sections (Figure 3) showed no inflammatory cells or foreign body reaction, no bone or vascular ingrowth into the implant, and no resorption or autolysis. Fibrous encapsulation was not observed in all specimens.

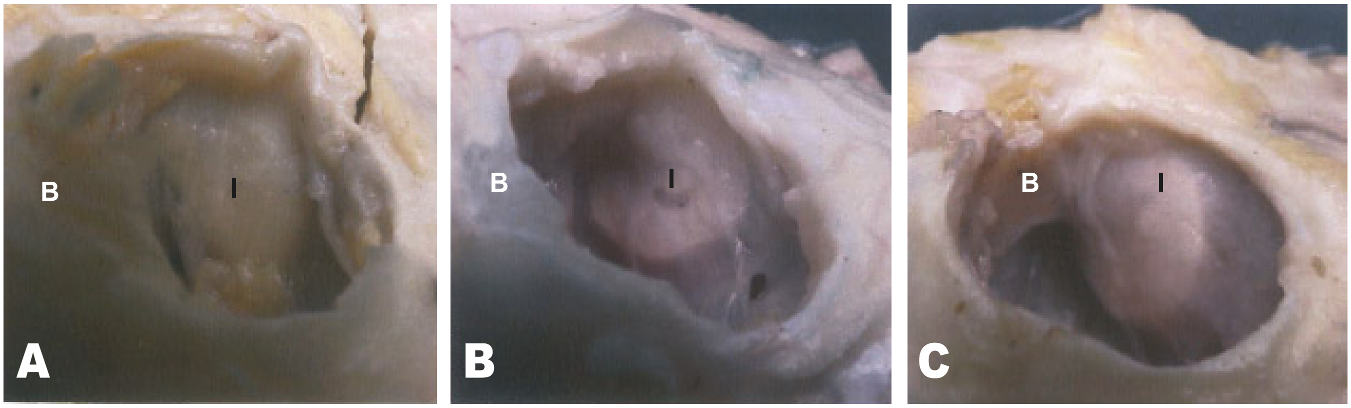

Figure 1. Gross examination of ostrich eggshell implants through intact periosteum at 1 (A), 2 (B), and 3 (C) months. The implant (I) is easily distinguished from the surrounding bone (B).

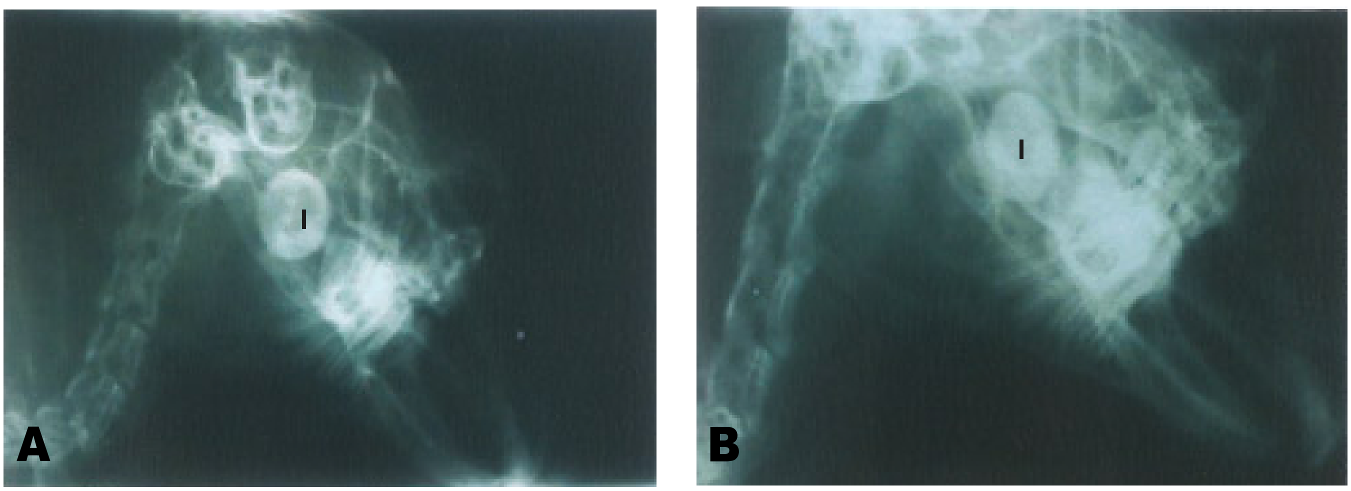

Figure 2. Radiographs taken 1 day (A) and 3 months (B) postoperatively show no change in radiodensity of implants (I).

