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Detailed Dissection Of Naso Orbito Ethmoidal Fractures: Critical Analysis Of Complications And Treatment Strategies

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Abstract:
Naso-orbital-ethmoidal (NOE) fractures present complex challenges in craniofacial trauma, often leading to significant functional and aesthetic issues. This review provides a comprehensive analysis of critical complications and contemporary treatment strategies for NOE fractures. Key complications, including herniation, orbital contents entrapment, enophthalmos, and diplopia, arise from common pitfalls such as inadequate supraorbital ridge reconstruction, damage to the orbital roof, and loss of the frontal sinus posterior wall. The review underscores the importance of using full-thickness rib or layered bone grafts to address supraorbital ridge flattening and highlights the necessity of reconstructing the orbital roof to manage large defects effectively. Achieving symmetry in the supraorbital rim and avoiding over-correction are emphasized as crucial challenges, particularly in the context of orbital dystopia in severe cranio-orbital injuries. Advances from traditional closed reduction to open techniques are evaluated, including the use of Walsham's forceps, septal forceps, and trans-nasal wiring. Surgical approaches such as glabella, bicoronal, and H-shaped incisions are reviewed, with recommendations for ensuring proper exposure, medial canthal ligament realignment, medial orbital rim reconstruction, and soft tissue adjustment. Effective management of nasoglabellar injuries and frontocranial reconstruction using wire fixation and miniplates or microplates is also discussed. This review highlights the need for meticulous surgical techniques and identifies areas for further research to improve outcomes in the treatment of NOE fractures.

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

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I. Introduction:

