Section: Miscellaneous

Original Research Article

ASSESSMENT OF STABILITY AND HEALING IN MANDIBULAR CONDYLAR FRACTURES MANAGED WITH LOCKING PLATE SYSTEMS VERSUS CONVENTIONAL MINIPLATES WITH EVALUATION OF BONE HEALING PATTERNS AND PATHOPHYSIOLOGICAL CHANGES

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ABSTRACT

Background: Mandibular condylar fractures are among the most common fractures of the maxillofacial region and pose significant challenges in achieving optimal functional and anatomical outcomes. **Objective:** To assess and compare the stability and healing outcomes of mandibular condylar fractures managed with locking plate systems versus conventional miniplates, focusing on bone healing patterns and associated biological responses.

Materials and Methods: This comparative observational study included patients with unilateral or bilateral mandibular condylar fractures treated surgically using either locking plate systems or conventional miniplates. Postoperative evaluation was conducted during a defined follow-up period to assess fracture stability, radiographic evidence of bone healing, occlusal alignment, and functional recovery. Healing patterns were analyzed using radiographic imaging, while clinical assessment included pain, mouth opening, and complications such as infection or malocclusion.

Results: Patients treated with locking plate systems demonstrated improved initial stability and more uniform bone healing patterns compared to those treated with conventional miniplates. Radiographic evidence indicated faster callus organization and reduced micromovement at the fracture site in the locking plate group. Clinically, better functional outcomes, including improved mouth opening and reduced postoperative discomfort, were observed. Complication rates were comparatively lower in the locking plate group.

Conclusion: Locking plate systems provide superior biomechanical stability and promote more favorable bone healing patterns in mandibular condylar fractures compared to conventional miniplates. Their use is associated with improved functional outcomes and reduced postoperative complications, making them a preferable option in appropriately selected cases.

Keywords: Mandibular condylar fracture, locking plate system, miniplates, bone healing, fracture stability, maxillofacial trauma.

INTRODUCTION

Mandibular condylar fractures constitute a significant proportion of maxillofacial injuries, accounting for approximately 25–40% of all mandibular fractures, and are frequently associated with functional disturbances such as malocclusion, limited mouth opening, and temporomandibular joint (TMJ) dysfunction.[1,2] The management of these fractures remains controversial, particularly regarding the optimal fixation technique that ensures both anatomical reduction and functional rehabilitation.[3] Open reduction and internal fixation (ORIF) have gained increasing acceptance due to their ability to provide direct visualization, anatomical alignment, and early mobilization.[4] Conventional miniplates have long been used as a standard fixation modality; however, their limitations include inadequate stability under functional loads, screw loosening, and micro-movement at the fracture site, which may compromise bone healing.[5,6] Locking plate systems represent an advancement in maxillofacial osteosynthesis by providing angular stability through a fixed screw–plate interface, minimizing the need for precise plate adaptation and reducing periosteal compression.[7] This biomechanical advantage is particularly important in the condylar region, where complex functional forces are exerted during mastication.[8] Several recent studies have suggested that locking plates may offer superior resistance to torsional and bending forces compared to conventional systems.[9] Bone healing in mandibular condylar fractures involves a complex cascade of biological processes, including inflammation, callus formation, and remodeling. Mechanical stability plays a crucial role in modulating these pathophysiological processes, directly influencing the quality and rate of bone regeneration.[10] Recent advancements in maxillofacial trauma management have emphasized the importance of biomechanical stability and early functional rehabilitation in mandibular condylar fractures. Locking plate systems have gained increasing attention due to their ability to provide angular stability without relying on friction between the plate and bone, thereby preserving periosteal blood supply and enhancing biological healing conditions. Biomechanical studies have demonstrated that locking plates reduce interfragmentary movement and provide superior rigidity under functional loading compared to conventional miniplates, particularly in anatomically complex regions such as the condylar neck.[11,12]

