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Original Article

Does the biplane three-dimensional miniplate design provide stable fixation for mandibular angle fractures? A clinical study and proposal for novel radiographic criteria

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ABSTRACT

Background: The posterior anatomical position and complex biomechanics of mandibular angle fractures (MAF) make their management more complicated than other mandibular fractures. The shortcomings of semi-rigid and rigid fixations have led to the development of a biplane three-dimensional (3D) miniplate design to fixate angle fractures in two perpendicular planes. The aim is to determine whether using a Biplane 3D miniplate could provide a feasible, effective, and reliable fixation for displaced MAFs.

Materials and Methods: This prospective, quasi-experimental, clinical study was conducted on adult patients with displaced MAFs. The primary outcome (occlusion) and secondary clinical outcomes (fracture stability and adequate mouth opening) were recorded in the first 2 weeks and the 2nd and 6th months postoperative. Appropriate reduction (secondary outcome) was assessed with novel radiographic criteria in the vertical and horizontal planes. Statistical analysis was performed using SPSS version 22 and included Fisher's exact and Chi-square tests. The level of significance was set at $P < 0.05$.

Results: Twenty-one patients with MAFs (nine isolated fractures) were operated on and followed for 3–6 months (mean: 4.95 months). Only two cases (9.52%) in the nonisolated fracture group showed mild occlusal derangement, which resolved with heavy elastic therapy. Adequate mouth opening was gradually resumed in both groups within the 1st month. No postfixation complications were observed. Radiographic criteria measurement revealed 14.29% and 28.6% mild vertical and horizontal radiographic malalignment without detectable clinical signs.

Conclusion: Biplane 3D miniplate fixation shows promising results in the management of MAFs with minimal complications, suggesting that it is safe and effective. Concomitant management of displaced mandibular fractures does not seem to affect treatment outcomes.

Key Words: Displaced angle fracture, internal rigid fixation, mandibular angle fracture, miniplate angle fixation, radiographic criteria, three-dimensional miniplate

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INTRODUCTION

The posterior anatomical position and complex biomechanics make mandibular angle fractures (MAF) management more complicated than that of other mandibular fractures.[1] The objectives of the ideal treatment are perfect anatomic reduction, stable fixation, and painless mobilization of the injured area around its articulation.[2] The use of various treatment methods, including a single superior border miniplate, a single inferior border plate (2.3/2.7 mm), two miniplates on the superior and inferior borders, and geometric plates for internal fixation of MAFs, indicates the lack of an optimal treatment approach.[3,4]

By introducing semi-rigid fixation using easily bendable miniplates with monocortical screws along the ideal line of osteosynthesis by "Champy *et al*.,"[5] rigid methods are being replaced by more functionally fixation techniques.[6] Therefore, single miniplate fixation based on the Champy *et al.* technique[5] has become the most common method for angle fractures in many facilities.[6,7] Despite its popularity and fewer complications compared to other fixation techniques,[4] the instability associated with single miniplate fixation at the superior border has raised concerns in biomechanical studies. This instability can lead to the opening of the fracture line at the lower border and cause lateral displacement of the proximal segment.[8,9]

The limitations of semi-rigid and rigid fixations have led to the development of quadrilateral three-dimensional (3D) miniplates, which can be considered a two-plate system providing functionally stable fixation with low complication rates.[4,10-12] Unlike other plates, the stability of 3D miniplates is achieved through a broad surface area and its configuration, not by thickness or length.[13] The advantages of the 3D miniplate include resistance to forces in multiple directions, stabilization in both tensile and compressive zones, less foreign material, malleability, and reduced palpability compared to conventional miniplate techniques.[14]

Previous studies indicated that there was little difference in most postoperative complications when comparing 3D miniplate fixations to conventional miniplate fixations.[15,16] However, recent meta-analyses have shown that the rate of postoperative complications with 3D miniplates is significantly lower than with other fixation methods, including those used for angle fractures.[17,18] Despite these findings, biomechanical studies have demonstrated that Champy fixation provides greater resistance and stability to vertical loading compared to 3D miniplates.[19,20]

A biplane 3D miniplate design has been introduced to fixate angle fractures in two perpendicular planes. This prospective study aims to evaluate the feasibility, effectiveness, and reliability of using a Biplane 3D miniplate in managing displaced MAFs. New radiographic criteria are also proposed to assess the vertical and horizontal alignment of angle fractures.

