

# Treatment Considerations for Comminuted Mandibular Fractures

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**Purpose:** We sought to assess the methods of treatment used and outcomes for a large sample of patients with comminuted fractures of the mandible.

**Patients and Methods:** The records of all patients who were identified as having comminuted fractures of the mandible over a 10-year period with sufficient follow-up were collected and analyzed for demographic information, treatment rendered, and outcomes. Standard descriptive statistics and non-parametric statistics were used to analyze the data.

**Results:** A total of 196 patients (167 males and 29 females) with 198 comminuted fractures met the inclusion criteria. The mandibular body was the most commonly affected region. Approximately half were sustained in altercations. Gunshot wounds created fractures that were more comminuted than other causes. The comminuted regions were treated by closed reduction and maxillomandibular fixation (MMF) in 35 fractures, open reduction with stable internal fixation in 146 fractures, and 17 were treated with external pin fixation. For those patients treated with open reduction, a single reconstruction bone plate was used in the majority of cases (114). For those patients treated open, 98 were treated using an intraoral approach and 52 were treated using an extraoral approach. The mean follow-up was 140.6 days. Complications occurred in 26 fractures (13%). The complications were malocclusion in 8 fractures and nonocclusal (ie, infection, nonunion, etc) in 18 fractures. There was a statistically significant relationship between the development of complications and the degree of fragmentation ( $P < .05$ ). There was also a significant relationship between treatment and the development of complications ( $P < .05$ ). Patients treated with external pin fixation had a 35.2% complication rate compared with a 17.1% complication rate for patients undergoing closed treatment with MMF, or patients treated with open reduction and stable internal fixation (10.3%). However, patients treated with external pin fixation had more severe injuries.

**Conclusions:** The results of this study show that, when possible, the use of open reduction and stable internal fixation is associated with a low complication rate. However, not all comminuted fractures are amenable to this treatment, and in those, alternatives such as closed reduction with MMF or the application of external pin fixation may be necessary.

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Comminuted fractures of the mandible have been treated by a number of methods, including closed

reduction, external pin fixation, internal wire fixation,<sup>1</sup> and more recently, open reduction and internal stable fixation using plates and/or screws. Historically, the accepted theory was that one should not open these injuries because one would strip the blood supply to the osseous fragments, resulting in sequestration and infection, especially for gunshot wounds.<sup>2-6</sup> However, this theory was challenged more than 50 years ago by Kazanjian during the first World War.<sup>7,8</sup> Concerning the management of gunshot wounds, Kazanjian stated “the majority of non-united fractures are due to inadequate immobilization of comminuted fragments of bone, and subsequent infection, rather than to initial loss of bone.”<sup>7,8</sup> To Kazanjian, it was clear—stabilization of the fragments

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was the most important requirement to obtain osseous union of comminuted fragments.

More recently, open reduction and stable internal fixation using plates and/or screws has been advocated for comminuted fractures.<sup>9-22</sup> Open reduction and internal fixation of comminuted fractures goes against the most basic of maxillofacial surgery dogma that states comminuted fractures should be treated closed to prevent stripping the blood supply from the fragments. Past experience with open reduction and internal wire fixation was not encouraging, and many cases of infection ensued, resulting in significant bone loss and associated morbidity. However, the above literature suggests that stripping some of the blood supply does not lead to increased incidence of infection as long as stabilization of the bony fragments is achieved.

During the past 10 years, comminuted fractures have been treated at our facility by a number of techniques, including closed reduction, external pin fixation, and open reduction with stable internal fixation. The goal has been to use open reduction and stable internal fixation when possible. However, there were instances when this was not possible. The purpose of this study was to review our experience with the treatment of comminuted fractures of the mandible to determine the success rate of different treatment regimes.

