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Characteristics of Electric Scooter-Related Maxillofacial Trauma, 2017–2024: A Retrospective Study

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Abstract

Objectives: The aims of this study were to investigate the maxillofacial trauma resulting from electric scooter accidents, and to identify risk factors associated with injury location. **Methods:** An 8-year retrospective cohort study was carried out, including all patients presenting with electric scooter-related maxillofacial fractures at a tertiary care center from 2017 through 2024. Data recorded for each patient included gender, age, date and cause of injury, contributing factors, type of facial fractures, other injuries, helmet use, and the length of hospital stay. **Results:** Maxillofacial fractures were diagnosed in 138 patients (18,5% of e-scooter accident presentations). The study included 93 male and 45 female patients (ratio 2:1), and the mean age was 25.8 ± 7.75 years (range 14-45 years). Patients aged 20-29 years formed the largest group (51%). Most patients (89%) sustained a single facial fracture. The most affected facial third was the lower third with 80 cases (58%), followed by the middle third (36%). The remaining patients were represented by a combination of the various thirds, the most represented of which was I-II (12%). The most recurrent patterns were multifocal mandibular fractures (55%), followed by fractures of the orbito-malar-zygomatic complex (33%). Dental injuries were also frequent and were recorded in 40 patients (29% of all cases). Concomitant injuries outside the facial region were documented in 32 patients (23%). Among these, orthopaedic limb injuries were most common (44% of patients with concomitant injuries). Contributing factors were identifiable in 102 patients (74%). Self-reported helmet use was low: 63% of patients reported never wearing a helmet and 27% reported inconsistent or occasional use. **Conclusions:** Accidents involving personal mobility vehicles have become one of the main causes of emergency room admissions in recent years. Although electric scooter-related maxillofacial fractures are a new phenomenon, awareness of their frequency, contributing factors, and anatomical distribution is important for emergency and trauma teams who assess these patients first. Early recognition and timely management are crucial because missed diagnoses or delayed treatment can lead to permanent facial deformity and functional disability. These findings can inform targeted public-health strategies and injury-prevention programs. In the future, helmet designs should be modified to improve maxillofacial protection in scooter-related injuries.

Keywords: electric scooter-related accidents; retrospective cohort study; maxillofacial trauma; injury prevention; helmet use; multi-directional impact protection system; traffic safety interventions

1. Introduction

Personal mobility vehicles (PMVs) are single-occupant, electrically powered, lightweight vehicles designed for personal transport, typically with speeds below 25 km/h. The most widely used

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PMV is the electric scooter (e-scooter). The rapid rise in e-scooter popularity has significantly impacted urban mobility. Low cost, convenience, and wide availability—particularly via app-based rental services—combined with the perception of environmentally friendly transport, are among the main factors driving interest in and use of e-scooters. They play an important role in large cities, mainly for short-distance travel and for avoiding peak traffic congestion [1–3].

As the number of e-scooter users has increased, the incidence of related accidents has also risen. Since 2012, the number of accidents has continued to rise [4]. In the early years, the increase was gradual, but since 2021 the number of cases has doubled year on year [5,6]. Injured individuals are most commonly riders, who fall after striking poor infrastructure or colliding with another vehicle. Characterising injury patterns and documenting crash circumstances are therefore important. Maxillofacial region is particularly vulnerable to injury in e-scooter accidents [4–7].

The aims of this study were to characterize the most common maxillofacial injuries resulting from e-scooter accidents and to identify risk factors associated with injury location and severity. We also analyzed the patients' sex, age, and time of injury to describe common circumstances. In addition, we evaluated the time from the accident to first medical assessment, and the length of hospital stay.

2. Materials and Methods

2.1. Standard Protocol Approvals

This protocol received formal approval from the Institutional Research and Clinical Ethics Committee (Internal Code: IRB 2014PI/083) and adhered to the ethical principles for medical research involving human subject as outlined in the Declaration of Helsinki.