DISCUSSION

The ideal orbital implant should provide good structural support over the defect, be nonreactive and well tolerated by surrounding tissues, be easily cut and positioned, be readily available, and associated with minor complications.[9-10]

Implants made from ostrich eggshell have desirable handling characteristics. They can easily be cut and shaped with a dental burr to cover different types of orbital defects.

The biocompatibility of an implant is based on the reaction of the surrounding tissue. The presence of giant cells and the more specific polymorphonuclear cells and necrotic tissue usually denotes foreign body reaction.[11] This study showed neither foreign body giant cells, polymorphonuclear cells, nor tissue necrosis. Thus, we surmised the ostrich eggshell implant to be a biocompatible material. This is supported by an earlier study of Dupoirieux in 1995, where the eggshell was placed as an intramuscular pouch in rodents. The biocompatibility of the eggshell implant was expected because the calcium

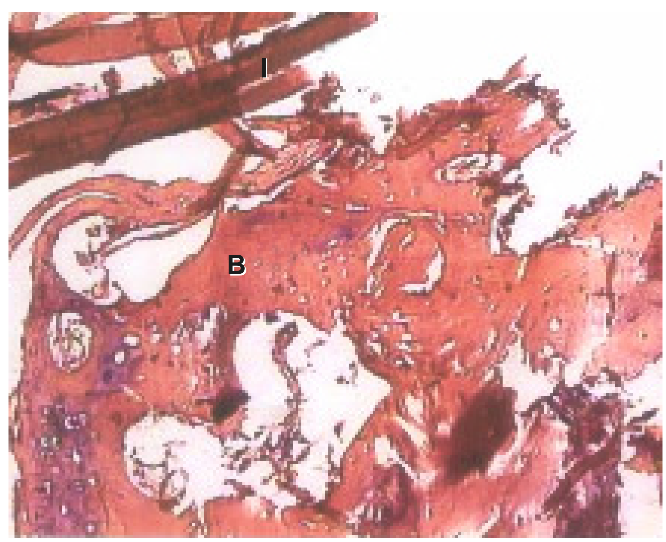

Figure 3. Histological examination of an eggshell onlay graft (I) shows no foreign body reaction and no fibrovascular ingrowth (B- orbital floor bone). (H & E, original magnification x 12.5).

carbonate, which is a natural component of bone, has already been shown to be biocompatible.[7, 8]

Implant extrusion can occur in all types of grafts. Dense alloplastic materials have higher incidence of extrusion when compared to bone grafts and porous alloplastic implants such as those made from hydroxyapatite and polyethylene.[12] These latter implants permit fibrovascular integration as well as bone ingrowth, preventing displacement.[13] The same characteristic of these porous implants also creates problems such as difficulty in mobilizing the implant during reoperation or explantation . The growth of orbital tissue into an implant may result in limitation of ductions of the globe due to adhesions of extraocular muscles or orbital fibroadipose tissue to the implant.[10]

The lack of porosity in eggshell implant prevents the invasion of a fibrovascular network that could help anchor the implant to the underlying bone. In this study, however, all the eggshell implants remained immobile. The tight fibrovascular adhesion between the orbital bone and the periosteum surrounding the implants kept them in place even though no capsule growth surrounding the implants was observed.