MATERIALS AND METHODS

Study design

This prospective, quasi-experimental, clinical study involved adult patients with unfavorable displaced MAFs who were referred to a trauma intensive care unit at Ahvaz Jundishapur University of Medical Sciences from April 2022 to November 2022. Patients with only one displaced mandibular fracture other than an angle fracture were also included. Patients were excluded from the study in any of the following cases:

- More than one concomitant mandibular fracture other than an angle fracture
- Concomitant condylar or maxillary fracture
- Comminuted fracture.

All patients completed the 3-month follow-up before May 2023. Preoperative panoramic views and 3D computed tomography (CT) scans were taken for patients. The primary predictor variable was the use of a biplane 3D miniplate for MAFs management.

Biplane three-dimensional miniplate design

A 1-mm square, four-hole 3D miniplate was modified to adapt to two perpendicular planes: the superior surface of the external oblique ridge and the lateral aspect at the mandibular angle, both perpendicular to the fracture line. The two reinforcing vertical struts were also bent at the junction of the superior and lateral aspects of the external oblique ridge to connect horizontal plates [Figures 1 and 2]. It stabilizes fracture segments securely using four monocortical titanium screws placed at each corner of the plate. As a result, this biplane 3D plate theoretically provides stability in three dimensions, enabling it to withstand vertical, horizontal, and tensile loads [Figures 1 and 2].

Surgical procedure

The patient underwent surgery under general anesthesia. The Erich arch bars were inserted, and temporary maxillomandibular fixation (MMF) was

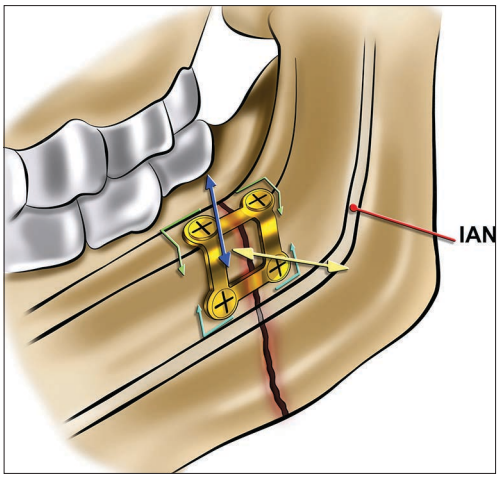

Figure 1: The schematic illustration of the force distribution in the vertical bars and neutralization of vertical and torsional forces in the biplane three-dimensional miniplate. This design enhances the horizontal plates' capacity to withstand various loads by distributing forces. The blue arrow indicates the direction of the vertical force, which could be neutralized by the upper and lower horizontal bars. The yellow arrow indicates the direction of horizontal and torsional forces, which could be neutralized by the 3D miniplate's biplane design. The green arrows show the distribution of tensile and compressive forces along the two reinforcing vertical struts. The red arrow indicates the inferior alveolar nerve.

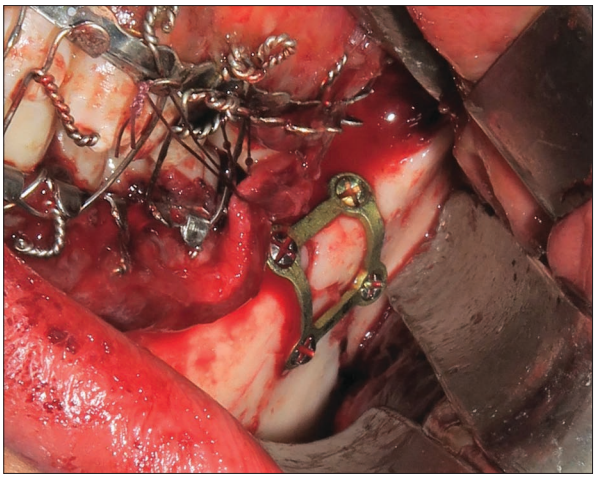

Figure 2: Intraoperative presentation of a reduced and fixated left displaced mandibular angle fracture using the biplane three-dimensional miniplate.

applied to restore preinjury occlusion. The Champy principles were followed in case of additional mandible fracture, and conventional miniplates were used for internal fixation. A full-thickness vestibular incision was made to access, reduce, and stabilize the MAF using Biplane 3D miniplate [Figure 2].