2.2. Study Design and Subjects

This single-center retrospective cohort analyzed the medical records of patients with acute maxillofacial fractures sustained in e-scooter-related accidents who were treated at the Department of Oral and Maxillofacial Surgery between January 2017 and December 2024. Inclusion criteria were (1) a history of maxillofacial trauma after an e-scooter accident and (2) imaging evidence of a facial bone fracture. Patients of any gender aged between 14 and 65 years at the time of injury were considered eligible. Collected variables included age, sex, date of injury, crash mechanism (collision vs fall, including specific circumstances), presumed contributing factors, type and location of facial fractures, injuries other body regions, length of hospital stay, and helmet use. The study cohort comprised patients requiring major surgical intervention for fracture stabilization, performed under general anesthesia. Exclusion criteria were incomplete records and minor superficial injuries (abrasions or contusions) without any facial fracture. Potential contributing factors were recorded when available (as reported by emergency services) or inferred from the crash circumstances: poorly maintained traffic infrastructure, excessive speed, alcohol use while riding, riding with headphones/earbuds, non-use of a helmet, and e-scooter malfunction or absence of safety features. Data confidentiality was strictly maintained throughout the study. All participant information was anonymized by assigning unique alphanumeric codes, and datasets were stored on encrypted, password-protected servers accessible only to the primary investigators, in compliance with standard data protection regulations.

2.3. Statistical Analysis

Statistical procedures were executed to evaluate the dataset. Data analysis was performed using IBM SPSS Statistics (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess the distribution of continuous variables; as non-normality was indicated, the Mann-Whitney U test was used for intergroup comparisons. Categorical data were assessed via Pearson's chi-squared test. For all analyses, a p-value ≤ 0.05 was established as the threshold for statistical significance.

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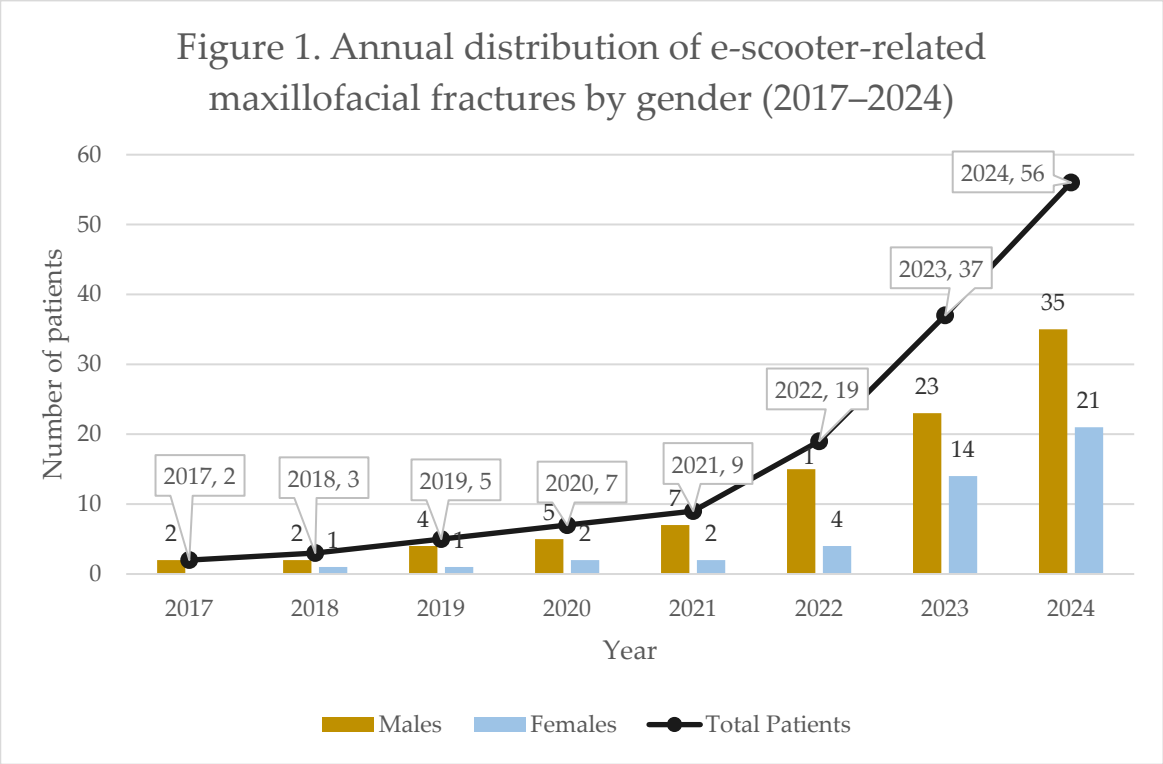
3. Results