The face plays a crucial role in overall function and aesthetics. Scarring or skeletal deformities in facial structures can have significant functional and psychological repercussions for patients.[1] Poor management of facial fractures can lead to pronounced post-traumatic deformities; the greater the displacement and separation of the fracture, the more conspicuous the deformity becomes.[2]Post-traumatic facial deformity arises from trauma and represents an acquired abnormality. Thus, it is vital to evaluate both the fracture and the extent of displacement of the fractured segments when addressing facial injuries.[3] Naso-orbito-ethmoid (NOE) fractures are intricate injuries involving the intersection of the nasal bone, ethmoidal sinus, frontal sinus, and anterior skull base, accounting for about 5% of facial fractures. This complex area is exceptionally delicate, with any damage potentially leading to severe functional and aesthetic consequences.[4] The NOE complex includes the nasal bones, nasal septum, frontal bone's nasal processes, maxillary frontal processes, ethmoid bone, lamina papyracea, lacrimal, and sphenoid bones. Due to its proximity to vital structures like the brain and eyes, fractures in this region can have profound impacts.[5] Key anatomical features such as the medial canthal ligament, lacrimal drainage system, and olfactory and infraorbital nerves are particularly susceptible to injury, complicating both diagnosis and treatment. NOE fractures may occur in isolation or alongside other midfacial fractures, including Le Fort I, II, and III, orbital blowout, and zygomatic bone fractures.[6]Due to the intricate anatomy of the NOE region, managing these fractures surgically is particularly challenging in the maxillofacial domain. The NOE complex is part of the medial vertical buttress system of the face, adjacent to the cranium, including the nasal bones, ethmoid bones, and frontal bone at the anterior skull base.[7]The ethmoid labyrinth separates the orbits and acts as a shock absorber during trauma, reducing the force transmitted to vital structures such as the orbital and cranial cavities.[8] Severe injuries or fragmentation can lead to anterior cranial base fractures and cerebrospinal fluid leaks. The frontal process of the maxilla and the lacrimal bone are crucial components of the NOE complex due to their proximity and impact on the fracture pattern. The medial canthal ligament is a significant soft tissue structure that connects the upper and lower eyelids to the nasal framework and encircles the lacrimal sac. Injuries to the medial canthal ligament can affect eyelid attachment and tear drainage.[9]When the soft tissue in this delicate area is damaged, it often collapses, leading to noticeable deformity; therefore, optimal initial alignment and repair are crucial for the best outcomes, as secondary corrections may not fully restore the pre-injury state.[10]Surgical intervention for NOE fractures is indicated in cases of loss of nasal projection, facial asymmetry, and functional issues such as diplopia, epiphora, enophthalmos, and hypoglobus, with additional concerns including damage to the lacrimal duct and potential cerebrospinal fluid leakage, particularly when associated with skull base fractures.[11] A key factor for surgical intervention is medial canthal tendon displacement, which can significantly disrupt facial balance through bony fragment dislocation (Markowitz type I and II) or ligament detachment (Markowitz type III), leading to traumatic telecanthus.[12]An increase in the intercanthal distance or a traumatic telecanthus exceeding 35 mm is typically regarded as abnormal and generally requires surgical intervention. Thus, the decision to proceed with surgery is often based on the diagnosis of dislocated fractures with medial canthal tendon misalignment following a comprehensive clinical evaluation and Computed Tomography scans.[13] Minor NOE fractures with slight displacement and no medial canthal tendon misalignment may resolve on their own, leading to ongoing debate regarding the management of fractures with minimal visible dislocation on Computed Tomography.[14]Acute midface injuries often present with significant mucosal swelling and nasal congestion, which usually improve over time. However, these symptoms may obscure functional nasal impairments, potentially leading to missed diagnoses of chronic nasal obstruction after initial NOE fracture treatment.[15]Significantly, chronic nasal obstruction from NOE fractures without nasal septum deviation has not been previously reported.[16]The NOEM complex, involving the nasal bones, nasal septum, frontal processes of the maxilla, ethmoid bone, and lacrimal bones, presents significant diagnostic and treatment challenges due to its complex anatomy and its impact on both function and appearance.[17] These fractures, often resulting from motor vehicle accidents, falls, or assaults, are evaluated using multidetector Computed Tomography at our Level I trauma center.[18] This high-resolution imaging provides crucial axial, sagittal, coronal, and three-dimensional views essential for assessing complex injuries, planning preoperative procedures, and guiding patient consultations.[19] Recognizing facial fracture patterns involves understanding the role of facial buttresses in absorbing impact forces and protecting critical areas like the neurocranium and cervical spine.[20]NOE fractures constitute about 5% of facial injuries, with road traffic accidents being a major cause, especially in regions with high rates of two-wheeler accidents like the Indian subcontinent.[21]Reconstructing the orbital wall with conventional plates and screws is extremely challenging and often leads to complications such as facial deformities, nasal and forehead indentations, and telecanthus, often necessitating reoperation. Therefore, minimizing cosmetic and functional complications is crucial to improving medical care and enhancing patient quality of life.[22]Currently, plates and screws are commonly used in facial reconstruction and are manufactured in standardized shapes and sizes. During surgery, these plates are adjusted to fit the contours of the face, but their deformation constraints present several drawbacks. A three-dimensional (3D) printer can create an object in the desired shape by utilizing computer-aided design and converting it into 3D design data, while layering materials to produce the final product.[23]Research into 3D printing for patient-customized craniomaxillofacial reconstruction is advancing, with evidence suggesting that 3D printing often yields superior functional and aesthetic outcomes compared to traditional plates and screws in fracture treatment. However, specific studies on nasoethmoid orbital fractures are limited. Thus, the development of patient-customized prostheses for nasoethmoid orbital fractures using 3D printing technology is crucial.[24]

