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Management of Naso-Orbito-Ethmoid Fractures: A 10-Year Review

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Abstract

Context: The naso-orbito-ethmoid (NOE) area is an intricate structure composed of the nasal, lacrimal, maxillary, frontal, and ethmoid bones. The treatment of NOE fractures is one of the most challenging issues in the management of maxillofacial injuries. The management of these fractures requires a thorough knowledge of midfacial anatomy, surgical techniques, and the available implements in order to obtain optimal aesthetic and functional results. The aim of this study was to review current knowledge (i.e., from the past ten years) concerning NOE fractures and the related surgical techniques.
Evidence Acquisition: An extensive electronic literature search was performed via international and national databases, including MEDLINE/PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), DOAJ, Iranian Science Information database (SID), Iranmedex, and Irandoc. Literature published between October 2004 and October 2014 was searched for using specific keywords. The references from each study were also searched. Finally, all articles relevant to the selected keywords and the topic of the study were reviewed.
Results: High-energy blunt or penetrating traumas are the most common cause of NOE fractures. NOE fractures account for some 5% and 15% of adult and pediatric facial fractures, respectively. These fractures are characterized by three major post-injury symptoms, namely increased intercanthal distance, diminished nasal projection, and impaired nasofrontal and lacrimal drainage. The prompt management of NOE fractures is of the utmost importance in avoiding secondary deformities. Surgical treatment is guided by the pattern and classification of the injury. The surgical approach also varies according to the fracture type and other concomitant facial injuries. If the fractured fragment cannot be reduced satisfactorily by closed reduction, the operation should be converted into an open reduction and internal fixation. The most common method for medial canthopexy is transnasal wiring.
Conclusions: Nowadays, advances in radiographic imaging along with the evolution in minimally invasive surgical techniques have led to more conservative treatment modalities that may minimize post-injury complications and improve aesthetic outcomes.

Keywords: Maxillofacial Injuries, Facial Injuries, Naso-Orbito-Ethmoid, Medial Canthal Tendon, Canthopexy, Lacrimal Duct Obstruction, Epiphoria

1. Context

The naso-orbito-ethmoid (NOE) complex is an intricate midface structure that consists of the nasal, lacrimal, maxillary, frontal, and ethmoid bones. This complex is bordered anteriorly by the nasal bones, the frontal process of the maxilla, and the frontal bone. Moreover, the area's inferior bound is the lower border of the ethmoidal labyrinth, while the lateral bound is formed by the lamina papyracea of the ethmoid bone and the lacrimal fossa. Understanding the anatomy of the NOE complex requires a familiarity with the key structures of this region. The medial canthal tendon splits before inserting into the frontal process of the maxilla. These two limbs of the tendon surround the lacrimal fossa. This critical central fragment of the NOE complex is surrounded posteriorly by the lacrimal bone, anteriorly by the nasal bones and pyriform aperture, cranially by the frontal bone, inferiorly by the maxilla, medially by the ethmoid air cells, and laterally by the orbit and its contents.

The NOE complex is responsible for the projection of some midfacial structures, as well as the normal position of the extraocular muscles and the medial canthal ligament, and it also provides support for the globe and lacrimal system.

One of the goals of the treatment of facial fractures is to reconstruct the pre-traumatic facial appearance, including the facial width, projection, and height (1). The restoration of the normal function of the facial structures is another aim in facial fracture management (2). Secondary or late reconstruction is much more difficult than the primary treatment of NOE fractures (3). Therefore, the treatment of NOE fractures in a timely manner is helpful in correcting aesthetic and functional defects (4). Moreover, the early management of NOE fractures, even in the case of severely comminuted type III fractures, is of considerable importance to avoid secondary deformities (5). Finally, the frontal sinus should be carefully evaluated radiographically (6). A recently published review study has explained in detail the management of frontal sinus fractures resulting from NOE fractures (7).

Recent advances in techniques for the reconstruction of the craniofacial skeleton have resulted in a need to update our knowledge regarding new methods for the management of NOE fractures.

The aim of the present study was to review current knowledge regarding NOE fractures and the related surgical techniques based on literature published over the last ten years.