This improved mechanical environment contributes to more predictable fracture stabilization and facilitates early return to function. Conversely, conventional miniplates, while widely utilized due to their cost-effectiveness and surgical familiarity, may not consistently provide sufficient stability in high-load regions, increasing the risk of complications such as hardware failure, malocclusion, and delayed union. Emerging clinical and radiographic evidence suggests that locking plate systems are associated with more organized callus formation, reduced inflammatory response, and improved overall healing outcomes.[13,14,15] These differences in healing patterns and biomechanical performance highlight the need for further comparative evaluation to guide clinical decision-making, particularly in settings were optimizing both functional recovery and resource utilization is critical. Despite growing interest in locking systems, comparative evidence evaluating their impact on healing patterns and biological responses remains limited. Therefore, this study aims to assess and compare the stability and healing outcomes of mandibular condylar fractures managed with locking plate systems versus conventional miniplates, with particular emphasis on bone healing patterns and associated pathophysiological changes.

MATERIALS AND METHODS

This comparative observational study was conducted at a tertiary care maxillofacial surgery center over a period of 12 months. The study included patients presenting unilateral or bilateral mandibular condylar fractures who required open reduction and internal fixation. A total of 60 patients were recruited using non-probability consecutive sampling and were divided into two equal groups based on the fixation technique employed. Patients aged between 18 and 60 years with radiographically confirmed displaced condylar fractures were included in the study. Patients with pathological fractures, previous mandibular surgeries, systemic diseases affecting bone healing (such as uncontrolled diabetes or osteoporosis), or those lost to follow-up were excluded. Written informed consent was obtained from all participants prior to inclusion.

All surgical procedures were performed under general anesthesia by experienced maxillofacial surgeons using standardized surgical approaches. In Group A, fractures were stabilized using locking plate systems, while in Group B, conventional titanium miniplates were used. Anatomical reduction of fracture fragments was achieved in all cases prior to fixation. Postoperative care was standardized across both groups, including antibiotic therapy, analgesics, and physiotherapy for jaw mobilization. Patients were followed up at regular intervals (1 week, 4 weeks, 8 weeks, and 12 weeks postoperatively). Clinical evaluation included assessment of pain using the Visual Analog Scale (VAS), maximum interincisal mouth opening (measured in millimeters), occlusal stability, and presence of complications such as infection, malocclusion, or hardware failure. Radiographic evaluation was performed using orthopantomogram (OPG) and/or CT imaging to assess fracture alignment, callus formation, bone density, and evidence of resorption or delayed healing. Data were

entered and analyzed using SPSS version 25. Continuous variables such as mouth opening and pain scores were expressed as mean ± standard deviation and compared using independent sample t-tests. Categorical variables such as complications were analyzed using chi-square tests. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 60 patients were analyzed, with 30 patients in each group (locking plate group and conventional miniplate group). The baseline demographic characteristics were comparable between the two groups, with no statistically significant differences observed in age or gender distribution. The mean age in the locking plate group was slightly higher compared to the miniplate group; however, the difference was not statistically significant ($p>0.05$). Male predominance was observed in both groups as shown in table 1.

Table 1: Baseline Demographic Characteristics

Variable	Locking Plate Group (n=30)	Miniplate Group (n=30)	p-value
Mean Age (years)	34.6 ± 8.2	32.9 ± 7.5	0.38
Gender (Male/Female)	22 / 8	21 / 9	0.77

Patients treated with locking plate systems demonstrated better clinical recovery. At 12 weeks, the mean maximum mouth opening was significantly greater in the locking plate group compared to the miniplate group ($p<0.05$). Pain scores were also consistently lower in the locking plate group during follow-up visits as shown in table 2.

Table 2 shows male predominance in both groups.

Parameter	Locking Plate Group	Miniplate Group	p-value
Mouth Opening (mm)	38.5 ± 3.1	33.2 ± 3.8	0.001*
Pain Score (VAS)	1.8 ± 0.9	3.1 ± 1.2	0.002*
Occlusal Discrepancy (n)	2 (6.7%)	6 (20%)	0.12

Statistically significant

Radiographic evaluation revealed superior bone healing patterns in the locking plate group. Patients in this group exhibited earlier callus formation, better alignment, and reduced fracture gap compared to those treated with conventional miniplates as shown in table 3.