Postsurgical and follow-up protocol

Two light-guiding elastics were applied to the patients for 2 weeks while patients were trained to remove and reinstall elastics to nourish and maintain oral hygiene. In case of any postoperative occlusal derangement, dynamic MMF with heavy elastic was applied to adjust the occlusal relationship.[21] Patients were maintained on a liquid and nonchewing diet for the first 2 weeks and a soft diet for the next 2 weeks, then the diet was gradually increased. An independent assessor measured clinical outcomes at the first 2 weeks, the second, and the third to 6th months. Postsurgical panoramic views were taken in the first 2 days and the 2nd month. Furthermore, a 3D CT scan was taken within the 1st week to assess the reduction and miniplate positioning.

Intraoperative and clinical assessments

The primary outcome variable was occlusion. The secondary clinical outcome variables were fracture stability and maximum mouth opening (MMO). All outcome variables were also evaluated in the isolated and nonisolated angle fracture groups to investigate the effect of another fracture on the biplane 3D miniplate fixation.

- Occlusion was considered satisfactory when the patient could occlude on both sides perfectly. Malocclusion is the presence of occlusal derangement (interocclusal gap), mild derangement (1–2 mm gap) that requires correction by nonsurgical means, and severe derangement (>2 mm gap), which requires reoperation[12]
- Fracture was considered stable without interfragmentary mobility and unstable in fracture segment mobility. The Intraoperative fracture stability was assessed by applying pressure to the proximal segment after fixation. Postoperative fracture stability was evaluated using both the thumb and index finger of both hands through digital pressure in two fracture segments
- Mouth opening was considered adequate if the distance between the upper and lower teeth was more than 30 mm and considered inadequate if it was <30 mm.[12]

Radiographic assessment

The following radiological measures were secondary outcome variables:

1. Vertical alignment of fracture segments is assessed by measuring the mandibular nerve canal alignment across the fracture line in the postoperative panoramic view [Figures 3 and 4].

The evaluation follows this classification:

a. Appropriate alignment: The mandibular canal aligns properly across the fracture line [Figure 5a]

b. Mild malalignment: The fracture malalignment is <50% of the canal's height [Figure 5b]
c. Moderate malalignment: The fracture malalignment is >50% but less than the full height of the canal [Figure 5c]
d. Severe malalignment: The fracture malalignment exceeds the full height of the canal [Figure 5d].

2. Horizontal alignment of fracture segments is assessed by measuring the mandibular inferior border alignment across the fracture line in the axial view of a 3D CT scan [Figure 6].

Figure 3: Preoperative panoramic radiographic view of severely displaced left angle and body fractures.

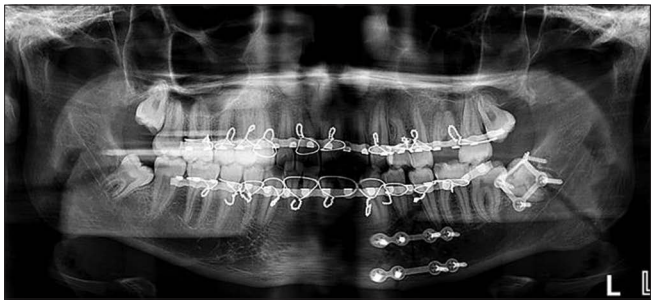

Figure 4: Panoramic view of biplane three-dimensional miniplate fixation for the left angle and conventional miniplates fixation for the left body. Note the appropriate vertical alignment of the angle fracture, as indicated by the alignment of the mandibular nerve canal across the fracture line.

The evaluation follows this classification:

a. Appropriate alignment: The inferior border of the mandible is properly aligned across the fracture line [Figure 7a]
b. Mild malalignment: Malalignment of the fracture is <50% of the inferior border's width [Figure 7b]
c. Moderate malalignment: Malalignment of the fracture is >50% but less than the full width of the inferior border [Figure 7c]
d. Severe malalignment: Malalignment of the fracture exceeds the full width of the inferior border [Figure 7d].

Statistical analysis

Demographic characteristics and prevalence were demonstrated with descriptive statistics. Statistical analysis of results was performed using SPSS version 22 (IBM Corp., Armonk, NY, USA) and included both Fisher's exact and Chi-square tests. Results were considered statistically significant if the $P < 0.05$.

Ethical approval and considerations

This study is based on a research project approved by the local ethical committee of "Ahvaz Jundishapur University of Medical Sciences" (code: IR.AJUMS.REC.1394.711) and registered in the Iranian Clinical Trials Registry (registration number: IRCT2017052834186N1). It was performed following the Helsinki Declaration. Informed consent was obtained from all subjects, and privacy rights were considered.

