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Original Research Article

Evaluation of Clinical and Radiographic Outcomes Following Management of Condylar Fractures Using 3-Dimensional Plating System: A Prospective Observational Study

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Abstract
Background: *Mandibular condyle fractures are among the most common maxillofacial injuries, often causing functional impairments such as restricted jaw mobility and occlusal discrepancies. The advent of 3-dimensional (3D) plating systems has introduced a promising approach for enhanced fixation and rehabilitation. This study evaluates the efficacy of 3D plating systems in improving mandibular function following surgical intervention for condylar fractures.*
Methods: *A prospective study was conducted on 15 patients with clinically and radiographically diagnosed mandibular condylar fractures at a tertiary hospital in Western Maharashtra. Surgical intervention involved open reduction and internal fixation (ORIF) with a titanium 3D plating system via a retromandibular approach. Functional parameters, including mouth opening, lateral movement, and protrusive movement, were assessed preoperatively and postoperatively over a 24-week follow-up period. Data were analyzed using paired t-tests, with significance set at $P < 0.05$.*
Results: *The mean preoperative mouth opening was 17.13 mm (SD = 3.62), which improved significantly to 37.73 mm (SD = 2.15) postoperatively (mean difference = 20.60 mm; 95% CI: 18.26–22.94; $P < 0.001$). Lateral movement increased from 4.40 mm (SD = 1.96) to 8.67 mm (SD = 1.45) (mean difference = 4.27 mm; 95% CI: 3.30–5.24; $P < 0.001$), and protrusive movement improved from 4.67 mm (SD = 2.13) to 8.13 mm (SD = 1.19) (mean difference = 3.47 mm; 95% CI: 2.42–4.51; $P < 0.001$). Improvements were significant from the second week onward for mouth opening and lateral movement and by the sixth week for protrusive movement.*
Conclusions: *The use of 3D titanium plating systems in mandibular condyle fractures provides significant functional recovery, with substantial improvements in mandibular mobility over a 24-week period. This approach offers an effective solution for restoring jaw function, making it a valuable option in maxillofacial surgery. Further studies with larger cohorts are recommended to validate these findings and refine surgical protocols.*

Keywords: *Mandibular condyle fractures, 3D titanium plating, Open reduction and internal fixation (ORIF), Mandibular mobility, Maxillofacial trauma management.*

Introduction
The mandible plays a pivotal role in the maxillofacial skeleton due to its distinct structure and function.[1] As a robust, horse-shoe-shaped bone, it consists of several critical regions: the body, ascending ramus, and angle. Its two lateral halves fuse at the midline during embryonic development, forming the symphysis menti, with structural features like the mental trigone providing support to the chin. The mandible is unique as it's the only movable bone in the craniofacial skeleton, apart from the ossicles, enabling crucial functions such as mastication. Its vulnerability to trauma, particularly in motor vehicle accidents and sports injuries, is well-documented, with mandibular fractures especially involving the condyle being among the most common.[2-4] The condylar process is critical for craniomandibular articulation at the temporomandibular joint (TMJ), and its fractures can lead to significant complications, including functional limitations, displacement, and even severe conditions like displacement into the middle cranial fossa.[5,6]

Management of mandibular condylar fractures has long been debated, with both non-surgical and surgical approaches available.[7-9] In recent times, open reduction and internal fixation (ORIF) have gained favor due to their advantages in restoring function more quickly and avoiding prolonged immobilization.[10,11] Various fixation systems have been developed to improve outcomes, with innovations such as the use of mini dynamic compression plates, miniplates, and even biodegradable plates. More recently, 3D titanium plates have emerged as a game-changing solution, offering enhanced stability and ease of use.[12] These plates, designed to resist forces in three dimensions, have shown promising results in mandibular fracture fixation, reducing surgery time and minimizing tissue damage. This study aims to further explore the efficacy of 3D plating systems in the treatment of mandibular fractures, contributing valuable data to guide future clinical decisions in this field.

