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PRS GLOBAL OPEN

ORIGINAL ARTICLE
Craniofacial/Pediatric

Patterns of Craniomaxillofacial Trauma at an Urban Level I Trauma Center

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Background: There is a paucity in the literature concerning craniomaxillofacial trauma (CMF) in the USA. Better recognition of these fracture patterns and their management clarifies how to best evaluate and treat them.

Methods: A retrospective chart review was conducted of CMF trauma patients who required surgical intervention at a level I trauma center between 2015 and 2018. Descriptive statistics and univariate and bivariate analyses were conducted ($\alpha = 0.05$).

Results: A total of 1001 patients were included. Most patients were Black (n = 665; 66%) and/or male individuals (n = 813; 57%) with an average age of 37 years (range 15 -110). The most common etiologies were assault (n = 471; 44%), motor vehicle collision (n = 238; 22%), and fall (n = 117; 11%). The mechanism of injury was a determinant of fracture type ($P = 0.045$). The most common CMF injuries were mandibular fracture (n = 953; 95%), maxillary fracture (n = 815; 81%), and orbital fracture (n = 206; 21%). Male sex predicted panfacial fractures ($P = 0.045$). Black patients experienced more severe CMF trauma compared with other races ($P < 0.001$). ORIF was the most common treatment for mandibular (n = 481; 73%) and maxillary (n = 62; 66%) fractures.

Conclusions: Etiology and patterns of CMF trauma differ globally, with assault and motor vehicle collisions being the leading causative factors in our patient population. Patient demographics are relatively consistent worldwide, with most injuries occurring in 30- to 40-year-old men. This study offers insight into at-risk populations and guidance on their management. *(Plast Reconstr Surg Glob Open 2024; 12:e5596; doi: 10.1097/GOX.0000000000005596; Published online 23 February 2024.)*

INTRODUCTION

Trauma to the craniofacial skeleton is commonplace at trauma centers throughout the world, and although these injuries occur by a variety of mechanisms, there are definite demographic patterns.[1] Previous clinical investigations have paid particular attention to the pediatric population because trauma is the leading cause of death for children.[2] However, when considering adult craniomaxillofacial trauma, the literature is less robust. The most recent publications have been technique-based and focus on patient outcomes after particular surgical techniques or approaches are used.[3] In doing so, we have neglected the fundamentals of these injuries: the etiology of their presentations, the demographics of our patient population, and how these factors may have changed over time. Recent literature is sparse concerning epidemiological trends and treatment patterns. This study presents a comprehensive review and analysis of craniomaxillofacial trauma at a level I trauma center in an urban city in the United States. It offers insight into recognizing at-risk populations, injury patterns, and how to anticipate their management.

Craniomaxillofacial trauma is a broad term that includes disruption of the cranial or facial skeleton that involves the mandible, maxilla, bony orbit, frontal bone, zygoma, and temporal bone, or "complex fractures," which involve any multiple of the previously listed facets. These injuries can be stratified by impact force, which range from low-impact injuries (eg, ground-level falls) to high-impact injuries (eg, motor vehicle accidents, ballistic injuries). Injuries occur after assault, motor vehicle collisions

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Received for publication September 13, 2023; accepted December 15, 2023.

Presented at the American Society of Plastic Surgeons—The Meeting, 2021.

DOI: 10.1097/GOX.0000000000005596

Disclosure statements are at the end of this article, following the correspondence information.

(MVCs), work-related incidents, ballistic injuries, suicide attempt, falls, and many others. Understanding the common causes of these injuries allows for better screening; diagnosis; and eventually, for preemptive action on the national scale. It further invites recognition of equipment needs at medical centers managing the specific populations at risk for these injuries, particularly depending on mechanisms of injury (MOIs).

There is controversy about how to treat craniomaxillofacial injuries, as they are multifarious in nature. This dissent is largely due to the intrinsic variety, complexity, and limited understanding of these injuries[4]; thus, treatment decisions are often multifactorial and rely heavily on physician expertise and experience. Although they require proficiency, many residency programs provide limited training of craniofacial trauma.[5] By investigating common treatments for each type of injury, a more evidence-based treatment algorithm can be presented. This can further enhance training programs and assist in guiding physicians managing these injuries with less exposure to such facial trauma patients.

