Oral Maxillofac Surg (2014) 18:123–152
DOI 10.1007/s10006-012-0374-1

REVIEW ARTICLE

Fixation of mandibular angle fractures: clinical studies

Bruno Ramos Chrcanovic

Received: 2 September 2012 / Accepted: 12 November 2012 / Published online: 24 November 2012

Abstract
Purpose The purpose of this study was to review the literature regarding the evolution of current thoughts on fixation of mandibular angle fractures (MAFs).
Methods An electronic search in PubMed was undertaken in August 2012. The titles and abstracts from these results were read to identify studies within the selection criteria. Eligibility criteria included studies from the last 30 years (from 1983 onwards) reporting clinical studies of MAFs.
Results The search strategy initially identified 767 studies. The references from 1983 onwards totaled 727 articles. Fifty-four studies were identified without repetition within the selection criteria. Two articles showing significance in the development of treatment techniques were included. Additional hand-searching yielded 13 additional papers. Thus, a total of 69 studies were included.
Conclusions Prospective randomized controlled studies of MAFs repair techniques are scarce. The available data at best predict that complications are associated with all kinds of fixation techniques. The similar results of complications in studies using different methods of fixation indicate that biomechanics are only one factor to be considered when treating MAFs. A second fracture in the mandible (which was observed in the majority of the studies' population) can confound the outcome data because the fixation requirements of a double fracture are often different from those for an isolated fracture. It can be necessary additional effort intended for increase of stability when using biodegradable plate system to fixate MAFs. The use of 1.3 mm malleable miniplates was associated with an unacceptable incidence of plate fracture, suggesting that this is not the most adequate system to treat MAFs. The use of the 3D grid plates has shown good clinical results. The efficiency of locking miniplate system is yet to be proven because there are few clinical studies with its use to fixate MAFs, although they have shown good results. When considering the use of semirigid or rigid fixation systems, the use of two miniplates outweigh the advantages of the use of one reconstruction plate, although the use of miniplates is not recommended for displaced comminuted MAFs. Although it has been shown that absolute rigid fixation is not necessary for fracture healing, any system that provides superior stability without impacting negatively on other aspects of the procedure, i.e., time, exposure, and cost, should be favored. MAFs can be treated in a highly effective way and with a relatively low rate of complications with monocortical miniplate fixation. The large number of studies on the treatment of MAF reflects the fact that a consensus has not been reached for a single, ideal treatment method.

Keywords Mandibular angle fracture · Maxillomandibular fixation · Wire osteosynthesis · Internal fixation · Plate · Miniplate · External pin fixation · Lag screw

B. R. Chrcanovic (✉)
Department of Prosthodontics, Faculty of Odontology,
Malmö University, Carl Gustafs väg 34,
SE-205 06 Malmö, Sweden
e-mail: bruno.chrcanovic@mah.se

B. R. Chrcanovic
e-mail: brunochrcanovic@hotmail.com

Introduction

About 19–40 % of all facial fractures are fractures of the mandible, and 12–30 % of all mandibular fractures (MFs) are fractures of the mandibular angle [1–6]. Among MFs, the angle is the first most frequent region for fractures caused by sportive activities, the second most frequent region for fractures caused by violence and the third most fractured region in cases of traffic accidents involving automobiles [6]. Moreover, the treatment of mandibular angle fractures (MAFs) is affected with the highest postsurgical complication rate of all MFs [7–10]. The frequent involvement of the mandibular angle in facial fractures can be attributed to its thin cross-sectional bone area and the common presence of a third molar [11]. Before the advent of antibiotics, open reduction of MFs was associated with a high frequency of infection. Techniques to repair jaw fractures were further influenced by the limits of the technology of the day [12]. Traditional methods of mandible fracture fixation included wire osteosynthesis and maxillomandibular fixation (MMF). These injuries are currently treated by plate/screw osteosynthesis and, depending on the case, the bone segments are secured by one-miniplate fixation, two-miniplate fixation, a lag screw, or by a single rigid plate at the inferior border of the mandible.