RESULTS

Patients' demographic and fracture-related data are presented in Table 1. Twenty-one displaced unilateral MAFs using biplane 3D miniplates on 21 patients (males $n = 18$; 85.71%) with a mean age of 23.47 were surgically managed and followed for 3–6 months (mean = 4.95). A traffic accident was the

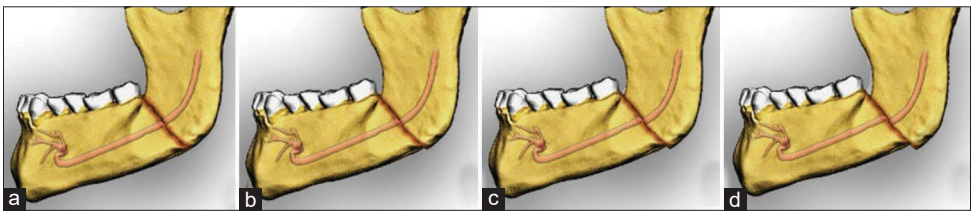

Figure 5: The schematic view illustrates the radiographic criteria for assessing vertical fracture alignment based on the postsurgical panoramic view. (a) Appropriate alignment: The mandibular canal aligns properly across the fracture line. (b) Mild malalignment: The fracture malalignment is < 50% of the canal's height. (c) Moderate malalignment: The fracture malalignment is > 50% but less than the full height of the canal. (d) Severe malalignment: The fracture malalignment exceeds the full height of the canal.

most common etiology (n = 16; 76.2%). Nine isolated cases (42.86%) and 12 (57.14%) were nonisolated angle fractures. There was no difference between the two groups regarding age, gender, injury mechanism, and follow-up time.

The clinical and radiographic outcomes of using biplane-3D miniplates overall and in isolated and nonisolated groups are presented in Table 2.

Only two cases (2/21 = 9.52%) in the nonisolated group presented with mild occlusal derangement, which resolved with 2 weeks of heavy elastic therapy. All patients showed fractured segment stability after fixation and during follow-up time.

Adequate mouth opening (>30 mm) was obtained in 8 (38%), 15 (71.43%), and 21 (100%) cases at the 1st, 2nd, and 4th follow-up weeks, respectively. Hardware failure, infection, and wound dehiscence were not detected in any patient.

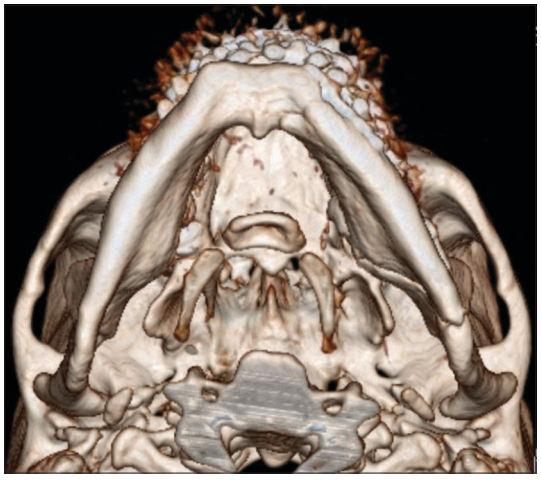

Figure 6: Postoperative axial three-dimensional (3D) computed tomography-scan view of the inferior border of the Left angle and body fractures fixation using a biplane 3D miniplate for angle fracture. Note the appropriate horizontal alignment of the angle fracture according to the inferior mandibular border across the fracture line.

Three (14.29%) and six (28.6%) cases showed mild vertical and horizontal malalignment in the first 2 days and within the 1st week postoperatively. Vertical and horizontal appropriate alignment were measured in favor of the isolated angle fracture group; however, the intergroup difference was not statistically significant.

DISCUSSION

The present clinical study was performed to answer whether fixation by a Biplane 3D miniplate is feasible, effective, and reliable for managing displaced MAFs. Assessment of postoperative occlusion as a primary outcome variable revealed an appropriate outcome. Other clinical outcomes showed favorable results. Also, assessment of novel radiographic criteria revealed acceptable fractured segment alignment in both vertical and horizontal plans.

