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Rapid Revascularization Following Application of Ovine Forestomach Matrix Graft in Complex Facial and Scalp Trauma

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Abstract

Background: Facial and scalp trauma can result in significant aesthetic and functional impairment. Despite the head and neck having excellent blood supply, severe soft tissue injuries can compromise perfusion and limit healing of underlying bony fractures. Ovine forestomach matrix (OFM) has demonstrated well-documented success in regenerating native tissue and promoting wound healing and was selected as a part of surgical management.

Methods: In these two cases, we report facial trauma secondary to a motor vehicle accident and a scalp trauma secondary to electrocution. The ability of OFM graft to promote rapid revascularization was assessed by indocyanine green (ICG)-SPY angiography to evaluate graft incorporation and enhanced perfusion post-application. The patient's were followed to monitor healing progress and assess for any complications.

Results: ICG-SPY angiography showed enhanced perfusion to the defects following OFM graft application that previously appeared to have compromised vascular supply. One defect achieved near complete 100% epithelialization at week 7 and the second defect was able to advance to a spit-thickness skin graft for final closure. There were no graft-related complications reported.

Conclusion: These cases describe the utilization of OFM graft to augment tissue perfusion and wound healing in combination with ICG-SPY angiography to assess for defect vascularity. The successful incorporation of the grafts contributes to the growing evidence supporting the use of OFM in soft tissue reconstruction and its use in head and neck trauma.

Keywords

Extracellular matrix, Facial reconstruction, Facial trauma, ICG angiography, Ovine forestomach matrix, SPY angiography

Introduction

Trauma remains a leading cause of facial and scalp injuries. While these injuries are not usually life-threatening, the consequences are often life changing [1]. The general management approach should be systematic and typically follows the guidance of Advanced Trauma Life Support protocol [1]. Facial and scalp trauma requiring reconstructive surgery pose significant challenges due to the complexity of facial anatomy and the critical need for both cosmesis and function [2]. In reconstructive surgeries, techniques traditionally aim to manipulate healthy tissues and anatomy to facilitate recovery of the defect. This relies on healthy tissues being well-vascularized and interacting with damaged tissues to initiate the tissue regeneration process.

Advances in soft tissue engineering and surgical procedures have enabled opportunities to innovate and use a combination of new materials, tools, and techniques to improve outcomes. The development of biomaterials has led to the production and surgical application of tissue-derived extracellular matrix grafts,

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such as ovine forestomach matrix (OFM). These grafts can be used in reconstructive surgeries to facilitate tissue repair at both cellular and molecular levels. In particular, they have been shown to support rapid revascularization, which aids bacterial clearance, tissue viability, and graft or flap take [3]. Additionally, novel technologies to evaluate tissue perfusion and the efficacy of surgical reconstruction have provided new means of identifying potential surgical complications. Imaging modalities, such as intraoperative laser angiography, can provide peri-operative support to help accurately assess the vascular status of tissues, and interestingly, can also assess performance of employed ECM grafts [4]. These imaging technologies further support operative planning and decision-making to provide the optimal functional and aesthetic outcomes. This case report details the use of OFM graft in two traumatic injuries of the face or scalp with sequential indocyanine green (ICG)-SPY angiography to monitor perfusion before and after graft application.

Case 1

A 66-year-old Creole-speaking male presented with severe right-sided facial trauma following an accident involving a semi-truck. The patient exhibited a complex avulsion laceration involving the right forehead, zygomatic, and maxillary regions, with exposed bone and a frontal bone chip fracture. The patient also had multiple abrasions of the nasolabial region, the tip of the nose, and nasal dorsum-laceration of the anterior scalp measuring 3 × 3 cm. Additional injuries included a non displaced nasal bone fracture. There was a complete loss of vision in the right eye and severe glaucoma noted in the left eye. Neurologically, the patient was obtunded with a Glasgow Coma Scale score of 14 and experienced loss of consciousness post-incident. The right frontal branch of the facial nerve was noted to be non-functioning. Otherwise, the patient was febrile but hemodynamically stable.