Both the 5-mm and 10-mm implants behaved similarly with regard to positional stability. Kohn[14] reported that larger implants have higher incidence of complications such as lacrimal obstruction and cutaneous erosion secondary to implant migration and extrusion. These were not observed in this study although longer follow up is necessary as implant extrusion has been reported within months to years after surgery.[15]

Resorption is a realistic concern with bone grafts and other natural implants.[13] Zins et al[16] reported bone resorption of 11.6% to 53.3% as early as 10 weeks in experimental animals. In their study, resorption of bones placed in the craniofacial region of the rabbits and monkeys was measured by computing for the difference in the percent total graft area before and at 5, 10, and 20 weeks after implantation. In our study, gross examination showed that the dimensions (diameter and thickness) of the eggshell grafts did not change. Radiographic examination similarly showed no change in the radiodensity of the eggshell grafts at 1, 2, and 3 months after implantation. The process of resorption is related to vascularization and composition of an implant.[17] Since eggshell implants are inert and no vascularization occurred, it is not surprising that they did not undergo resorption during the study period.

The incidence of infection with eggshell implant was not established in this study because the graft was placed onlay on an intact orbital floor. Creating an orbital floor defect was attempted but abandoned because of technical difficulties. The surgical field was small and deep, allowing only minimal maneuvering of surgical instruments. The procedure would also compromise the orbital soft tissues and the globe.

This study is limited by its short time frame. Future studies should consider prolonging the harvest time to observe whether fibrovascularization and implant resorption or extrusion would eventually occur. Nevertheless, the ostrich eggshell implant has demonstrated biocompatibility and stability and can be used as bone-substitute graft for orbital floor defects.

References

1. Manson PM, Iliff N. Management of blow-out fractures of the orbital floor. II. Early repair of selected injuries. *Surv Ophthalmol* 1991; 35: 280-292.
2. Putterman AM. Management of blow-out fractures of the orbital floor. III. The conservative approach. *Surv Ophthalmol* 1991; 35: 292-298.
3. Burres SA, Cohn AM, Mathog RH. Repair of orbital blow-out fractures with Marlex mesh and Gelfilm. *Laryngoscope* 1998; 91: 1881-1886.
4. Young U, Schuster RH, Harris LW. Intracerebral hematoma complicating split calvarial bone-graft harvesting. *Plast Reconstr Surg* 1990; 86: 763-765.
5. Jackson IT, Helden G, Marx R. Skull bone grafts in maxillofacial and craniofacial surgery. *J Oral Maxillofac Surg* 1986; 44: 949-955.
6. Thadani V, Penar PL, Dartington J. Creutzfeldt-Jakob disease probably acquired from a cadaveric dura mater graft. *J Neurosurg* 1988; 69: 766-769.
7. Dupoirieux L. Powdered eggshell. A pilot study on a new bone substitute for use in maxillofacial surgery. *J Cranio-Maxillofac Surg* 1995; 23: 187-194.
8. Dupoirieux L. Ostrich eggshell as a bone substitute: A preliminary report of its biological behavior in animals - a possibility in facial reconstructive surgery. *Br J Oral & Maxillofac Surg* 1999; 37: 467-471.
9. Browning CW. Alloplast materials in orbital repair. *Am J Ophthalmol* 1967; 63: 955-962.
10. Rubin PAD, Bilyk JR, Shore JW. Orbital reconstruction using porous polyethylene sheets. *Ophthalmology* 1994; 101: 1697-1708.
11. Alpaslan C, Alpaslan GH, Oygur T. Tissue reaction to three subcutaneously implanted local hemostatic agents. *Br J Oral Maxillofac Surg* 1997; 35:129-132.
12. Zingg M, Chowdhury K, Laederach K, et al. Treatment of 813 zygoma-lateral orbital complex fractures. *Arch Otolaryngol Head Neck Surg* 1991; 117: 611-620.
13. Salyer KE, Hall CD. Porous hydroxyapatite as an onlay bone-graft substitute for maxillofacial surgery. *Plast Reconstr Surg* 1989; 84: 236-244.
14. Tse DT. Cyanoacrylate tissue adhesive in securing orbital implants. *Ophthalmic Surg* 1986; 17: 577-580.
15. Jordan DR, Onge PS, Anderson RL. Complications associated with alloplastic implants used in orbital-fracture repair. *Ophthalmology* 1992; 99: 1600-1608.
16. Zins JE, Whitaker LA. Membranous versus endochondral bone: Implication for craniofacial reconstruction. *Plast Reconstr Surg.* 1983;72: 778-784.
17. Smith ID, Abramson M. Membranous versus endochondral bone autografts. *Arch Otolaryngol* 1974; 99: 778-784.