## Patients and Methods

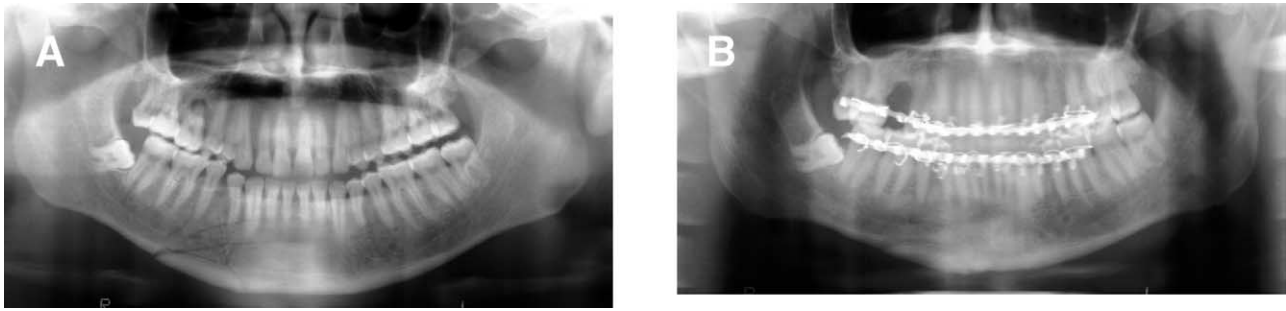
The records of patients treated for fractures of the mandible at Parkland Hospital from the 10-year period of January 1, 1991, to December 30, 2001, were reviewed in this retrospective study. Those fractures that were comminuted were collected. Comminution was defined as multiple lines of fracture in one region of the mandible. To be included, there had to be at least one free osseous fragment 1 cm or more in diameter. Other inclusion criteria were sufficient follow-up (until the time active treatment was ceased, ie, arch-bar removal, osseous union, etc); good-quality preoperative, postoperative, and follow-up radiographs; and surgical photographs available for review. The medical records were used to collect the following information: age, gender, race, cause of the injury, region of the mandible that was comminuted, amount of comminution, associated mandibular fractures, the presence of a tooth in the comminuted region and whether or not it was removed during surgery, time between injury and surgery, treatment received, surgical approach if treated open (extraoral vs intraoral), and type of fixation devices used (if any). An attempt to determine why the patients were treated as they were also was collected from the medical records, when available. Outcome measures that were tabu-

lated were date of last follow-up visit, occlusal relationship at that visit, and the occurrence of any complications in the follow-up period (defined as a need to medically or surgically intervene for any reason related to the comminuted region).

To determine the significance of differences between those patients who developed postsurgical complications (not including malocclusion) and those who did not, Pearson  $\chi^2$  cross-table analyses were performed. Those patients who had complications and those who did not were crossed with the character of the comminuted fracture, the cause of the injury, and the treatment received. For this analysis, the character of the fracture was given the score of minimal if there were only 1 free fragment, moderate if there were 2 to 4 free fragments, and maximum if there were 5 or more free fragments. For the analysis of treatment, the cases were divided into closed reduction, external pin fixation, or open reduction and internal fixation. To determine the significance of differences between those patients who developed malocclusion and those who did not, Pearson  $\chi^2$  cross-table analyses were performed. The final occlusal relationship (normal vs malocclusion) was crossed with the character of the comminuted fracture, the cause of the injury, and the treatment received as just described. The relationship between the cause and the degree of fragmentation was also examined using Pearson  $\chi^2$  cross-table analysis.

## Results

One hundred ninety-six patients met the inclusion criteria and were included in this study. There were 167 males and 29 females, ranging in age from 12 to 60 with a mean age of 30.1 years. Ninety-two were black, 60 were non-Hispanic whites, 43 were Hispanic, and 1 was of Pacific Rim descent. The cause of the fractures were altercations in 109, motor vehicle collisions in 45, gunshot wounds in 36, and falls in 6 patients. Two patients had bilateral comminuted fractures, and 1 patient had comminution of multiple regions of the mandible. All other patients had comminution in only one region of the mandible, although many patients had associated mandibular fractures that were not comminuted ( $n = 84$ ). The body was most commonly affected ( $n = 99$ ), followed by the symphysis ( $n = 49$ ), the angle ( $n = 31$ ), and the ramus ( $n = 18$ ). One patient had comminution throughout the entire mandible. Seventy-seven cases had severe comminution, with multiple fragments and lines of fractures. Forty-four fractures had a single free bone fragment, 33 had 2, 29 had 3, 13 had 4, and 2 had 5 free fragments. A tooth was in the comminuted region in 135 cases and the tooth/teeth was/ were removed during the surgery in 66 cases.



**FIGURE 1.** Pre-treatment (A) and 8 weeks post-treatment (B) radiographs of a patient with a comminuted right mandibular body fracture that was minimally displaced (see space between the lower right premolars) and only moderately mobile. The patient was treated closed with 5 weeks of MMF and the fracture healed unevenly.