Methods

This was a prospective study, conducted in a tertiary hospital in Western Maharashtra over a period of 1.5 years. The study examined 15 patients with condylar fractures. Patients with clinically and radiographically diagnosed condylar fractures with or without other associated fractures of mandible (angle, parasymphysis, symphysis and body) were included in the study. Patients with comminuted fractures, malunited fractures, infected fractures of the mandibular condyle, diacapitular fractures that may preclude fixation as the mode of management, patients with a previous history of maxillofacial trauma / surgical procedures that may confound occlusal status, mandibular movements and neurological deficit,patients with condylar fractures coexisting along with fractures of the midface, completely/partially edentulous patients where an inadequate number of teeth does not permit assessment of occlusion and intermaxillary fixation and patients with medical illness or systemic condition(s) that may pose a risk while administration of general anaesthetic agents and complicate wound healing were excluded from the study.

Demographic data, history and clinical examination were recorded for all patients. The patients were clinically evaluated regarding the status of mouth opening, the deviation on mouth opening, range of lateral excursive movements and protrusive movements; pain, tenderness and swelling in the region of TMJ and for occlusal discrepancies viz., open bite and crossbite. Extraoral and intraoral photographs were taken for records. Radiographic assessments were performed through orthopantomography and cone-beam computed tomography, with fractures classified according to the Strasbourg Osteosynthesis Research Group guidelines. Surgical intervention involved open reduction and internal fixation (ORIF) of fractures, using a titanium 3D plating system and performed through a retromandibular incision. Each patient underwent detailed preoperative assessments and inter-maxillary fixation (IMF), followed by the ORIF procedure under general anesthesia. Postoperative care included antibiotics, pain management, dietary restrictions, and careful monitoring to promote recovery. Patients were observed for up to 24 weeks, with follow-up assessments of mandibular movements, occlusal alignment, and healing progress. The entire data is statistically analysed using Statistical Package for Social Sciences (SPSS version 21.0, IBM Corporation, USA) for MS Windows. The p-values less than 0.05 are considered to be statistically significant.

Tables

Table 1: - Demographic and clinical findings of the study group

Parameters	N (%)
Age	
<30	13.3
31-40	60
41-50	13.3
51-60	13.3
Gender	
Male	73.3
Female	26.7
Mode of injury	
Accidental fall	13.3
Interpersonal altercation	6.7
Motor Vehicle Accident	80
Classification as per Strasbourg Osteosynthesis Research Group	
Condylar Base	73.3
Condylar Neck	26.7
Classification as per Bhagol et al	
Class 2	33.3
Class 3	66.7

Table 2: - Comparison of preoperative and postoperative jaw movements in patients

	Pre OP (n=15)		Post OP (n=15)		Mean Difference (95% CI)	P-value
	Mean	**SD**	**Mean**	**SD**		
Mouth opening (mm)	17.13	3.62	37.73	2.15	20.60 [18.26-22.94]	0.001***
Lateral movement (mm)	4.40	1.96	8.67	1.45	4.27 [3.30 – 5.24]	0.001***
Protrusive movement (mm)	4.67	2.13	8.13	1.19	3.47 [2.42 – 4.51]	0.001***
P-values by Paired t-test. P-value<0.05 is considered to be statistically significant. ***P-value<0.001.						

Table 3: Comparison of mean jaw movements at each follow-up interval

	Pre OP	Post OP (immediate)	1 week	2 weeks	3 weeks	6 weeks	12 weeks	24 weeks
Mouth opening (mm)								
Mean	17.13	19.40	22.93	26.20	31.33	35.13	36.67	37.73
SD	3.62	3.40	2.22	2.81	4.45	3.52	2.72	2.15
P value		**0.08^{NS}**	**<0.001***	**<0.001***	**<0.001***	**<0.001***	**<0.001***	**<0.001***
Lateral movement (mm)								
Mean	4.40	4.87	5.27	6.20	6.80	7.87	8.13	8.67
SD	1.96	2.03	1.87	1.32	1.32	1.19	1.41	1.45
P value		**0.532^{NS}**	**0.228^{NS}**	**0.007**	**<0.001***	**<0.001***	**<0.001***	**<0.001***
Protrusive movement (mm)								
Mean	4.67	4.67	5.13	5.67	5.87	7.07	7.73	8.13
SD	2.13	1.95	1.55	1.29	1.30	1.39	1.28	1.19
P value		**1^{NS}**	**0.498^{NS}**	**0.127^{NS}**	**0.07^{NS}**	**<0.001***	**<0.001***	**<0.001***
P-values by Paired t-test. P-value<0.05 is considered to be statistically significant. NS - Non significant ***P-value<0.001.								