During the 8-year study period, out of 742 patients were evaluated for e-scooter-related accidents. E-scooter-related facial fractures were diagnosed in 138 patients (18,5% of all e-scooter accident presentations). The study cohort included 93 male patients (mean age 26.5 ± 7) and 45 female patients (mean age 24.35 ± 5.5) ($p = 0.052$), with a male:female ratio 2:1, and the overall mean age was 25.8 ± 7.75 years (range 14-45 years). Since 2017, the number of e-scooter-related accidents each year has been steadily increasing. In the early years, this increase was gradual, but since 2021, the number of cases has doubled year on year. The number of patients admitted each year with e-scooter-related facial fractures is summarized in **Figure 1**.



By age group, young adults were most frequently affected. Patients aged 20-29 years formed the largest group (71 patients, 51%), followed by those aged 30-39 years (31 patients, 22.5%). The age distribution by decade and sex is shown in **Figure 2**.

There was no significant difference in incidence across different months of the year or between different days of the week. Contributing factors were identifiable in 102 patients (74%), and some patients had multiple contributing factors. The main contributing factors were: no helmet use (87 patients, 63%); involvement of other motor vehicle (36 patients, 26%); riding with headphones/earbuds (30 patients, 22%); riding during early evening (dusk) (28 patients, 20%); unsafe road conditions (e.g., rain, roadworks) (19 patients, 14%); alcohol and/or illicit drug use (18 patients, 13%); mechanical failure of the e-scooter (10 patients, 7%); and competitive or high-speed riding (5 patients, 3%). Self-reported helmet use was low: 63% of patients reported never wearing a helmet, 27% reported inconsistent or occasional use, and 10% reported always wearing a helmet while riding. Contributing factors are shown in **Figure 3**.

Most patients (89%) sustained a single facial fracture, while 11% sustained multiple facial fractures. The most affected facial third was the lower third with 80 cases (58%), followed by the middle third (55 patients, 40%). The remaining patients were represented by a combination of the various thirds, the most represented of which was I-II (17 patients, 12%). The most recurrent patterns were multifocal (bifocal, trifocal) mandibular fractures (76 patients, 55%), followed by fractures of the orbito-malar-zygomatic complex (45 patients, 33%). The distribution of main fracture type was as

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follows: mandible (80 patients, 58%), orbito-zygomatic-maxillary complex (45 patients, 33%), nasal (10 patients, 7%), and frontal (2%). The distribution of fracture types is shown in **Figure 4**. Mandibular condylar area was the most frequently fractured site (62 cases, 77.5% of patients with mandibular fractures).

Figure 2. Gender and age-group distribution of patients with e-scooter-related maxillofacial fractures