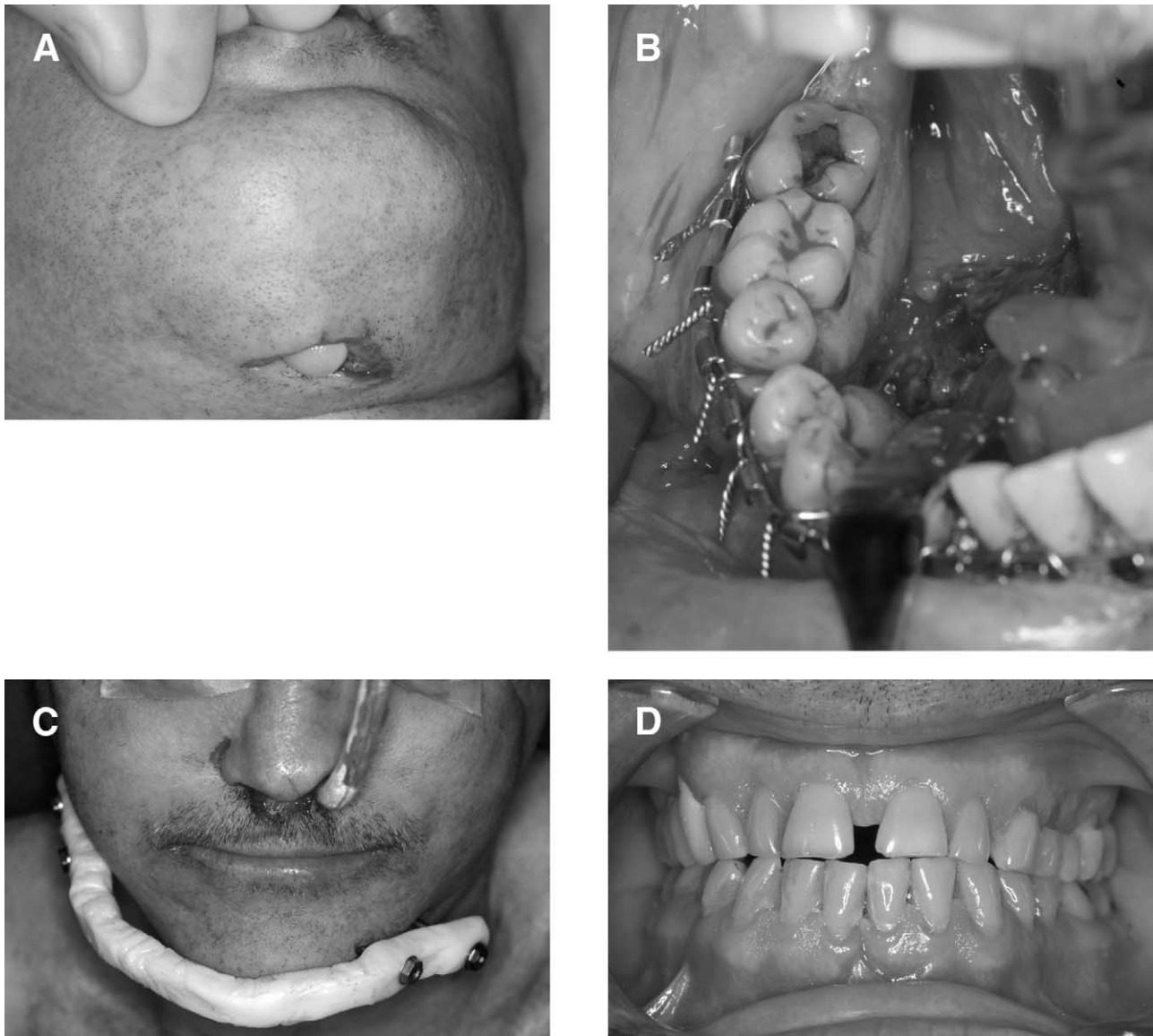
The timing of treatment of the patients varied considerably, ranging from the same day as the injury up to 77 days after the injury, with a mean of 3.7 days. The comminuted regions were treated by closed reduction and maxillomandibular fixation (MMF) in 35 fractures and open reduction with stable internal fixation in 146 fractures, and 17 were treated with external pin fixation. For those patients treated in an open manner, a single reconstruction bone plate was used in 114 cases (54 were locking reconstruction plates), 11 had a single mandibular bone plate (positional), 11 had a single 2.0-mm miniplate, 6 had double 2.0-mm miniplates, and 4 used multiple lag screws with or without small bone plates. For those patients treated with open reduction and internal fixation, 98 were treated using an intraoral approach and 52 were treated using an extraoral approach.

Of the patients treated closed ( $n = 35$ ), it was apparent from the medical records that most of them were treated this way for the sake of expediency. These were fractures that had multiple lines of fracture but without displacement, or with very little displacement. In others, mostly gunshot wounds, there was so much comminution and soft tissue disruption that the goal was to maintain the spatial relationship of the residual mandibular fragments until healing could occur. If there were sufficient teeth on each side of the comminuted segment to facilitate MMF, it was used (Fig 1). If not, external pin fixation was selected. The 17 patients treated with external pin fixation fell into 2 main groups. There were 11 whose comminuted region had so much fragmentation and loss of bone that it was unclear whether the patient would go on to osseous union. Most of these cases had sustained gunshot wounds. In these cases, it was thought that open treatment would result in the need to remove many of the displaced fragments, so the decision was made to maintain the normal spatial relationship of the residual mandibular fragments and allow healing to progress. A second group of 6 patients, all of whom sustained gunshot wounds, had so

much tissue detached from the comminuted mandibular segments that it was thought that any surgical approach would completely devitalize the remaining fragments. This was especially true of gunshot wounds to the floor of the mouth, where the lingual musculature and mucosa had been completely detached from the mandible (Fig 2). A transoral surgical approach would have detached all of the remaining blood supply because the buccal/labial mucosa and musculature were the only remaining soft tissues attached.