Initial surgical management involved extensive debridement of necrotic tissue and foreign material (Figure 1a). The exploration involved debridement and cleansing of the highly contaminated wound on the upper and lower lip, right cheek, forehead, and scalp. Skin and subcutaneous tissues were removed, with portions of muscle removed at its deepest resection. Hemostasis was achieved to allow complex repair of the lip and cheek defects. ICG-SPY angiography (Stryker Corp/Novadaq Technologies, Kalamazoo, Mich.) showed minimal perfusion of the facial flaps and deep tissue, including periosteum, before the matrix application, indicating severe vascular compromise (Figure 2a). Initial defect measured 12 cm × 3 cm × 2 cm. This was followed by application of a 7 × 10 cm 2-layer OFM graft (Myriad MatrixTM, Aroa Biosurgery Limited, Auckland, New Zealand) secured to the lateral temporal region wound bed (Figure 1b).

Following the index exploration, debridement, lavage, and primary graft application, a second operation was performed 48 hours later for further debridement and re-evaluation of tissue viability. Repeat ICG-SPY angiography was performed intra-operatively and demonstrated significant enhancement in blood supply, indicative of rapid revascularization (Figure 2b). Areas of necrosis were noted and underwent further debridement, including the area immediately above and below the eye, and tissue over zygomatic bone. A

Figure 1: Orbital wound treatment course before and after OFM graft: (a) Peri-operative image following initial debridement of necrotic tissue and foreign body removal (Day 0); (b) Placement of 7 × 10 cm OFM graft (Day 0); (c) Definitive closure of the wound following OFM graft placement and flap reconstruction (Day 3); (d) Post-operative follow-up demonstrating near 100% epitheliazation (Week 7).

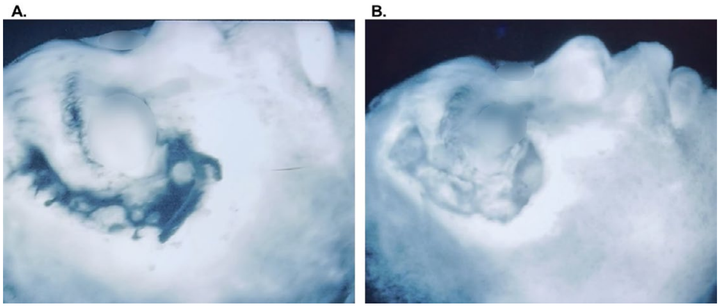

Figure 2: ICG-SPY angiography of facial trauma defect: (a) Prior to application of OFM graft, the crescent shaped wound overlying the right temporal region and lateral aspect of the eye appeared to have poor perfusion indicated by darker shading; (b) Imaging two days following OFM graft application revealed notably increased wound perfusion.

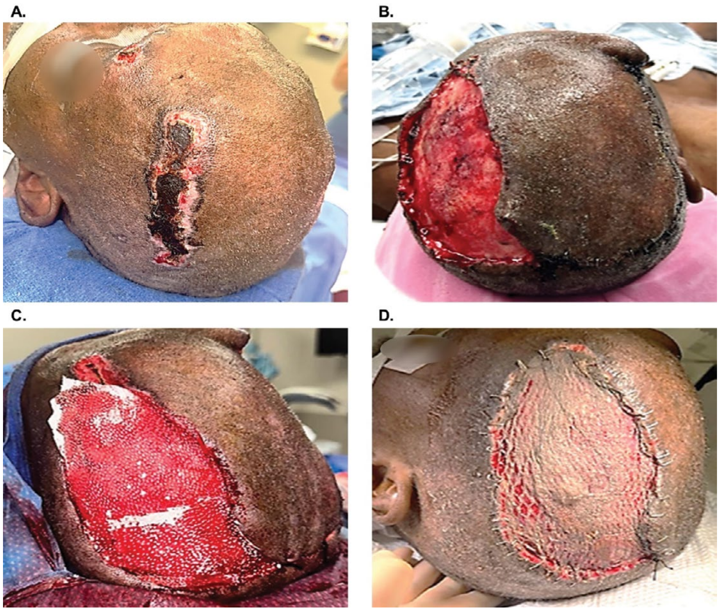

Figure 3: Scalp defect secondary to electrocution, placement of OFM graft, and at STSG prior to final closure: (a) Initial exit wound of the left scalp prior to surgical debridement; (b) Defect following surgical debridement; (c) Placement of OFM graft to the wound bed; (d) STSG following OFM graft placement and 5 days of NPWT.

fasciocutaneous flap was elevated off the zygomatic arch, inferior cheek, and lower lid to mobilize tissue medially and superiorly. An additional OFM graft was secured in the base of the wound before closure. A small area was left open and packed with Xeroform (Xeroform, McKesson, USA) to allow drainage. ICG-SPY angiography was further employed to confirm adequate tissue perfusion. At post-operative day 3, the reconstruction and final closure remained intact (Figure 1c). The patient's subsequent recovery was marked by improved wound healing without major complications. At 7-week follow-up, near 100% epithelization was achieved with a successful aesthetic outcome (Figure 1d). There were no complications noted.