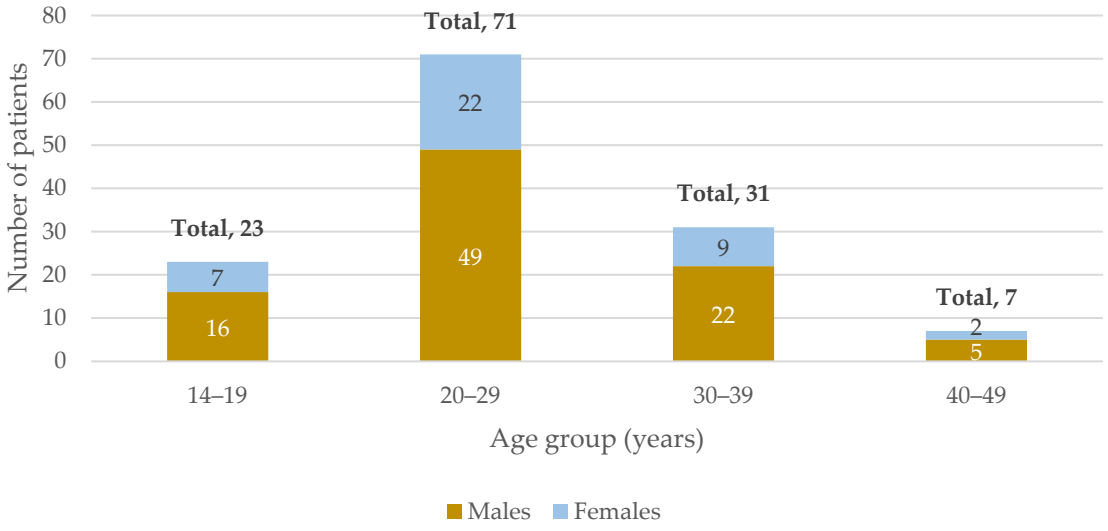
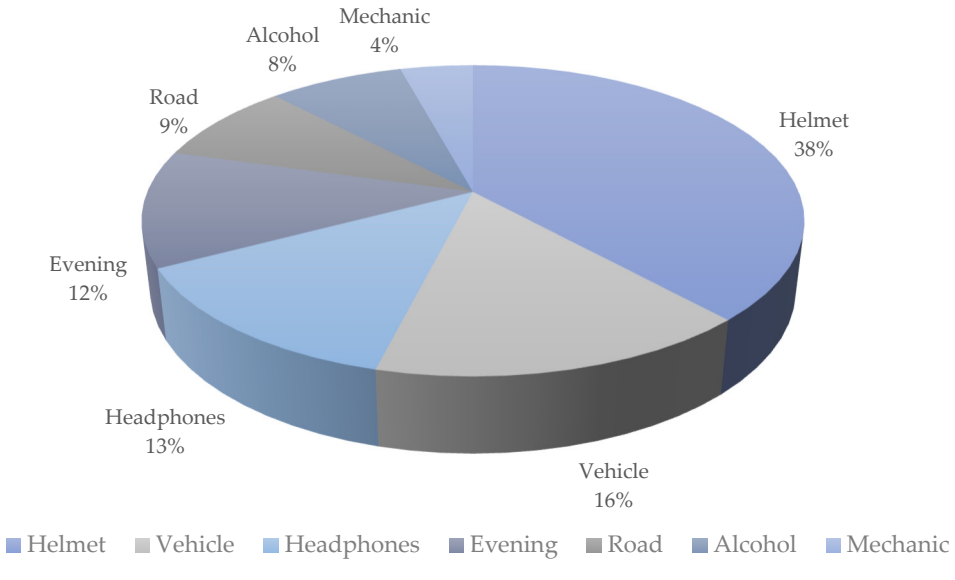