2. Evidence Acquisition

We electronically searched international and national databases, including MEDLINE via PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), DOAJ, Iranian Science Information Database (SID) (http://www.sid.ir/), Iranmedex (http://www.iranmedex.com/), and Iranian Research Institute for Information Science and Technology (Irandoc) (http://www.irandoc.ac.ir) for articles published from October 2004 to October 2014 using specific keywords. The utilized keywords were "naso-orbito-ethmoid," "naso-ethmoido-orbital," "ethmoido-orbito-nasal," "canthopexy," and "medial canthal ligament." The references from each study were also searched in order to identify any articles that were not found during our initial literature search. Only those articles relevant to the selected keywords and the topic of the study were included. All of the retrieved papers and related review papers were evaluated and cited.

Two authors (M.K. and P.S.) performed database searches, while the other two authors (M.E. and S.S.) performed the data extraction procedure, independently. In the case of disagreement between the evaluators, the disagreement was resolved by discussion and a final consensus was agreed on.

3. Results

3.1. Etiology and Prevalence of NOE Defects

The bony structures of the NOE complex, particularly the delicate bones of the medial orbit, are highly susceptible to fractures. High-energy blunt or penetrating traumas are the most common cause of NOE fractures. Different etiological factors may be associated with defects in the NOE region, including trauma and congenital deformities, of which trauma is the most common etiological factor. NOE fractures usually occur due to blunt trauma (8, 9), mostly stemming from motor vehicle accidents (10, 11), industrial accidents, assault, and falls from height (9). Such fractures pose a significant diagnostic and therapeutic challenge (12-14). Other potential causes of NOE defects are relatively rare, including neoplasms of the NOE region such as neurofibromatosis, fibrous dysplasia, and retinoblastoma, as well as congenital deformities such as facial cleft, hypertelorism, lymphovenous malformation, and bilateral orbital frontal encephalocele. Fractures of the NOE complex account for approximately 5% of facial fractures in adults (15). In children, the incidence is higher and NOE fractures account for nearly 15% of all facial fractures (6, 16). The difference can be attributed to the increased skull to face ratio in children when compared to adults. Furthermore, the frontal sinus does not appear until an individual is approximately five years of age, increasing the incidence of skull fracture and intracranial injury due to blunt trauma in this period. Based on the literature, NOE fractures occur most commonly in adult males and boys (9, 17-19).

3.2. Classification of NOE Fractures

The most common classification method for NOE fractures is based on the attachment of the medial canthal ligament and the comminuting intensity of the central fragment of bone (6). This scheme, which was suggested by Markowitz et al. (2), is clinically useful for both the diagnosis and management of NOE fractures. Figure 1 demonstrates this classification scheme (20). Type I fractures include a single-segment central fragment in which the medial canthal ligament is attached to a relatively large segment of fractured bone. This is the most common type of fracture (6). In type II fractures, the central fragment is comminuted, although the fractures remain external to the medial canthal ligament insertion. Type III fractures are conditions in which the insertion of the medial canthal ligament is comminuted. According to Nguyen et al.'s study, the least common fractures in this classification are type III fractures, accounting for 1% - 5% of all NOE fractures (6).

Another classification for NOE fractures concerns unilateral or bilateral fractures. The unilateral involvement of the NOE complex is more common (17, 21).

NOE fractures can also be classified based on concomitance with other facial fractures (22). This can include the occurrence of NOE fractures and orbitozygomatic fractures, NOE fractures and craniofacial fractures, NOE fractures and panfacial fractures, and isolated NOE fractures.

Although the classification system introduced by Markowitz et al. (2) is the most widely used system among maxillofacial trauma surgeons, it may not take into account the differences in midface-skull proportions and frontal sinus pneumatization between children

