Review Article

Mid-facial fractures and their current classification systems: narrative review

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Background: The review aims at identifying the classification system used for mid-facial fractures and its applications in clinical settings. Mid-facial fractures are a significant health concern due to frequent vehicle accidents that result in damage to the oral and maxillofacial regions. Additionally, these accidents may result in life-threatening hemorrhaging, respiratory failure, serious head trauma, or possibly other functioning impairments. Over 1 million people die each year, and more than 25 million individuals are injured due to road accidents. Accurate diagnosis is one of the most difficult challenges that must be overcome while treating these types of fractures. In this sense, classifying facial fractures aids in diagnosis and directs therapy.

Methods: The data for this review was obtained from various databases such as Google search, PubMed, ScienceDirect. The key words such as mid-face fractures, Le Fort fractures, classifications and review were used in combinations and along with their synonyms to search for data. Duplicates were removed to gain a comprehensive and through data.

Key Content and Findings: Facial fractures involving the zygomatico-maxillary and naso-orbito-ethmoidal complexes provide unique functional and aesthetic challenges, making knowledge of the most common patterns and classifications crucial. Treatment regimens are correspondingly planned. As a result, there have been numerous classification methods developed to date. These classification systems along with computed tomography-guided evaluation are extremely useful to the surgeons.

Conclusions: Precise diagnosis and surgical treatment are critical for the successful management of complex fractures. This review focuses on the modified classification system for dealing with mid-facial fracture consequences, as well as their diagnosis and treatment. Knowledge of all these classifications aid clinician to reach correct diagnosis and thus plan the treatment.

Keywords: Midface; fractures; classification systems; safety considerations; Le Fort classification

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Introduction

The nasal, ethmoidal, palatal, sphenoid, zygomatic, and maxillary bones, as well as associated paranasal sinuses, make up the midface. The midface is located between the cranial base and the dental occlusal plane. It serves as a functional and aesthetically pleasing structure. Trauma to this region can be life threatening which potentially cause fatal bleeding, obstruct the airway and head injury (1). Mid-facial fractures are a significant health concern due to frequent vehicle accidents that result in damage to the oral and maxillofacial regions. Two-wheeler's account for roughly 73 percent of all automobiles in developing countries such as India (2). This figure is significantly higher than other developed nations. As a result, the number of two-wheeler accidents is higher than in developed countries. This accident rate is further increased by lack of use of helmets. The development of expressways has enhanced the speed of four-wheelers (3). This, combined with a lack of seat belt use, has resulted in unprecedented high-impact trauma (4). Low- and middle-income countries are responsible for 93% of all road fatalities, despite the fact that they own 60% of the world's automobiles. Even in high-income countries, people from low socioeconomic backgrounds are more likely to be involved in traffic accidents. Although India has only 1% of the world's total motor vehicles, it is responsible for 6% of all road traffic accidents (RTAs). Rapid growth in the number of new cars on the road has made it hard for roads to grow quickly enough (5). Moreover, the very complicated structure of the bones in the middle third of the facial skeleton, as well as their interrelationships, produces a unique situation with fractures of various forms and the treatment planning for these fractures has also become increasingly difficult due to improper classification of these fractures (6). Furthermore, there exist a possibility of life-threatening complications such as cerebrospinal fluid (CSF) leak that is associated with Le Fort II and III type of fractures, due to the complex anatomy of midface (7). Therefore, understanding the overall mid-facial anatomy, techniques to identify the fractures and treatment possibilities is crucial. Reviews of midface trauma have mainly concentrated on approaches and treatment option, but this review will look into the classification systems of midface fractures (8,9). The purpose of this literature review is to provide an update on current trauma patterns involving midface fractures and to classify them in order to facilitate diagnosis and treatment. Thus, here we present this article in accordance with the Narrative Review reporting checklist (available at https://fomm.amegroups.com/article/view/10.21037/fomm-22-63/rc).

