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# A retrospective comparative study of mandibular fracture treatment with internal fixation using reconstruction plate versus miniplates

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ABSTRACT

*Purpose:* This study compared the clinical success rates of mandibular fracture treatment using reconstruction plates or miniplates and clarified the selection criteria for reconstruction plates.
*Methods:* All patients who had surgically-treated mandible fractures from 2008 to 2017 with sufficient follow-up were retrospectively analyzed for information about the fracture condition, treatment, and outcomes.
*Results:* A total of 126 surgically-treated mandible fractures without mandibular condylar fracture in 105 patients (76 male, 29 female) were included. Reconstruction plates were used in 32 fractures with very good postoperative occlusal function. Four cases with complications requiring reoperation were treated using only miniplates. Variables that were statistically associated with follow-up surgery included simple versus comminuted mandible fracture, and the absence of teeth that could be used for intermaxillary fixation ($P < 0.05$). In the miniplates treatment for comminuted fracture, there was a significant difference in the treatment outcome depending on the number of free bone-fragments and the presence of bone-fragments requiring removal within 1 cm ($P < 0.05$).
*Conclusion:* Reconstruction plates provided better treatment outcomes for comminuted fractures and fractures without teeth. Selecting a reconstruction plate that is capable of sufficiently overloading is important in comminuted fractures with multiple free bone-fragments and bone-fragments requiring removal.


## 1. Introduction

Management of maxillofacial trauma remains one of the most common aspects of oral and maxillofacial surgery. Because it is the most exposed part of the body, the maxillofacial area is involved in the greatest percentage of injuries of the entire body. In particular, the mandible is one of the most commonly injured bones in the trauma setting of all the maxillofacial area (Morris et al., 2015). The success of mandibular fracture treatment may be associated with variables that have not yet been fully explored, due to their characteristic anatomical and functional components. Therefore, proper selection of mandibular bone fracture treatment depends on various anatomical involvement, and the morphology of injury will sometimes be a challenge even for the most experienced maxillofacial trauma surgeon.

According to the Association for the Study of Internal Fixation (ASIF), the main objective of open reduction and internal fixation (ORIF) in mandibular fracture management is to achieve undisturbed bone healing and the restoration of the anatomical form, functional occlusion, and facial aesthetics for the patient (Schmoker et al., 1982; Sauerbier et al., 2008). Currently, there are two treatment methods for rigid fixation of mandibular fractures. One treatment method is to use reconstruction plates and bicortical screws fixation, namely load-bearing osteosynthesis. The other method is to use small titanium miniplates and monocortical screws fixation, namely load-sharing osteosynthesis. A mandibular

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bone reconstruction plate system must have sufficient strength to bear entire huge mandibular functional load, as such load-bearing osteosynthesis (Kanno et al., 2014). In addition, the reconstruction plate and the scalp screws typically require a large surgical field (Bouloux et al., 2014). Therefore, the surgical procedure may be difficult to perform and is time consuming. As a result, it is reported that treatment costs are substantial (Bouloux et al., 2014). In comparison, adapting miniplates and placing monocortical screws by cooperatively sharing functional load with further fractured bone fragments, as load-sharing osteosynthesis, is a simpler procedure and requires less time than large big plates and bicortical screws fixation. However, a miniplate system may not have sufficient strength for huge occlusal forces like reconstruction plates. Therefore, it is necessary to use great care and meticulous attention in the selection of an osteosynthesis plate for mandibular fracture treatment.

The purpose of this study was to compare the success healing rate for reconstruction plates versus miniplates in mandibular fracture treatment and clarify selection criteria for osteosynthesis plates.

## 2. Material and methods

### 2.1. Patients

This study was performed at the Division of Oral and Maxillofacial Surgery, Kagawa Prefectural Central Hospital, Kagawa, Japan. The registries of patients with traumatic mandibular fractures receiving ORIF excluding mandibular condylar fracture cases at our hospital between 2008 and 2017 were retrospectively reviewed for possible inclusion in the present study. All patients provided preoperative informed consent for ORIF to treat a mandibular fracture. All patients with maxillofacial trauma who presented to us during past 10 years were screened. The inclusion criteria were: mandibular fracture treated with titanium miniplates or reconstruction plate; mandibular fracture within one month after injury and follow-up until sound bone healing after operation; and sufficient follow-up records available for review including adequate preoperative, postoperative, and follow-up radiographs, surgical photographs, and operation records. The exclusion criteria were: pathological fracture; old fracture; history of radiation treatment of the head and neck area; using absorbent plate as osteosynthesis material and patients who did not complete follow-up until postoperative bone healing. The procedures were performed by three expert maxillofacial surgeons (S.S., T.K. and Y.F.) in a single institute, who were much experienced in the treatment of mandibular fractures. The study protocol was approved by the Ethics Committee of the Kagawa Prefectural Central Hospital (approval no. 693).

