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Research Article

FRACTURE COMPLEXITY AND IMPLANT COSTS IN MAXILLOFACIAL TRAUMA PATIENTS UNDERGOING OPEN REDUCTION AND INTERNAL FIXATION

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Abstract
Maxillofacial trauma frequently requires open reduction and internal fixation (ORIF) using various implant systems that may increase operative costs, particularly in complex fractures. This study aimed to analyze the relationship between fracture complexity and implant costs in maxillofacial trauma patients undergoing ORIF. A retrospective cross-sectional study was conducted using retrospective medical records from 35 patients treated at PKU Muhammadiyah Karanganyar Hospital during 2025–2026. Statistical analysis was performed using the Shapiro–Wilk test and the Independent Samples T-Test. Most patients were male (80.0%) with a mean age of 36.86 ± 18.44 years. Simple fractures accounted for 57.1% of cases, whereas complex fractures accounted for 42.9%. A total of 66 implant components were used during ORIF procedures, with AT-DRV screws accounting for the largest proportion (69.7%). while multiple-point fixation was the most common fixation strategy (40.0%). The mean implant cost was 6.80 ± 3.76 million rupiahs. Statistical analysis showed no statistically significant association between fracture complexity and implant cost ($p = 0.845$). However, interpretation is limited by the retrospective design and small sample size ($n = 35$) may have limited the statistical power to detect a true association. Furthermore, the retrospective study design limits causal inference and depends on the completeness and accuracy of the available medical records.

Keywords: Implant Cost, Internal Fixation, Maxillofacial Trauma, Fracture Complexity.

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INTRODUCTION

Maxillofacial trauma remains one of the most challenging injuries encountered in Otorhinolaryngology-Head and Neck Surgery (ORL-HNS) because it involves not only facial skeletal disruption but also functional, esthetic, and psychosocial consequences. Injuries involving the maxilla, mandible, zygoma, orbit, and adjacent soft tissues may impair mastication, respiration, speech, visual function, and facial symmetry, thereby significantly affecting patients' quality of life. In addition to clinical consequences, maxillofacial trauma also imposes a considerable economic burden due to the need for radiological evaluation, operative intervention, implant utilization, hospitalization, and postoperative rehabilitation (Maniaci et al., 2025).

Globally, trauma remains a major cause of morbidity and mortality, particularly among individuals of productive age. Maxillofacial trauma predominantly affects young adult males and is most commonly associated with high-energy mechanisms such as road traffic accidents, interpersonal violence, and occupational injuries. In developing countries, including Indonesia, traffic accidents continue to represent the leading etiology of maxillofacial fractures (Ridho et al., 2024; Samieirad et al., 2017). These injuries frequently involve the midface region due to its relatively thin bone structures and complex facial buttress system, making it highly susceptible to fracture following direct high-impact trauma.

Open reduction and internal fixation (ORIF) has become the standard surgical approach for displaced maxillofacial fractures because it enables anatomical reduction and stable rigid fixation using titanium plates and screws. Appropriate fixation is essential to restore facial projection, occlusion, orbital integrity, and masticatory function while minimizing long-term deformity and functional impairment. However, the complexity of fracture patterns often determines the number of fixation points, implant types, and stabilization strategies required during surgery (Raghoebar et al., 2022; Degala et al., 2021). Recent evidence has also suggested that less extensive fixation approaches, such as two-point fixation in selected zygomaticomaxillary fractures, may still provide satisfactory biomechanical and clinical stability while potentially reducing implant utilization (Nainoor et al., 2024).

Complex fractures involving multiple anatomical regions or comminuted bone fragments generally require multidimensional stabilization using a greater number of plates and screws compared with simple fractures. Consequently, implant utilization during ORIF procedures may substantially increase operative expenses. Previous studies have demonstrated that implant systems and fixation strategies contribute significantly to treatment costs in maxillofacial trauma surgery (Altiparmak et al., 2020; Siddiqui et al., 2024). In resource-limited healthcare settings, optimization of implant utilization has therefore become increasingly important to maintain operative cost-efficiency without compromising anatomical stability and clinical outcomes.

