

# Tissue repair after orbital reconstruction using polypropylene mesh implants: A histological study in dogs

## Reparo tecidual após reconstrução de órbita com implante de malha de polipropileno: um estudo histológico em cães

### Abstract

**Purpose:** This experimental study aimed to assess the histological outcomes of orbit reconstruction with a polypropylene mesh implant in an animal model using dogs.

**Methods:** The right and left orbits of 12 dogs were fractured in order to simulate orbital fractures similar to those occurring in humans as a result of trauma. The orbits were reconstructed with a polypropylene mesh positioned approximately 10 mm beyond the bone defect borders. The 24 orbits were divided into four groups of six: one group was given one polypropylene mesh layer; another group received two layers; a third group was given three polypropylene mesh layers; and the fourth group did not receive any implant (control group). The dogs were divided into clusters of four animals and were euthanized 15, 30, or 60 days after the surgery. The orbit medial wall was removed, and samples were subjected to histological polypropylene mesh analysis by optical microscopy. Data were analyzed using a non-parametric test with a 5% level of significance.

**Results:** It was found that the polypropylene mesh caused a mild to moderate tissular reaction.

**Conclusion:** The implant was well tolerated even with two or three overlapping layers.

**Key words:** Polypropylene mesh; orbital reconstruction; orbital trauma; alloplastic implant

### Resumo

**Objetivo:** Trata-se de estudo experimental em que se reconstruíram os continentes orbitais de 12 cães com implante de tela de polipropileno.

**Metodologia:** Os continentes orbitais foram fraturados simulando as fraturas orbitais que ocorrem em humanos devido ao trauma e reconstruídas com tela de polipropileno cortadas com extensão de cerca de 10mm além da margem do defeito ósseo. Utilizaram-se uma, duas ou três camadas de tela de polipropileno nas órbitas teste e algumas órbitas, somente fraturadas, serviram como controle. Os cães foram sacrificados nos tempos de 15, 30 e 60 dias de pós-operatório; os tecidos das órbitas teste e controle foram removidos e preparados para análise histológica em microscopia óptica. Os resultados obtidos pela análise histológica foram submetidos a análise estatística não paramétrica com 5% de significância.

**Resultados:** A tela de polipropileno causou reação tecidual de leve a moderada nos tecidos.

**Conclusão:** O implante foi bem tolerado, mesmo quando a tela foi superposta em duas ou três camadas.

**Palavras-chave:** Tela de polipropileno; reconstrução orbital; trauma orbital; implante aloplástico

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## Introduction

The incidence of human trauma from vehicular accidents has increased in recent years. Even though new technologies such as three-point safety belts, padded bumpers, slow deforming automobile bodies, front and side air bags, ABS brakes, and side-protecting bars have been introduced in current vehicles, traumas resulting from accidents still occur. The safety mechanisms that are developed for individuals' protection are not able to protect them fully from the effects of car crashes, which often cause serious damage to individuals that go beyond the blunt force impact on the people inside the vehicle (1). The energy produced by the accident can spread all over the human body and cause a number of lesions, the head and the face being often involved (2). Victims of such accidents frequently arrive at emergency rooms with extensive lesions caused by blunt force trauma and their complex treatment poses a challenge.

Fractures on the face and on the zygomaticomaxillary complex are highly significant due to their complexity and their likelihood of resulting in damage to the orbits (3). Depending on the type of lesion, treatment may require time-consuming surgery. For comminuted fractures or those fractures involving orbital bone loss, reconstruction with some kind of graft or implant is indicated. Bone grafts are difficult to control because of their degree of resorption and the possibility of necrosis and poor bed adaptation, as well as the need for an additional surgery to collect them (2).

Alloplastic implants can be performed on orbits as a method of reconstruction (3). Ortheses made of silicon (2), polyethylene (4), high-density porous polyethylene (5), Teflon (6), bioabsorbable copolymers (7), hydroxyapatite (8), and titanium (9) are well known and are often used in facial reconstruction. Titanium meshes and porous polyethylene plates (Medpor®) support the orbit content weight and prevent entrapment caused by the orbit wall defect, offering superior resistance to deflection.