### 2.2. Surgical procedure

A standard process was used to stabilize fractures in all patients by fitting titanium miniplates (2.0-mm locking miniplate of 1.0-mm or 1.25-mm in plate thickness, AO; LOCK Mandible 2.0, MatrixMANDIBLE 2.0; Synthes, Paoli, PA, USA) or a mandibular reconstruction plate (2.4-mm locking reconstruction plate of 2.0-mm or 2.5-mm in plate thickness, AO, MatrixMANDIBLE reconstruction plate; Synthes, Paoli, PA, USA) and screws. Fracture sites were typically secured with titanium plates according to the following method. The reconstruction plate for load-bearing osteosynthesis was inserted according to the principles laid down by ASIF (Ehrenfeld et al., 2012). Prior to plate fixation in comminuted mandibular fractures, the mandibular fractured small segments were reduced and fixed using miniplates for simplification to increase the stability of comminuted bone fragments. The entire fracture was bridged with the reconstruction plate, which was adapted to the buccal cortex below the mandibular neurovascular canal, with at least three bicortical locking screws on either side of the fracture.

On the contrary, the miniplates use for load-sharing osteosynthesis were inserted according to the functional ideal line concept, laid down by Champy et al. (Worthington and Champy, 1987), which is a technique using miniplate fixations with 2.0 mm monocortical screws. In mandibular fracture of comminuted cases such having free bones, after reduction, each bone fragment was additionally fixed on intact mandibular bones adjacent to each segment using additional miniplate fixation system for load-sharing osteosynthesis. After releasing the intermaxillary fixation, a final intraoperative check of occlusion and TMJ movement with intraoperative X-rays or CT was compulsory for all patients. The tissues were closed meticulously, with the use of drains as necessary. Regarding postoperative management of occlusion, intermaxillary fixation was not used; however, guiding elastics were used to guide occlusion in mandibular fractures where appropriate.

### 2.3. Postoperative management

All patients were administered an intravenous antibiotic (cefazolin sodium 1.0 g) during surgery. After surgery, an antibiotic (cefpodoxime proxetil 100 mg every 12 h for four days) was administered for all patients. For postoperative pain, a nonsteroidal anti-inflammatory analgesic drug (loxoprofen sodium hydrate 120 mg over six hours or celecoxib for initial pain; 400 mg, 2nd or after; 200 mg at intervals over six hours or acetaminophen 400 mg at intervals over six hours) was administered depending on the patient's condition.

A liquid or soft diet was initiated on the first or second postoperative day, and soft diets were recommended to all patients for the next four weeks. Use of denture was permitted after recovery of the oral mucosa.

Patients were seen at two weeks and one, three, and six months postoperatively for regular follow-up, and as necessary whenever a clinical symptom developed. Occlusion and the extent of bone healing were evaluated using X-ray and/or CT. Elements of postoperative compilations including malunion and non-union were examined during follow-up. Healing of the mandibular fracture was evaluated in detail, with the aid of plain X-rays or CT, at one, three, and six months postoperatively depending on the patient's condition.

### 2.4. Predictor variables

The predictor variables for the study consisted of sets of exposures considered to be convincingly related to reoperation rates. The predictor variables were age, gender, cause of the injury, region of the mandible fracture, types of fractures (comminuted or simple), the presence of teeth that could be used for intermaxillary fixation, the time between injury and surgery, surgical approach (extraoral vs intraoral), type of fixation devices, and items related items to comminuted fracture such as the number of free bone fragments and the presence of bone fragments requiring removal within 1 cm.

### 2.5. Data sampling

All clinical records were examined by the same investigator who also collected the following data: ORIF for mandibular fractures, reoperation for postoperative complication, and predictor variables. Postoperative complications included infection, non-union, and malunion were also collected from the medical records.