The follow-up periods ranged from 46 to 2,996 days with a mean of 140.6 days. Complications occurred in 26 fractures (13%) (Table 1). The complications were malocclusion in 8 fractures and nonocclusal (ie, infection, nonunion, etc) in 18 fractures (Table 1). Fourteen of the 26 fractures that developed complications contained 5 or more osseous fragments (severe injuries), 8 fractures contained between 2 and 4 osseous fragments, and 4 fractures had a single free osseous fragment. There was a statistically significant relationship between the development of complications and the degree of fragmentation ( $P < .05$ ). There was also a significant relationship between treatment and complications ( $P < .05$ ) with external pin fixation having a 35.2% rate of complication compared with 17.1% for patients treated closed, or 10.3% for patients treated open with stable internal fixation.

Of the 8 patients with malocclusion, it was minor (amenable to occlusal equilibration) in 4 patients and major (not treatable by nonsurgical means) in 4 others. Two patients were edentulous making occlusal assessment impossible. There was no statistically significant relationship between the development of malocclusion and either the character of the fracture (number of fragments), the cause (ie, altercation, gunshot, etc) or the type of treatment rendered (closed reduction, external pin fixation, open reduction, and internal fixation). Two patients had orthognathic surgery to correct the malocclusion, the other 2 did not return for treatment. Of the 8 fractures in patients



**FIGURE 2.** Photographs of a patient who sustained a gunshot wound to the submental region. The wound extended into the floor of the mouth (A), disrupting the soft tissues attached to the lingual surface of the free dento-osseous segment (under retractor, B). External pin fixation was chosen to treat the fracture (C), and a slight malocclusion resulted (D), but the dento-osseous segment survived and the fracture healed.

with malocclusion, 4 contained 5 or more free osseous segments (severe), 3 had between 2 and 4 osseous fragments, and 1 had a single free segment.

In addition to the malocclusions, postsurgical complications occurred in 18 of the comminuted segments. Six patients had postoperative infections, of whom 5 were treated in the outpatient clinic with intraoral incision and drainage and oral antibiotics. The other patient developed osteomyelitis requiring intravenous antibiotics. The most prevalent complication was nonunion, occurring in 7 patients, of whom 6 required bone grafting to effect osseous union (Fig 3). The other patient was initially treated closed for an angle fracture and had postoperative rotation of the ramus. He was taken to surgery for open reduction

and reconstruction bone plate fixation. There was good bone contact so no bone graft was necessary, and the patient healed uneventfully. Two patients who had severe comminution of the mandibular body had “bowing” of the inferior border so that it was lower than the opposite, uninjured side (Fig 4). The cause was inability to obtain intimate bony contact of all the small fragments so that some were never accurately reduced. Neither patient requested treatment for the asymmetry. Another patient with a poor dentition who had comminution of the symphysis and an associated condylar fracture that was treated closed healed with lateral flaring of the ramus, making the face slightly wider on one side. This was treated by the addition of a polyethylene implant on the defi-

**Table 1. TWENTY-SIX FRACTURES WITH COMPLICATIONS**

	n	Cause	Region	No. of Fragments	Treatment	Comments
Minor malocclusion	4	3 Alt	2 Angle	1 Fx with ≥5 frags	3 ORIF	4 Treated with occlusal equilibration
		1 GSW	2 Body	3 Fxs with 2 to 4 frags	1 EPF	
Major malocclusion	4	2 Alt	3 Body	3 Fxs with ≥5 frags	3 ORIF	2 Treated with orthognathic surgery, 2 received no treatment
		1 GSW	1 Symph	1 Fx with 1 frag	1 EPF	
Infection	6	5 Alt	4 Angle	4 Fxs with 2 to 4 frags	4 ORIF	5 Minor, 1 osteomyelitis
		1 GSW	1 Ramus 1 Symph	2 Fxs with 1 frag	2 CR	
Nonunion	7	5 GSW	5 Body	All Fxs with ≥5 frags	4 EPF	6 Required bone grafting
		2 Alt	1 Ramus 1 Symph		3 CR	
Bowling of inferior border of mandible	2	Both MVCs	Both Body	1 Fx with ≥5 frags	Both ORIF	No treatment requested
				1 Fx with 2 to 4 frags		
Lateral flaring of ramus	1	Fall	Symph	≥5 frags	ORIF	Contour augmentation to deficient side
Devitalization of associated dentoalveolar segment	1	GSW	Body	≥5 frags	ORIF	Removal of segment
Trismus	1	GSW	Angle	≥5 frags	CR	No further treatment

Abbreviations: Alt, altercation; CR, closed reduction with maxillomandibular fixation; EPF, external pin fixation; frag, fragment; Fx, fracture; GSW, gunshot wound; MVC, motor vehicle collision; ORIF, open reduction and stable internal fixation; Symph, symphysis; Tx, treated.