Results

The mean ± SD of age of the study group was 38.6 ± 8.4 years with a male to female sex ratio of 2.75:1. Other clinical findings of the study group are given in Table 1.

The study evaluated mandibular function by comparing preoperative and postoperative values of mouth opening, lateral movement, and protrusive movement in patients with condylar fractures treated with a 3-dimensional plating system. For mouth opening, the preoperative mean was 17.13 mm (SD = 3.62), which significantly improved postoperatively to 37.73 mm (SD = 2.15), with a mean difference of 20.60 mm (95% CI: 18.26–22.94; P < 0.001). Lateral movement also showed marked improvement, increasing from a preoperative mean of 4.40 mm (SD = 1.96) to 8.67 mm (SD = 1.45) postoperatively, with a mean difference of 4.27 mm (95% CI: 3.30–5.24; P < 0.001). Similarly, protrusive movement improved significantly from a preoperative mean of 4.67 mm (SD = 2.13) to a postoperative mean of 8.13 mm (SD = 1.19), with a mean difference of 3.47 mm (95% CI: 2.42–4.51; P < 0.001). These results, confirmed by paired t-tests, demonstrate statistically significant improvements across all three parameters (P < 0.001), underscoring the effectiveness of the 3-dimensional plating system in enhancing mandibular function post-surgery.

The study tracked the progression of mouth opening, lateral movement, and protrusive movement in patients following treatment with 3-dimensional plating over a 24-week period. For mouth opening, the mean preoperative value of 17.13 mm (SD = 3.62) showed significant improvements over time, reaching 37.73 mm (SD = 2.15) by the 24th week. Initial postoperative gains were observed immediately after surgery (mean = 19.40 mm; SD = 3.40), though this increase was not statistically significant (P = 0.08). Significant improvements were seen by the second week (P < 0.001), with continued growth at each follow-up, confirming a substantial increase in mouth opening post-surgery.

Lateral movement also improved consistently, with the mean increasing from 4.40 mm (SD = 1.96) preoperatively to 8.67 mm (SD = 1.45) at 24 weeks. Although the immediate postoperative mean of 4.87 mm (SD = 2.03) was not statistically significant (P = 0.532), subsequent evaluations demonstrated significant increases starting at the three-week mark (P = 0.007), which continued through each follow-up.

Protrusive movement saw similar improvements, with the preoperative mean of 4.67 mm (SD = 2.13) rising to 8.13 mm (SD = 1.19) at the end of the 24-week period. Early postoperative values did not indicate significant change, with a mean of 4.67 mm (SD = 1.95) immediately after surgery (P = 1), and gradual, non-significant increases up to three weeks. Significant changes in protrusive movement began by six weeks (P < 0.001), with continued improvement over the remaining follow-ups. (Table 3)