Table 3: Radiographic Healing Assessment

Parameter	Locking Plate Group	Miniplate Group	p-value
Early Callus Formation	26 (86.7%)	18 (60%)	0.02*
Good Alignment	28 (93.3%)	21 (70%)	0.03*
Bone Resorption Observed	2 (6.7%)	7 (23.3%)	0.04*

Statistically significant

Complication rates were lower in the locking plate group. Hardware-related complications such as loosening and instability were more commonly observed in the miniplate group as shown in table 4.

Table 4: Postoperative Complications

Complication	Locking Plate Group	Miniplate Group	p-value
Infection	1 (3.3%)	3 (10%)	0.30
Hardware Failure	1 (3.3%)	5 (16.7%)	0.08
Malocclusion	2 (6.7%)	6 (20%)	0.12

DISCUSSION

The findings of this study demonstrate that locking plate systems provide superior biomechanical stability and improved healing outcomes compared to conventional miniplates in mandibular condylar fractures. These results are consistent with recent literature emphasizing the advantages of angular stable fixation systems.[3,7] Mechanical stability is a critical determinant of fracture healing, particularly in load-bearing regions such as the mandibular condyle. Locking plates function as internal fixators, reducing interfragmentary movement and preserving periosteal blood supply, which enhances osteogenesis.[8,9] In contrast, conventional miniplates rely on friction between the plate and bone, which may lead to instability under functional loading.[5] Radiographically, this study demonstrated more uniform and rapid callus formation in the locking plate group. This aligns with findings reported by Neff et al., who highlighted improved bone healing dynamics with locking systems due to reduced microstrain at the fracture site.[2] Similarly, a study reported better functional outcomes and fewer complications with rigid fixation techniques in condylar fractures.[4] From a pathophysiological

perspective, reduced micromotion minimizes prolonged inflammatory responses and promotes early transition to the reparative phase of bone healing.[10] The lower incidence of bone resorption observed in the locking plate group further supports the role of stability in maintaining bone integrity. Functionally, improved mouth opening and reduced pain observed in this study are likely attributable to early mobilization and stable fixation, which prevent joint stiffness and muscle spasm.[6] These findings agree with a systematic review by Chrcanovic, which emphasized that rigid fixation enhances postoperative functional recovery.[1] A key strength of this study lies in its comparative design, which enabled a direct evaluation of clinical and radiographic outcomes between locking plate systems and conventional miniplates under standardized surgical and follow-up conditions. The use of both objective radiographic parameters and subjective clinical indicators, such as pain scores and functional mouth opening, provided a comprehensive assessment of fracture healing and patient recovery. Additionally, the inclusion of consistent follow-up intervals allowed monitoring of both early and late healing responses. These methodological strengths enhance the internal validity of the findings and support the growing body of evidence favoring locking plate systems in maxillofacial trauma management.[16,17]

Despite these strengths, certain limitations must be acknowledged. The relatively small sample size and single-center design may limit the generalizability of the findings to broader populations. Furthermore, the use of non-probability sampling introduces potential selection bias. The follow-up period, although sufficient to assess early healing outcomes, may not fully capture long-term complications such as temporomandibular joint dysfunction or late hardware failure. Additionally, cost-effectiveness analysis was not performed, which is particularly relevant in low-resource settings where affordability plays a crucial role in treatment decisions. Similar limitations have been highlighted in previous studies evaluating fixation techniques in mandibular fractures.[18,19] Based on the findings of this study, future research should focus on multicenter randomized controlled trials with larger sample sizes to further validate the superiority of locking plate systems. Long-term follow-up studies are also recommended to evaluate functional outcomes, joint health, and patient quality of life over extended periods. Moreover, incorporating cost-benefit analyses and patient-reported outcome measures would provide a more holistic understanding of treatment efficacy. Clinically, the adoption of locking plate systems should be considered, particularly in cases requiring enhanced stability and early mobilization, while individualized treatment planning remains essential to optimize outcome. [20]

CONCLUSION

Locking plate systems offer superior biomechanical stability, improved bone healing patterns, and better functional outcomes in the management of mandibular condylar fractures compared to conventional miniplates. Their ability to reduce micromovement and enhance biological healing responses makes them a preferred option in appropriately selected cases.

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