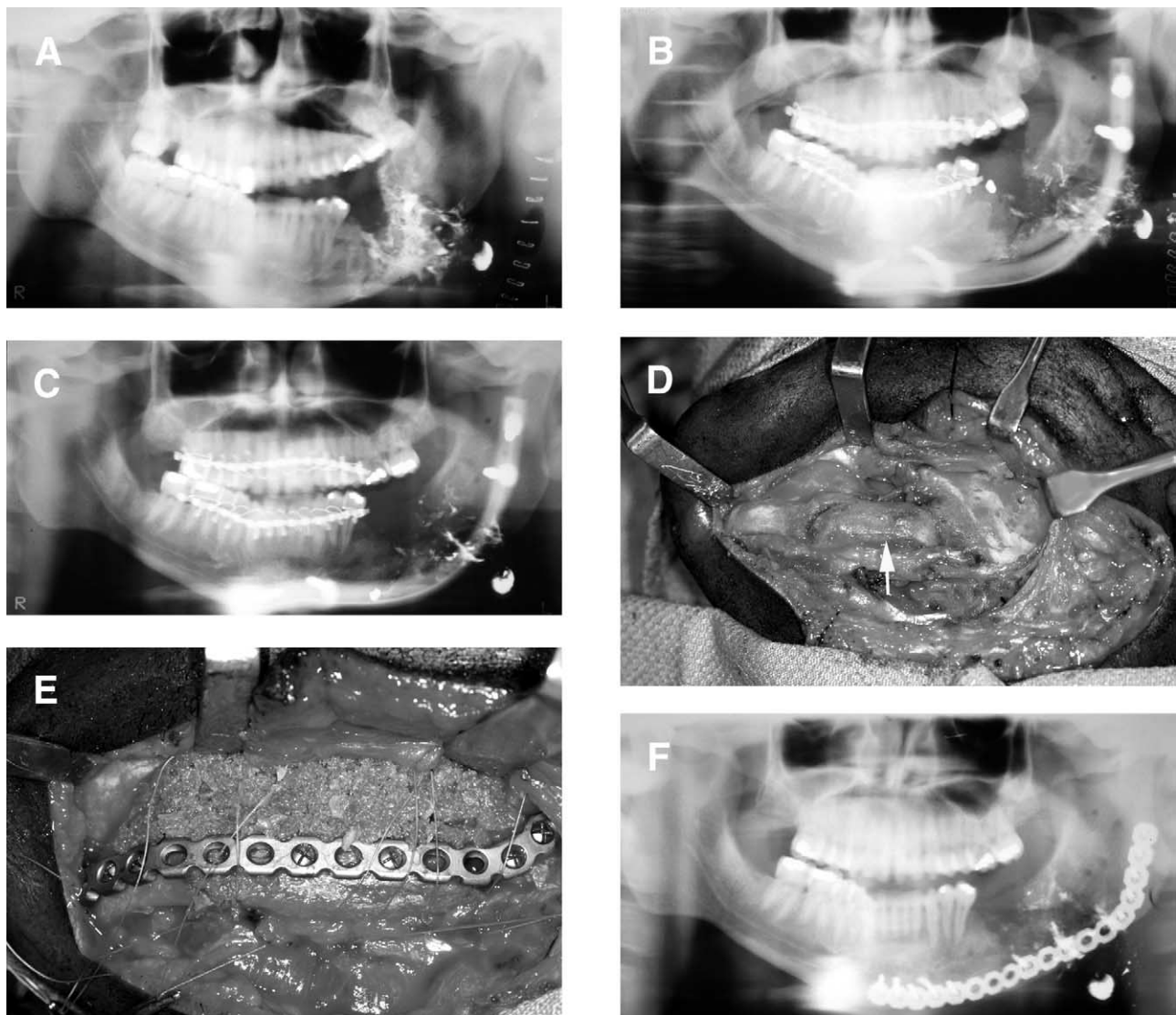
cient side. Another patient’s symphysis region was very comminuted and the dentoalveolar segment containing 4 teeth was left in place despite the fact that it had little soft tissue attachment in the hope that it might survive. The dentoalveolar segment was attached to the arch bar for stabilization after reconstruction bone plate fixation was applied to the basal bone. Two weeks later this segment had to be removed because it was devital. Last, one patient with a gunshot wound to the ramus developed trismus that was refractory to physiotherapeutic measures. The patient was left with an interincisal opening of 32 mm.