Although maxillofacial fracture severity can be described using detailed anatomical classifications, such as Le Fort classifications, zygomaticomaxillary complex fracture patterns, or the number of involved anatomical regions, the present study adopted a dichotomous classification of simple and complex fractures. This approach was selected to facilitate clinically applicable comparisons of implant utilization and implant-related costs in a retrospective dataset with a limited sample size while reflecting differences in surgical complexity and stabilization requirements.

Despite the growing clinical importance of implant-related expenditure, studies specifically evaluating the relationship between fracture complexity and implant costs remain limited, particularly in Indonesia. Most previous studies have focused primarily on epidemiological characteristics or overall hospitalization costs rather than implant utilization patterns and fixation strategies during ORIF procedures. In addition, variability in surgeon preference, biomechanical considerations, and fixation-point selection may influence implant use independently of fracture classification.

Therefore, this study aimed to analyze the relationship between fracture complexity and implant costs among maxillofacial trauma patients undergoing ORIF procedures at PKU Muhammadiyah Karanganyar Hospital. We hypothesized that fracture complexity would be associated with higher implant costs.

RESEARCH METHOD

Research Design

This study was an analytic observational study with a cross-sectional design using retrospective medical record data of maxillofacial trauma patients treated at PKU Muhammadiyah Karanganyar Hospital during the 2025-2026 period. The study aimed to analyze the association between fracture complexity and implant costs in maxillofacial trauma patients undergoing operative management.

Research Target

The target population consisted of all maxillofacial trauma patients undergoing operative treatment, while the actual population included maxillofacial trauma patients who underwent ORIF during the study period. The sampling technique used was total sampling, in which all subjects meeting the inclusion and exclusion criteria were included in the study. Sample size calculation was not performed because all eligible data available during the study period were included. Based on medical records and computed tomography (CT) scan findings, a total of 35 patients met the study criteria.

The inclusion criteria included patients diagnosed with maxillofacial fractures confirmed clinically and radiologically, patients who underwent ORIF procedures, and patients with complete medical records regarding fracture complexity, implant utilization, and implant costs. The exclusion criteria included incomplete medical records, undocumented implant utilization data, and patients who did not undergo ORIF procedures.

Research Procedure

Data were obtained from medical records, CT scan findings, operative reports, and implant utilization reports of maxillofacial trauma patients who underwent ORIF using plate, screw, or wire fixation systems. Fracture complexity was classified a priori based solely on anatomical involvement. Simple fractures were defined as fractures involving a single anatomical region, whereas complex fractures were defined as fractures involving two or more anatomical regions. Implant selection, fixation strategy, and stabilization requirements were not considered in this classification. The classification was determined retrospectively from the documented CT scan diagnosis and operative records and was reviewed and verified by an Otorhinolaryngology–Head and Neck Surgery (ORL–HNS) specialist. Because this study used retrospective secondary data, no blinding procedure or formal inter-rater reliability assessment was performed. Implant cost was defined as the total expenditure related to implant utilization during operative management.

Additional variables analyzed descriptively included age, sex, cerebral edema, and the number of plates, screws, and wires used. Collected data included patient characteristics, fracture location, fracture complexity, implant utilization, total number of implants used, and total implant cost.

Instruments, and Data Collection Techniques

The instruments used in this study consisted of medical records, CT scan evaluation reports, and implant utilization documentation from the operating room database. Data collection was conducted retrospectively by reviewing patient medical records and operative reports during the study period. Relevant clinical and operative variables were recorded using a structured data collection form.

Data Analysis Technique

Statistical analysis was performed using JASP software. Descriptive analysis was used to describe subject characteristics. Categorical variables were presented as frequencies and percentages, while numerical variables were presented as mean, median, standard deviation, minimum value, and maximum value.