Figure 3. Contributing factors



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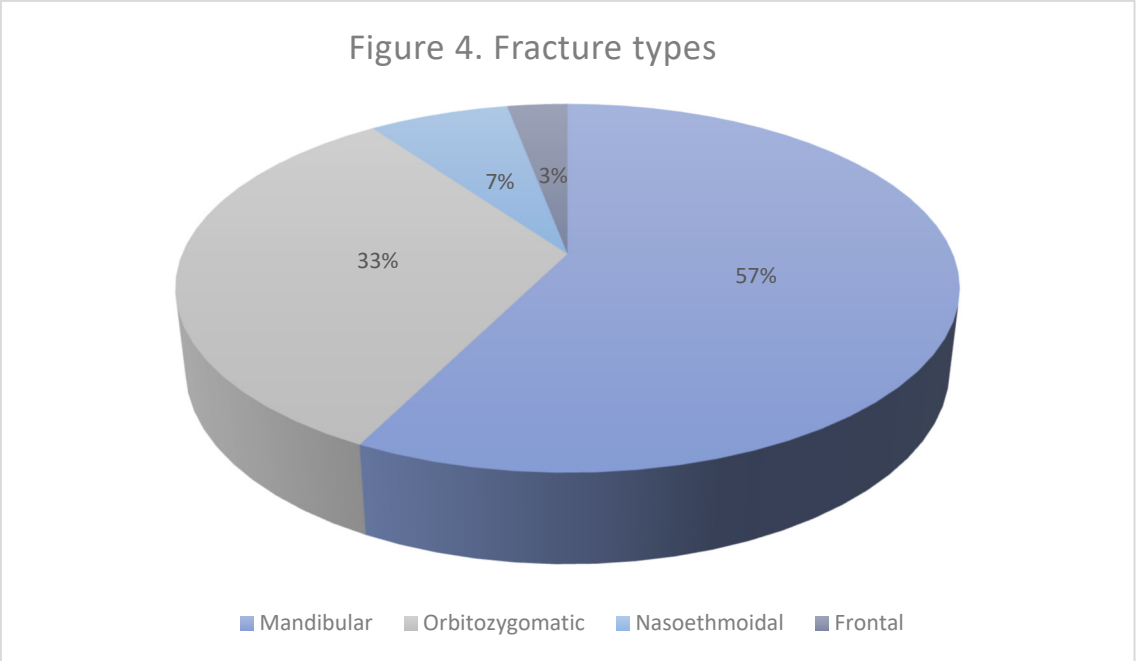

Most patients did not require prolonged hospitalization. Among patients with isolated facial fractures, the main hospital stay was 4 ± 1.4 days, including preoperative stay. Concomitant injuries outside the facial region were documented in 32 patients (23%). Among these, orthopaedic limb injuries were most common (21 cases, 65% of patients with concomitant injuries). Dental injuries were also frequent and were recorded in 19 patients (59% of all cases). The most common dental injury was tooth fracture (59% of dental injuries), followed by avulsion (27%) and tooth luxation (14%). In 63% of cases with dental injuries, upper anterior teeth were involved. Traumatic brain injuries (e.g., intracranial injury or concussion) were noted in 11 patients (34%) and were associated with a longer hospital stay (mean 28±5 days). None of the patients with a concomitant cranial injury were wearing a helmet at the time of the e-scooter crash.

4. Discussion

Private use of e-scooters began around 2012, but uptake accelerated with the emergence of digital platforms and app-based shared mobility. The system was subsequently introduced in large Spanish cities, including Seville in August 2019, with the entry of multiple platforms [3–5]. Overall, the incidence of motor-vehicle-related trauma has declined in many settings because of improved safety measures such as seatbelts and airbags [8]. In contrast, injuries associated with emerging micromobility modes, particularly e-scooters, have increased as their use has expanded. This trend has also been observed in Seville since the introduction of shared e-scooter services in 2019. Seville is a flat city in southern Spain with a mild climate for much of the year, which favors micromobility use. However, the growing incidence of e-scooter-related injuries cannot be explained solely by rider behavior; it also reflects broader shortcomings in infrastructure planning and implementation [6–8].

One important factor is the design and layout of scooter-lane infrastructure, which often shares space with bicycle lanes and creates conflict points with both motorized traffic and pedestrians [3,4]. In Seville, some of these lanes intersect roads with limited driver visibility, increasing the risk of collisions between e-scooter riders and motor vehicles. This is clinically relevant because, in our cohort, the most severe facial fractures were most associated with crashes involving other motor vehicles. These findings suggest that infrastructure design may influence not only crash frequency but also injury severity.

A second contributing factor is that the early rollout of shared e-scooter services appears to have outpaced both public education and regulatory preparedness [3]. Shared e-scooter companies began operating in Seville in August 2019 without comprehensive municipal regulation [4]. The City

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Council later launched an official pilot program in July 2021, selecting two operators to deploy 2,000 vehicles with designated parking points. Nevertheless, the service was discontinued in July 2025 due to persistent accident rates and regulatory noncompliance. Although the per-minute street rental model has been withdrawn, private rental and guided-tour services remain available, and private e-scooters continue to be authorized in Spain under increasingly restrictive local conditions. This sequence highlights the need for infrastructure planning, regulation, and rider education to precede, rather than follow, large-scale deployment of micromobility services [4].