Figure

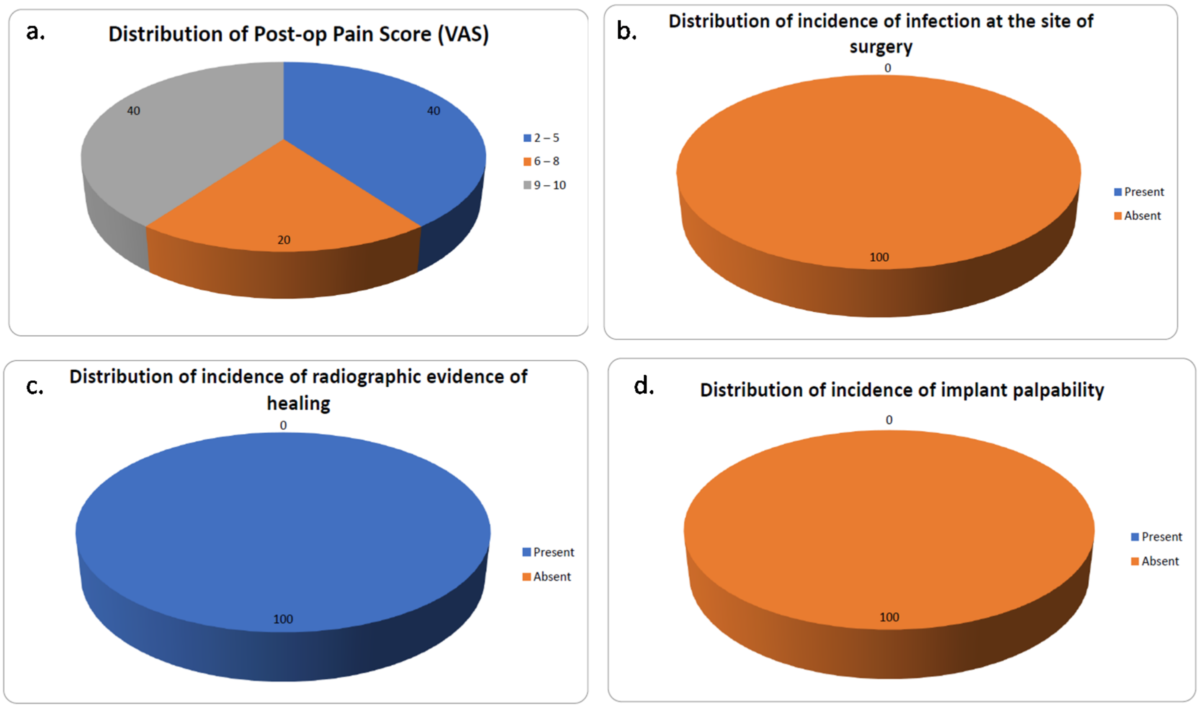

Figure 1: Distribution of a. Post OP VAS score, b. incidence of infection at surgery site, c. incidence of radiographic evidence of healing, d. incidence of implant palpability

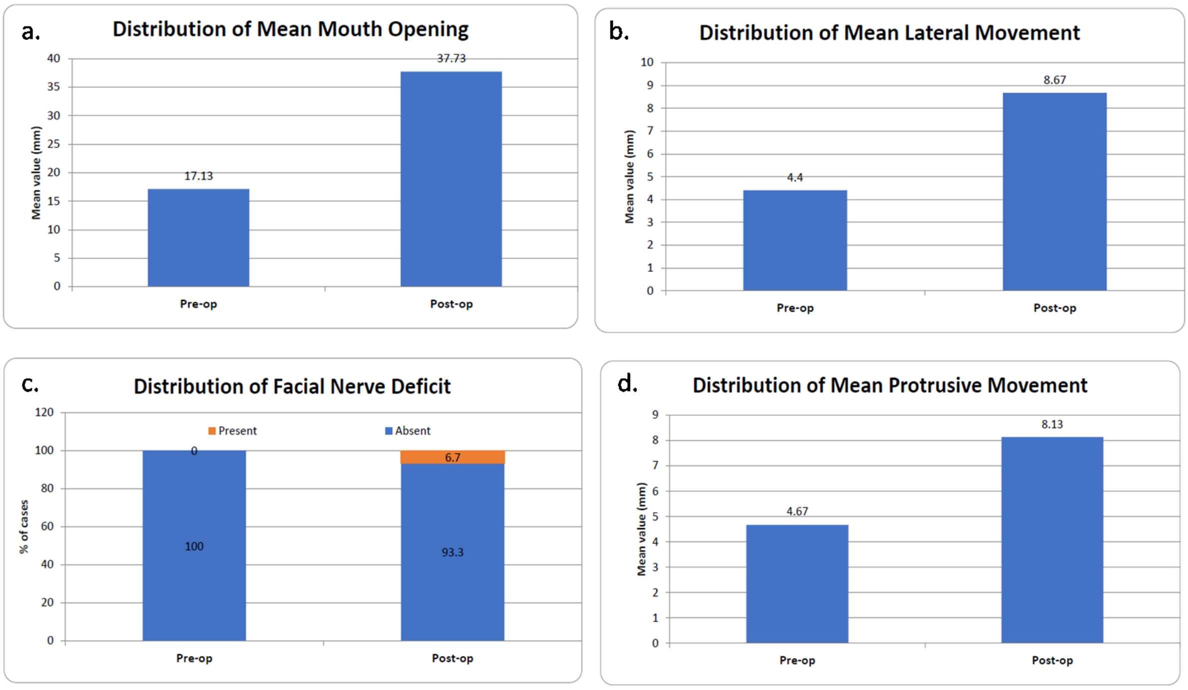

Figure 2: Distribution of a. mean mouth opening, b. mean lateral movement, c facial nerve deficit, d. mean protrusive movement