Normality testing was performed using the Shapiro-Wilk test. The association between fracture complexity and implant cost was analyzed using the Independent Samples T-Test for normally distributed data and the Mann-Whitney test for non-normally distributed data. Statistical significance was defined as $p < 0.05$.

This study received ethical approval from the Health Research Ethics Committee of Dr. Moewardi Regional General Hospital with ethical clearance number 810/V/HREC/2026 issued on May 12, 2026, prior to study implementation.

RESULTS AND DISCUSSION

The results of this study provide an overview of patient characteristics, fracture distribution, implant utilization patterns, fixation strategies, and the relationship between fracture complexity and implant costs among maxillofacial trauma patients undergoing ORIF.

Table 1. Patient Characteristics

No.	Variable	Category	n (%)	Mean ± SD	Min-Max
1	Age			36.86 ± 18.44	15 –70
2	Gender	Male	28 (80)		
		Female	7 (20)		
3	Fracture Complexity	Simple	20 (57.1)		
		Complex	15 (42.9)		
4	Cerebral Edema	Present	28 (80)		
		Absent	7 (20)		
5	Cost			6.80 ± 3.76	0.55–18.58

Based on Table 1, this study involved 35 patients with maxillofacial trauma, with a mean age of 36.86 ± 18.44 years and an age range of 15-70 years. The majority of the subjects were male were male (28 patients, 80.0%), whereas seven patients (20.0%) were female. Based on fracture complexity, 20 patients (57.1%) had simple fractures and 15 patients (42.9%) had complex fractures. Cerebral edema was documented in 28 patients (80.0%), while seven patients (20.0%) had no documented cerebral edema. The presence of cerebral edema was determined based on radiological findings and documentation in the patients' medical records. The mean implant cost was 6.80 ± 3.76 million Indonesian rupiahs, ranging from 0.55 to 18.58 million rupiahs.

Table 2. Results of the Shapiro-Wilk Normality Test

Variable	Shapiro-Wilk	p-value
Age	0.880	0.001
Implant Cost	0.939	0.053

Based on Table 2, the Shapiro-Wilk normality test indicates that the age variable is not normally distributed (p = 0.001), whereas the implant cost variable is normally distributed (p = 0.053). Therefore, the analysis of the relationship between fracture complexity and implant cost was conducted using an independent sample T-Test.

Table 3. The Relationship Between Fracture Complexity and Implant Cost

Statistical Test	Value	p-value
Independent Samples T-Test	-0.198	0.845

Based on Table 3, an analysis of the relationship between fracture complexity and implant cost using an independent sample T-Test yielded a p-value of 0.845 (p > 0.05). These results indicate no statistically significant relationship between fracture complexity and implant cost in maxillofacial trauma patients.

