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Orthopedic injury patterns and clinical outcomes in electric scooter-related trauma

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ABSTRACT

Aims: Electric scooter (e-scooter) use has risen sharply in urban areas, accompanied by an increase in related traumatic injuries. This study aimed to evaluate the orthopedic burden of e-scooter accidents, identify injury patterns associated with surgical management, and analyze postoperative outcomes.

Methods: A retrospective cohort study was conducted on 320 patients presenting with orthopedic injuries related to e-scooter accidents between January 2022 and January 2025. Demographic, clinical, and radiographic data were extracted from electronic health records. The relationship between specific injury features—open fractures, dislocations, and multiple fractures—and surgical intervention was assessed using univariate analysis and visualized through a cumulative risk model. Descriptive analysis was performed for operative subgroups based on surgical technique.

Results: Among 320 patients (mean age: 31.8±12.0 years, 74% male), 96 (30%) underwent surgery. Operative patients were significantly older (39.2±12.2 vs. 28.6±10.4 years, $p<0.001$) and more likely to present with open fractures (31% vs. 0.9%, $p<0.001$), dislocations (24% vs. 2.7%, $p<0.001$), and multiple fractures (65% vs. 21%, $p<0.001$). Hospital stay was longer (4.8±2.2 vs. 1.2±0.9 days, $p<0.001$) and complication rates higher (19% vs. 0.9%, $p<0.001$) in the operative group. Surgical likelihood increased with the number of high-risk injury features: from 9.5% with none to 100% with all three. Among operative patients, open reduction and internal fixation (ORIF) was most common (64%). External fixation had the longest hospital stay, while intramedullary nailing showed the highest complication rate.

Conclusion: E-scooter-related trauma results in a substantial orthopedic burden. Open fractures, dislocations, and multiple injuries significantly increase the likelihood of surgery and postoperative complications. Early recognition of these features may support surgical planning and improve trauma triage in urban emergency settings.

Keywords: E-scooter, orthopedic trauma, fracture, dislocation, surgery, complication

INTRODUCTION

Electric scooters (e-scooters) have rapidly emerged as a popular mode of urban micro-mobility, particularly in metropolitan areas with dense traffic and limited public transportation options. Their affordability, accessibility, and convenience have contributed to widespread use, especially among younger individuals and urban commuters.[1,2] However, the growing adoption of e-scooters has been accompanied by a significant rise in associated injuries, many of which require emergency department evaluation and orthopedic management.[3,4]

Several studies have highlighted the high incidence of musculoskeletal trauma among e-scooter users, including upper and lower extremity fractures, dislocations, and soft tissue injuries.[5,6] Notably, these injuries often occur in the absence of protective equipment, such as helmets or pads, which increases the risk of both cranial and orthopedic damage.[7] Orthopedic injuries constitute a major subset of e-scooter trauma, frequently necessitating surgical intervention, prolonged hospitalization, and rehabilitation.[8,9]

The injury mechanism typically involves high-speed impact or falls, with a substantial proportion occurring due to loss of balance, road obstacles, or collisions with vehicles.[10] Clinical outcomes in this patient population can vary significantly based on fracture type, injury severity, and patient age, but data remain limited regarding prognostic patterns and hospital resource utilization.[11] Furthermore, e-scooter-related trauma poses a rising burden on emergency and orthopedic services, underlining the need for targeted epidemiological assessments and preventive strategies.[12]

This study aims to examine the orthopedic injury profiles, surgical intervention rates, and clinical outcomes of patients presenting with e-scooter-related trauma to a tertiary care emergency department.

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METHODS

This retrospective observational study was conducted at a tertiary care university hospital and included all patients who presented to the emergency department with orthopedic injuries related to e-scooter accidents between January 1, 2022, and January 1, 2025. Ethical approval was obtained from the Ethics Committee of İstanbul Yeni Yüzyıl University Research Ethics Committee for Health Sciences Researches Not Requiring Science and Medical Intervention (Date: 07.05.2025, Decision No: 2025/05-1551), and the study was conducted in accordance with the Declaration of Helsinki.