Takeaways

Question: What are the most common presentations of craniomaxillofacial trauma? How are they managed?

Findings: A retrospective chart review over 3 years at a high-volume urban level I trauma center identified over 1000 patients with craniomaxillofacial trauma. Male patients aged around 30 years are the most common victims of craniomaxillofacial trauma. Assault and motor vehicle collisions are the most common causes of injury. Mandibular fractures were the most common injury, followed by maxillary fractures. Both are most commonly treated with open reduction internal fixation. The mechanism of injury is predictive of the craniomaxillofacial injury. Black patients disproportionately experienced more severe craniomaxillofacial trauma than patients of other races.

Meaning: Healthcare providers should have a higher suspicion for certain craniomaxillofacial trauma injuries based on the mechanism of injury and patient demographics.

MATERIALS AND METHODS

This was a retrospective chart review of patients who sustained craniomaxillofacial (CMF) trauma and were surgically repaired at Grady Memorial Hospital between January 2015 and December 2018. This study was approved by Emory University School of Medicine institutional review board and Grady's Oversight Research Committee. Emory Medical Care Foundation database was used to identify patients using specific CPT billing codes associated with repair of CMF trauma (ie, 21310, 21337, 21360, 21365, 21385, 21386, 21387, 21390, 21400, 21401, 21406, 21407, 21408, 21453, 21461, 21462, 21470). The study inclusion criteria were (1) patients diagnosed with CMF trauma [mandibular, maxillary, orbital, nasal bone, zygomaticomaxillary complex (ZMC), naso-orbito-ethmoid, frontal sinus, and temporal bone fractures or combination thereof]; (2) 18 years of age and older; and (3) treated at Grady Memorial Hospital by the CMF trauma team, which consists of a combination of oral and maxillofacial surgery, otolaryngology (ENT), and/or plastic and reconstructive surgery. Exclusion criteria were patients younger than 18 years of age and patients who did not undergo surgical intervention. The collected variables were (1) demographics (age, gender, and race); (2) MOI [assault, fall, MVC, motorcycle or bicycle accident, ballistic injury, work-related accident, suicide attempt, neurological incident (ie, syncope, seizure, cerebrovascular accident), home/chore-related injury, EtOH(alcohol)-related injury, abscess, horse kick, explosion, pedestrian versus train, failed prior treatment, sports-related injury, airplane crash, or unknown]; (3) laterality; (4) anatomic location of injury (mandible, maxilla, frontal sinus, orbital, ZMC, temporal bone, naso-orbito-ethmoid, nasal bone, nasal septum, pan-facial); (5) involvement of other craniofacial injuries (teeth involvement, foreign body removal, associated injuries); and (6) treatment variables (method of reduction, access incision, type of reconstruction material, hardware removal). Patients were de-identified before data analysis.

Statistical analysis with chi square and Kruskal Wallis test was performed along with descriptive statistics. Analyses were performed via Excel (Microsoft Excel for Mac, version 16.44), with a P value less than 0.05 considered statistically significant.

RESULTS

A total of 1001 patients met the inclusion criteria. Patients were predominantly men (n = 813; 81%), with a male-to-female ratio of 4.3. The mean age was 37 years (range 15–110 years). The difference of age between male and female patients was not statistically significant ($P = 0.28$). The gender of the patient was deemed to be a determinant of the type of fracture involved ($P = 0.045$). This was notable with 12 male patients with pan-facial fractures compared with 0 female patients. The racial distribution was African American (n = 665, 66%), White (n = 233, 23%), Hispanic (n = 56, 6%), Asian (n = 9, 1%), other (n = 5, 0.5%), and unknown (n = 33, 3%). The race of the patient was found to be a determinant of the type of fracture ($P < 0.00001$). This was made evident by African Americans having a disproportionate number of mandibular, orbital, and ZMC fractures compared with other races and types of fractures. No other races were found to be determinants of specific injuries.