However, various plates and treatment modalities have been introduced for MAF treatment; controversy over an optimal MAF technique continues.[1,3,4,22] Despite the popularity and low complication rates of the Champy technique as a functional fixation method,[6,7] the stability of single miniplate fixation for MAF has been challenged in biomechanical studies.[8,9] However, it was indicated that this instability and consequent fracture line opening at the lower border did not affect occlusion and esthetic outcomes.[6] The shortcomings of semi-rigid and rigid fixations have led to the development of a quadrilateral 3D miniplate that provides a functionally stable fixation with low complication rates.[4,10]

Evaluation of the primary outcome variable showed a satisfactory occlusal relationship. Two cases of occlusal derangement in the nonisolated angle fracture group could be due to the second fracture effect. Regardless of mild or severe occlusal derangement, the result of the present study is in agreement with

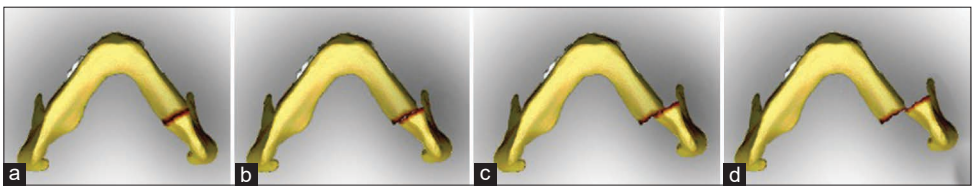

Figure 7: The schematic view illustrates the radiographic criteria for assessing horizontal fracture alignment based on a postsurgical axial view of the inferior border. (a) Appropriate alignment: The inferior border of the mandible is properly aligned across the fracture line. (b) Mild malalignment: Malalignment of the fracture is <50% of the inferior border's width. (c) Moderate malalignment: Malalignment of the fracture is >50% but less than the full width of the inferior border. (d) Severe malalignment: Malalignment of the fracture exceeds the full width of the inferior border.

Table 1: Demographic and fracture-related data of twenty-one patients with displaced mandibular angle fractures

Case number	Age (years)	Gender	Fracture site	Mechanism of injury	Associated fracture	Follow-up time (months)
1	27	Male	Left angle	Assault	-	6
2	24	Male	Left angle	TA	-	5
3	19	Male	Right angle	TA	Left parasymphysis	4
4	18	Male	Left angle	TA	-	4
5	27	Male	Right angle	TA	-	6
6	18	Male	Right angle	TA	-	6
7	17	Female	Left angle	TA	Right parasymphysis	3
8	21	Male	Left angle	Assault	Left parasymphysis	4
9	25	Male	Right angle	TA	Left parasymphysis	6
10	24	Male	Right angle	TA	Left body	6
11	34	Male	Left angle	TA	Left body	4
12	18	Male	Left angle	TA	Right body	4
13	19	Female	Left angle	TA	Right parasymphysis	6
14	24	Male	Right angle	TA	Left parasymphysis	5
15	23	Male	Right angle	TA	-	5
16	22	Male	Left angle	Assault	-	3
17	29	Male	Right angle	Falling	-	4
18	32	Male	Left angle	TA	Right parasymphysis	6
19	31	Male	Right angle	TA	Right body	6
20	20	Male	Left angle	Falling	Left parasymphysis	6
21	21	Female	Right angle	TA	-	5

TA: Traffic accident

Table 2: Clinical and radiographic outcomes of the use of biplane three dimensional miniplates for management of displaced mandibular angle fractures in overall and in isolated and nonisolated groups

Variable	Follow-up time (week)	Isolatedangle fracture (*n*=9), *n* (%)	Nonisolated angle fracture (*n*=12), *n* (%)	*P*
Clinical outcome variables				
Satisfactory occlusal relationship	1st week	9 (100)	10[a] (83.33)	0.208
	2nd week	9 (100)	12 (100)	N/A
	4th week	9 (100)	12 (100)	N/A
	8th week	9 (100)	12 (100)	N/A
Fracture stability	1st week	9 (100)	12 (100)	N/A
	2nd week	9 (100)	12 (100)	N/A
	4th week	9 (100)	12 (100)	N/A
	8th week	9 (100)	12 (100)	N/A
Adequate mouth opening (≥30 mm)	1st week	5 (55.55)	5 (41.66)	0.538
	2nd week	7 (77.77)	8 (66.66)	0.586
	4th week	9 (100)	12 (100)	N/A
	8th week	9 (100)	12 (100)	N/A
Radiographic outcome variables				
Vertical alignment of fracture segments (panoramic view)	Appropriate alignment	8 (88.8)	10 (83.33)	`0.725
	Mild malalignment	1 (11.1)	2 (16.6)	0.727
	Moderate malalignment	-	-	N/A
	Severe malalignment	-	-	N/A
Horizontal alignment of fractured segments (3D CT-scan axial view)	Appropriate alignment	7 (77.77)	8 (66.66)	0.586
	Mild malalignment	2 (22.22)	4 (33.33)	0.586
	Moderate malalignment	-	-	N/A
	Severe malalignment	-	-	N/A