Patients were eligible for inclusion if they presented with musculoskeletal trauma resulting from an e-scooter-related incident and underwent orthopedic evaluation in the emergency department. Exclusion criteria included patients without documented radiological findings, cases with isolated soft tissue injuries not requiring orthopedic follow-up, and missing data in core variables such as age, sex, or injury mechanism.

Demographic and clinical data were retrospectively extracted from the hospital's electronic medical record system. Variables included age, sex, helmet use, presence of alcohol consumption, mechanism of injury (fall vs. collision), anatomical region of injury, fracture type (e.g., comminuted, transverse), number of fractures, presence of dislocation, and open vs. closed fracture status. The requirement for surgical treatment, type of surgical procedure, length of hospital stay, and complications were also recorded. To assess injury burden, three binary features—presence of open fracture, dislocation, and multiple fractures (≥2 distinct sites)—were identified for each patient. A cumulative severity score ranging from 0 to 3 was assigned accordingly. These scores were then used to explore the association between injury complexity and surgical intervention rate. Among surgically treated patients, subgroup analysis was performed according to the surgical technique: open reduction and internal fixation (ORIF), intramedullary (IM) nailing, or external fixation. In our cohort, external fixation was employed as the definitive treatment rather than a temporary stabilization measure. This approach was chosen primarily in cases of open fractures with significant soft tissue compromise. All surgical procedures were performed by orthopedic trauma surgeons with a minimum of five years of post-residency experience. Surgeries were conducted within the same trauma team at a single tertiary center, minimizing variability in surgical technique and perioperative decision-making.

Statistical Analysis

The data analyses were performed using R software (version 4.4.2; R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were expressed as mean±standard deviation or median [interquartile range] based on their distribution, which was assessed using visual inspection of histograms. Categorical variables were reported as counts and percentages. Comparisons between patients who underwent surgical intervention and those managed nonoperatively were performed using the Wilcoxon rank-sum test for continuous variables and Pearson's Chi-squared or Fisher's exact test for categorical variables, as appropriate.

To assess the cumulative relationship between injury severity and surgical intervention, three binary injury features—open fracture, dislocation, and multiple fractures (≥2)—were identified. Each patient was assigned a cumulative severity score (0–3) based on the number of features present. The proportion of patients undergoing surgery was then calculated across all feature count levels and displayed both in tabular form and as a segmented trajectory plot.

Among surgically treated patients, descriptive subgroup analysis was performed based on the surgical technique (ORIF, IM nailing, or external fixation). For each group, mean length of hospital stay and complication rate were calculated. Additionally, the most frequently observed fracture region and AO classification were identified. These results were summarized in **Table 1** and further illustrated with a bubble plot visualizing postoperative burden (length of stay, complication rate, and sample size) across surgical techniques.

All p-values were two-sided, and a p-value <0.05 was considered statistically significant. No imputation was performed for missing data.

RESULTS

A total of 320 patients with orthopedic injuries related to e-scooter accidents were included in the study. The mean age was 31.8±12.0 years, and 74% were male. Surgical intervention was performed in 96 (30%) patients.

Patients who underwent surgery were significantly older than those treated nonoperatively (39.2±12.2 vs. 28.6±10.4 years, p<0.001). Open fractures were observed in 30 patients in the operative group (31%) and 2 in the nonoperative group (0.9%). Dislocations occurred in 23 operative patients (24%) and 6 nonoperative patients (2.7%). Multiple fractures (≥2) were present in 62 operative patients (65%) and 47 nonoperative patients (21%) (p<0.001 for all). Fracture region and morphology also differed significantly: lower extremity and comminuted fractures were more common among patients who underwent surgery (**Table 2**).