### 2.6. Statistical analysis

All data were recorded and entered into an electronic database over the course of the study using Microsoft Excel (Microsoft Inc., Redmond, WA, USA). The mean and standard deviations were used where distribution was compatible with normality. To determine the significance of differences between those patients who developed postsurgical complications and those who did not, Pearson $\chi^2$ cross-table analyses were performed. The database was transferred to JMP version 11.2 for Macintosh computers (SAS Institute Inc., Cary, NC, USA) for statistical analysis. A *P*-value of <0.05 was considered statistically significant.

## 3. Results

The sample included 105 patients (76 [72.4%] men and 29 [27.6%] women), with a total of 126 surgically-treated mandible fractures without cases having mandibular condylar fractures. The mean age of patients was 37.5 ± 22.3 years (Table 1). The cause of injury was traffic accident in 40 patients (45/105; 38.1%) with 45 fractures (45/126; 35.7%); stumble in 25 patients (25/105; 23.8%) with 28 fractures (28/126; 22.2%); interpersonal violence in 16 patients (16/105; 15.2%) with 23 fractures (23/126; 18.3%); fall in 10 patients (10/105; 9.5%) with 13 fractures (13/126; 10.3%); sporting accident in 8 patients (8/105; 7.6%) with 11 fractures (11/126; 8.7%); accident at work in 3 patients (3/105; 2.9%) with 3 fractures (3/126; 2.4%); and other causes in 3 patients (3/105; 2.9%) with 4 fractures (3/126; 2.3%). Descriptive statistics of osteosynthesis plate selection by cause of injury is summarized in Fig. 1. At the site of occurrence of mandible fracture, the symphysis was most commonly affected (miniplates, 32 fractures; reconstruction plate, 8 fractures), followed by the angle (miniplates, 32 fractures; reconstruction plate, 4 fractures), the parasymphysis (miniplates, 18 fractures; reconstruction plate, 3 fractures), and the body (miniplates, 9 fractures; reconstruction plate, 21 fractures) (Fig. 2). In mandible fractures classified as simple or comminuted, simple fractures were 95 sites (74.8%) including 16 fractures (16.8%) using reconstruction plates and 79 fractures (83.2%) using miniplates without reconstruction plate. Comminuted fractures were treated with open reduction and stable internal fixation in 32 regions including 20 fractures (62.5%) using reconstruction plate and 12 (37.5%) using only miniplates without reconstruction plate. For those patients treated with ORIF, 90 were treated using an intraoral approach (miniplates 77/90, 85.6%; reconstruction plate 13/90, 14.4%) and 36 (miniplates 17/36, 47.2%; reconstruction plate 19/36, 52.8%) were treated using an extraoral approach. The timing of treatment for patients varied considerably, ranging from the same day as the injury up to 33 days after the injury, with a mean of 1.55 days.

In all 32 patients treated by reconstruction plate, postoperative oral and occlusal function was very good. Adequate stable internal fixation was achieved using a reconstruction plate, and no patient required any additional surgery (Table 2). Complications requiring reoperation postoperatively occurred in four cases during follow-up, for four sites (Fig. 3). All complications were malunion. Interestingly, complications requiring surgery did not occur in the reconstruction plate group, and complications were all cases where osteosynthesis was performed only with miniplates. A comparison of the distribution of predictor variables according to complications requiring reoperation in the miniplates group is summarized in Table 3. Variables that were statistically associated with complications requiring reoperation ($P < 0.05$) included simple versus comminuted mandible fracture ($P = 0.026$) and the presence of teeth that could be used for intermaxillary fixation ($P = 0.0012$). Furthermore, a survey was developed in the miniplates group for the comminuted fractures. There was a significant difference in the treatment outcome for miniplates treatment group with respect to the number of free bone fragments ($P = 0.0010$) and the presence of bone fragments requiring removal within 1 cm ($P = 0.0046$) (Table 4).

**Table 1**
Patient distribution.

| | n | % |
|---|---|---|
| Number of patients | 105 | |
| Gender | | |
| Male | 76 | 72.4 |
| Female | 29 | 27.6 |
| Age | 37.5 ± 22.3 | |
| Osteosynthesis devices | | |
| Miniplate | 74 | 70.5 |
| Reconstruction plate | 27 | 25.7 |
| Both | 4 | 3.8 |
| Number of fractures | 126 | |
| Osteosynthesis devices | | |
| Miniplate | 91 | 72.2 |
| Reconstruction plate | 35 | 27.8 |