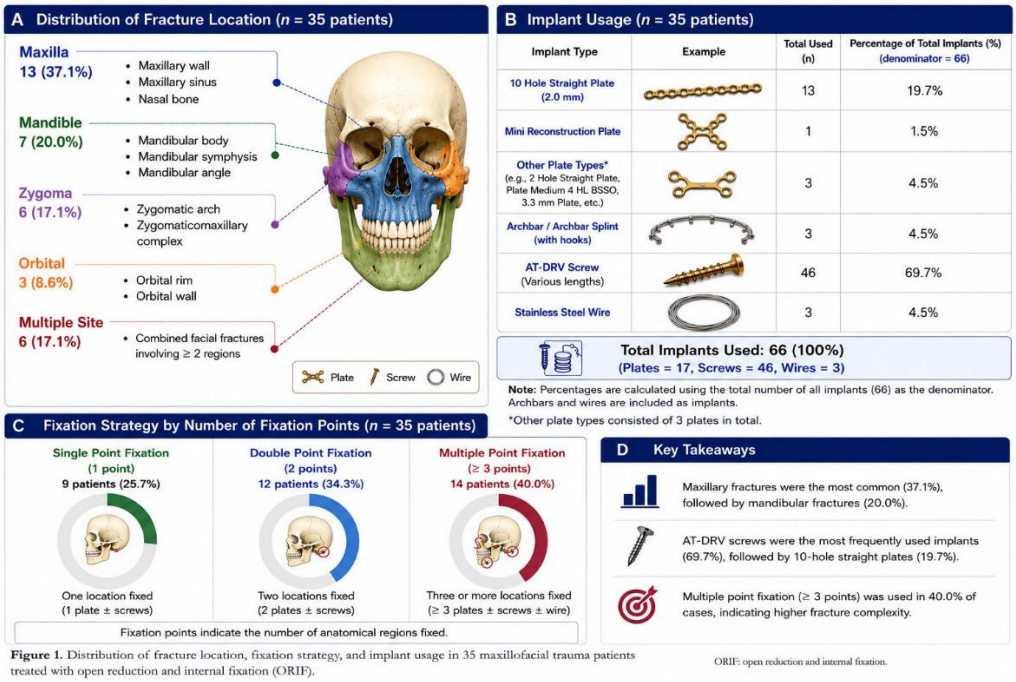

Figure 1. Distribution of Fracture Location, Fixation Strategies, and Implant Utilization Among Maxillofacial Trauma Patients Undergoing ORIF Procedures

Based on Figure 1, multiple-point fixation (≥3 fixation points) was the most frequently used fixation strategy, accounting for 14 patients (40.0%), followed by double-point fixation in 12 patients (34.3%) and single-point fixation in 9 patients (25.7%). These findings suggest that stabilization at multiple anatomical points was commonly required to achieve adequate biomechanical stability during ORIF procedures, particularly in patients with more extensive fracture patterns.

Table 4. Distribution of Implant Components Used During ORIF Procedures

Type of Implant	Number (n)	Percentage (%)
AT-DRV Screw	46	69.7
10 Hole Straight Plate	13	19.7
Stainless Steel Wire	3	4.5
Archbar Splint with Hooks	3	4.5
Mini Reconstruction Plate	1	1.5
Total Implant	66	100

Percentages were calculated based on the total number of implant components used during ORIF procedures (n = 66). Archbar splints with hooks and stainless steel wires were included as implant components because they were used as fixation devices during fracture management. Implant utilization during ORIF procedures comprised a total of 66 implant components. AT-

DRV screws were the most frequently used implant components, accounting for 46 (69.7%), followed by 10-hole straight plates with 13 (19.7%). Two-hole straight plates, archbar splints with hooks, stainless steel wires, mini reconstruction plates, and medium 4-hole BSSO plates accounted for 2 (3.0%), 3 (4.5%), 3 (4.5%), 1 (1.5%), and 1 (1.5%) implant components, respectively. Overall, the implant components consisted of 17 plates (13 ten-hole straight plates, 2 two-hole straight plates, 1 mini reconstruction plate, and 1 medium 4-hole BSSO plate), 46 screws, 3 archbar splints with hooks, and 3 stainless steel wires. These findings indicate that screw fixation constituted the major component of implant utilization during ORIF procedures, reflecting its essential role in achieving stable fixation of maxillofacial fractures.

Main Findings

The present discussion aimed to interpret the study findings in relation to fracture complexity and implant-related costs in maxillofacial trauma patients undergoing ORIF procedures.

The findings demonstrated that most patients were males of productive age with fractures predominantly involving the midface region, particularly the maxilla. These findings may be explained by the higher exposure of productive-age males to high-energy trauma mechanisms such as traffic accidents and occupational mobility. In addition, the midface region has relatively thin bone structures and a complex facial buttress system, making it more susceptible to multiple fractures following direct high-energy impacts. This explanation supports the epidemiological findings reported by Ridho et al. (2024) and Samieirad et al. (2021), which identified traffic accidents as the leading cause of maxillofacial trauma in males.