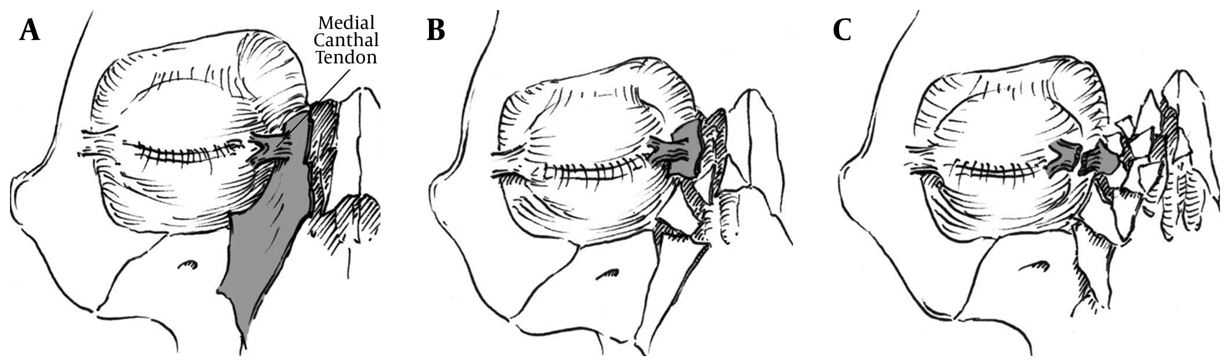

Figure 1. Markowitz type I fractures include a single-segment central fragment in which the medial canthal ligament is attached to a relatively large segment of fractured bone. Markowitz type II fractures include the comminuted central fragment with the medial canthal tendon still attached. Markowitz type III fractures are conditions in which the insertion of the medial canthal ligament is comminuted (Reprinted with permission from Hopper et al.'s study (20)).

and adults (23). Burstein et al.'s classification provides a more thorough appreciation of pediatric NOE fracture patterns with concomitant skull fractures (24). It incorporates the aforementioned anatomic differences and the greater involvement of the frontal basilar skull. Figure 2 demonstrates the Burstein classification in more detail (23).

3.3. Diagnosis of NOE Fractures

The best way to confirm the diagnosis of NOE fractures is a combination of clinical examination and computed tomography (CT) scan (3). A maxillofacial CT scan with 1 - 2 mm slices can ascertain midfacial fractures (9). Three-dimensional (3-D) reconstructions are also useful in combination with traditional two-dimensional views, since 3-D reconstructions may offer increased accuracy in the detection of fractures of the NOE region at the piriform aperture (25). The medial orbital region and the lacrimal fossa are two of the key areas to assess in radiographic images. The assessment of the axial cuts in cross-sectional images can also provide important information about the NOE complex as well as the degree of disruption in the region of the medial canthal tendon attachment (7). Subjective signs of NOE fractures include edema of the medial canthal region, nasolacrimal duct obstruction, diplopia, anosmia, and nasal congestion. Objective signs of NOE fractures include the mobility of the intercanthal region in palpation, rounding of the medial canthus, widening of the nasal bridge, and telecanthus. In cases of suspected NOE fractures, telecanthus and loss of nasal projection are hallmark clinical findings. Telecanthus refers to an increased intercanthal distance, with a normal intercanthal distance in Caucasian individuals being approximately 35 mm (7, 9). A distance exceeding 40 mm is classified as telecanthus and it may indicate that surgical treatment is required (22). Although post-traumatic cerebrospinal fluid leaks resulting from maxillofacial fractures are uncommon (26), if such leaks are suspected on clinical examination, then beta-2 transferrin testing of clear rhinorrhea can confirm the leakage (27).

3.4. Surgical Approaches

The goal of NOE fracture treatment is the obviation of three major issues, namely the establishment of proper nasal projection, narrowing of the intercanthal distance, and the establishment of the nasofrontal and lacrimal fluid route (22). External plates and splints were once used for the management of NOE fractures (9). However, current treatments are mostly based on open reduction and internal fixation. It should be noted that prompt surgery and initial correction of the NOE anatomical region yields much better results when compared to late revision surgeries. However, most authors have advocated the postponement of surgery for 3 - 7 days to allow for the recession of edema (22). Surgical approaches for accessing the NOE region are inferior lid incisions including subciliary and transconjunctival approaches. If NOE fractures are concomitant with midfacial fractures, inferior lid incisions can be applied with a transoral approach. Moreover, on the condition that the NOE fractures are accompanied by a fracture of the upper third of the face, a coronal approach is indicated. Generally, the fracture treatment principles in pediatric patients remain the same as those for adults (7).