Eleven of the 18 fractures with nonocclusal complications had 5 or more osseous fragments, 5 had between 2 and 4 fragments, and 2 had a single fragment. There was no statistically significant relationship between the development of nonocclusal complications and the character (number of fragments) of the fracture. However, the majority of the complications (11 of 18) occurred in the 69 patients whose fractures were classified as maximum (≥5 fragments). This represents a complication rate of 13.7% for the more comminuted fractures, compared with 6.9% and 4.5% for moderately and minimally comminuted fractures, respectively. There was a statistically significant relationship between the type of treatment and the

development of nonocclusal complications ( $P < .01$ ). Patients treated with external pin fixation had a 23.5% complication rate compared with a 17.1% complication rate for patients undergoing closed treatment with MMF, or patients treated with open reduction and stable internal fixation (5.5%). Of the 17 comminuted fractures treated with external pin fixation, 4 developed nonunions requiring bone graft reconstruction. There also was a statistically significant relationship between the development of nonocclusal complications with the cause of the injury ( $P < .05$ ). Gunshot wounds had a 22.2% rate of nonocclusal complications, with falls, altercations, and motor vehicle collisions being 16.6%, 6.4%, and 4.4%, respectively (the 16.6% rate of complication in the 6 patients injured in a fall represents only 1 patient.) The cause of the injury was statistically associated with the degree of fragmentation of the mandible ( $P < .001$ ), with gunshot wounds having more severe fragmentation than the other causes.

**Discussion**

The results of this retrospective review show that patients with comminuted fractures of the mandible can be successfully treated by a number of methods. Closed treatment with MMF, external pin fixation, or



**FIGURE 3.** Panoramic radiograph of a patient with a gunshot wound to the left mandibular body/ramus, avulsing some of the bone and fragmenting what was left (A). The patient was placed into MMF while external pin fixation was applied. A postoperative radiograph shows the segments have been stabilized and the patient has not been placed into postsurgical MMF (B). Unfortunately but not surprisingly, this patient developed a nonunion. A radiograph taken 6 weeks after surgery shows that bone is present along the inferior border but it is of poor quality (C). Bone graft reconstruction was therefore necessary. The patient was first placed into MMF and an extraoral approach to the mandible was used to expose the fracture site. (D) Consolidation of the basal bone (arrow), which is of a soft, callus-like quality. A reconstruction bone plate was adapted and attached to the residual mandibular fragments. The MMF was released and the occlusion checked before adding bone graft to the defect (E). The patient healed unevenly after that and a radiograph taken 6 weeks later shows consolidation of the graft (F).

open treatment using stable internal fixation devices all worked when applied under the appropriate circumstance. In fact, the most surprising finding was the relatively low complication rate in these difficult fractures (13%). Complication rates for noncomminuted fractures of some regions of the mandible, for instance the angle, have been much higher at our institution with some or the treatment methods that were used.<sup>23-25</sup>

Open reduction with stable internal fixation was used in the majority (74%) of the comminuted fractures in this study. This should not be surprising in light of our philosophy for treatment of mandibular

fractures used during the study period. We have tried to avoid MMF or external pin fixation unless it is absolutely necessary, and therefore, when possible, open treatment and stable internal fixation was used for most patients in this review. In most cases where stable internal fixation was applied, plates were used to span the region of comminution, providing stability across the region, most commonly in the form of a reconstruction bone plate. Often, small fragments were lagged to the plate or small plates and screws were used to reduce the fragments before the final fixation device (reconstruction plate) was applied (Fig 5).



