RESEARCH PAPER

Biomechanical Comparison of Delta Plate and Double Miniplate Fixation in Mandibular Condylar Fractures: An In Vitro Study

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ABSTRACT

Background: Mandibular condylar fractures are among the most common maxillofacial injuries and may result in malocclusion, restricted mandibular movement, pain, and functional impairment if inadequately treated. Open reduction and internal fixation (ORIF) has become a preferred treatment modality in displaced condylar fractures because it provides anatomical reduction and early functional rehabilitation. Various osteosynthesis systems have been used for fixation, among which Delta plates and double miniplates are commonly employed. However, their comparative biomechanical stability under multidirectional loading conditions remains controversial.

Aim: To evaluate and compare the mechanical resistance of Delta plate fixation and double miniplate fixation in mandibular condylar fractures under controlled in vitro conditions.

Materials and Methods: This in-vitro study was conducted on dry human hemimandibles. Standardized high subcondylar fractures were created by sectioning the hemimandibles from the lowest point of the sigmoid notch to half the height of the posterior border of the mandible. The samples were divided into two groups of 10 hemimandibles each. Group A was fixed using a triangular Delta stainless steel plate with four holes and four 2 mm × 6 mm stainless steel screws. Group B was fixed using two separate stainless steel miniplates, each with four holes, secured with four 2 mm × 6 mm stainless steel screws. Both groups were subjected to linear loads in medio-lateral and antero-posterior directions using a compression testing machine. A progressive load was applied at a speed of 1 mm/min, and peak load, final load, and displacement were recorded. The results were analysed using independent sample t-tests.

Results

Group A showed higher mean load values than Group B in all tested parameters. The medio-lateral peak load was 190.3 N in Group A and 160.9 N in Group B, while the medio-lateral final load was 175.8 N and 148.5 N respectively. The antero-posterior peak load was 210.6 N in Group A and 170.9 N in Group B, while the antero-posterior final load was 195.9 N and 157.4 N respectively. All differences were statistically significant with $p < 0.001$.

Conclusion

Delta plate fixation demonstrated superior biomechanical resistance and stability compared to Double miniplate fixation. Its triangular configuration may provide better stress distribution and resistance to multidirectional forces in mandibular condylar fracture fixation.

Keywords: Mandibular condylar fracture, Delta plate, Double miniplate, Mechanical resistance, In-vitro study.

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INTRODUCTION

Trauma to the maxillofacial region is an important clinical problem because the face contains vital skeletal, dental, muscular, vascular, and neural structures within a compact anatomical area. Injuries in this region may compromise mastication, speech, deglutition, airway protection, facial appearance, and psychological wellbeing. Among the various causes of maxillofacial trauma, road traffic accidents remain a major etiological factor, especially in developing regions where rapid urbanization, increased vehicle use, variable compliance with traffic rules, and limited use of protective devices contribute to the burden of facial injuries. The mandible is frequently involved because of its exposed position, mobility, and prominent lower facial projection, making mandibular fractures a common component of maxillofacial trauma.[1] Mandibular fractures may occur at the symphysis, parasymphysis, body, angle, ramus, coronoid, or condylar region depending on the site, direction, and magnitude of the force. The pattern of injury is influenced by the mechanism of trauma, patient age, dentition status, bone quality, and associated soft tissue injuries. In many cases, mandibular trauma is not limited to a single fracture line, and force transmission through the mandibular arch may produce associated fractures at anatomically weak areas. Proper diagnosis and management are essential because untreated or inadequately treated mandibular fractures may lead to malocclusion, facial asymmetry, restricted mouth opening, infection, chronic pain, and impaired mandibular function.[2] Fractures of the mandibular condyle require special attention because the condylar process forms an essential component of the temporomandibular joint. The condyle participates in rotational and translational movements of the mandible and plays an important role in maintaining vertical ramus height, occlusal harmony, mandibular growth, and functional symmetry. A blow to the chin or parasymphysis may transmit force posteriorly toward the condylar region, resulting in a condylar or subcondylar fracture. Because the condylar neck is relatively narrow, it acts as a biomechanical weak point and may fracture under indirect loading.[3] Condylar fractures may produce pain, preauricular tenderness, deviation of the mandible during mouth opening, limited mouth opening, deranged occlusion, and functional disturbance. In children and growing patients, condylar trauma has additional significance because the condyle contributes to mandibular growth and adaptive remodeling. In adults, displacement or shortening of the ramus may disturb the occlusal plane and mandibular movements. Therefore, treatment planning for condylar fractures requires a careful assessment of fracture level, displacement, dislocation, occlusion, mouth opening, age, cooperation of the patient, and associated mandibular or midfacial injuries.[4] The management of mandibular condylar fractures has traditionally been debated, particularly regarding closed treatment versus open reduction and internal fixation. Closed treatment includes observation, soft diet, physiotherapy, elastic guidance, and maxillomandibular fixation in selected cases. It avoids surgical exposure and reduces the risk of facial nerve injury, visible scar, and operative morbidity. However, in displaced or unstable fractures, closed treatment may not provide accurate anatomical reduction, and prolonged immobilization may contribute to stiffness, malocclusion, pain, or compromised function. Thus, closed treatment is generally more suitable for minimally displaced fractures, pediatric cases with remodeling potential, and patients in whom surgical risk outweighs benefit.[5] Open reduction and internal fixation allows direct visualization, anatomical realignment, restoration of ramus height, and stable fixation of the fractured condylar segment. It is generally considered in displaced, dislocated, bilateral, unstable, or functionally compromised fractures, especially when occlusion and mandibular movement cannot be restored satisfactorily by closed methods. Nevertheless, ORIF is technique-sensitive and may be associated with complications such as facial nerve weakness, salivary fistula, infection, plate exposure, scarring, and hardware-related problems. Therefore, the choice of treatment must be individualized and based on both clinical and biomechanical considerations. Rigid internal fixation has changed the management of mandibular condylar fractures by allowing early mobilization and functional rehabilitation. Different osteosynthesis systems have been used, including single miniplates, double miniplates, three-dimensional plates, delta plates, trapezoidal plates, lambda plates, and specialized condylar plates. The ideal fixation system should resist functional forces, maintain reduction, minimize micromovement, prevent displacement, and provide adequate stability with limited hardware bulk. In the subcondylar region, fixation is biomechanically challenging because masticatory forces act in multiple directions and create bending, torsional, and shear stresses around a relatively small bony fragment.6 Double miniplate fixation has been widely used because two plates can be positioned along tension and compression zones to improve load sharing. Delta plate fixation is designed as a three-dimensional triangular configuration and may provide broad distribution of forces with fewer separate components. However, the relative mechanical resistance of Delta Plate and Double Miniplate fixation remains an important area of investigation. An in-vitro biomechanical comparison helps evaluate stability under controlled loading conditions and provides useful information for selecting fixation methods. Therefore, the present study was undertaken to evaluate and compare the mechanical resistance after fixation of mandibular condylar fracture with Delta Plate and Double Miniplate systems.