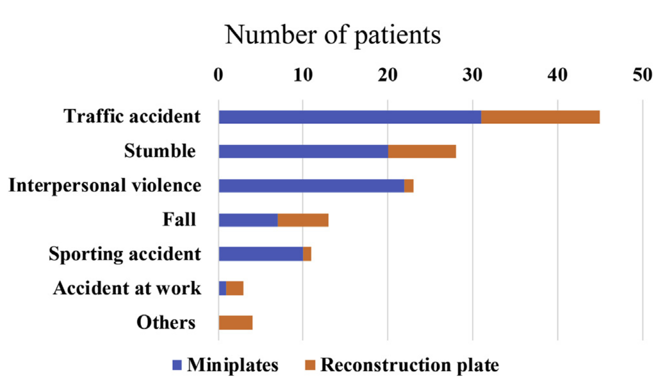


**Fig. 1.** Cause of mandibular fracture and selection of osteosynthesis plate for treatment.

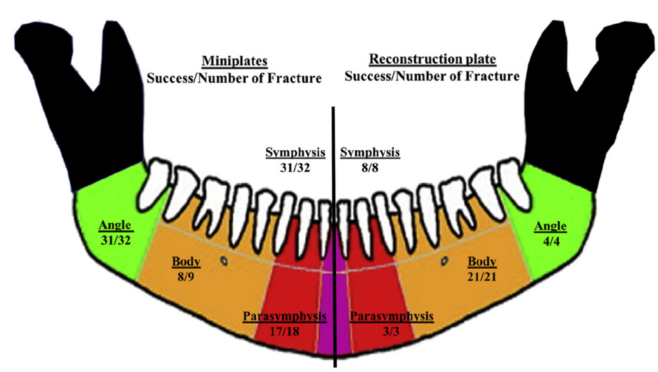


**Fig. 2.** Site of mandibular fracture and selection of osteosynthesis plate for treatment.

**Table 2**
The success rate of treatment with reconstruction plate and miniplate.

| | Miniplates | Reconstruction plate |
|---|---|---|
| Good course | 91 (95.8%) | 32 (100%) |
| Postoperative complications requiring reoperation | 4 (4.2%) | 0 (0%) |
| Total | 95 | 32 |

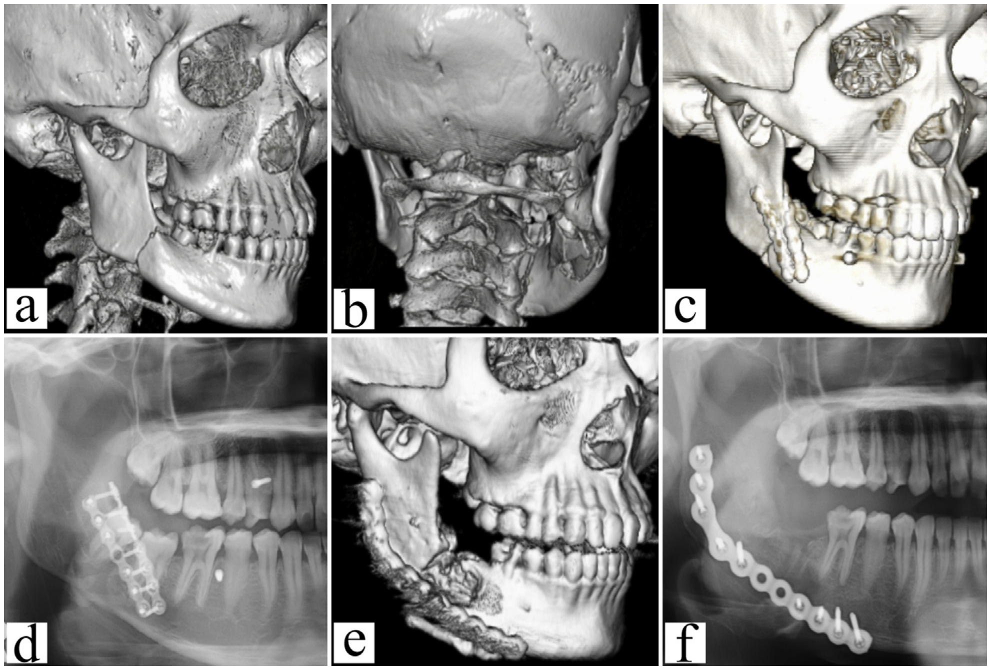


**Fig. 3.** Complications requiring reoperation case of the comminuted mandibular fracture following the miniplates use for load-sharing osteosynthesis: a, b) Three-dimensional CT of the patient before operation showing comminuted fracture at the right mandibular angle; c) Fixation using miniplates at the external oblique ridge and a secondary miniplate for additional fixation adjacent to each segment improving bone buttressing and fracture alignment; d) A panoramic radiograph at the postoperative 1st showing malunion with infection; e) Reoperation using a reconstruction plate; f) A panoramic radiograph at the postoperative 6th months showing complete sound bone healing after reoperation with a reconstruction plate.