MOI was most commonly assault (n = 471; 44%), MVC (n = 238; 22%), fall (n = 117; 11%), ballistic injury (n = 79; 7%), failed prior treatment (n = 32; 3%), sports-related injury (n = 24; 2%), unknown (n = 22; 2%), bicycle accident (n = 18; 2%), work-related accident (n = 15; 1%), suicide attempt (n = 15; 1%), neurological incident (n = 11; 1%), motorcycle accident (n = 9; 0.8%), home/chore-related injury (n = 8; 0.7%), other

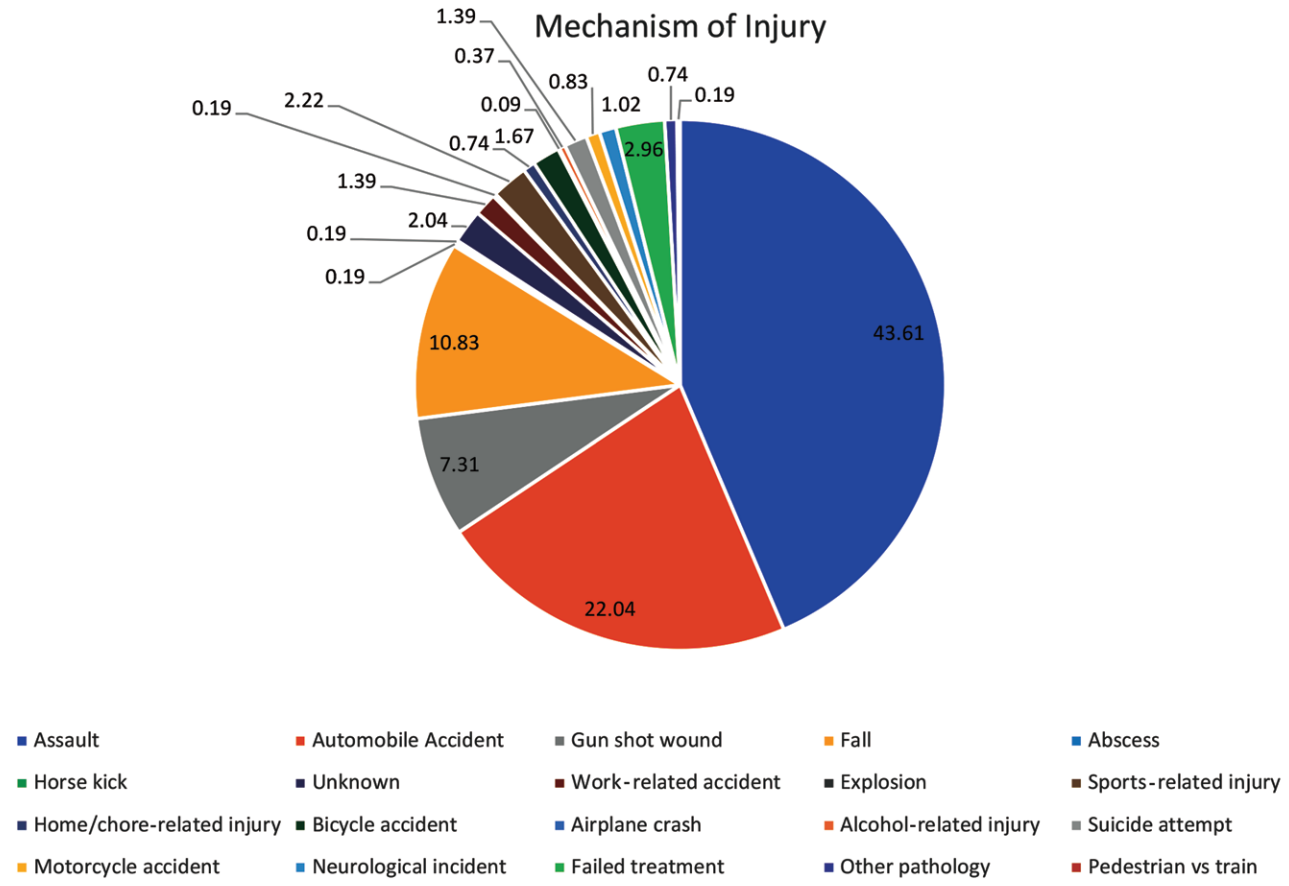

Fig. 1. MOI of craniomaxillofacial trauma. This figure demonstrates the prevalence of various MOIs for craniomaxillofacial trauma.