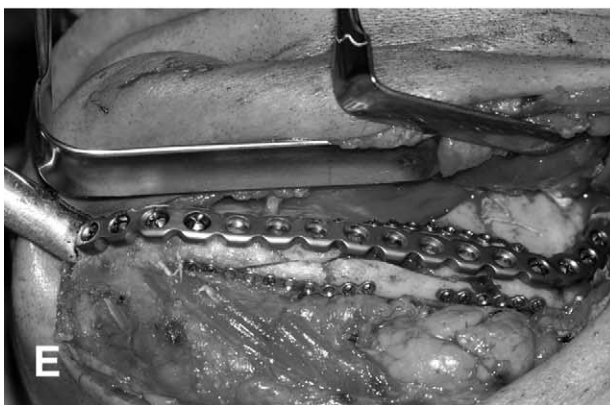
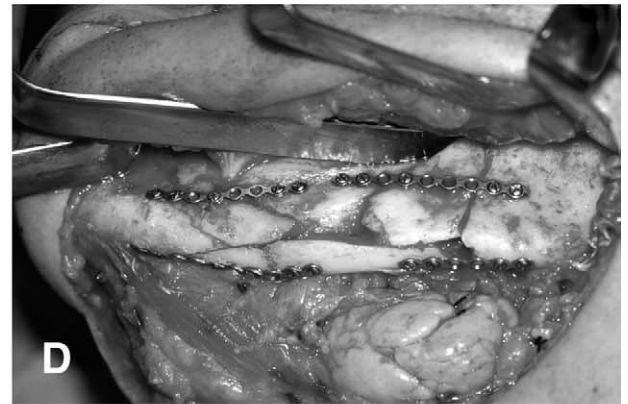
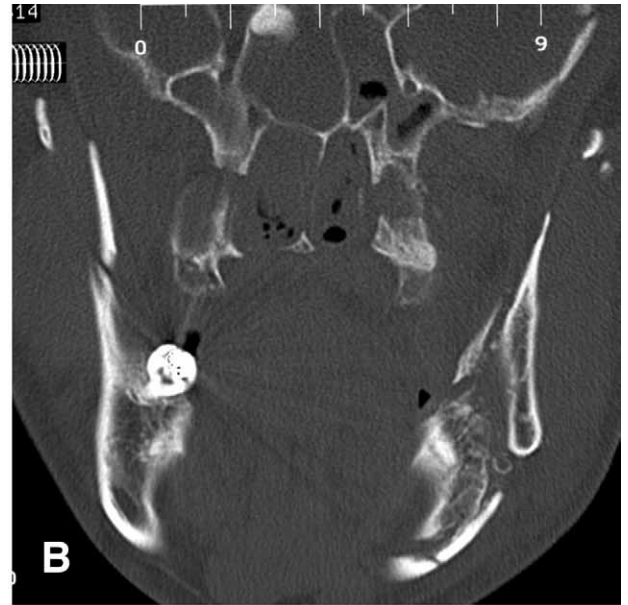
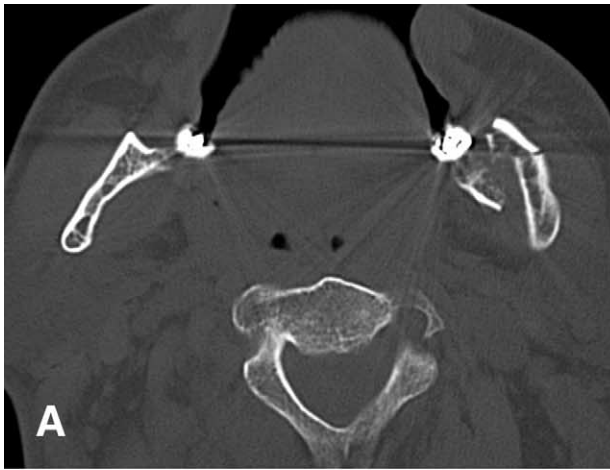
**FIGURE 4.** (A) Frontal view of patient 6 months after open reduction and stable internal fixation of a comminuted fracture of the right mandibular body (4 segments). Note the asymmetry with the right inferior border lower than the left. (B) Panoramic radiograph taken 6 months after the injury showing that the large osseous segment at the inferior border was not adequately reduced. Despite osseous union, the inferiorly positioned bone creates the facial asymmetry.

One variable that was statistically associated with the development of postsurgical complications was the treatment rendered. Four of 17 comminuted fractures (23.5%) treated with external pin fixation developed nonunion, requiring bone grafts. Additionally, 2 patients developed malocclusion, 1 minor and 1 major. This rate of complication (35.3%) is higher than for fractures treated closed (17.1%) and much higher than patients treated with open reduction and stable internal fixation (5.5%). However, it is evident that patients treated with external pin fixation were more severe injuries. Thirteen of the 17 fractures treated with external pin fixation had resulted from high-energy injuries, including 11 gunshot wounds and 2 motor vehicle collisions. Several of these had very tenuous soft tissue attachments to the residual mandibular fragments that would have made open treatment more risky. Closed treatment in these cases was therefore chosen. External pin fixation was used when there were inadequate teeth on either side of the comminuted fracture to control the spatial relationship of the remaining mandibular fragments with MMF. If there were adequate teeth, MMF was used for these injuries.