E-scooter-related trauma has become an increasingly important cause of maxillofacial injury. Regional differences in injury rates likely reflect variation in exposure, riding habits, rider demographics, and reporting practices. Importantly, official road-traffic statistics may underestimate the true burden because single-vehicle falls are often not reported to police. Hospital-based data, therefore, provide an important complementary perspective on the epidemiology of e-scooter injuries [9]. Similarly, Uluk et al. showed that combining police and hospital records yields a more complete picture of e-scooter incidents than either data source alone [10].

The demographic profile of our patients is consistent with previous studies [6,9,11], with young adult males comprising most cases. Based on our results, there is insufficient evidence to conclude that age systematically differs by sex in our study, although a borderline trend towards significance was observed ($p = 0.052$). Riders in their teens, twenties, and thirties are more likely to use e-scooters frequently and may also exhibit greater risk-taking behavior. However, simply classifying a crash as involving a motor vehicle does not fully explain its mechanism. Some events may be related to rider error, such as distraction, excessive speed, or one-handed riding, whereas others may be attributable to driver behavior or contextual risk factors such as intoxication, phone use, or riding in groups.

Our fracture distribution differs somewhat from that reported in other European series. Salzano et al., in a multicentric Italian study conducted in 10 maxillofacial departments between 2020 and 2023, found that the middle third of the face was the most affected region (45.5%), followed by the lower third (39.3%) [11]. In contrast, in our series the lower third was the most affected facial region, accounting for 80 cases (58%), followed by the middle third in 31 patients (22.5%). The remaining cases involved combinations of facial thirds, most commonly lower-middle involvement in 17 patients (12%). Kowalczewka et al., in a Polish cohort, reported mandibular fractures in 37.5% of patients and orbit zygomatic fractures in 20%, findings that are more comparable to our own observations [12].

Therefore, consistent with prior reports, the mandible was the most frequently fractured facial bone in e-scooter accidents. In our cohort, mandibular fractures represented 58% of all fractures. This pattern is biomechanically plausible. Falls from an e-scooter often result in direct impact to the chin, one of the most exposed and prominent parts of the face, which transmits force to the mandibular condyles. The relative structural vulnerability of the condylar neck may explain why this region is frequently involved. Clinically, condylar fractures may present with preauricular pain, swelling, limited mouth opening, and malocclusion. For this reason, our management protocol emphasizes careful assessment of mouth opening, lateral excursions, and occlusion to reduce the risk of missed condylar injuries at initial evaluation.

Dental trauma was also frequent. In our series, dental injuries were recorded in 19 patients, with tooth fracture being the most common lesion, followed by avulsion and luxation. The upper anterior teeth were most often involved. These findings are in line with previous reports and further support the substantial impact of e-scooter crashes on the lower and anterior facial region [15,16].

Facial fractures in e-scooter riders are often accompanied by injuries outside the maxillofacial region, emphasizing the need for multidisciplinary trauma assessment. In our cohort, 23% of patients sustained concomitant injuries beyond the face, most commonly orthopedic trauma to the upper or lower limbs. These findings support the use of structured trauma protocols and appropriate imaging, including computed tomography when indicated, rather than focusing only on obvious facial injuries [17,18]. Traumatic brain injury, including intracranial injury or concussion, was identified in 11

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patients and was associated with longer hospital stay. Notably, none of these patients had been wearing a helmet at the time of the crash.

Helmet use remains one of the most effective strategies for reducing injury severity in e-scooter crashes. Previous studies suggest that helmets may prevent 65% to 88% of serious head injuries [1,19–21]. In our series, however, helmet use was very low: 63% of patients reported never wearing a helmet, 27% reported occasional or inconsistent use, and only 10% reported always wearing one. Importantly, none of the patients who sustained traumatic brain injury had been wearing a helmet. These findings reinforce the protective value of helmets, even though helmet non-use should not be interpreted as a cause of the crash itself, but rather as a determinant of injury severity once a crash occurs. At the same time, current helmet designs have important limitations in relation to maxillofacial trauma. Standard e-scooter helmets are designed primarily to protect the cranium and upper face, leaving the lower face, especially the jaw and chin, relatively exposed [4–7,18]. This limitation is highly relevant in view of our findings, since the lower third of the face was the most frequently affected region and mandibular fractures were especially common. Thus, although helmets appear effective in reducing traumatic brain injury, they do not adequately address the facial injury pattern that characterizes many e-scooter crashes.