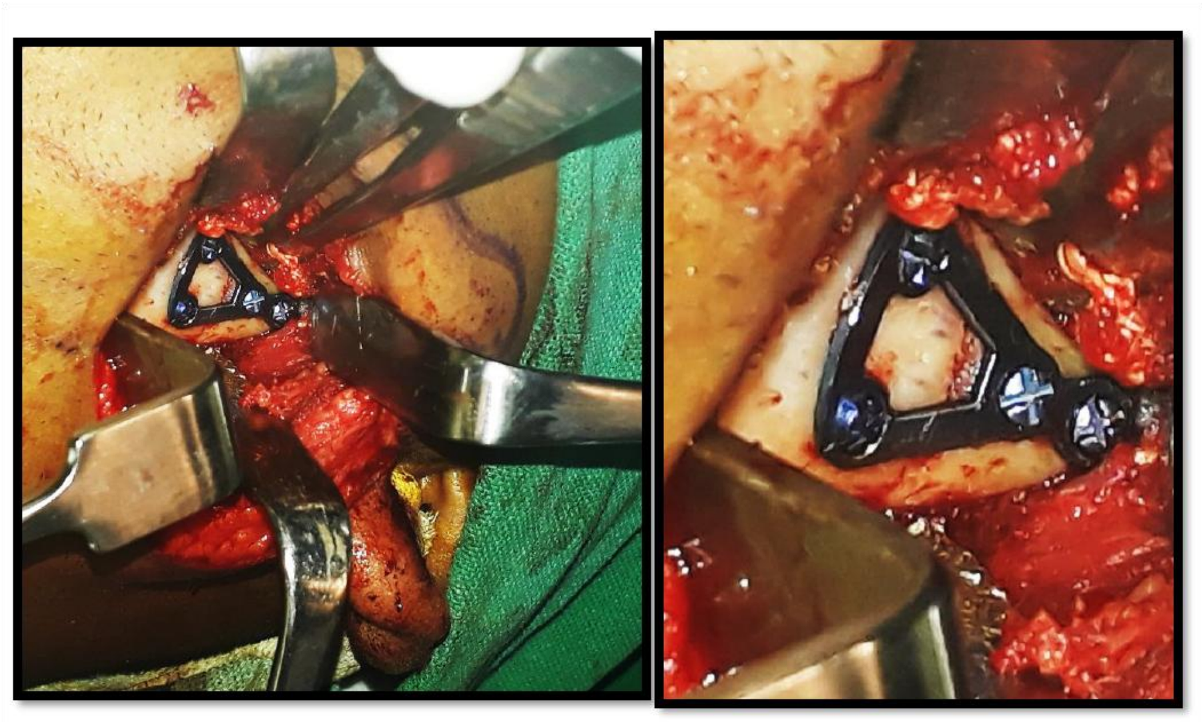

Figure 3: Fixation of the fracture using the 3D plate

Discussion

The unique morphology of the mandible and its prominent position in the facial skeleton makes it particularly vulnerable to trauma. The condylar region constitutes the most frequent site for mandibular fractures accounting for 17.5% to 52% of all mandibular fractures.[13,14] Out of these, 80% of condylar fractures are unilateral while 20% are bilateral.[15] The most common incidence of these fractures occurs between the ages of 20 and 39 years, while the male: female ratio is 3:1. In our study of fifteen subjects, 11 belonged to the age group of 20 to 40 years, and the male-female ratio was 2.75:1 which is commensurate with the incidence rates previously reported in other studies.[16]

The everlasting debate regarding the choice among surgical and non-surgical options for treatment of mandibular condyle is still on with many surgeons opting for either of the two and achieving clinically similar results.[17] Zide and Kent, in their landmark study, tried to lay down guidelines for selecting the suitable treatment option for condylar fractures.[18,19] The most critical determinants in the assessment of condylar fractures are the displacement of the condyle and shortening of the ramus height. Many studies have found that patients with a displacement of 10° or more, or shortening of ramus height by 2mm or more are benefited by surgical treatment irrespective of the level of condylar fracture.[20,21] Bhagol A, Singh V, Kumar I and Verma A, proposed a classification for management of subcondylar fractures using these two determinants and categorised fractures as minimally displaced, moderately displaced and severely displaced fractures.[22] In our study, 10 (66.7%) patients had severely displaced fractures and remaining 5 (33.3%) had moderately displaced fractures and based on the guidelines, all were treated surgically.