Anatomic considerations

Anatomy continues to be the rock-solid foundation on which all surgery is designed. A thorough understanding of anatomy leads to a better comprehension of fractures and, eventually, surgical planning. Cheung *et al.* examined ten dry skulls and their images generated by computed tomography (CT), as well as the measurement of maxillae bone thickness in five different anatomical locations (paranasal, infra-orbital, posterior sinus wall, zygomatic, and alveolar region) (9). The paranasal region's cortical bone thickness was reported to be 4.16±1.98 mm, infra-orbital region's 1.16±0.51 mm, zygomatic region's 4.01±0.55 mm, posterior maxilla 32 region's 0.96±0.25 mm, and alveolar region was 2.10±0.47 mm. For secure fixation, it was recommended that bone-borne screws be put to the thickest sections, the paranasal and zygomatic regions suggesting the significance of buttresses in facial reconstruction (10). Arman *et al.* did an anthropometric study of the maxilla frontal wall on dry human skulls. A total of 60 maxillae were investigated from 30 adult dry West Anatolian skulls (11). The thickness and size of the maxilla were measured, which is significant when restoring facial structures. The thickness of the paranasal region was found to be 3.50±2.11 mm, the infraorbital margin was 3.72±1.78 mm, and the alveolar region was 2.08±1.84 mm (11).

To optimize results and minimize late post-traumatic abnormalities, Parashar and Sharma assessed the anatomic, diagnostic, and treatment aspects (12). During primary care, many unfavorable effects emerge because of untreated underlying structural injury. Facial fractures can be successfully treated with several methods as long as basic surgical principles in terms of diagnosis, stability, and patient rehabilitation are followed. The authors concluded that a detailed understanding of anatomy is essential to accomplish fixation appropriately. Kühnel and Reichert described the typical architecture and classification of facial bone (7). For each facial bone, the author discussed clinical signs, symptoms, radiographic evaluation, and surgical management. Each of this research established, either directly or indirectly, the critical role of buttresses in fracture reduction and fixation.

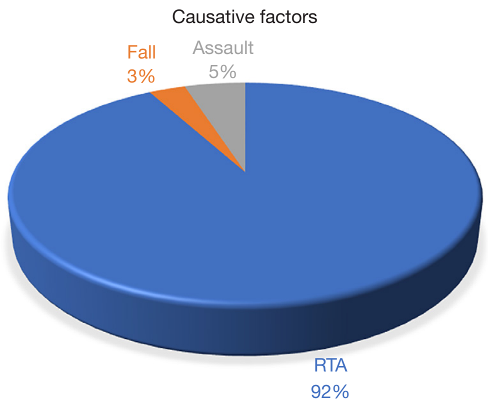

Figure 1 Pie chart representing the causative factors in percentage distribution. RTA, road traffic accident.

Causative factors

The contributing factors of maxillofacial trauma have evolved over time. The force and speed of collision are proportional to the vehicle's speed, which is growing year after year. As a result of these variations in causative factors, the nature of fractures has altered over time. A number of research have been conducted around the world to determine the incidence, prevalence, and pattern of maxillofacial trauma (5,6,8,13,14). Research conducted on African populations and a few on east Asian populations indicated that RTAs were the leading cause of maxillofacial injuries (15) (*Figure 1*). Children and adults were injured throughout Africa, except in the northeastern states, where assault was the major cause of injury. The majority of patients were aged 21 to 30, with a significant male-to-female ratio. Later legislations were proposed by their government to improve regulations aimed at preventing road traffic crashes, as well as to strictly enforce existing laws targeted at reducing craniofacial injuries in children and adults (16).

In Brazil, it was observed that the major cause of maxillofacial injuries, particularly in young male adult patients, was RTAs, followed by physical assault, bicycle falls, and a range of other reasons. In a 4:1 male to female ratio, men had more fractures. Conducting routine epidemiological surveys has been suggested to be critical for implementing preventative strategies and enhancing understanding about the etiology of face and other anatomical fractures (17-19). Recently, a survey done in Pondicherry, India, revealed that RTAs resulting in fractures, adnexal, and globe injuries accounted for the bulk of injuries in this community. The primary risk factors were excessive alcohol intake and a lack of protective eyewear. Moreover, patients who sustained damage to the open globe or posterior area had a poor visual prognosis (19).