II. Etiopathogenesis:

Impacts to the central midface with significant force and speed can result in NOE fractures. The main causes of these fractures include motor vehicle collisions and violent assaults. Positioned prominently at the front of the face, the NOE complex is particularly susceptible to such trauma.[25] Compared to other craniofacial bones, such as the frontal or zygomatic bones, the NOE complex is more readily damaged by even moderate force.[26] NOE fractures often lead to telecanthus, characterized by an increased distance between the eyes, due to the displacement of the medial canthal tendon from its normal position.[27] For telecanthus to manifest, fractures must involve the medial and inferior orbital borders, the lateral nasal bone, the fronto-maxillary junction, and the naso-maxillary buttress.[28]The extent of bony displacement associated with the MCT can range from minimal to extensive, which helps in classifying NOE fractures into three categories.[29]Type I NOE fractures are the simplest, with no bone comminution and affecting only the medial orbital rim and medial canthal tendon, generally amenable to anatomical realignment.[30]Type II fractures are more severe, with comminution of the bone beyond the medial canthal tendon attachment, but the medial canthal tendon can still be used for surgical repair due to its continuity with the large fractured segment.[31] Type III fractures are the most complex, bilateral, and complete, involving comminution with fracture lines extending into the medial canthal tendon insertion site, making the small bone fragment to which the medial canthal tendon is attached unsuitable for surgical reconstruction.[32]The NOE complex is part of the medial vertical buttress system of the face, abutting the cranium. It comprises the nasal bones, the ethmoid bones encompassing the sinuses, which also form the medial wall of the orbit articulating with the frontal bone at the anterior skull base.[33]This ethmoid labyrinth, which separates both orbits, functions as a shock absorber during trauma, thus reducing the impact on critical structures such as the orbital and cranial cavities.[34]Extensive injury or comminution can result in associated anterior cranial base fractures causing cerebrospinal fluid leakage as well. The frontal process of the maxilla and the lacrimal bone are also integral to the complex due to their proximity and involvement in the fracture pattern occurring in the region.[35]Apart from the bony structures, the medial canthal ligament is a crucial soft tissue component. The ligament not only anchors the upper and lower eyelids to the nasal complex but also encompasses the lacrimal sac at its anterior, posterior, and superior aspects.[36] Certain authors have found that the posterior limb is not always present or clearly defined in some cases. The ligament, attached to the edges of the lacrimal fossa in the lacrimal bone, helps in draining the lacrimal sac during blinking, thus facilitating tear drainage. Therefore, injuries affecting the attachment of the medial canthal ligament can impact the medial eyelid attachment and/or the drainage of tears from the lacrimal sac.[37]The skin and soft tissues drape over the complex like a cloth over a framework, and when the area crumples following an injury, the soft tissue envelope collapses as well, causing distinct deformity. If not addressed properly, this can result in persistent deformity of the region. The collapsed soft tissue heals and scars over the deformed bony complex, and secondary correction at a later date may not restore the pre-injury status. Therefore, optimal primary realignment and repair offer the best chance of achieving the most favorable results.[38]

III. Discussion:

The treatment of NOE fractures has evolved significantly over time. Dawson and Fordyce in 1953first identified ethmoidal fractures, and Converse and Smith in 1963 described involvement of the medial orbital wall, introducing the term "naso-orbital."[39]Stranc and Epker refined the terminology to "naso-orbito-ethmoid" in 1973, while Gruss in 1985 preferred "naso-ethmoid-orbital."[40]Rowe and Williams emphasized the complexity of NOE fractures and the necessity of primary management.[41]Markowitz and Manson in 1991 highlighted the role of the medial canthal ligament, categorizing fractures into Type I, Type II, and Type III based on the condition of the canthal ligament.[42]Diagnosing and treating NOE fractures requires a comprehensive approach integrating detailed imaging and clinical assessment. Key issues identified during clinical evaluation include displacement, malposition of the medial canthal tendon, traumatic telecanthus, and symptoms like double vision, excessive tearing, sunken eyes, or cerebrospinal flui leaks.[43] High-resolution multidetector computed tomography is essential for visualizing the fractures' extent and configuration through axial, sagittal, coronal, and 3D reconstructions.[44]This imaging guides surgical planning and patient consultations. Treatment varies by fracture type: Type I fractures are managed with minimally invasive techniques and trans-nasal fixation for restoring facial symmetry; Type II fractures require stabilization with micro-plates or titanium meshes; Type III fractures, the most intricate, involve reconstructing orbital borders and medial canthal tendon insertion using a bicoronal surgical approach for optimal visibility and precise fixation.[45]This method reduces aesthetic disruption and prevents severe complications such as traumatic telecanthus and nasal dorsum sinking. Despite the potential for complications like alopecia and altered sensation, the patient in this case did not experience these, showcasing the effectiveness of the surgical strategy and technique.[46]