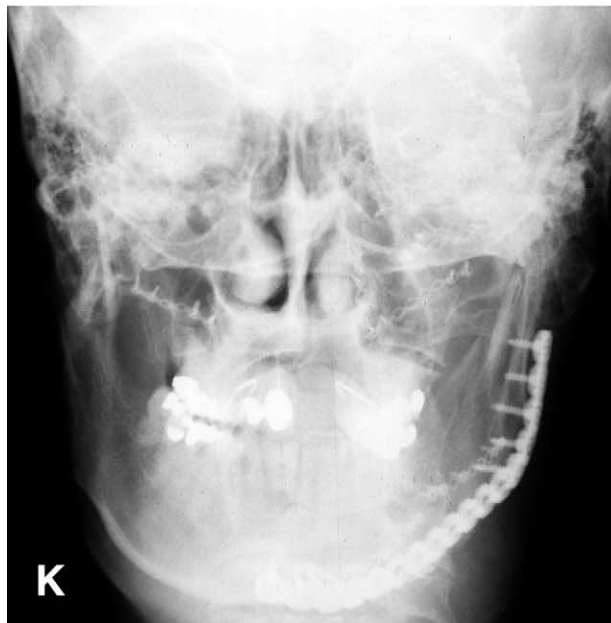
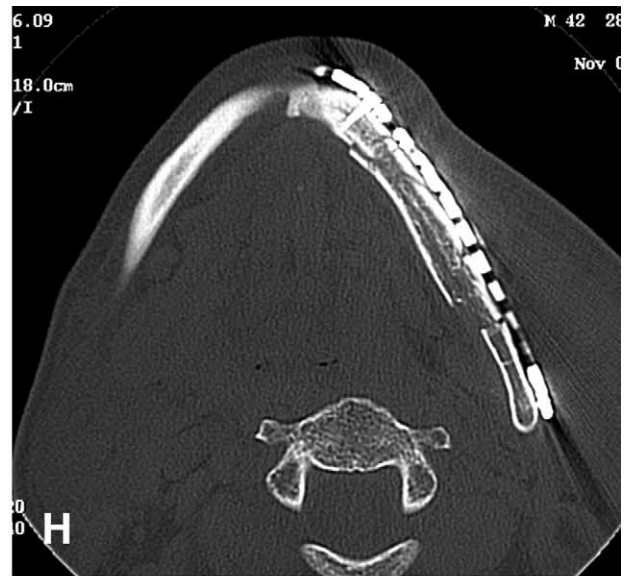
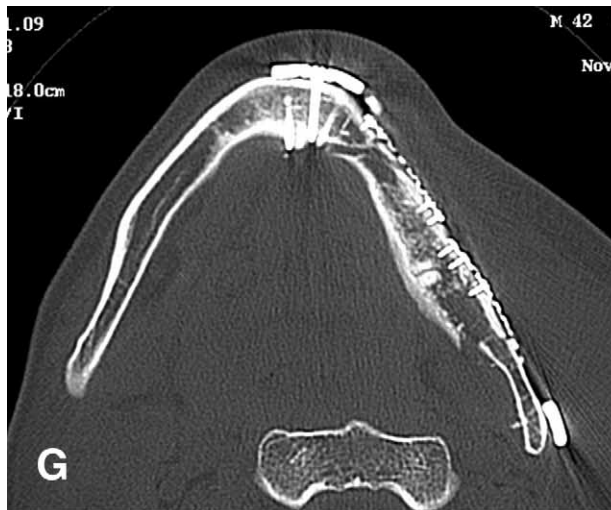
Another variable statistically associated with complications was the cause of the injury. Gunshot wounds had a 27.8% incidence of complications (occlusal plus nonocclusal), probably relating to the large amount of energy imparted to the mandible by the

missile(s). Not surprisingly, gunshot wounds were statistically associated with more severe fragmentation than other causes. The multiply fragmented fracture was associated with more complications than those fractures with fewer fragments. Eleven of the 18 nonocclusal complications (ie, infection, nonunion, etc) were associated with fractures that were multiply fragmented, ten of which were caused by either gunshot wounds or motor vehicle collisions. Despite these statistics, however, the overall complication rate for nonocclusal complications was still quite low (9%).

Occlusal complications in this study were not associated with the use of closed treatment and MMF. All malocclusions were in patients treated with either external pin fixation or open reduction and stable internal fixation. Table 1 shows that 6 of the 8 malocclusions were in patients treated open, and 2 were in patients treated with external pin fixation. Although it might appear that open reduction and stable internal fixation caused more malocclusions than the other methods of treatment, when related to the number of fractures treated, only 4.1% of patients treated open developed malocclusion, whereas 11.7% of patients treated with external pin fixation did. A 4.1% rate of malocclusion for patients treated open seems quite acceptable when examined in the context of the types of fractures being studied. Comminuted fractures are often more difficult to reduce and most







**FIGURE 5.** Pretreatment computed tomography scans of a patient who had a multiply-fragmented left mandibular angle/body fracture (A, B). The fracture was treated open using an extraoral approach (C). The patient was placed into MMF while the osseous fragments were reduced using small plates and screws (D). A locking reconstruction bone plate was then adapted from the ramus to the symphysis, bridging the comminuted region (E). Postoperative CT scans (F, G, H) show that the morphology of the mandible has been reconstructed. Radiographs taken 3 months later show that the fragments have consolidated (I, J, K).

often require long reconstruction bone plates to bridge the comminuted region. The majority of fractures treated in this study (114 of 198; 57.6%) and the vast majority of patients treated with open reduction (114 of 146; 78%) used reconstruction bone plates. The adaptation of these large bone plates takes skill

and time, and the contour is not always perfect. This can cause postoperative malocclusion that may or may not be amenable to simple management. Fortunately, 4 of the 8 patients with malocclusion were easily treated with elastics or occlusal equilibration. The introduction of locking reconstruction bone

plates approximately halfway through this series may have resulted in better occlusal results. None of the patients treated with locking reconstruction bone plates developed a malocclusion. Similar favorable occlusal results have previously been reported for the locking reconstruction bone plates.<sup>26</sup>

This study cannot compare the efficacy of the 3 main forms of treatment, because it was clear from the medical records that the injuries and therefore the treatment groups were not all similar. Many patients who had external pin fixation or closed reduction and MMF applied were deemed not amenable to open treatment, in most cases because of a tenuous blood supply to the residual mandibular fragments. The results of this review show, however, that when possible, open reduction and stable internal fixation produces a very low complication rate. Whether this same sample of patients would have as favorable results using closed methods of treatment is something that can only be determined in a randomized prospective study.

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