pathology (n = 8; 0.7%), EtOH-related injury (n = 4; 0.4%), abscess (n = 2; 0.2%), horse kick (n = 2; 0.2%), explosion (n = 2; 0.2%), pedestrian versus train (n = 2; 0.2%), and airplane crash (n = 1; 0.1%; Fig. 1). Notably, some MOIs were complex (involving several mechanisms such as ballistic injury and suicide attempt, fall and EtOH-related injury, or fall and neurological incident), resulting in a combined total of 1080 MOIs reported for the 1001 patients in the study. The MOI was found to be a determinant of the type of fracture ($P < 0.00001$). This is highlighted by falls disproportionately being related to mandibular fractures, compared with other MOIs and other types of fractures (Fig. 2).

Regarding anatomic location of the CMF fractures, the text below describes the involvement and prevalence of each type of injury:

Mandibular fractures (n = 953; 95%): symphysis (n = 55; 5%), parasymphyseal (n = 254; 25%), body (n = 262; 26%), angle (n = 290; 29%), intracapsular condyle (n = 53; 5%), subcondylar (n = 138; 14%), coronoid (n = 14; 1%), ramus (n = 101; 10%), comminuted mandible (n = 132; 10%), unknown [combined unknown, other, and not applicable (NA)] (n = 72; 7%).

Right side involvement (n = 146; 15%), left side (n = 189; 19%), bilateral (n = 362; 36%), unclear (n = 49; 5%). Teeth involved in fracture line [yes (n = 308; 31%), no (n = 566; 57%), unclear (combined unknown and NA; n = 22; 12%)].

Maxillary fractures (n = 815; 81%): Le Fort I (n = 75; 7%), Le Fort II (n = 58; 6%), Le-Fort III (n = 31; 3%), unknown (combined other, unknown, and NA; n = 207; 21%). Right side involvement (n = 14; 1%), left side (n = 22; 2%), bilateral (n = 86; 9%), unknown (combined unknown and NA; n = 191; 20%).

Frontal sinus fractures (n = 26; 3%): Anterior table (n = 13; 1%), posterior table (n = 0; 0%), both (n = 13; 1%), unclear (combined unknown and NA; n = 975; 97%).

Orbital fractures (n = 206; 21%): Orbital floor (n = 138; 14%), other orbital wall (n = 23; 2%), orbital floor and other orbital wall (n = 45; 4%). Right side involvement (n = 77; 8%), left side (n = 92; 9%), bilateral (n = 29; 3%), unknown (n = 8; 0.8%).

Zygomatic fractures (n = 181; 18%): ZMC (n = 128; 13%), zygoma (n = 51; 5%), other (n = 2; 0.2%). Right side fractures (n = 72; 7%), left side (n = 89; 9%), bilateral (n = 17; 2%), unknown (n = 3; 0.3%).

Temporal bone fractures (n = 6; 0.6%): The temporal bone was fractured bilaterally (n = 1, 0.1%).

Naso-orbito-ethmoidal fractures (n = 40; 4%): type 1 (n = 6; 0.6%), type 2 (n = 10, 1%), type 3 (n = 6; 0.6%), unspecified (n = 22; 2%). Right side (n = 7; 0.7%), left side (n = 7; 0.7%), bilateral (n = 22; 2%), unspecified (n = 4; 0.4%).