Diagnosis

Damage to the mid-facial bones can now be studied more easily by evaluating the skull and its fractures using a variety of imaging techniques. In many cases, CT has supplanted the conventional radiograph (CT). CT scanning combines two distinct technological domains: conventional X-ray technology and advanced computer technology (20). As a result, CT scanning is a type of radiography that combines thin layer radiography (tomography) with computer synthesis. The most advanced multi-slice CT system can acquire four data slices in 350 milliseconds and reconstruct a 512×512 matrix image from millions of data points. Indeed, CT scans are a promising alternative for assessing the pattern of injuries in the craniofacial region (21). Furthermore, CT is more sensitive than plain-film radiography in diagnosing trauma, such as mandibular fractures. Three-dimensional scans are frequently used by surgeons to plan procedures to alignment restoration and repair aesthetic defects. Additionally, these scans can be advantageous for radiologists on occasion, as they can provide a comprehensive perspective on complicated midface fractures (22). Among the developing breakthroughs in CT imaging, the expanding use of cone-beam CT stands out as it may be utilized in walk-in clinics to diagnose low-energy mandible fractures (23). Also, these CT scans can be used intraoperative and have a high spatial resolution while requiring a low radiation dosage. Due to the technique's limitations, including the requirement that the patient remain upright for the majority of units and the absence of contrast, it is ineffective in patients who have sustained polytrauma. Given the obvious advantages of CT in facial trauma, magnetic resonance (MR) imaging seems to have a limited role in the field, but the improved techniques such as diffusion-weighted imaging (DWI) have contributed additional utility for such trauma. MR evaluation employing DWI and apparent diffusion coefficient (ADC) levels is an imaging feature that does not require intrusive scanning and can aid in the identification of benign from malignant causes in orbital, nasal, paranasal, and skull base lesions (23).

Table 1 Methodology in brief

Items	Specification
Date of search	March 01, 2017 to June 01, 2022
Databases and other sources searched	Google search, PubMed, ScienceDirect
Search terms used	Midface fractures, causative fractures, classifications
Timeframe	No filters
Inclusion criteria	Review articles, case series, original research, English language only
Selection process	The data was collected by KAB, MSC and SMK. It was assessed by PVK and KAK. Any disputes were handled by DK and consensus obtained

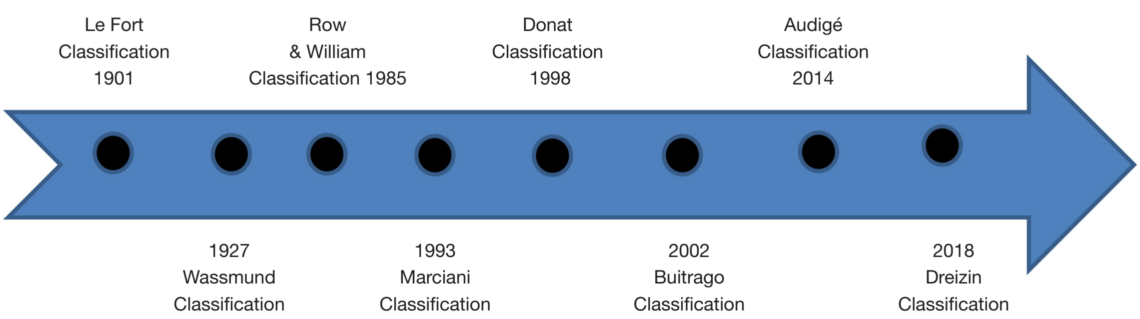

Figure 2 Timeline representing midfacial fracture classification.

Methods

The data for this review was obtained from various databases such as Google search, PubMed, ScienceDirect. A language preference of English was used, but restrain on number of years was removed. The keywords such as midface fractures, Le Fort fractures, classifications and review were used in combinations and along with their synonyms to search for data. Duplicates were removed to gain a comprehensive and through data (*Table 1*).

Discussion

Classification systems

Facial fractures involving the zygomatico-maxillary and naso-orbito-ethmoidal (NOE) complexes, in particular, provide unique functional and aesthetic challenges, making knowledge of the most common patterns and classifications crucial. Treatment regimens are correspondingly planned. As a result, there have been numerous classification methods developed to date (*Figure 2*).

It was in 1901 when Rene Le Fort, a Frenchman, categorized fractures and gained widespread popularity through his tests on various cadavers. He dubbed the linea minoros resistentiae three distinct fracture patterns. Le Fort I happened at the palatal level, Le Fort II occurred at the maxillary level, and Le Fort III occurred as a craniofacial dysjunction (24) (*Figure 3*). The Le Fort I (horizontal/low-level fracture) fractures are caused by downward stresses on the maxillary rim. This originates in the horizontal plane near the base of the nose. The fracture line travels backwards across the lower third of the pterygoid laminae from the lateral margin of the anterior nasal opening below the zygomatic buttress. Le Fort II (pyramidal/mid-level fracture) fractures begin at the bridge of the nose and extend obliquely into the orbits' medial and inferior orbital rims. It then proceeds posteriorly in a horizontal direction over the hard palate, involving the pterygomaxillary buttresses, resulting in the disarticulation of the pyramid-shaped face skeleton from the rest of the skull. Finally, the Le Fort III (transverse/high-level fracture) fracture line travels from the nasofrontal area to the zygomatic arch, through the pterygoid plates' upper half, and through the medial, posterior, and lateral orbital walls (25). *Figure 3* illustrates the fracture types.