[a]Two with mild occlusal derangement. Nonisolated angle fracture: Angle fracture accompanied by another mandibular fracture. 3D: Three dimensional; N/A: Not available; CT: Computed tomography

Zix *et al*.,[22] Vineeth *et al.,*[12] and Hochuli-Vieira *et al*.[23] with 6.6%–20% occlusal derangement, and in contrast to Al-Moraissi *et al*.[1] and Al-Tairi *et al*.[24] with no report of malocclusion. This variation could be due to concomitant mandibular fractures, small sample sizes, or inadequate plate adaptation.[12,24,25]

Interfragmentary stability is essential for undisturbed healing and the prevention of infection, malocclusion, or nonunion.[12] In the present study, intraoperative and postoperative fracture instability was not observed in any cases, which disagrees with Vineeth *et al*., who reported 10% segmental mobility.[12]

Biomechanical studies suggest that 3D miniplate fixation generally performs better than the Champy technique.[8,9] However, research by Negreiros Lyrio *et al*. and Tharakan *et al*. demonstrated that Champy fixation offers superior resistance and stability to vertical forces.[19,20] It is important to note that these *in vitro* studies did not assess other directions of force, such as torsional force, where 3D plates might theoretically provide greater resistance. Similar to the Champy fixation, the upper horizontal bar of the biplane 3D miniplate provides more stability against vertical forces.

Regarding mouth opening, patients had limitation (MMO < 30 mm) before surgery, which decreased to 60% and 33.3% in the 1st and 2nd weeks of follow-up. All patients resumed adequate mouth opening at the 1st-month follow-up. Others have reported similar results.[1,12,24]

A recent study showed that the number of complications in 3D miniplate fixation is significantly lower compared to other fixation techniques.[18] The conventional 3D miniplate is placed at a safe distance from the mucosal incision line and is covered with a greater bulk of soft tissue, which helps prevent wound dehiscence and plate exposure.[1,7,14] Despite the upper horizontal limb of the biplane 3D miniplate being closer to the incision line, no wound dehiscence was observed, in line with the findings related to conventional 3D miniplates.[1,14] The smaller profile of the biplane 3D miniplate, including its reduced thickness (1 mm) and shorter length of the upper horizontal limb compared to a conventional miniplate, may help explain the absence of dehiscence. In the current study, infection and hardware failure were not observed in patients, consistent with studies using 3D miniplates.[1,12,24,25]

New radiographic criteria were introduced and implemented to evaluate the adequacy of reduction and stabilization in managing MAFs. In most cases, Biplane 3D miniplate fixation revealed appropriate vertical and horizontal alignment and mild but undetectable malalignment in limited subjects.

Using a broad-sized 3D miniplate with eight screws on the lateral aspect of the angle fracture is not only more time-consuming but also more complex than applying a single plate on the external oblique ridge.[26] In this context, fixating the biplane 3D miniplate to the superior and lateral aspects of the external oblique ridge tends to result in less soft-tissue detachment and can help reduce surgical time. In addition, this miniplate does not necessitate percutaneous screw insertion and maintains a safer distance from the mandibular nerve, thereby reducing the risk of nerve injury.

There are some limitations to the study that could impact its strength and findings, including a small sample size, a lack of a control group, the absence of randomization, and a short follow-up period. Due to the lack of a control group, many findings are presented descriptively. The radiographic criteria used in the present study are novel but require validation through further research. The experience of the surgeon (K.K) with the 3D miniplate technique may also limit the generalizability of the results.

CONCLUSION

Despite the limitations of the present study, biplane 3D miniplate fixation shows promising results in the management of MAFs with minimal complications, suggesting that it is safe and effective. In addition, management of concomitant displaced mandibular fractures does not impact treatment outcomes.

For future research, randomized controlled studies are recommended to compare this method with other techniques. A biomechanical study is proposed to evaluate the mechanical behavior of the biplane 3D miniplate. The use of prefabricated biplane 3D miniplates may also help reduce operating time and facilitate surgical procedures.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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