The surgical treatment of NOE fractures is guided by the pattern and classification of injury. The surgical approach also varies according to the fracture type and other concomitant facial injuries. Non-displaced type I fractures with a single central fragment and an intact medial canthal tendon attachment often require no surgical intervention, and the patients can be followed clinically. However,

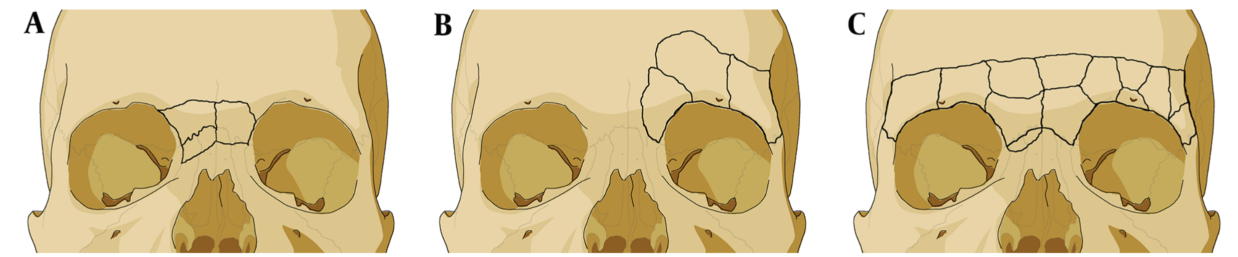

Figure 2. A, a Burstein type I fracture is localized to the upper NOE complex and frontal bone, while medial to the superior orbital foramen; B, a Burstein type II fracture involves half of the superior orbital wall, although it does not involve the NOE; C, a Burstein type III fracture is bilateral and involves the superior orbital walls, upper NOE, and bilateral frontal bones (Reprinted with permission from Liau et al.'s study (23))

displaced and/or unstable type I fractures will require open reduction and internal fixation, which can be managed through a maxillary transvestibular approach, possibly in combination with a transorbital approach (transconjunctival or transcutaneous). These fractures often require fracture reduction and mini-plate fixation of the frontal process of the maxilla (7). Figure 3 depicts a case of a type II NOE fracture accompanied by a Le Fort II fracture that was fixed using mini-plates. In type II and especially type III fractures, after reduction and fixation of the fractured segments, medial canthopexy should be carried out in order to reposition the medial canthal ligament. The most common method for medial canthopexy is transnasal wiring (Figure 4). However, in the present review we mostly sought to focus on new and novel modified treatment techniques. Hence, novel techniques for medial canthopexy are discussed in detail below.

3.4.1. Using the Frontoglabellar Area for Wire Fixation

After the reflection of a coronal flap, a shallow hole is created in the glabellar area of the frontal bone using a bur. Then, the medial canthal ligament is located and a wire is passed through it. Two holes are created in the frontoglabellar region and the wires are fastened. The advantages of this approach include the elimination of bolster, the prevention of injury to contralateral delicate bones and lacrimal apparatus, and the invisibility of the wires due to the presence of thick soft tissue (28).

3.4.2. Transcutaneous Medial Canthal Tendon Incision to the Medial Orbit

An incision some 1.5 - 2 cm in length is made anterior to the anterior part of the medial canthal ligament. Then, the anterior part of the medial canthal ligament, the medial wall of the orbit, and the nasal bridge are exposed. The incision used in this approach is more posterior, smaller in size, and more esthetic than a Lynch incision. Moreover, this approach allows the management of the fracture without complications such as telecanthus, diplopia, and a considerable scar (29).

3.4.3. Using Micro-Anchor Devices

This method involves a nickel-titanium (nitinol) anchor (1.3 mm in diameter and 3.7 mm in height), 4 - 0 Ethibond suture, and the associated inserter and perforator devices. After making a cutaneous incision anterior to the medial canthal ligament, subperiosteal dissection is continued to the lacrimal crest. A hole is created posterior and superior to the lacrimal crest using the perforator device. Thereafter, the micro-anchor is placed by the inserter device and held by the suture. This technique has the advantage of eliminating the dissection of the contralateral side (30).