The treatment goals kept in consideration while managing condylar fractures were; anatomical reduction of the fractured fragments, restoration of occlusion, correction in the range of mandibular movements and facilitating early return to function with minimum surgical trauma. In order to access the condyles, numerous approaches have been described. All the transcutaneous incisions are designed keeping in mind, the terminal branches of the facial nerve, the marginal mandibular branch in particular, which passes in the vicinity of the lower border of the mandible. Submandibular or Risdon's approach allows the inferior mandible and facilitates the distraction of the ramus inferiorly but has a disadvantage of being far from the actual area of interest and providing limited surgical exposure to the site.[23] The retromandibular approach is more useful for exposure, reduction and fixation of the fractures using plates and screws.[23] The dissection is carried out through the substance of parotid gland, which poses a risk for post-operative complications like sialocoele or formation of a salivary fistula. The retromandibular incision and an APTM approach gives a quick and rather direct approach to high and low subcondylar fractures for fixation and also to the gonial angle for the downward distraction of the mandibular ramus.[24] With this incision and approach, there is a more noticeable scar in comparison with other incisions and also a potential risk of damage to the facial nerve. Manisali M, Amin M, Aghabeigi B and Newman L reported an incidence of postoperative facial nerve weakness to be 30%.[25] In our study, we approached all the fractures using the retromandibular incision and APTM approach. We encountered one patient with the facial nerve weakness in the postoperative period, which was statistically insignificant. This deficit could be attributed to retraction related injury. Furthermore, the patient recovered gradually without intervention by the end of their follow-up period.

A variety of methods of modalities exist in common use for direct fixation of fracture fragments like the anchor screw, two miniplates and Y plates.[26] Farmand M and Dupoirieux L shared their experiences about the use of 3-dimensional plates in fixation of mandibular fractures which were its easy use, excellent resistance against torque forces and compact form of the plate.[27] The initial design of 3-dimensional plates used for mandible was quadrangular with 1mm thick connecting struts. This ensured an easy adaptation of the plate onto the bone while ensuring a good blood supply due to the presence of implant free area between these arms. Meyer et al. worked on this concept and applied in the region of the condyle and designed a delta-shaped plate.[28] With the open reduction and fixation of mandibular condylar fractures, the internal fixation should be sufficiently rigid to withstand physiological strains and to achieve optimum results. In order to achieve this, two osteosynthesis plates are applied, one along with the posterior border of the mandible, i.e. the zone of compression and second, just inferior to the sigmoid notch, i.e. the zone of traction. The 3-dimensional plates for the condyles were initially developed as trapezoidal plates in order to replace the two-miniplate osteosynthesis with a single bone implant. These new plates merged the concepts both the 3-D plates and the double adaptation miniplate technique. The trapezoidal shape allows the precise location of the anterior arm over the ‘ideal’ osteosynthesis line. The anterior arm acts as a tension bonding plate and replaces the superior plate of the double plate technique. The posterior arm, placed along the axis of the condylar neck, resists the bending strains along that line. Deforming-forces while functional movements on a fractured condyle act from five different directions – posteroanterior, anteroposterior, lateromedial, mediolateral and torsion forces. The 3-dimensional nature of the plate due to its triangular shape provides internal stability, as well as more optimal leverage. To counteract posterior or anterior loads onto the proximal fragment, the base of the plate is safely fastened in the distal fragment with two screws set apart at a distance to provide optimal leverage.