International evidence suggests that regulatory approaches to helmet use have shown mixed results. Stassen et al. reported that helmeted riders sustained significantly fewer maxillofacial injuries than non-helmeted riders, although helmet use did not clearly reduce the total number of e-scooter crashes [22]. In Copenhagen, a mandatory helmet law monitored through computer-vision analysis was associated with a significant increase in helmet use [23]. By contrast, in Oxfordshire the effect of helmet-related interventions appeared more limited [24]. These differences suggest that legislation and public-health campaigns may vary in effectiveness depending on enforcement, public uptake, and local riding culture. In Spain, until recently, helmet use in urban areas was mandatory only for riders younger than 16 years, whereas for adults it remained recommended rather than compulsory. Our findings support stronger promotion of helmet use across all age groups and suggest that stricter legislation may help reduce both head injuries and maxillofacial trauma.

However, improved compliance alone may not be sufficient. The mismatch between current helmet design and observed injury patterns indicates a need for innovation in protective equipment. Future helmet systems should offer greater facial coverage and improved impact absorption, particularly in the mandibular and maxillary regions. Several approaches appear promising. These include helmets with extended lower-face protection, modular facial shields, and smart systems that adapt protection to impact conditions. Inflatable “airbag” helmets also represent an important area of development and may offer advantages over traditional rigid designs in selected e-scooter scenarios [4].

Technological innovation beyond protective equipment may also contribute to safer riding environments. Anagnostopoulos et al. described systems in which traffic signals detect approaching users through smartphone communication and adapt signal timing accordingly [25]. Vehicle-to-vehicle and vehicle-to-rider communication systems are also being explored as a means of warning drivers and riders of each other’s presence before a collision occurs [4]. Such approaches may be particularly useful in urban settings where poor visibility and frequent infrastructure conflict points increase crash risk.

Rotational protection has become an important aspect of modern helmet design, because oblique impacts generate rotational head motion that is closely linked to brain injury mechanisms. Recent studies, such as Bonin et al. and Han et al., identified that MIPS (Multi-directional Impact Protection System) is one of the most widely studied commercial systems for mitigating this motion, and experimental studies have reported lower rotational kinematics in helmets equipped with MIPS than in comparable non-MIPS configurations under oblique impact conditions [26,27]. Recent research has also used WG11 oblique impact test conditions for model validation and helmet assessment [26]. However, helmet performance varies substantially across models and design solutions, indicating that protection depends on the overall helmet design rather than on a single technology alone [28,29].

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This issue is particularly relevant in e-scooter crashes, where experimental studies have shown that bicycle helmets can markedly reduce linear head acceleration and some rotational injury metrics, while severe head and neck injury risk may still remain high [30]. These findings support the use of helmets specifically designed and evaluated for oblique-impact protection.

More broadly, our findings reflect how changes in urban transport are reshaping injury patterns. Bicycle-related maxillofacial trauma has been studied extensively, but the increasing use of electric scooters has introduced additional and partly distinct patterns of craniofacial injury. Comparative studies between bicycle- and e-scooter-related trauma would be valuable in identifying whether prevention strategies should be mode-specific [15,16].