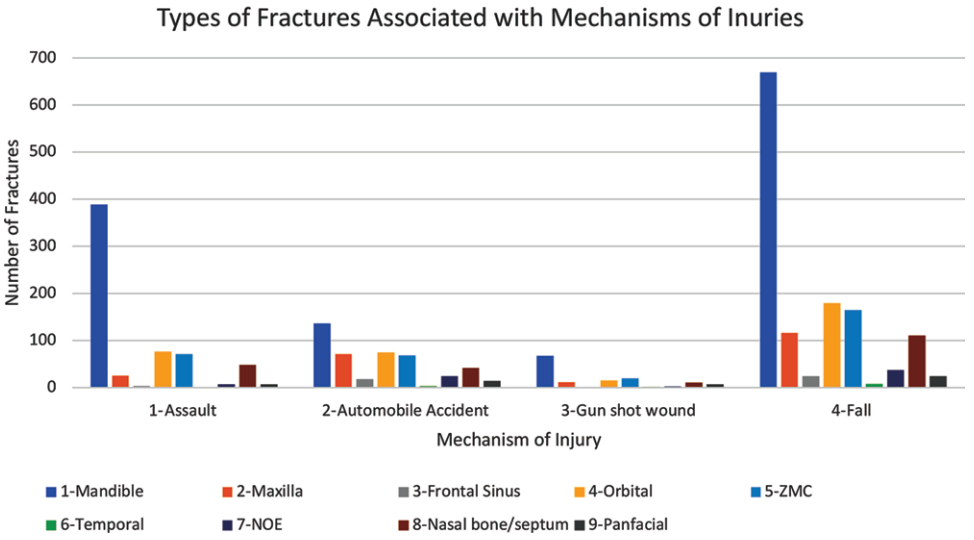

Fig. 2. Craniomaxillofacial fractures associated with the four most common MOIs. This figure demonstrates the distribution of the different craniomaxillofacial fractures for the four most common MOIs in this patient population (ie, assault, motor vehicle accident, gunshot wound, and fall).

Nasal bone fractures (n = 115; 11%): right side involvement (n = 9; 0.9%), left side (n = 9; 0.9%), bilateral (n = 93; 9%), septum (n = 37; 4%).

Pan-facial fractures (n = 12; 1%): Regarding surgical treatment, open reduction internal fixation (ORIF) was the most commonly used method (Fig. 3). The MOI is not a determinant for the type of treatment used (P = 0.35). When the operative treatment required removal of hardware, teeth, or foreign body, it was most common to remove hardware (61%), followed by tooth (39%), and lastly, foreign body (0.5%). The MOI did not determine whether hardware versus tooth versus foreign body had to be removed (P = 0.835), although most foreign body removals are associated with ballistic injuries and/or suicide attempts.

DISCUSSION

Epidemiological studies of craniomaxillofacial trauma have been performed across the world, and despite varying demographics, some common themes remain. Virtually all studies show a strong male predominance from a 3:1 male-to-female ratio up to 6.6:1.[6,7] Patients are most commonly in their twenties or thirties.[8,9] Van Hout et al found that craniomaxillofacial traumas most commonly occur during the spring and during weekends, and 15% involve alcohol. Mandibular fractures are most common (42%), followed by ZMC fractures.[10]

Previous studies have indicated that etiology of the injuries may differ depending on the region. According to the European Maxillofacial Trauma (EURMAT) project (a multicenter prospective study), craniomaxillofacial injuries were due to assault (39%), falls (31%), MVC (11%), sports (11%), work (3%), and others (5%).[10] The European Maxillofacial Trauma project's findings were not dissimilar to that of New Zealand (where assault was most common), yet vastly different to studies performed in India, where MVCs are the predominant mechanism.[11] In India, Gandhi's 4-year retrospective review reported that craniomaxillofacial trauma was most commonly due to MVCs, falls, and assaults.[7] Shankar et al also performed a retrospective study in India and found MVCs to be 73% of fractures.[9] This regional difference is hypothesized to be due to the differences in seatbelt laws. It further highlights the change in at-risk population based on geographical location, and therefore, the need to adapt screenings based on these factors and appropriate index of suspicion in treating these injuries.