Furthermore, the sides of the triangle act alternately as a tension band depending on load direction. Against torsion forces, the plate is more resistant because the two sides of the triangle and the anchoring screws have a distance in the horizontal; consequently, lower loads are transmitted into the bone due to better leverage. For medial tilt, tension forces are applied on the plate. No particular thickness of the plate is required if the surfaces of the reduced bone fragments support each other. If there is an interfragmentary gap after osteosynthesis, the thickness of the plate is essential because the plate must withstand bending forces. The delta-shaped modification further facilitates engagement of a higher and narrower condylar neck fractures where the adaptation of miniplates would be otherwise difficult. This also reduces the time consumed in the adaptation of two plates. The average time taken for the management of our surgeries was 150.9 ± 21.4 min. Overall, Using the new delta-shaped plate for condylar neck fractures has three main advantages; neutralisation of changing strains at the anterior, lateral, and posterior borders; the additional stabilisation provided by a compression miniplate; and a small, manageable osteosynthesis plate.[29]

The primary purpose of treating the fractures of the mandible, and condyle, in particular, is to facilitate mandibular functions. On observing the results of our study, one may notice that on average, patients showed minimal improvement in the immediate postoperative period. This can be attributed to the post-operative pain, muscular guarding and postoperative oedema. However, a statistically and clinically significant improvement can be noted at the end of the first week onwards when compared to the pre-operative values. In between the follow-up intervals, significant weekly improvements can be noticed up to the end of the sixth week, after which there is a marginal improvement. A duration of six weeks is the average requirement for mandibular healing.[30]

Similarly, we observed that the mean protrusive and lateral range of motion were statistically significant (p-value < 0.05) suggestive of satisfactory restoration of functional movements after reduction and fixation. However, a statistically significant outcome was noted only after the second week in lateral movements and at the end of the third week in protrusive movements which, in turn, can be attributed to patient's lack of motivation to attempt such movements due to post-operative pain and oedema. While comparing the mean lateral and protrusive movement at each follow-up appointment with the previous one, we see a statistically insignificant outcome (P-value >0.05). When average improvement in these motions is distributed over the follow-up period, it gives a small magnitude for measurement. These values, although statistically insignificant, are important clinically and show a steady and gradual improvement.

Post-operative pain scores in all the patients were high (mean = 8.26). Adequate pain management was done with analgesics in the postoperative period. We see a statistically insignificant, although a clinically significant difference in the mean pain score at the end of the first week. This could be as patients tend to overestimate the pain, which is further compounded by the post-anaesthetic discomfort and the emotional factor associated with the surgery and hospital stay. All the patients showed a gradual and significant improvement in pain score at each subsequent follow-up appointment. At the end of the follow-up period, the mean pain score was 0.13 and statistically very significant when compared to the immediate post-op period (P-value < 0.001).

Post-operative malocclusion was found in one patient, whereas remaining (93.3%) did not have any such discrepancies. This finding was commensurate with the observations of Meyer et al. in 2008.[30] Additionally, three patients had a deviation in mouth opening in the post-operative period who were given training elastics for a period of 2 to 4 weeks, and the end of the follow-up period, such discrepancies had resolved. All patients had a minimally visible if not wholly inconspicuous, linear scar in the retromandibular region without any incidence of dehiscence, SSI or salivary complications *(Figure 3)*. All patients showed evidence of adequate healing on radiographic examination and no osteolysis around the bone implants was encountered.

All patients in our study showed a decent surgical outcome with satisfactory occlusal function and no incidence of implant palpability, failure or peri-implant infection in the follow-up period.

The limitations of this study include its small sample size, which restricts the generalizability of the findings to broader populations. Additionally, the study lacks a control group to compare surgical versus non-surgical outcomes, limiting our ability to assess the effectiveness of different treatment modalities. Furthermore, pain assessment relied on patient self-reporting, which could introduce subjective variability.

Conclusion

Our study is a single operator prospective observational study which shows that 3-dimensional plates are efficacious and have several advantages due to their inherent geometry for fixation of fractures of the mandibular condyle. A plethora of studies have been mentioned in the literature, and they find 3-dimensional plates to be superior to the other methods of fixation available for practice. Our study, based on relatively small sample size, used the fixation system and achieved satisfactory clinical and radiographic outcomes in the management of patients with condylar fractures. We note that ease of adaptation, even on a smaller proximal fragment, shorter duration of surgery and overall lesser implant material as compared to the conventional fixation systems were the salient features of 3-dimensional plates. It is recommended that long term comparative trials with a larger sample size might be more conclusive in establishing a definite opinion and guidelines for the use of such plates.

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