There is no general agreement as to the amount of bone loss that is considered critical and capable of producing visual conditions. For Patrick et al. (10), the critical defect on orbit walls is over 1 cm<sup>2</sup> of bone loss. Grant et al. (11) classified bone losses on orbit walls and found that visual disturbances occurred with bone defects larger than 1 cm<sup>2</sup> (29%) and 2 cm<sup>2</sup> (100%).

Polypropylene meshes are recommended for bone defects smaller than 2 cm<sup>2</sup> for their pliability and their ability to deflect the weight of the orbit content when even up to three layers are overlapped. Polypropylene mesh is currently utilized in surgeries (12-16) to rebuild or support soft tissues and can also be used in infected loci (17). It has been employed to reconstruct part of the orbit in cases where bone matter has been lost (18). From the success obtained in other anatomical loci and with different functions (13-16), its utilization in reconstructing orbit bones is promising. The use of polypropylene mesh to rebuild orbits in the case of blow-out fractures has been reported in the literature (3,4,18,19), but few supporting studies are available in

cases where overlapping of layers is needed to reinforce the implant structure.

The present study evaluated through optical microscopy the tissular reaction of dog orbits after one to three layers of polypropylene mesh were implanted to replace bone loss on the orbit wall. It included observation of the capacity of the implant to prevent periorbital tissue from herniating into anatomical spaces in juxtaposition with the orbit.

## Methodology

The study involved 12 mixed-breed adult male dogs weighing approximately 33-44 pounds each. The animals were randomly selected from the Federal District animal disease service. The animals were divided into three groups (groups I-III), with four dogs in each group. During the experiment, they were cared for according to the principles determined by the ethics committee for animal research.

### Surgical technique

The medial orbital wall was the site chosen for the implant of the material to be studied, due to its similarity to human orbits (Fig. 1). The animals were given antibiotics prior to the surgical procedure and analgesia immediately after it.

Surgeries occurred under general anesthesia. After orotracheal intubation, trichotomy of medial superciliary regions and local antiseptics, incisions extending to the medial eyelid commissure were performed on the superciliary regions; the medial cantal ligament was preserved from the skin to the periosteum. The periosteum was detached and raised together with the intraorbital structures in order to give access to the medial orbital wall. A defect of approximately 0.6 cm<sup>2</sup> (approximately 1/4 of the orbit medial wall size) at the center of the medial wall was produced. The margins of the defect, including the medial orbital edge, were left intact so as to simulate a blow-out type floor fracture where matter loss occurs in which either graft or implant is indicated for its reconstruction.

Round fragments of polypropylene mesh approximately 10 mm in diameter larger than the defect were cut so that the edges could cover the defect and were supported by the bone surrounding the bone loss. The mesh fragments were placed over the lesion in such a way that they would maintain close contact with the bone and remain in place by apposition only, without any kind of clamping (Fig. 2).

The orbit medial walls were reconstructed with one, two, or three overlapping polypropylene mesh layers or left as they were without an implant, according to the group to which the animal belonged. Interventions followed this sequence: dog 1 received one polypropylene mesh layer on the right orbit, and the left one remained untreated as a control; dog 2 received two mesh layers on the right orbit and one layer on the left orbit; dog 3 received three mesh layers on the right orbit and the left orbit remained untreated as a control; dog 4 received three mesh layers on the right orbit and two layers on the left orbit. Groups II and III were subjected to the same protocol described for group I.



Fig. 1. Aspect of the medial orbital wall in a dog skull.

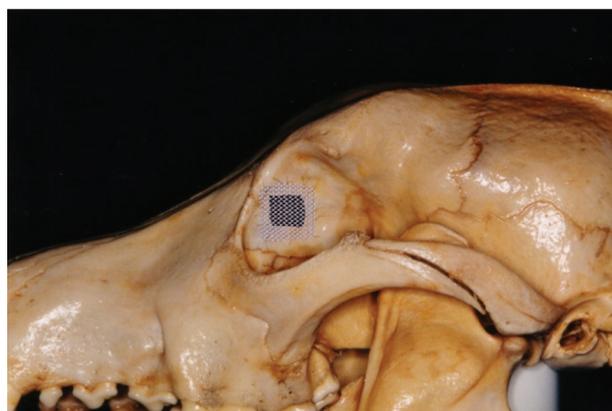


Fig. 2. Aspect of the polypropylene mesh implanted on the medial orbital wall in a dog skull.