The present study also demonstrated that implant utilization was dominated by AT-DRV screws and 10-hole straight plates, while multiple-point fixation was the most frequently applied fixation strategy. These findings can be explained biomechanically because the facial buttress system functions as the primary support structure responsible for maintaining facial projection, occlusion, and force distribution. Fractures involving multiple buttress regions reduce skeletal stability and therefore require rigid fixation at several anatomical points to restore structural integrity. In fractures such as Zygomaticomaxillary Complex (ZMC), Le Fort II, and Le Fort III fractures, fixation aims not only to restore bone continuity but also to preserve orbital dimensions, facial symmetry, and masticatory function (Degala et al., 2021; Raghoebar et al., 2022). Consequently, more complex fractures generally require a greater number of plates and screws to achieve adequate multidimensional stabilization.

Descriptively, patients with complex fractures demonstrated a tendency toward higher implant utilization and higher implant-related costs compared to patients with simple fractures. However, statistical analysis showed no significant relationship between fracture complexity and implant costs. These results suggest that implant costs during ORIF procedures are not determined solely by fracture complexity classification. Previous studies have shown that the financial burden of ORIF materials in craniomaxillofacial trauma can be substantial, particularly in resource-limited settings where implant costs may represent a significant proportion of healthcare expenditure (Shaye et al., 2023).

One possible explanation is that implant utilization is strongly influenced by operator decision-making and individualized fixation strategies during surgery. In several cases, surgeons may choose fewer fixation points while still maintaining sufficient biomechanical stability, resulting in implant use that does not increase proportionally with fracture complexity. Operative efficiency may therefore depend not only on fracture severity but also on the surgeon's ability to optimize fixation according to biomechanical requirements, which may contribute to improved cost-efficiency in maxillofacial surgery (Franke et al., 2024).

Although no statistically significant relationship was identified, clinically the complex fracture group still demonstrated greater tendencies toward increased implant use and higher operative costs. This discrepancy between clinical and statistical significance may be related to

the relatively small sample size and variability among cases included in the study. Differences in fracture patterns, anatomical involvement, fixation techniques, implant systems, and operator preferences may contribute to considerable variations in implant costs between patients. Previous studies have also demonstrated that implant selection and fixation systems significantly influence operative expenses in facial fracture surgery (Mims & Wang, 2020).

In addition, certain facial regions such as the infraorbital rim, zygomatic buttress, and frontozygomatic suture may require stronger rigid fixation despite similar overall fracture classifications, thereby increasing implant utilization in selected cases (Rana et al., 2022). The findings of this study differ from previous studies by Siddiqui et al. (2024) and Altiparmak et al. (2020), which reported that increasing fracture complexity was associated with significantly higher operative costs due to greater implant requirements and longer hospitalization.

In the present study, however, this relationship was not statistically significant. This difference may be explained by the relatively limited sample size, heterogeneity of fixation strategies among operators, and the use of modified ORIF techniques in selected complex fractures. In some ZMC fractures, for example, reduction from three-point fixation to two-point fixation may still provide adequate clinical stability while reducing implant utilization and operative expenses (Degala et al., 2021; Arjmand et al., 2023).

Clinical Implications and Novelty

Another noteworthy finding was the relatively high proportion of patients with documented cerebral edema (80.0%), indicating that most injuries resulted from high-energy trauma with associated intracranial involvement. Previous studies have demonstrated that maxillofacial trauma is commonly associated with traumatic brain injury, especially following high-velocity traffic accidents, thereby increasing the complexity of clinical management and multidisciplinary care requirements (Othman et al., 2023). In addition, associated cranial or intracranial injuries may further increase hospitalization burden and operative costs in maxillofacial trauma patients (Weitzman et al., 2025).