While the Le Fort classification is oversimplified, it

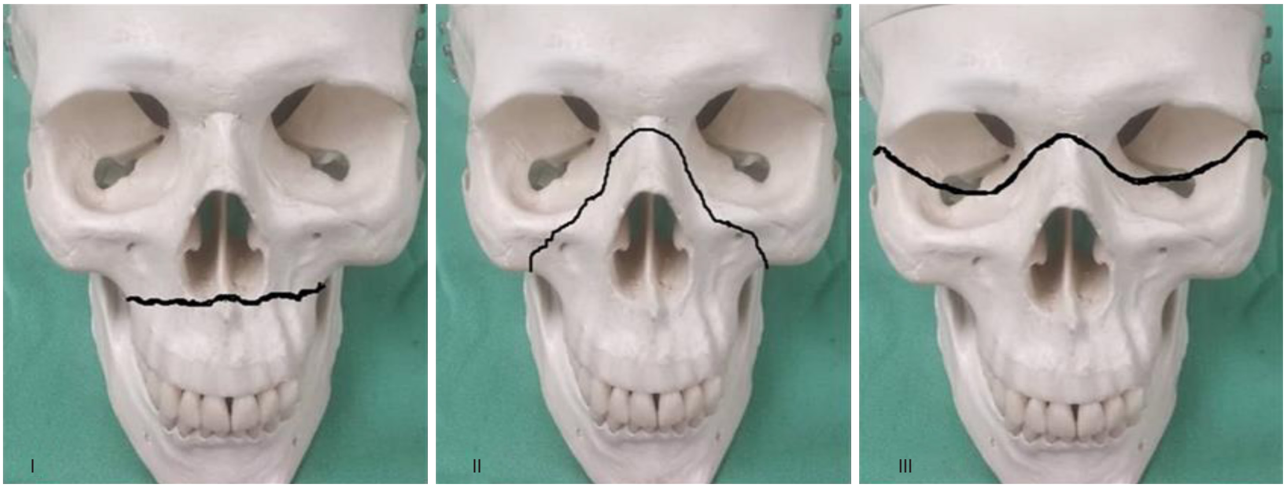

Figure 3 The diagram represents Le Fort fracture types: the lines depict the fracture pattern in Le Fort I, II and III fractures.

Table 2 Comparison of Marciani classification [1993] to Le Fort classification, with Wassmund modification, system

Le Fort classification, with Wassmund modification, system
Le Fort I: low maxillary fracture
Le Fort II: pyramidal fracture
Le Fort III: craniofacial dysjunction
Le Fort IV: cranial base fracture and Le Fort II or III
Marciani classification [1993]
Ia: low maxillary fracture/multiple segments
IIa: pyramidal and nasal fracture
IIb: pyramidal and NOE fracture
IIIa: craniofacial dysjunction and nasal fracture
III b: craniofacial dysjunction and NOE fracture
IVa: supraorbital rim fracture
IVb: supraorbital rim and fracture of anterior cranial fossa
IVc: orbital wall and fracture of anterior cranial fossa

NOE, naso-orbital-ethmoidal.