Case 2

A 72-year-old male presented status-post electrocution with an exit wound to the left scalp (Figure 3a). Extensive surgical debridement was performed extending from the forehead to the posterior aspect of the scalp (Figure 3b) prior to creation of an advancement flap. The initial defect post-debridement was measured at 12 cm × 3 cm × 1 cm. The surgical site then underwent ICG-SPY angiography, and it was determined to have poor perfusion (Figure 4a). For this reason, a 10 × 20 cm^2 2-layer OFM graft was inserted and secured to the wound bed (Figure 3c). Negative pressure wound therapy (NPWT) was applied to the scalp for 5 days in an attempt to increase the vascular bed of granulation tissue and work in combination with the OFM graft. Upon removal of NPWT, repeat ICG-SPY angiography was performed and enhanced perfusion was noted indicating incorporation of the OFM graft (Figure 3d). Confirmation of tissue vascularity allowed a split-thickness (STSG) to be performed with success (Figure 4b). At week 7 follow-up, the defect was healing with no complications noted.

Discussion

The use of regenerative matrices, like OFM, in facial trauma surgery has been widely adopted due to their ability to facilitate rapid vascular in growth

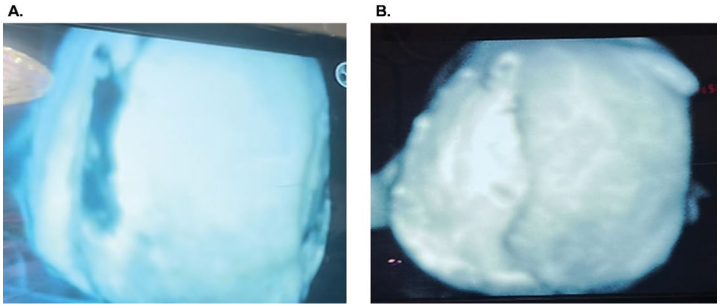

Figure 4: ICG-SPY angiography of scalp trauma defect: (a) Prior to application of OFM graft, the left scalp defect appeared to have poor perfusion indicated by darker shading; (b) Imaging 5 days following OFM graft application and NPWT revealed notably increased tissue perfusion.

and integration with existing tissue, both of which are essential for healing in highly aesthetic areas. These cases are both notable for the use of ICG-SPY angiography, which provided a real-time evaluation of the perfusion status before and after the application of the OFM graft. This technology proved invaluable in guiding the surgical approach and in assessing the immediate effectiveness of the implanted graft. To our knowledge, this is the first published work combining the peri-operative use of ICG-SPY angiography with OFM in treating complex facial and scalp trauma.

Surgical management in complex facial trauma

With large and complex facial or scalp wounds, initial management and the surgical approach is not always straightforward. Involvement of vital and delicate structures combined with the challenges of multi-layered injuries makes for challenging surgical reconstructions. Additional concerns regarding compromised vascular access, functional deficits, and scarring risks pose additional considerations in peri-operative planning. This is particularly applicable for injuries involving the forehead and cheek, where neurovascular injuries are of great concern and require a clean and vascularized bed to perform adequate repairs [5]. The ideal management of these injuries begins with lavage of the wound followed by debridement to remove necrotic and foreign materials. Cleansing of the wound then allows for better visualization of underlying anatomical structures and vascular compromise to aid operative planning and hemostasis. While the face typically has a robust blood supply, successful reconstructive approaches need to also consider the viability of local vessels and perfusion to achieve satisfactory functional and aesthetic outcomes. Additionally, a large contributing factor towards early complications following reconstructive surgeries is poor tissue perfusion [4,6]. Compromised vascular access and poor perfusion are detrimental to the maintenance and recovery of healthy tissues within reconstructive surgery [7]. Inadequate assessment of perfusion status will cause tissue to become necrotic and require further debridement. To mitigate these risks, it is important to use accurate means to evaluate tissue perfusion intraoperatively. While clinical judgement provides a quick means of assessment, it is not always easy or reliable. This challenge may be further complicated by impaired visualization secondary to the complex local trauma. This is where the implementation of tools like ICG-SPY angiography may be of particular benefit.