Additionally, these patterns are not static. Kraft et al performed a 15-year study that included 15,000 patients and found that MVCs were decreasing across developed nations as seatbelt laws led to behavioral change of the population.[8] This trend, in addition to modern airbags and improved vehicle technologies, has decreased the incidence of craniomaxillofacial injuries caused by MVCs. Because of these findings, they found that assault was increasingly becoming relevant, which was the most common MOI in our patient population.

The similarities and differences of craniomaxillofacial injuries are likely multifactorial. As described above, some laws (eg, seatbelt laws) and technologies (eg, airbags) likely influence traumas. Other causes are likely cultural and socioeconomic. For example, domestic violence is more prevalent in some areas of the world, alcohol is illegal in some locations, and prominence of patients driving as opposed to riding bicycles or using public transportation differs from place to place, sometimes even within the same country. These potential influencers of craniomaxillofacial trauma are outside the scope of this study, but should be taken into consideration when comparing geographical trauma presentations.

Our population was found to be congruent with that reported in the literature. Most commonly, our patients were men in their 20s and 30s (male-to-female ratio of

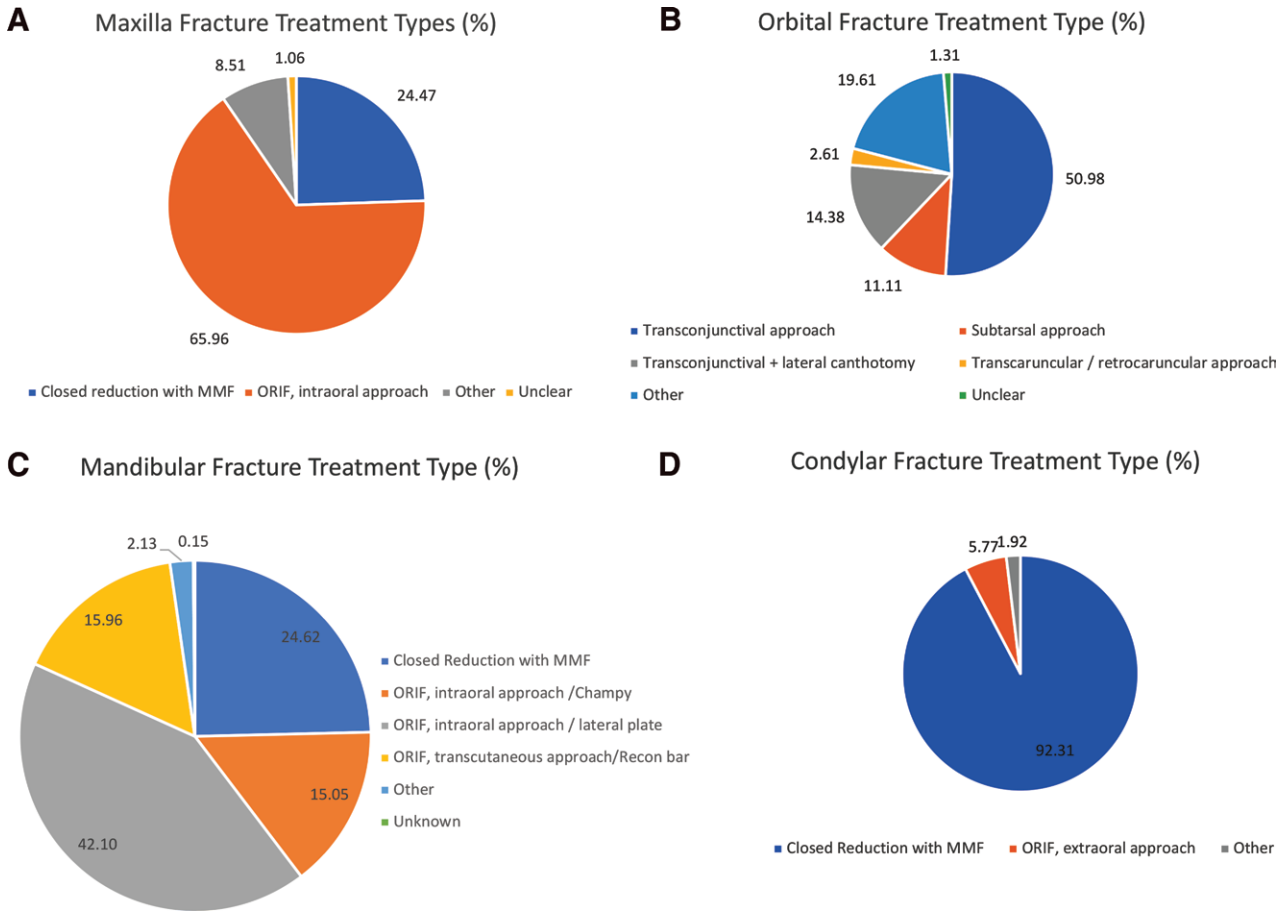

Fig. 3. Treatments for craniomaxillofacial trauma injuries by fracture type. A, Distribution of surgical management for maxilla fractures. It highlights the high prevalence of ORIF. B, Distribution of surgical management for orbital fractures. Transconjunctival approach was the most common treatment. C, Distribution of surgical management for mandibular fractures. ORIF via intraoral approach with a plate was most common. D, Distribution of surgical management for condylar fractures. Closed reduction internal fixation was most prevalent.

4.3:1). Our patient demographics reflected those of the city of Atlanta, with a majority of Black patients: 66% Black/African American, 23% White, 6% Hispanic, and 1% Asian (compared with the city of Atlanta which is 48% Black/African American, 41% White, 5% Hispanic, and 5% Asian). Most injuries were due to assault (44%), MVC (22%), fall (10.8%), and gunshot wound (7%). Unfortunately, we anticipate our trends to change over time to reflect increases in gun violence in both our city and country. Therefore, it is important to recognize that gunshot wounds may eventually become a more common MOI for these patients.