3.4.4. Unitransnasal Canthopexy

After making an incision 2 mm from the medial canthal ligament, two holes are created 2 mm apart from each other into the nose. Polypropylene suture is then passed through each hole using a No. 14 angiocatheter. The end of the suture is held by the insertion of a hemostat into the nose and evicted. The ends of the suture are tied. Thereafter, the medial canthal ligament is held in place by the other end of the sutures. When using this method, the nasal bone and orbit of the contralateral side remain undamaged (31).

3.4.5. Transcaruncular-Transnasal Suture

After the reflection of the coronal flap, the NOE region is exposed. Vicryl or polydioxanone suture is inserted into the periosteum in the region of the attachment capsule of the medial canthal ligament and then evicted from the caruncle. Next, it is again passed from the caruncle towards the attachment. Finally, the suture is tied. This approach provides benefits such as requiring less operation time, excellent control of the magnitude of canthopexy, and the elimination of foreign body reaction (21).

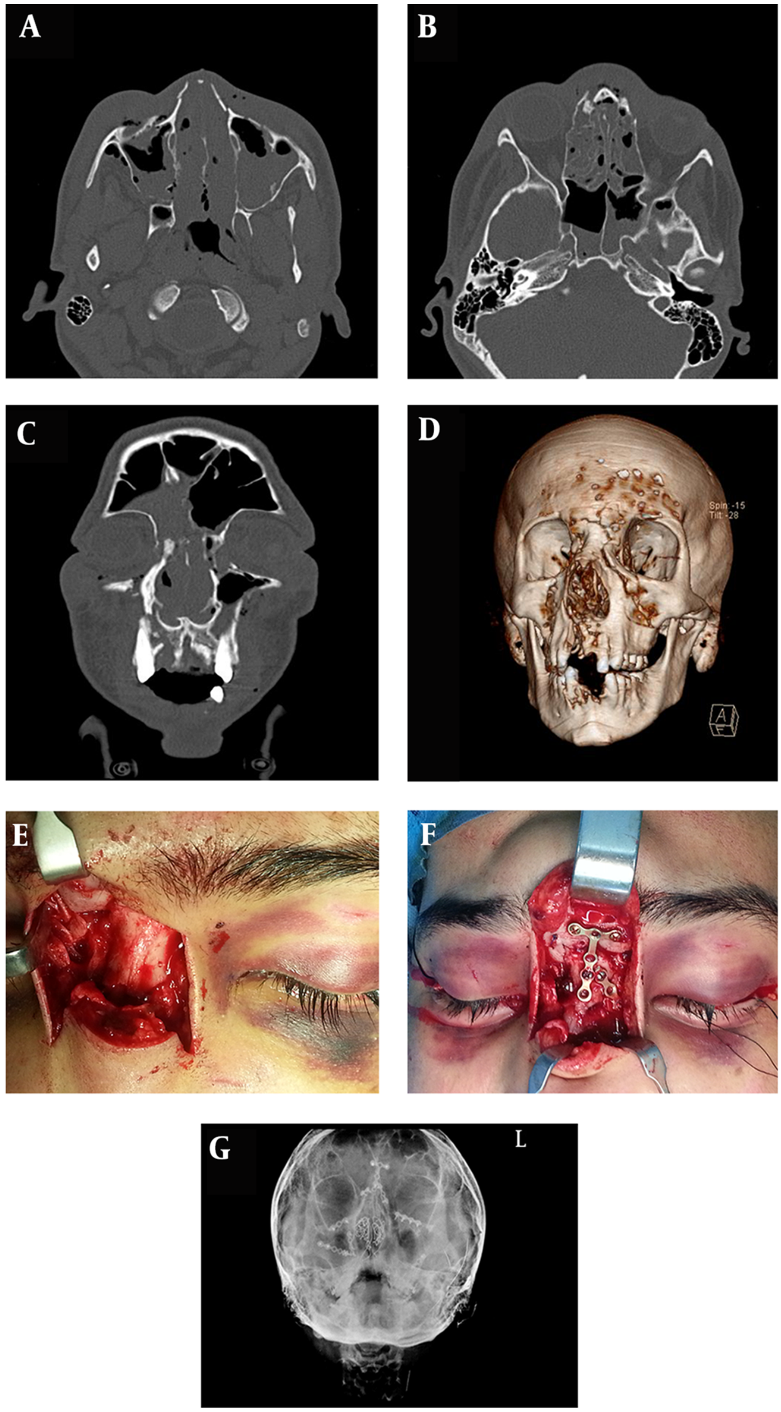

Figure 3. Preoperative CTs of a patient in A and B, axial and C, coronal views depict the nasal bone and nasal bridge fracture as well as the NOE and Le Fort fracture; D, the aforementioned fractures can also be traced in a three-dimensional CT; E, surgical exposure of the NOE fracture. F, plates and screws used for fracture reduction and stabilization; G, postoperative Waters projection showing the fixation of the facial fractures (Courtesy of Dr. Mehrnoush Momeni)

3.4.6. Precaruncular Medial Canthopexy

After the placement of the eye-shield, a conjunctival incision is made anterior to the caruncle. Dissection is continued above the Horner muscle to the posterior lacrimal crest. Periorbital tissue is reflected from the medial wall.