Perfusion assessment techniques

Intraoperative laser angiography is a vascular imaging modality traditionally used in ophthalmology. It can be applied both intraoperatively and post-operatively to visualize blood flow. Specifically, ICG-SPY angiography was used in this case. The procedure utilizes indocyanine green to allow for visual assessment of blood flow in superficial tissues. By providing real-time tissue perfusion assessment, it has proven beneficial in improving clinical outcomes in various settings [8,9]. Moreover, it also supports real-time decision-making processes, including flap design and tissue resection. With a suitable safety profile and short half-life, this also enables its repeated use within short timeframes. This technique has been applied successfully in reconstructive surgeries to allow early risk stratification and reduce the development of necrosis and other complications [6].

In contrast, alternative means of intraoperative and post-operative perfusion assessment include the use of hand-held Doppler and laser Doppler flowimetry [10]. These may be considered less optimal tools as they were shown to be less accurate and more cumbersome [11,12]. Additionally, fluoresce in is sometimes used as an alternative contrast medium but is restricted by its long half-life as it can cause false positives and limits the potential for re-evaluation [13].

Role of extracellular matrix

During peri-operative planning, the nature and size of tissue defects may influence the decision to use extracellular matrix (ECM) grafts. Matrix grafts are bio-scaffolds made of absorbable biomaterials and are used in various reconstructive procedures to support cellular infiltration and proliferation [14]. These are usually derived from human, porcine, or bovine tissues that have been decellularized to preserve the tissue structure. In these cases, we chose to utilized OFM, which is derived from sheep forestomach and contains > 150 extracellular matrix biomolecules critical in facilitating the soft tissue healing process [15]. The use of matrix grafts reduces reconstructive complications via both biological and physical mechanisms and can be used in both acute and chronic settings. The biochemical and cellular modulating effects of ECM grafts such as OFM can help improve the inflammatory and proteolytic conditions of the wound environment and facilitate the healing processes [16]. The ECM itself will provide structural support and improve angiogenesis and remodeling. Additionally, variations of ECM and products with biomolecular and nanomolecular adjuncts can be used to achieve better healing environments [17]. Ensuring adequate perfusion to the grafts would maximize its function in augmenting the wound healing process and enable effective cell migration to the wound site to repair the defect. ECM-based graft materials have been used in various reconstructive surgeries to facilitate the development of functional and vascularized soft tissues [14,18]. Its resistance to infection also provides great utility in large, contaminated wounds, as was observed in these cases. Furthermore, previous studies have demonstrated low infection rates, making it a suitable medium to use even in a contaminated field. While OFM has not been used extensively in facial reconstructive surgery, there is some evidence for its components in achieving satisfactory cosmetic outcomes for people with facial thermal burns as well as facilitating facial nerve regeneration in animal studies [19,20].

The use of repeated ICG-SPY angiography can assist in ensuring adequate perfusion of the wound bed and matrix. The initial use in these cases revealed severe compromise and provided a baseline of the pre-operative tissue perfusion status. Enabling a comparable and objective perfusion 48 hours after the initial reconstructive procedure allows early identification of non-viable implants and assessment of whether further debridement is required. Likewise, should there be early post-operative concerns of inadequate perfusion, ICG-SPY angiography would enable earlier interventions to restore or remove them. Interestingly in this case, angiography confirmed the OFM graft was performing as expected by improving the vascularity of the wound bed. The ability to monitor vascular status is of particular interest when used in combination with OFM due to its known ability to stimulate angiogenesis [3] and ultimately neovascularization and successful tissue remodeling. This gave confidence to proceed with primary closure and resolution of the cases.

Conclusion

The application of OFM graft in complex facial and scalp trauma can significantly enhance revascularization, as demonstrated by ICG-SPY angiography. These cases underscore the potential utility of combining regenerative materials with advanced imaging techniques to improve outcomes in reconstructive surgery.

Conflict of Interest

AD is a consultant for Aroa Biosurgery Limited (Auckland, New Zealand).

Sources of Support

AD is a consultant for Aroa Biosurgery Limited (Auckland, New Zealand).

Author Statement

All authors contributed equally to the production of this manuscript.

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