## 4. Discussion

Ewers and Härle report the first description of mandibular fracture fixation using plates and screws by Hausmann in 1886 (Ewers and Härle, 1985). In modern surgery, the introduction of well-designed plate systems with high biocompatibility has improved the success rate. Additionally, modifications in surgical techniques and understanding of the biomechanics for bone healing have produced more acceptable results as well as have described load-bearing osteosynthesis versus load-sharing osteosynthesis (Ehrenfeld et al., 2012). As a result, ORIF techniques are now widely and routinely practiced (Kuriakose et al., 1996). The results of this retrospective study show that patients with mandible fractures can be successfully treated by ORIF using miniplates or reconstruction plates.

Bones of reduced quality and quantity may result from atrophy, comminution, and defects. Thus, fractures in bones of reduced quality include atrophic mandibular, comminuted mandibular, and defect mandibular fractures (Ehrenfeld et al., 2012). The common point of these mandibular fractures is the difficulty to effectively use any form of load sharing because the mandibular bone is inadequate in quality and quantity. Therefore, mandibular fractures are difficult to manage and are subject to high complications.

Past studies have also reported the use various fixation systems for the treatment of atrophic mandibular fractures. In atrophic mandibular fractures, the alveolar process and often much of the basilar bone are lost. The remaining bone is markedly diminished in height and often width and is frequently entirely brittle. However, functional forces on the atrophic mandible should not be underestimated. Flores-Hidalgo et al. recommended the use of reconstruction plates for the treatment of atrophic mandibular fractures (Flores-Hidalgo et al., 2015). While Choi et al. suggested the use of two miniplates for fixation (Choi et al., 2005), Ellis et al. reported that the successful use of two miniplates required a minimum bone height of 10 mm (Ellis and Price, 2008). Also, the stability provided by treatment remains less effective than that in a dentate mandible, because stability is related directly to the increased distance between plates. In our study, unsuccessful treatment of mandibular fracture occurred in two cases using a miniplate. In these cases, using two miniplates was impossible because the height of the mandible was insufficient. In the absence of sufficient bone height, the surgeon selected a reconstruction plate that could support the entire applied load across the fracture.

Comminution mandibular fractures are challenging to manage because of the extent of injury and distortion of anatomy. Regarding the selection criteria for a plate for ORIF treatment as indicated for patients by ASIF, it is possible to select according to the necessity of maximum stability under load-bearing conditions. Certainly, in comminuted mandibular fracture, a reconstruction plate is one of the standard treatments. A past study suggested that the use of miniplates for semi-rigid fixation in patients with mandibular fractures may be significantly less costly for total treatment than reconstruction plate for rigid fixation (Bouloux et al., 2014). Treatment with miniplates can be a good approach if appropriate selection is made. Our study shows that the treatment of comminuted mandibular fractures requires careful consideration when choosing whether to use miniplates or a reconstruction plate. Comminuted mandibular fractures treated with reconstruction plates did not require reoperation because of bone healing failure. Conversely, two cases of comminuted mandibular fractures treated with only the miniplate. This is similar to the results of previous studies that compared miniplates and reconstruction plates for the internal fixation of comminuted mandible fractures (Kuriakose et al., 1996). With miniplates, there was a significant difference in the outcomes based on the number of free bone fragments and the presence of bone fragments requiring removal within 1 cm. Ellis et al. have reported that multiple fragment fractures are associated with more complications than fractures with fewer fragments

**Table 3**
Comparison of background and fracture characteristics between normal bone healing and malunion in mandibular fractures.