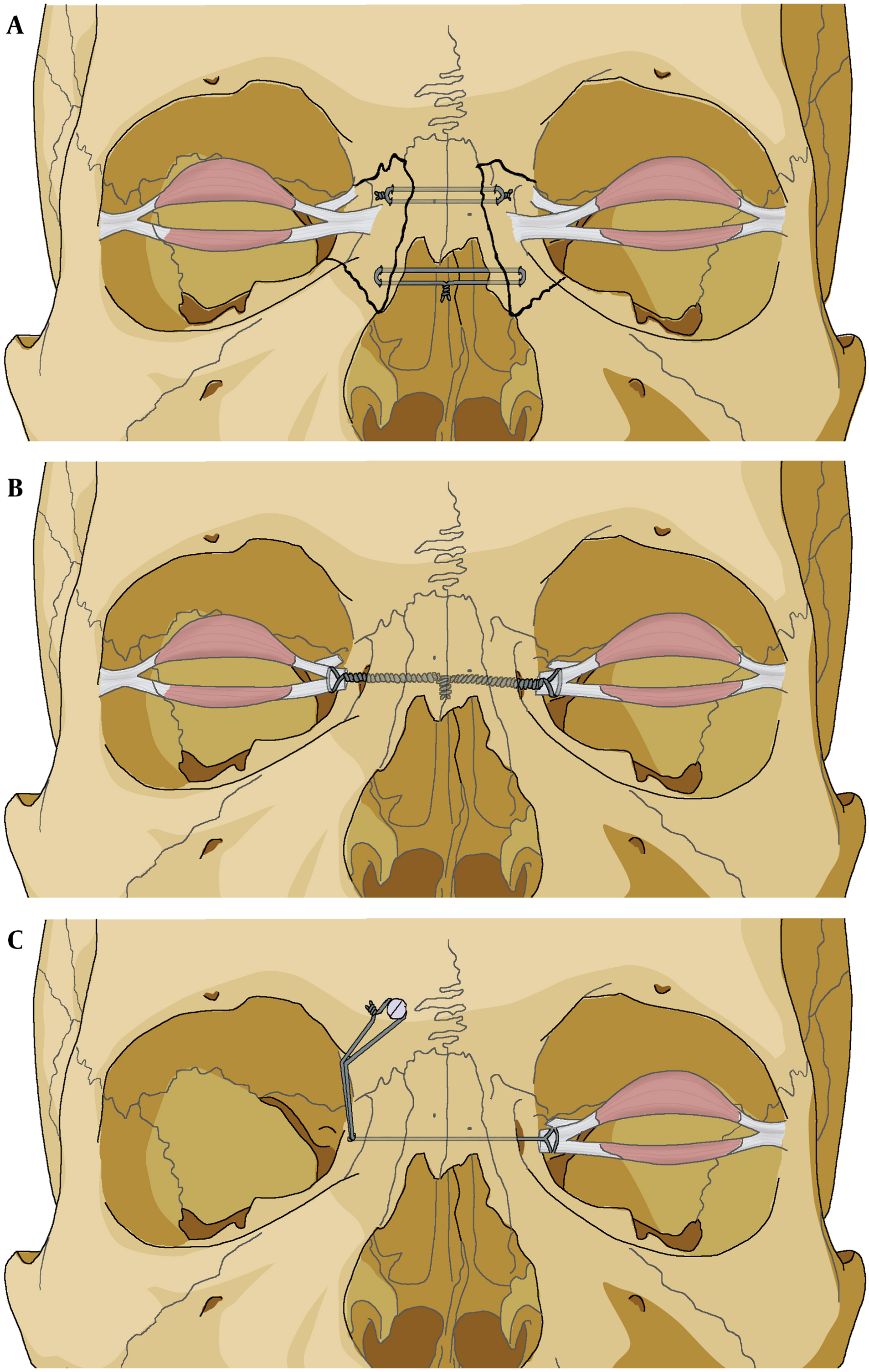

Figure 4. The Central Bone Segments or Medial Canthal Tendons are Stabilized to Each Other With Different Transnasal Wiring Techniques

A 6 mm screw is placed superior and posterior to the lacrimal crest. An unabsorbable suture is tied around the screw. Then, the medial tarsal plate and the closest part to the lid margin are sutured. This method can be used when ectropion is present. Moreover, it does not require the manipulation of the contralateral side (32).

3.4.7. Using a transcaruncular Barb and Mini-Plate

After the reflection of the coronal flap, the needle is passed through the caruncle so that the barbs are involved with the caruncle. Then, a mini-plate is fixed in the glabella medial to the orbit. The barb engages the canthal tendon and the wire is passed through an intraorbital mini-plate fixed in a stable section of the frontal bone (Figure 5). The mini-plate hole chosen to pass the wire through should approximate the vector of the normal canthal tendon position. This technique is applicable in cases of the comminution of the medial wall of the orbit and it does not require the transnasal passage of the wire. Thus, there is no need for the manipulation of the contralateral side (33).

3.4.8. Using a Malleable Awl

A Steinmann pin is used in this technique. The pin is bent using a plier into a semilunar shape with the diameter of the intercanthal distance. A cutaneous incision is made in order to locate the medial canthal ligament. After the subperiosteal dissection and reflection of the lacrimal sac, two holes are drilled in the lacrimal fossa of both sides using a 5 mm bur. The pin is then inserted from the fractured area into the intact area. Four wires are placed in the pin and pulled to the other side. Two of these wires are used in order to hold the medial canthal ligament, while the other two are used for the placement of the bolster. This method presents benefits such as the posterior placement of the wires and the fixation of the bolster using the wires. Its disadvantages include the need for wide incisions and a substantial scar (34).

3.5. Complications of NOE Fractures

A five-year prospective study involving 1024 cases of facial fractures demonstrated that NOE fractures present the highest rate of complications of all facial fractures (35). Fractures of this region are supposed to cause significant functional and aesthetic defects (36). It should be noted that most complications associated with NOE fractures result from inappropriate diagnosis or inadequate treatment at the time of the initial injury. Characteristic deformities related to inadequately treated NOE fractures include a shortened and retruded nose, shortened palpebral fissures, telecanthus, enophthalmos, and ocular diplopia (12).