However, despite the severity of associated injuries, implant-related costs in the present study still appeared to be influenced more by individualized fixation planning rather than fracture complexity classification alone. The novelty of this study lies in its specific evaluation of implant utilization patterns and implant-related costs based on fracture complexity and fixation strategies during ORIF procedures.

Unlike previous studies that mainly evaluated epidemiological patterns or overall hospitalization costs, this study focused specifically on the relationship between fracture complexity, fixation point selection, and implant expenditure. The findings suggest that individualized fixation approaches based on biomechanical stability may optimize implant utilization and improve operative cost efficiency without compromising anatomical reduction or postoperative clinical outcomes. Similar principles have been emphasized in maxillofacial internal fixation literature, where stable fixation should be achieved using biomechanically appropriate and efficient fixation strategies (Yadav, 2021).

The findings of this study also have important clinical and practical implications. Evaluation of plate, screw, and wire utilization distribution may contribute to implant logistics planning, hospital cost efficiency evaluation, and the development of more cost effective maxillofacial trauma fixation protocols. Optimization of fixation points and appropriate implant selection may reduce unnecessary implant use while maintaining adequate biomechanical stability and functional outcomes. This approach may be particularly beneficial in healthcare facilities with limited resources and high rates of traffic accident-related trauma.

Study Limitations

The relatively small sample size in this study may have reduced the statistical power to detect associations between fracture complexity and implant cost. In addition, the retrospective

study design depended on the completeness and accuracy of medical record documentation. Heterogeneity in implant utilization may also have resulted from differences in ORIF strategies, surgeon experience, fixation preferences, and determination of fixation points in each case. Furthermore, this study did not evaluate other factors potentially influencing implant cost, such as operative duration, implant system type, length of hospitalization, and postoperative clinical outcomes. Therefore, future prospective studies with larger sample sizes and more comprehensive biomechanical and cost-effectiveness analyses are still required.

Recommendations for Future Research

Future studies are recommended to involve larger sample sizes and prospective study designs to evaluate the relationship between fracture complexity and implant cost more accurately. Additional analyses regarding fixation points, operative duration, implant systems, and postoperative clinical outcomes are also necessary to determine the most effective and cost-efficient ORIF strategies in maxillofacial trauma management.

CONCLUSION

This study demonstrated that most maxillofacial trauma patients undergoing ORIF were productive-age males, with midface fractures being the predominant injury pattern. Implant utilization was dominated by AT-DRV screws, while multiple-point fixation was the most frequently employed stabilization strategy. Although patients with complex fractures tended to require higher implant utilization and implant-related costs compared to those with simple fractures, the association between fracture complexity and implant cost was not statistically significant. These findings suggest that increasing fracture complexity does not necessarily correspond to a linear increase in implant costs. Variations in ORIF strategies, selection of fixation points, biomechanical considerations, and implant-use efficiency by surgeons may contribute to minimizing implant utilization without compromising anatomical stability and clinical outcomes.

The results of this study highlight the importance of individualized and cost-effective fixation approaches in the management of maxillofacial trauma and may serve as a basis for evaluating implant-use efficiency and operative cost-efficiency in healthcare facilities. Future prospective studies with larger sample sizes and more comprehensive biomechanical and cost-effectiveness evaluations are recommended to further optimize ORIF strategies in maxillofacial trauma management.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used ChatGPT to assist in improving grammar, language quality, and academic readability of the manuscript. All outputs generated by the tool were critically reviewed, revised, and edited by the author(s), who take full responsibility for the final content of the publication.

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AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Methodology; Conceptualization; Data curation; Investigation.
Author 3: Investigation; Data Collection;; Sample Management.
Author 4: Formal analysis; Visualization; Writing - original draft.
Author 5: Statistical analysis; Validation; Writing - original draft
Author 6: Resources; Visualization; Data Interpretation; Writing - original draft.
Author 7: Supervision; Funding acquisition; Critical revision of the manuscript; Final approval of the manuscript.
Author 8: Critical revision of the manuscript; Final approval of the manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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