provides a concise way of discussing and summarizing the numerous fracture planes that occur (26). It is, however, insufficient for surgical planning in a given patient. Certain regions remain unexplored, and numerous scholars have sought to fill in the gaps with their own classifications, owing to the more complex nature of midface cracks created by Le fort. As a result, Wassmund developed a new modified classification system in 1927. According to this classification, fractures are graded from I to IV, where type 1 fractures are similar to Le Fort II, while type III fractures are similar to Le Fort III but do not involve the nasal skeleton (26). Row and Williams modified this categorization method in 1985, when they classified mid-facial fractures into two categories depending on the fracture and change in occlusion. Part A is made up of non-occluding fractures. This category includes fractures affecting the central region, such as the nasal septum/nasal bones, the maxillary frontal process, and fractures of type (a) and (b) that extend into the frontal bone, as well as fractures affecting the lateral region, such as the zygomatic bone, arch, and maxilla that do not include the dento-alveolar component (zygomatic complex). Occlusions affecting dento-alveolar, subzygomatic (Le Fort I or II fractures), and suprazygomatic (Le Fort III fractures) fractures are categorized as Part B fractures (27). However, fractures of the cranial base and various midface fracture configurations, involving extensively comminuted skeletal structure of the face segments, were not classifiable using the standard Le Fort categorization system. Thus, Marciani suggested a more exact system of characterizing fracture patterns in 1993 in order to characterize the fracture configuration, provide an accurate diagnosis, and select viable surgical procedures, as illustrated in *Table 2* (28).

Due to Marciani's extensive categorization, it was challenging for surgeons to adopt while doing operations. As a result, Donat *et al.* developed a new classification in 1998, using CT to identify maxillary and zygomatic fractures (29). Vertical buttress and horizontal beam fractures are used to classify these fractures. The technique makes use of three primary characteristics of laterality and support sites to explain the clinical pattern of the fractures. Later on, this classification failed to obtain the necessary popularity since it was difficult to learn and remember due to the convoluted categorization method and an excessive number of descriptors. Following that, Buitrago-Téllez *et al.* proposed a thorough categorization of craniomaxillofacial (CMF) fractures in 2002, categorizing the craniofacial region as type A, type B, or type C. Each type is further divided into three groups (e.g., A1, A2, A3) and three subsets (e.g., A1.1, A1.2, A1.3), ranging in intensity as A1.1 (least severe) to C3.3 (most severe). The craniofacial region is composed of three units: the lower midface (I), the upper midface (II), and the cranial base-facial unit (III). There are two types of fractures: lateral and central. Nondisplaced fractures are classified as type A, displaced fractures as type B, and complex/defect fractures as type C (30). Due to the complexity of the categorisation, practitioners had difficulty remembering. As a result, this classification did not garner the necessary popularity. Thus, Audigé created a software-based fracture classification system in 2014 (31). The software AO comprehensive injury automatic category (AOCOIAC) was used to classify fractures and document clinical data for each patient, including a sample of diagnostic imaging. It is a three-tiered hierarchical CMF fracture categorization method. In level 1 fracture pattern is assigned gross anatomic units like the mandible (code 91), the midface (code 92), the skull base (code 93), and the cranial vault (code 94) are the four major anatomical units; level 2 refers to fracture location within defined topographical regions; and level 3 refers to the fracture morphology within regions, which may include fragmentation, displacement, and bone anomalies along with certain anatomical systems. Despite the fact that this classification corrects all of Le Fort's faults, it is software- and code-dependent, making it difficult to comprehend and apply. Thus, Dreizin *et al.* introduced a new classification system for midfacial fractures in 2018, resulting in a distinct set of management principles for each subunit such as nose, internal orbits, NOE region, zygomaticomaxillary complex (ZMC), and upper jaw occlusion-bearing fragment (32). Nasoseptal fractures comprise almost 50% of all face fractures and are the most frequently fractured facial element. The frontal bone and the frontal process are connected to the two nasal bones by the frontal process. The frontonasal and nasomaxillary sutures of the maxilla generate the bony nasal pyramid. Because they are caused by elevated blunt trauma, NOE fractures are difficult to diagnose and treat. In orbital blow-out fractures, the volume of bony orbital increases due to wall out fracture and is initially matched by volume growth caused by bleeding and internal orbital edema, thereby hiding the severe forms of enophthalmos. ZMC fractures affect the zygomaticomaxillary buttress, the zygomaticosphenoidal suture; the frontozygomatic suture, and the zygomaticotemporal suture originating from the zygomatic arch. In maxillary and palatal fractures with occlusion at the lowest Le Fort level, the occlusion-bearing fragment is split from the upper midfacial subunits, becoming an independently controlled component composed primarily of the palate, alveolus, and maxillary dentition (33).