Restoration of the medial canthal ligament through canthopexy aims to reestablish normal intercanthal distance and improve aesthetic results.[47]According to Markowitz et al., only 3% of NOE fracture patients show

medial canthal tendon displacement, making its reinsertion critical for maintaining intercanthal distance.[48] Nasal dorsum reconstruction, combined with nasal fracture reduction, enhances nasal projection and function, especially in NOE type III fractures. Calvarial bone grafts used in this case offer a low resorption rate and favorable long-term results, with minimal morbidity due to the donor site's proximity to the reconstructive area, as described by Maves & Matt in 1986.[49]Pediatric NOE fractures are categorized differently due to distinct anatomical features such as midface proportions and variations in frontal sinus development. Burstein et al. introduced a classification system for these fractures:
Type I: Involves the upper NOE complex and frontal bone.
Type II: Affects half of the superior orbital wall without NOE involvement.
Type III: Impacts the superior orbital walls, upper NOE, and bilateral frontal bones.[50]

These fractures typically result from trauma and present with symptoms like significant nasal bleeding, midfacial swelling, and related signs. Diagnostic procedures focus on excluding head injuries, evaluating nasal deformities, and measuring the intercanthal distance. Computed Tomography imaging is crucial for diagnosis, with high-resolution scans and three-dimensional reconstructions facilitating precise surgical planning.[51]

Surgical techniques for NOE fractures include:

Reduction Techniques: Walsham's forceps for realignment, septal forceps for elevating depressed complexes, and trans-nasal wiring for cases where closed methods are insufficient.

Surgical Approaches: Options include existing lacerations, glabella approach, bicoronal approach, butterfly incision, vertical incision, and H-shaped incision.[52] Ed Ellis et al. recommend a methodical approach that includes ensuring adequate exposure, identifying and reconstructing the medial orbital rim, performing trans-nasal canthopexy, addressing septal fractures, and enhancing the nasal dorsum with bone grafts.[53] Finish with soft tissue readjustment. If required, trans-nasal wiring uses K-wire drivers or awls to narrow the area and restore canthal distance, with low-profile titanium plates supporting fixation.[54] Canthopexy may be needed for medial canthal ligament disruption or small bony fragments, aiming to medialize the central fragment and position the medial canthal ligament posteriorly for the best outcomes.[55]In addressing combined cranial and facial fractures, the surgical approach should adhere to established principles akin to those used in repairing congenital craniofacial deformities. This integrated approach involves both neurosurgical and reconstructive teams.[56] Initially, the dura mater is repaired to protect the cranial contents.[57] Subsequently, attention turns to the repair of craniofacial fractures. Despite concerns that extensive periosteal elevation might lead to facial bone necrosis , it is often necessary for effective reconstruction.[58] Rigid fixation and grafting of missing bone segments are employed, and interfragmentary wiring or plating is preferred over craniofacial suspension wiring, which can lead to undesirable midfacial compression and shortening.Particular attention must be paid to the frontal sinus mucosa, which differs from the nasal cavity's respiratory epithelium.[59] When the frontonasal duct is obstructed due to fractures or chronic infection, the sinus mucosa may develop cysts or mucocoeles. These can erode adjacent bone, potentially leading to serious complications such as orbital or intracranial abscesses, osteomyelitis, or meningitis. To mitigate these risks, some authors advocate for nasofrontal duct and frontal sinus obliteration.[60] However, the indications for obliteration, particularly using abdominal fat, are well established in cases of recurrent infection but less so in acute craniofacial trauma.[61] Existing studies have provided insights based on limited trauma cases and lack double-blind controls.[62]The notable report by Newman and Travis in 1973, covering 63 cases from 1961 to 1971, highlights that operative intervention often faced delays exceeding 48 hours, during which observation and antibiotic treatment were administered.[63]This underscores the need for more comprehensive research to define the optimal management strategies for frontal sinus involvement in acute craniofacial trauma.[64]The first 3D printer was developed in 1984, with the initial patent for a metal 3D printer filed in 1986.[65] Common manufacturing methods include mechanical processing and laser cutting or polishing of large stereoscopic materials. Alternatively, 3D printing involves layering solid, liquid, or powdered materials based on design specifications. Traditional machine processing is a cutting method that wastes a large amount of raw material. In contrast, 3D printing minimizes raw material usage by adding only the necessary amounts.As a result, 3D printing is extensively utilized in the medical field for personalized care and cost reduction. This technology is commonly employed to create customized prostheses, including hearing aids, dental materials, and prosthetic limbs. The advent of 3D printing has significantly reduced the manpower and time required to produce customized hearing aids, although manual ear modeling remains necessary due to individual variations. Additionally, dental prosthetics can be efficiently manufactured with 3D printers, facilitating the rapid creation of high-quality solutions.3D printing also offers benefits in fracture surgery and complex anatomical procedures by allowing the creation of customized prostheses and simulations before surgery.[66] This approach can reduce surgical time and minimize postoperative complications. Today, 3D printers are widely used in facial plastic surgery and reconstruction for orthognathic surgery, post-traumatic surgery, tumor surgery, cranioplasty, and implantation.[67] In a recent study, the mandible was 3D-modeled before partial resection, and the reconstruction prosthesis was pre-designed. Preparing templates in advance for maxillary surgery based on preoperative simulations led to improved postoperative outcomes for LeFort fracture surgeries.[68]However, research on customized prostheses for nasoethmoid orbital fractures remains limited. This study could establish a basis for developing customized 3D-printed prostheses, potentially offering superior aesthetic and functional results compared to traditional methods. The use of 3D printing has also demonstrated quicker procedures and enhanced accuracy in the placement of fixation, based on preoperative 3D Computed Tomography results.[69]