After the mesh implant, the skin was sutured using 5-0 nylon monofilament thread, simple stitches, and interrupted sutures, and the animals were sent to the postoperative room. Skin sutures were removed 10 days after the surgery in all groups.

The dogs of group I were housed until the 15<sup>th</sup> day after surgery, group II until the 30<sup>th</sup> day, and group III until the 60<sup>th</sup> day.

In order to collect tissue samples containing the implanted materials, the dogs were anesthetized, and medial superciliary incisions, as well as division of soft tissues with the help of scissors, were performed. The incisions were just long and deep enough to give access to the medial walls of the orbits to be osteotomized. The orbital medial walls were separated from the skull with their ridges through osteotomy with a spatula-type chisel and removed along with their surrounding soft tissues containing the implanted materials, which were cut out with the help of scissors.

Two tissue samples were removed from each of the 12 units (dog orbits) and sent for histological analysis.

### Histological analysis

The 24 tissue samples were fixed in a 10% formol solution, processed for 5 µm-thick serial histological sections in four different regions (a total of 96 histological sections), and stained with hematoxylin and eosin (H.E.).

The morphological interpretation of the histological sections was carried out by optical microscopy; the quantitative results were recorded on the appropriate qualitative and quantitative analysis sheet.

Inflammatory reactions were classified as absent, mild, moderate, or intense according to the criteria shown in Table 1. In the analysis, the presence of the following was noted: polymorphonuclear leukocytes, round cells (mastocytes, lymphocytes, histiocytes, and plasmatic cells), foreign body-type giant cells and epithelioids, macrophages, erythrocytes, fibroblasts, and hemorrhage.

The quantitative results were subjected to non-parametric statistical analysis using the Fisher and Mann-Whitney tests.

Table 1. Inflammatory response – adopted classification.

<b>Absent (score 0)</b> Apparently normal tissue
No apparent signs of inflammation
Predominance of fibroblasts
Highly organized fibroblast layer
<b>Mild (score 1)</b> Initial, poorly organized mild tissular reaction
None or few inflammatory cells
Space filled up by fibroblasts
Absent or rare engorged vessels
Absence of multinucleate cells
<b>Moderate (score 2)</b> Increased inflammatory tissular reaction
Presence of round cells (plasmacytes, lymphocytes and mastocytes)
Many macrophages and multinucleate cells per field
Engorged vessels
Presence of polymorphonuclear cells
Few fibroblasts
<b>Intense (score 3)</b> Intense inflammatory reaction with tissular disorganization
High concentration of macrophages and multinucleate cells
High quantity of round cells; polymorphonuclear-type cells can be seen
Engorged vessels
Areas of necrosis

### Results

The histological reaction was similar at 15, 30, and 60 days after implantation; it was present in 63%, 75%, and 88% of the units in the groups containing one, two, or three mesh layers, respectively.

Statistical analysis of the histological findings in the control and test groups showed a significant difference among the studied groups with respect to inflammation ( $P < 0.05$ ). Significant differences ( $P < 0.05$ ) among the experimental groups regarding the intensity of the inflammatory reaction were also found; inflammatory reactions were proportionately more intense in the test group (89% of the histological findings) than in the control group was (33%).