Regardless of the MOI, the most common surgical treatment option used was ORIF. Comparing the MOI and operative treatment, there was no pattern with statistical significance ($P = 0.35$). Decisions guiding operative intervention are largely directed by both physical and radiographic findings such as level of displacement, malocclusion, entrapment, and fracture orientation. At our institution, craniomaxillofacial trauma services are provided by surgeons trained in oral maxillofacial surgery, otolaryngology, and plastic surgery on a rotating daily schedule. Each physician's approach to management may differ based on their prior training clinical experience. Future studies could further delineate whether any specialty manages specific injuries differently and whether these differences affect patient outcomes. For now, this study offers insight into which management options to consider for each injury for clinicians with little experience treating such patients.

Mandibular fractures predominate in our population as it does in the literature. Maxillary fractures were the second most common injuries, which include dentoalveolar fractures and isolated maxillary sinus fractures that are largely treated nonoperatively in the acute setting. Thus, the second most common operative fracture pattern in our cohort involved the orbit (21%), followed by the zygoma (18%; includes ZMC and isolated zygomatic arch fractures). Although not common, pan-facial fractures were exclusively seen in men (12 patients), and often resulted from self-inflicted gunshot wounds. This stresses the at-risk population and their need for proper psychiatry screening in suicidal patients, particularly men, to best prevent such devastating injuries.

Mandibular fractures mostly involved the angle (29%), body (26%), and parasymphyseal region (25%),

and were most treated with ORIF (73%) versus closed reduction with maxillo-mandibular fixation (25%). This was not true, however, if the mandibular condyle was the fracture in question, as these were almost exclusively treated with maxillo-mandibular fixation alone (92%). The surgical approach to mandibular ORIF was intraoral (78%) versus extraoral, and AO techniques predominated (79%) over Champy techniques. Operative maxillary fractures were most often treated with ORIF (66%). Concerning orbital fractures, transconjunctival approaches were used in 65% of cases. These trends in approaches can offer guidance to surgeons with limited experience in treating craniomaxillofacial fractures and can further direct training for specialties managing these patients.