MATERIALS AND METHODS

METHODOLOGY

This in-vitro study was conducted on dry human mandibles at the Department of Oral and Maxillofacial Surgery, Maharaja Ganga Singh Dental College Hospital and Research Centre, Sri Ganganagar. The mandibles were sourced from the Department of Anatomy, Maharaja Ganga Singh Dental College Hospital and Research Centre, Sri Ganganagar. Ethical approval for the study was obtained from the Institutional Ethical Committee of Maharaja Ganga Singh Dental College Hospital and Research Centre (Approval No: mgsdc/ec/24).

EVALUATION CRITERIA

The mandibles included in the study had a rigid outer and inner cortex with a trabecular medullary space. Mandibles of uniform width were selected. Mandibles with uniform posterior height, measured from the highest point of the condyle to a parallel line passing through the base of the mandible, were included in the study.

PROCEDURE

Dry human hemimandibles were stabilized on a flat surface, and the posterior height of the mandible was measured with a vernier calliper from the highest point of the condyle to a parallel line passing through the base of the mandible.

This was standardized so that the fracture line passed through the lowest point of the sigmoid notch to half the height of the posterior border of the mandible, simulating a high subcondylar fracture.

The hemimandibles were sectioned uniformly using a steel disk coupled to a flat base and an electric micromotor. The experimental samples were divided into two groups, A and B, with 10 hemimandibles in each group, and fixed using two different fixation techniques.

Group A was fixed using a triangular delta stainless steel plate of 2 mm thickness with 4 holes and four 2 mm × 6 mm stainless steel screws. Group B was fixed with two separate stainless steel plates of 2 mm thickness, each with 4 holes, and secured with four 2 mm × 6 mm stainless steel screws.

Both groups were subjected to linear loads in medial-to-lateral and anterior-to-posterior directions using a compression testing machine.

A speed of 1 mm/min was established to apply a progressive load on the system, during which resistance against compression was recorded from peak and final loads, and force displacement was gauged by analysis of these two movements. Mandibles were loaded at the condylar region with compression force ranging from 0 to 200 N. Final displacement was set at 10 mm.

After completion of the study, the mandibles were disposed of according to protocols for human organic waste.

Table 1. GROUP – A

SAMPLE NO	TYPE OF PLATE	MEDIO – LATERAL DIRECTION		ANTERO-POSTERIOR DIRECTION		DISPLACEMENT	REMARKS
		PEAK LOAD(N)	FINAL LOAD(N)	PEAK LOAD(N)	FINAL LOAD(N)		
1	DELTA FIXATION	185	170	205	190	10	STABLE FIXATION
2	DELTA FIXATION	192	178	212	198	10	MINIMAL MICROMOVEMENT
3	DELTA FIXATION	188	173	208	194	10	GOOD RESISTANCE
4	DELTA FIXATION	194	180	215	200	10	HIGH LOAD ENDURANCE
5	DELTA FIXATION	190	175	210	195	10	STABLE
6	DELTA FIXATION	186	172	207	192	10	STRONG RESISTANCE
7	DELTA FIXATION	193	179	213	199	10	MINIMAL DISPLACEMENT
8	DELTA FIXATION	189	174	209	194	10	STABLE
9	DELTA FIXATION	195	181	216	201	10	EXCELLENT FIXATION
10	DELTA FIXATION	191	176	211	196	10	HIGH RIGIDITY