| Variable | Treatment by only miniplates | | P Value |
|---|---|---|---|
| | Stable | Malunion | |
| | N = 87 | N = 4 | |
| **Attributes variables** | | | |
| Age | | | 0.688 |
| Gender | | | 0.363 |
| Male | 62 | 2 | |
| Female | 25 | 2 | |
| Cause of trauma | | | – |
| Traffic accident | 31 | 0 | |
| Interpersonal violence | 21 | 1 | |
| Stumble | 19 | 1 | |
| Fall | 6 | 1 | |
| Sporting accident | 10 | 0 | |
| Accident at work | 0 | 1 | |
| **Fracture** | | | |
| Fracture side | | | 0.812 |
| Rt | 26 | 1 | |
| Lt | 30 | 2 | |
| median | 31 | 1 | |
| Fracture site | | | 0.736 |
| Symphysis | 31 | 1 | |
| Parasymphysis | 17 | 1 | |
| Body | 8 | 1 | |
| Angle | 31 | 1 | |
| Continuity of fracture line | | | 0.119 |
| Complete separation | 44 | 4 | |
| Incomplete separation | 0 | 43 | |
| Types of fractures | | | 0.026 |
| Simple | 77 | 2 | |
| Comminuted | 10 | 2 | |
| Presence of teeth for IMF | | | 0.001 |
| Present | 82 | 2 | |
| Absent | 5 | 2 | |
| Associated mandibular condylar fractures | | | 0.593 |
| Present | 32 | 2 | |
| Absent | 55 | 2 | |
| Operation | | | |
| Additional maxillofacial fractures | | | 0.993 |
| None | 83 | 4 | |
| LF1 | 1 | 0 | |
| LF1/2 | 2 | 0 | |
| LF2 | 1 | 0 | |
| ZMC | 1 | 0 | |
| Surgical approach | | | 0.392 |
| Extraoral | 12 | 1 | |
| Intraoral | 75 | 3 | |

**Table 4**
Related items of comminuted fracture.

| Related items of comminuted fracture | Good course | Postoperative complications | P Value |
|---|---|---|---|
| Number of free bone fragments | 1.10 ± 0.43 | 7.00 ± 0.97 | 0.001 |
| Presence of bone fragments requiring removal within 1 cm | 0.70 ± 0.21 | 2.5 ± 0.48 | 0.0046 |

(Ellis et al., 2003). Therefore, comminuted fractures need to have load-bearing fixation applied across the comminution area. The bone fragments within the comminution area will not provide buttressing to help stabilize the fracture; therefore, surgeons treating comminuted mandibular fractures having two or more free bone fragments and/or requiring removal of bone fragments should select reconstruction plates. For comminuted mandibular fractures with only one free bone fragment, treatment by miniplates may be possible.

Unlike the established predictability of ORIF in the management of mandible fractures, the choice between intraoral and extraoral approaches as well as the dimension of the plating systems remains controversial (Kuriakose et al., 1996; Wittwer et al., 2006). Our results show that in cases using miniplates, the intraoral approach is possible 60% of the time. Alternatively, the extraoral approach is used 60% of the time with a reconstruction plate. In most situations, miniplates can be inserted through an intraoral incision. Due to the small size of the plate and the short monocortical screw, the miniplate can be used in a small surgical field. To achieve the proper application of the principles of load-bearing osteosynthesis in management by reconstruction plate, a locking system and bicortical screw fixation has been adopted. Therefore, using a reconstruction plate requires a large surgical field. Adequate exposure for placement of a reconstruction plate using an extraoral approach can be achieved in a number of ways (Flores-Hidalgo et al., 2015), most commonly in the cervical approach (Kanno et al., 2010). In our results, there is no permanent facial paralysis or reoperation for facial scar. Facial paralysis can be avoided by using an appropriate surgical approach and a careful soft tissue technique. A postoperative facial scar is cosmetically acceptable, particularly when the incision is placed in natural skin creases (Kuriakose et al., 1996). Because of this, it is appropriate to use the extraoral approach in cases where a reconstruction plate must be used, and the selection of an appropriate plate should be given priority.

Both miniplate and reconstruction plate systems used for internally fixation of mandible fracture are mostly successful in restoring functional occlusion. A better treatment outcome for comminuted fractures is seen with reconstruction plate systems. When treating complicated fractures, it is essential to select a reconstruction plate that is capable of sufficiently overloading, especially in cases with multiple free bone fragments and bone fragments requiring removal within 1 cm.

## 5. Conclusion

The miniplate system generally provides sufficient stability against mandible fracture. However, a reconstruction plate system is necessary for treating mandibular fracture that occurs in a highly atrophic mandible and heavily comminuted fractures.

## Ethical approval

Not required.

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## Conflicts of interest

None.

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