This study has its limitations, primarily due to it being a retrospective chart review. The retrograde nature of the data collection meant some targeting information was not gathered due to it not being mentioned in the patients' chart. For example, whether the patient was wearing glasses at the time of injury or where they were seated in the car of an MVC was rarely mentioned in the patient's records. These details could offer important insight into the MOIs, managements, and outcomes, and were of interest, but lacking in records. This prevented us from taking into consideration some potential confounding variables. Similarly, the amount of alcohol involved in the trauma was difficult to ascertain in some cases. Examples of this include patients reporting being assaulted by a stranger, without mention of whether either person was inebriated. It is therefore possible that the alcohol involved in the reported mechanisms is inaccurate. Another constraint is the data pull being dependent on the procedure coding. Because of this, patients who underwent conservative management were excluded. Thus, the analysis focuses on surgical treatment of craniomaxillofacial trauma. Similarly, pediatric patients, including skeletally mature teenage patients were excluded, which prevents us from evaluating differences between such patient populations. Although this retrospective study has its shortcomings, it still provides insight into epidemiology of craniomaxillofacial trauma.

The institution at which patients were evaluated and treated is one of the highest volume treatment centers for blunt and penetrating trauma in the United States. Additionally, it is the only level I trauma center in a large urban city certified by the American College of Surgeons, providing it with a unique opportunity to study craniomaxillofacial trauma and the concomitant management of multisystem injuries that frequently accompany such injuries. We hope this study is used as the foundation for further studies at our institution and abroad, and as we further understand craniomaxillofacial fracture patterns, their etiologies, and the treatment patterns that address them such that surgeons managing these injuries can more readily improve patient outcomes.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

ACKNOWLEDGMENT

Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

REFERENCES

1. Streubel S-O, Mirsky DM. Craniomaxillofacial trauma. *Facial Plast Surg Clin North Am.* 2016;24:605–617.
2. Gassner R, Tuli T, Hächl O, et al. Craniomaxillofacial trauma in children: a review of 3,385 cases with 6,060 injuries in 10 years. *J Oral Maxillofac Surg.* 2004;62:399–407.
3. Khatib B, Gelesko S, Amundson M, et al. Updates in management of craniomaxillofacial gunshot wounds and reconstruction of the mandible. *Facial Plast Surg Clin North Am.* 2017;25:563–576.
4. Meara DJ, Jones LC. Controversies in maxillofacial trauma. *Oral Maxillofac Surg Clin North Am.* 2017;29:391–399.
5. Oh MS, Sethna AB, Henriquez OA. Craniomaxillofacial trauma experience in otolaryngology residency: a national survey of program directors. *Craniomaxillofac Trauma Reconstr.* 2019;12:134–140.
6. van Hout WM, Van Cann EM, Abbink JH, et al. An epidemiological study of maxillofacial fractures requiring surgical treatment at a tertiary trauma centre between 2005 and 2010. *Br J Oral Maxillofac Surg.* 2013;51:416–420.
7. Gandhi S, Ranganathan LK, Solanki M, et al. Pattern of maxillofacial fractures at a tertiary hospital in northern India: a 4-year retrospective study of 718 patients. *Dent Traumatol.* 2011;27:257–262.
8. Kraft A, Abermann E, Stigler R, et al. Craniomaxillofacial trauma: synopsis of 14,654 cases with 35,129 injuries in 15 years. *Craniomaxillofac Trauma Reconstr.* 2012;5:41–50.
9. Shankar AN, Shankar VN, Hegde N, et al. The pattern of the maxillofacial fractures—a multicentre retrospective study. *J Craniomaxillofac Surg.* 2012;40:675–679.
10. Boffano P, Roccia F, Zavattero E, et al. European Maxillofacial Trauma (EURMAT) project: a multicentre and prospective study. *J craniomaxillofac Surg.* 2015;43:62–70.
11. Lee K. Global trends in maxillofacial fractures. *Craniomaxillofac Trauma Reconstr.* 2012;5:213–222.