This study has several limitations. First, it was conducted at a single tertiary referral hospital in Andalusia, Spain. As a major regional center, our institution is likely to receive a higher proportion of severe craniofacial trauma, which may limit generalizability to less severe community cases. Second, minor injuries may have been underestimated because some patients are treated elsewhere, are not referred for specialist evaluation, or do not seek care. Third, certain fractures, particularly nondisplaced mandibular condyle fractures, may be missed initially when symptoms are mild. Furthermore, the limitations inherent to the retrospective nature of this study must be acknowledged, particularly regarding incomplete data in medical records. Such missing information is especially pertinent in the context of transfer hospitals lacking maxillofacial departments. Additionally, certain relevant cases may have been omitted due to inconsistencies in the clinical documentation concerning maxillofacial trauma and specific injury dates. To address these challenges, future strategies aimed at reducing the proportion of missing data should focus on the standardization of data collection and its integration with Emergency Medical Service reports and trauma registries. Finally, our sample size of 138 patients over 8 years reflects the relative infrequency of severe e-scooter-related maxillofacial trauma at the population level, even though it constitutes a clinically meaningful series. The inclusion of the COVID-19 pandemic period may also have affected temporal patterns, as mobility restrictions were associated with a marked reduction in trauma presentations during parts of 2020 [13], while other authors have reported relative increases in e-scooter-related facial trauma during later pandemic years [14].

In summary, electric scooter-related maxillofacial trauma appears to result from a combination of behavioral, infrastructural, and technological factors. The coexistence of suboptimal urban infrastructure and the limited facial protection offered by current helmets creates a compounded safety risk for riders [3,4,8]. Effective prevention will require a multifaceted response that includes better infrastructure design, regulatory frameworks introduced before service deployment, rider education, stronger helmet policies, and advances in helmet technology specifically aimed at protecting the lower face. International regulatory experiences and emerging safety technologies provide useful models for reducing the burden of electric scooter-related maxillofacial injury in the future.

5. Conclusions

To conclude, accidents involving personal mobility vehicles have become one of the main causes of emergency room admissions in recent years and, consequently, injuries associated with the use of electric scooters are a recent phenomenon that mainly affect the maxillofacial region due to the dynamic nature of the trauma. Our series reflects the increasing frequency of maxillofacial trauma resulting from accidents involving electric scooters at the population level. Mandibular fractures were the most frequent injury, with condylar fractures predominating, often resulting from direct impact to the chin during falls. Although scooter-related maxillofacial fractures are relatively common, awareness of their frequency, contributing factors, and anatomical distribution are important for emergency and trauma teams who assess these patients first. Early recognition and timely management are crucial because missed diagnoses or delayed treatment can lead to permanent facial deformity and functional impairment.

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Key contributing factors in our series included lack of helmet use, involvement of other motor vehicles, distraction (e.g., headphone use), and riding during early evening hours. These findings can inform targeted public health strategies and injury prevention programs. Measures to improve safety should include promotion of protective helmets along with infrastructure improvements, enforcement of traffic rules, education of riders and drivers, and advances in helmet technology. Despite this mode of transport becoming increasingly common over the years and being accepted within regulatory frameworks, traffic regulations are not sufficiently prepared to integrate scooters into transport systems due to inadequate legislation and insufficient implementation, such as face protection devices or safety training for electric scooter users. Although there has been a change in existing regulations related to the use of electric scooters, it is necessary to evaluate their effectiveness.

Author Contributions: Conceptualization, L.M.G.-P. and J.W.; methodology, L.M.G.-P. and J.W.; software, L.M.G.-P., J.W. and C.A.-D.; validation, L.M.G.-P. and J.W.; formal analysis, L.M.G.-P., J.W. and C.A.-D.; investigation, L.M.G.-P. and J.W.; resources, L.M.G.-P., J.W. and C.A.-D.; data curation, L.M.G.-P., J.W. and C.A.-D.; writing—original draft preparation, L.M.G.-P. and J.W.; writing—review and editing, L.M.G.-P., J.W. and C.A.-D.; visualization, L.M.G.-P. and J.W.; supervision, L.M.G.-P., J.W. and C.A.-D.; project administration, L.M.G.-P. and J.W.; funding acquisition, L.M.G.-P. and J.W. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of University Hospital, Seville, Spain (IRB 2014PI/083).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available upon reasonable request by contacting the corresponding author.

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Conflicts of Interest: None of the authors have any potential financial conflict of interest related to this manuscript.

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