Table 1. Postoperative outcomes by surgical technique in patients undergoing surgery

Surgical technique	n (%)	Mean LOS (±SD)	Complication (%)	Most frequent fracture region	Most frequent AO type
External fixation	16 (16.7%)	5.8±2.0	3 (18.8%)	Upper extremity	AO 41C
IM nail	19 (19.8%)	4.7±2.6	5 (26.3%)	Lower extremity	AO 41C
ORIF	61 (63.5%)	4.6±2.1	10 (16.4%)	Lower extremity	AO 41C

Table summarizes postoperative outcomes among surgical patients based on the technique used. Length of stay (LOS) is expressed as mean±standard deviation. "most frequent fracture region" and "most frequent AO type" reflect the highest-frequency categories observed within each surgical group. SD: Standard deviation, IM: Intramedullary, ORIF: Open reduction and internal fixation

Table 2. Demographic and fracture characteristics of patients with and without surgical intervention

Variable	All patients (n=320)	Nonoperative (n=224)	Operative (n=96)	p
Age, years	31.8±12.0	28.6±10.4	39.2±12.2	<0.001
Male sex	238 (74%)	162 (72%)	76 (79%)	0.2
Open fracture	32 (10%)	2 (0.9%)	30 (31%)	<0.001
Dislocation	29 (9.1%)	6 (2.7%)	23 (24%)	<0.001
Fracture count				<0.001
– 1	211 (66%)	177 (79%)	34 (35%)	
– 2	73 (23%)	41 (18%)	32 (33%)	
– 3	22 (6.9%)	5 (2.2%)	17 (18%)	
– 4	14 (4.4%)	1 (0.4%)	13 (14%)	
Fracture region				<0.001
– Upper extremity	168 (53%)	133 (59%)	35 (36%)	
– Lower extremity	123 (38%)	78 (35%)	45 (47%)	
– Pelvis	29 (9.1%)	13 (5.8%)	16 (17%)	
Fracture type				<0.001
– Transverse	109 (34%)	92 (41%)	17 (18%)	
– Oblique	95 (30%)	79 (35%)	16 (17%)	
– Comminuted	64 (20%)	29 (13%)	35 (36%)	
– Spiral	52 (16%)	24 (11%)	28 (29%)	
AO/OTA classification				<0.001
– 2R1A	94 (29%)	81 (36%)	13 (14%)	
– 2R3B	59 (18%)	45 (20%)	14 (15%)	
– 41C	54 (17%)	18 (8.0%)	36 (38%)	
– 44B	76 (24%)	58 (26%)	18 (19%)	
– 81B	37 (12%)	22 (9.8%)	15 (16%)	

Table 3. Contextual and treatment-related characteristics of patients with and without surgical intervention

Variable	All patients (n=320)	Nonoperative (n=224)	Operative (n=96)	p
Alcohol positive	44 (14%)	30 (13%)	14 (15%)	0.8
Helmet use	71 (22%)	59 (26%)	12 (13%)	0.006
Mechanism of injury				<0.001
– Fall	224 (70%)	176 (79%)	48 (50%)	
– Collision w/vehicle	73 (23%)	34 (15%)	39 (41%)	
– Fixed object	23 (7.2%)	14 (6.3%)	9 (9.4%)	
Injury location				0.4
– Road	208 (65%)	143 (64%)	65 (68%)	
– Sidewalk	85 (27%)	64 (29%)	21 (22%)	
– Park	27 (8.4%)	17 (7.6%)	10 (10%)	
Surgical type				<0.001
– None	224 (70%)	224 (100%)	0 (0%)	
– ORIF	61 (19%)	0 (0%)	61 (64%)	
– IM nail	19 (5.9%)	0 (0%)	19 (20%)	
– External fixation	16 (5.0%)	0 (0%)	16 (17%)	
LOS, days	2.3±2.2	1.2±0.9	4.8±2.2	<0.001
Complication	20 (6.3%)	2 (0.9%)	18 (19%)	<0.001

ORIF: Open reduction and internal fixation, IM nail: Intramedullary nail, LOS: Length of stay

Table 4. Surgical intervention rate by number of severe injury features

Number of severe injury features	n (%)	Surgical intervention (%)
0	190 (59.4%)	18 (9.5%)
1	94 (29.4%)	45 (47.9%)
2	32 (10.0%)	29 (90.6%)
3	4 (1.2%)	4 (100%)

Severe injury features were defined as: (1) open fracture, (2) dislocation, and (3) multiple fractures (≥2). The proportion of patients requiring surgical intervention increased substantially with the number of these features present.