Treatment considerations

Fracture management has evolved significantly throughout the years. Due to the complexity of the anatomy, it may be difficult to minimize and treat face bone middle third fractures. While the two-point focus theory remains true in the majority of cases, there may still be a functional or aesthetic issue. Paludetti *et al.* evaluated 90 patients' "degree of satisfaction" via clinical visits and a telephone interview (33). Eighty-eight individuals had a completely good surgical outcome, whereas the other two patients had an unsatisfactory aesthetic outcome. If extrinsic ocular muscles were incarcerated, all patients were operated on within 24 to 48 hours of the accident, and in some cases, within 10 days, even if they were in intensive care. In view of recent advancements in minimally invasive procedures that result in improved cosmetic outcomes (34). Gandi *et al.* investigated the two-point fixation of ZMC fractures using wire and small plates (35). Eighty patients with type II to IV Spissel and Schroll ZMC fractures were treated with wire and plate osteosynthesis over an 18-year period, out of 1,780 ZMC fractures. When compared to wire osteosynthesis, mini plate osteosynthesis has been shown to be a simple, rational, and successful treatment for fracture fragment stability (36). This method has been used successfully to return affected structures to their pre-injury state. Numerous clinical studies are discussed demonstrating the variety of fractures and surgical approaches that can be used to get an acceptable outcome. It is crucial to identify and treat problems promptly. Further, by combining topology optimization and finite element (FE) analysis, a novel strategy for healing a ZMC fracture has been developed. This technique utilises a patient-specific repairing thin (PSRT) implant in accordance with the buttress theory. The model was designed with the intention of doing topology optimization in order to obtain the optimal structure and volume for a hollow skeleton (HS) model. A biomechanical analysis of a ZMC fracture repair using the PSRT implant and two conventional mini-plates was conducted on posterior teeth with homogeneous axial loads of 250 N. At the crucial locations, significant stress gradients (30.67–96.26 percent) were observed, with distributions varying between the intact facial skeleton and mini-plate models (36).

Safety measures

As RTAs are the major cause of maxillofacial trauma, seat belts and helmets are critical for injury prevention. With a rise in the number of vehicles on the road, it is more critical than ever to follow traffic laws, one of which is the wearing of helmets and seat belts.

Brazil is ranked fifth in the world for road fatalities. It comes 15 years after Sao Paulo, Latin America's largest city, passed a legislation regulating the use of seat belts. Brazilian government policies and activities in public health have benefited the populace (37). According to a study conducted in Tehran, Iran, the rate of head and neck injury complications in motorcycle accident patients changes according to the type of helmet used. They documented the rate of occurrence, kind of injury, and discrepancies in serious injury protection between standard and nonstandard helmet wearers in this study, as well as the implications for serious injury protection. No significant changes in damage patterns were detected across different types of helmets and modifications impacting their use (38).

In Kerala, India, a 6-month comparison study was done to determine the efficacy of helmets in preventing face injuries. The data established that motorcycle helmets protect against maxillofacial trauma by reducing morbidity. Following the law's passage, there was a considerable decrease in motorcycle-related injuries reported, as well as an increase in helmet use and a better outcome for helmeted riders (39). In the United States, a study was conducted to see whether there was a correlation amongst automobiles, accidents, and demographic parameters and injuries to the occupants of the front seat in contemporary circumstances (40). Between 2009 and 2012, the study (USDOT) used the United States of America's (US) National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) data for database description and weighting criteria. The analysis was confined to vehicles that were less than or equal to 10 years old model at the time of the collision. The head and thorax are the most frequently injured during such accidents with thorax injuries being more predominant at the mass level and injuries to the head being equally prevalent at both severities. Furthermore, the addition of front seat passenger contributes to trauma; and, despite the absence of guidelines for far-side impact, fatalities continue to happen at velocities reflective of side impact testing environments (40).

Limitations and strengths

This review describes the classifications of midface fractures, but cannot find the perfect classification. A future work to suggest a clinically oriented classification would be welcome.

Conclusions

Fractures in the middle of the face skeleton manifest in a variety of ways and are difficult to recognize due to an inefficient classification system, resulting in a lack of early surgical interventions. As a result, precise diagnosis and surgical treatment are critical for the successful management of such complex fractures. Furthermore, the old Le Fort classification system has limited the appropriate treatment. As a result, this study focuses on the modified classification system for dealing with mid-facial fracture consequences, as well as their diagnosis and treatment.

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Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://fomm.amegroups.com/article/view/10.21037/fomm-22-63/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://fomm.amegroups.com/article/view/10.21037/fomm-22-63/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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