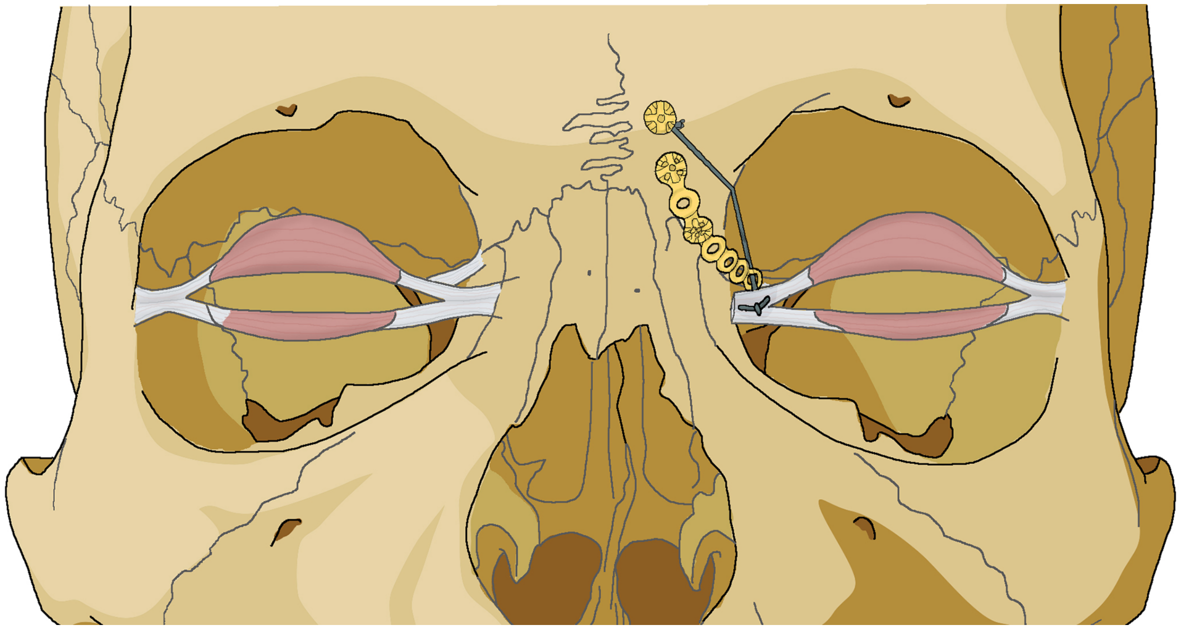

Figure 5. Medial Canthopexy Using a Unilateral Technique With a Transcaruncular Barb Secured to a Mini-Plate

One of the most common complications stemming from NOE fractures is traumatic telecanthus (10, 37) due to injury and the avulsion of the medial canthal ligament (38). Another esthetic imperfection associated with NOE fractures is nasal deformity (39) owing to the loss of nasal support (40). Moreover, enophthalmos (8) and midface retrusion (36) are other cosmetic defects that arise from NOE fractures.

Epiphoria may occur as a result of nasolacrimal system obstruction or post-operative eyelid malposition (18, 41, 42). It has a prevalence of about 47% (18, 43). If this condition has not been remedied after a follow-up period of three to six months, external dacryocystorhinostomy may be required (18, 41).

Diplopia may be another sequela of fractures of the NOE complex, and it may occur due to the lateral displacement of medial orbital wall fragments into the orbit (blow-in fracture) or the medial displacement of ethmoid bone fragments (blow-out fracture) (44). Other visual impairments and blindness can also occur in NOE fractures (8, 10, 45, 46). In his 19-year retrospective study, Ansari reported only one case of blindness among 19 patients with NOE fractures, which is the facial fracture type involving the least ocular injuries (47). In a review study conducted by Bossert and Girotto, the incidence of blindness-related facial fractures was reported to be around 3% (48).

Brain injury can be a life-threatening consequence of NOE fracture (11, 42) that occurs when bony fragments penetrate into the anterior cranial fossa (49). Cerebrospinal fluid rhinorrhea may also occur traumatically due to NOE fractures (11, 50).

Concomitant infection is rarely reported in NOE fractures. In a study of 1239 cases of maxillofacial fractures, Kyrgidis et al. reported seven cases of infection in NOE fractures together with panfacial fractures (17).

Pediatric NOE fracture is a challenging complication among all the maxillofacial fractures. Rigid fixation has been shown to result in growth restriction in animal models. Techniques utilizing absorbable plating systems are now commonly used for craniofacial surgery in pediatric patients, which obviates the potential need for plate removal, although no studies document the use of this technique in pediatric NOE fractures (9). Despite the potentially increased incidence of nasolacrimal duct obstruction causing epiphoria, transnasal wiring remains the treatment modality of choice for medial canthal stabilization in type II and type III NOE fractures in pediatric patients (9, 24).

4. Conclusions

Although surgical access has not changed dramatically over the past decade, technological progress has led to new and efficient tools being added to the surgeon's armamentarium, including improved surgical instrumentation, presurgical computerized planning and manufacturing processes, and intraoperative CT scanning for the real-time verification of surgical reduction. Advances in sophisticated imaging along with the evolution in minimally invasive surgical techniques have led to more conservative options that may provide better patient outcomes while minimizing the risks and morbidity associated with more traditional treatment approaches.

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