**Table 2.** Inflammatory response – Time of Evaluation.

Groups	Histological Findings				Total	
	Present		Absent		n	%
	n	%	n	%		
Control Group	2	33.3%	4	66.7%	6	100.0%
Test Group	16	88.9%	2	11.1%	18	100.0%
Total	18	75.0%	6	25.0%	24	100.0%

**Table 3.** Inflammatory response – histological findings in the control and test groups.

Time of Evaluation (days)	Histological Findings				Total	
	Present		Absent		n	%
	n	%	n	%		
15	5	62.5	3	37.5	8	33.3
30	6	75.0	2	25.0	8	33.3
60	7	87.5	1	12.5	8	33.3
Total	18	75.0	6	25.0	24	100.0

**Table 4.** Inflammatory response – Number of Layers.

Number of Layers	Histological Findings				Total	
	Present		Absent		n	%
	n	%	n	%		
None	2	11.1	4	66.7	6	25.0
One layer	6	33.3	0	0.0	6	25.0
Two layers	4	22.2	2	33.3	6	25.0
Three layers	6	33.3	0	0.0	6	25.0
Total	18	100.0	6	100.0	24	100.0

From the clinical evaluation, no entrapment of periorbital tissue in anatomical spaces near the orbital cavity was observed as a result of the bone defect produced.

## Discussion

The polypropylene mesh utilized with alloplastic implants in soft tissues is able to cause a low intensity tissular reaction and stimulate tissue resistance by helping it fulfill its functions (8). Even though the literature supports the application of polypropylene mesh in humans (16-19), most reports are limited to the analysis of the effects of the material when it is implanted in soft tissues. The few publications describing the use of polypropylene mesh in orbital reconstruction refer to case reports, descriptions of surgical techniques or successful implants (3,4,8,16-19).

In order to study the effects of the use of polypropylene mesh in dogs, a surgical technique was developed in an attempt to seek similarity with the technique that has been already described and established for human beings (1). The choice of the orbital medial wall of dogs is justified because, in this species, there are no other walls forming the orbit.

Although it is known that tissue reactions to an aggression are similar in dogs and humans, the orbital medial walls were used for the implant of the alloplastic material to be juxtaposed to the bone tissue so that the reactions provoked by it could be thoroughly assessed. Osteotomies carried out on the orbital medial walls of dogs simulate fractures in

human orbits where bone matter loss occurs, including those that are often observed in traumas to the face involving the naso-orbitomaxillary, Le Fort III and zygomaticomaxillary complexes, which extend to the orbital walls, as well as plain fractures on the floor, which are referred to as ‘blow-out’ fractures.

The implant juxtaposed to the bone covered the defect produced by the fracture and aimed at containing the orbital content tissues; it should prevent herniation of intraorbital muscles and fat to adjoining anatomical spaces, in order to avoid visual phenomena.

There is no consensus on the extension of the critical defect that can cause visual disturbances, but it may be over 1 cm<sup>2</sup> (10,11). For the purpose of the present study, it has been assumed that a 0.6 cm<sup>2</sup> bone defect in the canine orbit wall corresponds to approximately ¼ of this wall as compared to humans and can cause visual phenomena, thus indicating that bone defect extension rates differ between dogs and humans.

In order to decrease the pliability of the implant, up to three mesh layers were overlapped. With the consequent increase in implant volume, the intensity of the aggression to the tissues triggered by the presence of a foreign body was also increased.

Human orbits, unlike those of dogs, have four well-defined orbit walls made of bone that show both resistant and fragile areas. In cases in which the zygomaticomaxillary complex undergoes a trauma, the energy produced by the causative agent dissipates along all of the orbit extension and breaks

the bone in regions where there is frailty. Intraorbital tissues are generally driven to anatomical structures that are close to the orbital cavity, the maxillary sinus being the most affected because only a thin bone blade separates it from the orbit. The changed relationship between the orbit volume and its content can cause significant visual phenomena including diplopia, enophthalmus, and ophthalmoplegia.

It was observed that there was no dislocation of implanted matter or entrapment of periorbital tissues to the anatomical spaces circumscribing the orbit.

## Conclusions

The intensity of the inflammatory reaction observed through optical microscopy ranged from mild to moderate and was statistically significant; it also increased with increase in number of the overlapped mesh layers used. No dislocation of the implants or herniation of tissues from the orbital content to adjacent anatomical structures was observed in the sample, supporting the conclusion that the orbital content was held and sustained.

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