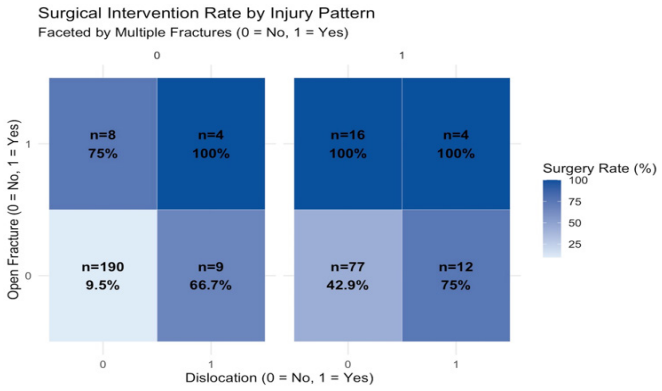

Figure 1. Proportion of patients undergoing surgical intervention stratified by number of severe injury features. Severe features include open fracture, dislocation, and multiple fractures (≥2 distinct fracture sites).

Contextual factors associated with surgery included lower helmet use (13% vs. 26%, p=0.006) and a higher rate of collisions with motor vehicles (41% vs. 15%, p<0.001). Length of hospital stay was significantly longer in the surgical group (4.8±2.2 vs. 1.2±0.9 days, p<0.001), and the overall complication rate was also higher (19% vs. 0.9%, p<0.001) (**Table 3**). Among the 18 patients in the surgical group who experienced complications, the most common events were surgical site infection (n=7), delayed union (n=4), implant failure (n=3), and transient peripheral nerve palsy (n=4). Infections were treated with intravenous antibiotics and local wound care; two cases required surgical debridement. Delayed union cases were managed conservatively with prolonged immobilization and bone stimulation protocols. Implant failures led to revision surgeries in two patients, while all nerve injuries resolved spontaneously within three months under conservative follow-up.

The likelihood of surgical intervention increased substantially with the accumulation of predefined injury features. Among patients with none of the three features (open fracture, dislocation, or multiple fractures), only 9.5% underwent surgery, compared to 47.9% with one feature, 90.6% with two features, and 100% with all three (**Table 4, Figure 1**).

This stepwise gradient highlights the additive risk model for surgical decision-making in orthopedic e-scooter trauma.

Among patients who underwent surgery, ORIF was the most common technique (n=61; 63.5%), followed by IM nailing (n=19; 19.8%) and external fixation (n=16; 16.7%). All patients treated with external fixation (n=16) had open fractures, and external fixation was used as the final surgical strategy rather

than a temporizing step. Mean length of stay was longest in the external fixation group (5.8 ± 2.0 days), and complication rates were highest in the IM nail group (26.3%). The most frequently encountered AO classification among all surgical subgroups was 41C (**Table 1, Figure 2**).

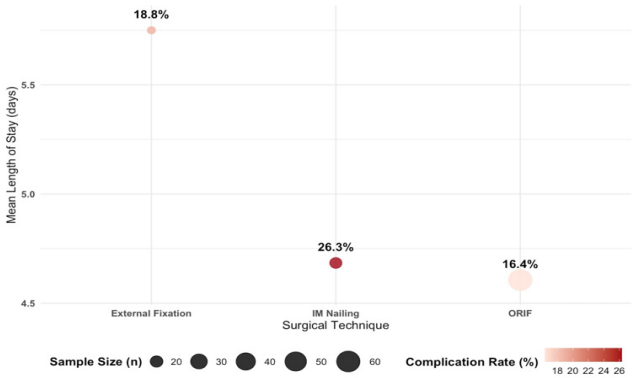

Figure 2. Clinical outcome distribution by surgery type in e-scooter–related injuries

DISCUSSION

This study examined orthopedic trauma patterns among individuals involved in e-scooter accidents and demonstrated that nearly one-third of cases required surgical intervention. Patients in the operative group were significantly older and more likely to present with high-risk injury features such as open fractures, dislocations, and multiple fracture sites. These clinical indicators were strongly associated with the decision to operate and with poorer short-term outcomes, including longer hospital stay and increased complication rates. Moreover, a stepwise relationship was observed between the number of injury features and the likelihood of surgery, suggesting a cumulative effect of injury severity on surgical necessity.