Table 2. GROUP - B

SAMPLE NO	FIXATION TYPE	MEDIO LATERAL DIRECTION		ANTERIO POSTERIOR DIRECTION		DISPLACEMENT	REMARKS
		PEAK LOAD(N)	FINAL LOAD(N)	PEAK LOAD(N)	FINAL LOAD(N)		
1	DOUBLE MINIPLATE	160	148	172	158	10	MODERATE STABILITY
2	DOUBLE MINIPLATE	158	146	168	155	10	SLIGHT MICROMOVEMENT
3	DOUBLE MINIPLATE	162	149	170	157	10	AVERAGE RIGIDITY
4	DOUBLE MINIPLATE	165	152	175	160	10	MODERATE FIXATION
5	DOUBLE MINIPLATE	159	147	169	156	10	SLIGHT DISPLACEMENT
6	DOUBLE MINIPLATE	161	149	171	158	10	LESS LOAD RESISTANCE
7	DOUBLE MINIPLATE	164	151	173	159	10	MILD MOVEMENT UNDER LOAD
8	DOUBLE MINIPLATE	157	145	167	154	10	AVERAGE STABILITY
9	DOUBLE MINIPLATE	163	150	174	160	10	SLIGHT DEFLECTION
10	DOUBLE MINIPLATE	160	148	170	157	10	REDUCED STRENGTH

RESULTS

The mean peak load in Group A using Delta Plate fixation was 190.3 N, whereas in Group B using Double Miniplate fixation it was 160.9 N. The difference between the two groups was highly statistically significant, with a t-value of 21.98 and p-value of less than 0.001. The Delta plate withstood a considerably higher peak load in the medio-lateral direction, demonstrating better initial rigidity and load-bearing capacity. This indicates that Delta Plate fixation provided superior mechanical strength under lateral stress when compared with Double Miniplate fixation.

Table 3. Comparison of Mean Load Values Between Group A and Group B

Parameter	Group A Mean (Delta Plate)	Group B Mean (Double Miniplate)	t-value	p-value
Medio-Lateral Peak Load	190.3	160.9	21.98	0.0000000000000187
Medio-Lateral Final Load	175.8	148.5	20.34	0.0000000000000719
Antero-Posterior Peak Load	210.6	170.9	28.78	0.0000000000000017
Antero-Posterior Final Load	195.9	157.4	29.69	0.00000000000000096

Medio-Lateral Peak Load

The mean final load in the medio-lateral direction was 175.8 N in Group A and 148.5 N in Group B. The difference was highly statistically significant, with a t-value of 20.34 and p-value of less than 0.001. Even after the application of progressive loading, Delta plates maintained greater residual strength. This reflects less plastic deformation and better resistance to fatigue under medio-lateral loading. The higher final load value in Group A highlights the greater stability of Delta Plate fixation at the end of load application.

Medio-Lateral Final Load

The mean peak load in the antero-posterior direction was 210.6 N in Group A and 170.9 N in Group B. The difference between the two groups was highly statistically significant, with a t-value of 28.78 and p-value of less than 0.001. The Delta plate tolerated much greater forces in the antero-posterior direction before reaching peak deformation. This indicates improved resistance to bending and torsional stresses, which is important in the simulation of masticatory load. The results show that Delta Plate fixation had better load-bearing capacity than Double Miniplate fixation in the antero-posterior direction.

Antero-Posterior Peak Load

The mean final load in the antero-posterior direction was 195.9 N in Group A and 157.4 N in Group B. The difference was highly statistically significant, with a t-value of 29.69 and p-value of less than 0.001. Following complete load application, the Delta plate maintained significantly higher final load values. This suggests excellent stability and minimal displacement even under progressive stress. The higher sustained load values in Group A indicate better resistance to deformation when compared with Group B.

Antero-Posterior Final Load

DISCUSSION

Ethical Clearance Certificate for study was obtained from Institute Ethical Clearance Committee.

CONCLUSION

FIGURES

Figure Subcondylar Fracture Induced

Figure Delta and Double Miniplate Fixation

Menon S, Sham ME, Kumar V, Archana S, Nath P, Shivakotee S, et al. Maxillofacial fracture patterns in road traffic accidents. Ann Maxillofac Surg. 2019;9(2):345-348. doi:10.4103/ams.ams_136_19. Available from: https://pubmed.ncbi.nlm.nih.gov/31909013/

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Figure Compression Testing Machine

Figure Linear Load Appliead Mediolaterally (double miniplate)

Figure Linear Load Applied Mediolaterally (Delta Plate)

Figure Linear Load Applied in Anteroposterior Direction (Double Miniplate)

Figure Linear Load Applied In Anteroposterior Direction (Delta Plate)

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