IV. Technical Problems And Pitfalls:

Based on our experience with these intricate cases, several critical challenges and pitfalls have emerged. Insufficient reconstruction of the supraorbital ridge often results in flattening, which can be effectively addressed using full-thickness rib grafts or layered bone grafts.[70] Damage to the orbital roof may lead to isolated or comminuted fractures, and loss of the frontal sinus's posterior wall necessitates reconstructing the orbital roof to separate the anterior cranial fossa from the orbit. Minor defects in the orbital roof can be manageable if the posterior wall is intact, but larger defects require attention to prevent complications such as herniation, entrapment of orbital contents, enophthalmos, and diplopia.[71] Achieving symmetry when reconstructing a complete loss of the supraorbital rim is challenging, with excess bone potentially causing exophthalmos, especially if the orbital roof is also reconstructed.[72] Accurate contouring of the supraorbital rim and roof is essential to avoid over-correction. Identifying true orbital dystopia can be difficult, particularly with severe cranio-orbital injuries and midface damage; failure to address this during initial reconstruction can result in a persistent and difficult-to-correct orbital dystopia.[73] Restoring orbital position requires thorough exposure and reconstruction of the zygomatic arch and lateral orbital rim to establish a stable facial framework with correct projection and width. Precise reconstruction of the inner facial structures, including the orbital rims and naso-ethmoid region, is crucial for realigning a displaced orbit. [74]Severe nasoglabellar injuries may cause substantial destruction or loss of the glabella and nasal bones, necessitating immediate bone graft reconstruction. For the frontocranial region, careful interosseous wire fixation provides stable reconstruction, although maintaining contour can be challenging with extensive comminution. Long miniplates or microplates, accurately contoured to the skull, can help preserve contour and minimize collapse. Securing individual fragments with specially designed miniscrews, 3 or 4 mm in length, prevents damage to the dura and ensures stability.[75]

V. Conclusion:

To enhance our understanding of NOE fractures, it is essential to undertake comprehensive longitudinal studies that focus on precise fracture classification and optimal surgical timing. Although these fractures are relatively rare, they can cause significant functional and aesthetic problems, particularly in pediatric cases where growth considerations come into play. Current research gaps include managing associated injuries, utilizing digital tools, and identifying risk factors for poor outcomes. There is a pressing need for further research to refine our grasp of patient-specific factors, surgical techniques, and postoperative recovery. The management of NOE and frontal sinus fractures is intricate, demanding careful attention to the medial canthal ligament and naso frontal duct to ensure favorable outcomes. Effective treatment planning is critical and involves the meticulous selection of surgical incisions, fixation methods, and bone graft applications to prevent suboptimal aesthetic results. For complex naso-orbito-occlusal fractures, early diagnosis and intervention are crucial to minimize long-term complications and achieve optimal aesthetic and functional results.

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