The increasing popularity of e-scooters in urban settings has introduced new public health challenges, particularly with regard to injury burden among young adults. However, this trend has been accompanied by a marked increase in trauma presentations related to e-scooter accidents, many of which involve orthopedic injuries. In recent studies, extremity fractures—especially involving the lower limbs—have been among the most frequently reported injury types, often requiring surgical management.[13] Moreover, low helmet usage and frequent collisions with motor vehicles contribute to the severity of injuries sustained.[14] As the availability of personal mobility devices grows, healthcare systems are increasingly confronted with the burden of managing high-energy fractures and their associated complications.[15,16]

In this study, we found that 30% of e-scooter-related orthopedic injuries required surgical intervention, with open fractures, dislocations, and multiple injuries being significant predictors of operative management. Our findings align with those reported by Bracher et al.,[17] who observed a similarly high rate of surgery in patients presenting with e-scooter trauma in Switzerland, particularly when multiple injuries were present. Hourston et al.[18] also documented a predominance of long bone fractures requiring operative stabilization in their UK-based case series, reinforcing the invasive burden these injuries pose.

With respect to surgical techniques, our results indicated that ORIF was the most frequently used approach, followed by IM nailing and external fixation. The complication rate was highest among those undergoing IM fixation, which may reflect the complexity of fractures in that group. This trend was echoed by Metry et al.,[19] who reported increased length of stay and complication rates in patients treated surgically, emphasizing the need for individualized perioperative planning in orthopedic e-scooter trauma. Ang et al.,[20] analyzing injuries in Singapore, highlighted the spectrum of operative interventions required for e-scooter accidents and emphasized the resource implications of managing these often-preventable injuries.

The results of this study point to the importance of preventive strategies to reduce the orthopedic consequences of e-scooter-related trauma. In our cohort, helmet use was significantly lower among patients requiring surgery, suggesting that increasing public awareness and promoting protective equipment could contribute to injury reduction. Urban mobility policies such as speed restrictions and dedicated scooter lanes may also help prevent high-energy collisions that frequently result in fractures and surgical interventions. In addition, there is currently no trauma scoring system specifically designed for e-scooter injuries, despite the growing frequency and distinctive characteristics of these cases. Such a tool could assist clinicians in early risk assessment and treatment planning. Another limitation in the current literature is the lack of long-term outcome data, including physical function and quality of life after surgical management. Future studies focusing on these aspects would be valuable for optimizing post-discharge care and rehabilitation protocols.

Limitations

This study has several limitations that should be considered. Its retrospective design inherently restricts control over confounding variables and may be prone to documentation bias. Data were obtained from a single tertiary center, which may limit the generalizability of the findings to other populations or healthcare systems. Additionally, information on long-term functional outcomes, rehabilitation, and reoperation rates was not available. Finally, although a severity scoring model based on injury patterns was explored, no validated trauma score specific to e-scooter-related orthopedic injuries currently exists, which may affect the interpretability of cumulative risk.

CONCLUSION

Injuries related to e-scooter accidents often involve high-energy trauma and require surgical treatment in a substantial subset of patients. Open fractures, dislocations, and multiple injuries are key predictors of operative management and are associated with increased hospital burden. Recognizing these injury patterns early may facilitate clinical decision-making, improve triage efficiency, and guide resource allocation in orthopedic and emergency care settings.

ETHICAL DECLARATIONS

Ethics Committee Approval
Ethical approval was obtained from the Ethics Committee of İstanbul Yeni Yüzyıl University Research Ethics Committee for Health Sciences Researches Not Requiring Science and Medical Intervention (Date: 07.05.2025, Decision No: 2025/05-1551).

Informed Consent
Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process
Externally peer-reviewed.

Conflict of Interest Statement
The authors have no conflicts of interest to declare.

Financial Disclosure
The authors declared that this study has received no financial support.

Author Contributions
All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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