The classical method of fixation proposed by Champy et al. [13] in the case of MAFs is designed to apply a miniplate at the superior border of the mandible in the area of the external oblique line with monocortical screws. However, questions concerning the stability provided by miniplate fixation of MAFs have become a point of contention among surgeons [14], based on recent clinical and experimental studies. In addition, this is an important subject because fracture line stability is perceived to be a major determinant of the clinical outcome, since the level of interfragmentary motion strongly influences the morphological patterns of osseous repair [15]. Not all MAFs require operative treatment, but all successful treatment of mandible fractures depends on undisturbed healing in the correct anatomical position under stable conditions [16].

Although there is a widely accepted consensus about the need for surgical reduction and fixation of a MAF, a variety of different treatment modalities have been described [17]. In the literature, discussion is still ongoing about the preferred type of fixation. Fixation of MAFs is possibly more critical than fixation of fractures located in other regions of the mandible. MAFs are biomechanically complex because the major stress-bearing trajectories of the mandible are disrupted in this area [18]. As the philosophies of treatment of maxillofacial trauma alter over time, a periodic review of the different concepts is necessary to refine techniques and eliminate unnecessary procedures. This would form a basis for optimum treatment. The purpose of this study was to review the literature regarding the evolution of current thoughts on fixation of MAFs.

Materials and methods

Objective The objective of this study was to review the literature regarding the evolution of current thoughts on fixation of MAFs.

Data source and search strategies An electronic search without language restrictions was undertaken in July 2012 in the PubMed website (US National Library of Medicine, National Institutes of Health). The following terms were used in the search strategy:

{Subject AND Adjective}
{*Subject*: (mandibular angle fracture [text words])
AND
Adjective: (fixation OR wire osteosynthesis OR plate OR miniplate OR lag screw [text words])}

Only references from the last 30 years (from 1983 onwards) were considered. All reference lists of the selected and review studies were hand-searched for additional papers that might meet the eligibility criteria for inclusion in this study. The titles and abstracts (when available) from these results were read for identifying studies meeting the eligibility criteria. For studies appearing to meet the inclusion criteria, or for which there were insufficient data in the title and abstract to make a clear decision, the full report was obtained and assessed.

Inclusion criteria Eligibility criteria included studies related to the subject (fixation of MAFs) and published since 1983. The studies had to be conducted on patients who have displaced or nondisplaced, comminuted or noncomminuted, unilateral or bilateral MAFs. The study could have been conducted in humans or animals. The study could have applied closed functional therapeutic regimen (CTR) or open reduction internal fixation (ORIF). Randomized controlled clinical trials, cohort studies, case–control studies, cross-sectional studies, and case series were included. Studies not specifically focused on MAFs (i.e., studies comprising fractures of all mandibular regions), but reporting separate outcomes and complications for treatment of MAFs were also considered.

Exclusion criteria Review articles without original data, case reports articles, technical notes, in vitro biomechanical essays, and computer-based (finite element analysis) studies were excluded, although references to potentially pertinent articles were noted for further follow-up.

Results

The study selection process is summarized in Fig. 1. The search strategy initially identified 767 studies. The initial screening of titles and abstracts resulted in 186 full-text papers; 132 were cited in more than one research of terms. Thus, 54 studies were identified without repetition. Despite not being published within the restriction of time proposed here, two articles were included due to its clinical importance [13, 19]. Additional hand-searching of the reference lists of selected studies yielded 13 additional papers. The literature review is based on these 69 articles, and the important points of these studies are presented below. The main results of the included studies are presented in Tables 1 and 2.

Michelet et al. [19] were the first to present “miniaturized screwed plates,” which can be considered the first “prototype” of the modern miniplates. The miniplates, with 4 mm of width and 12, 18, and 25 mm of length, were fixated with two to four screws 5 to 7 mm long, each with a diameter of

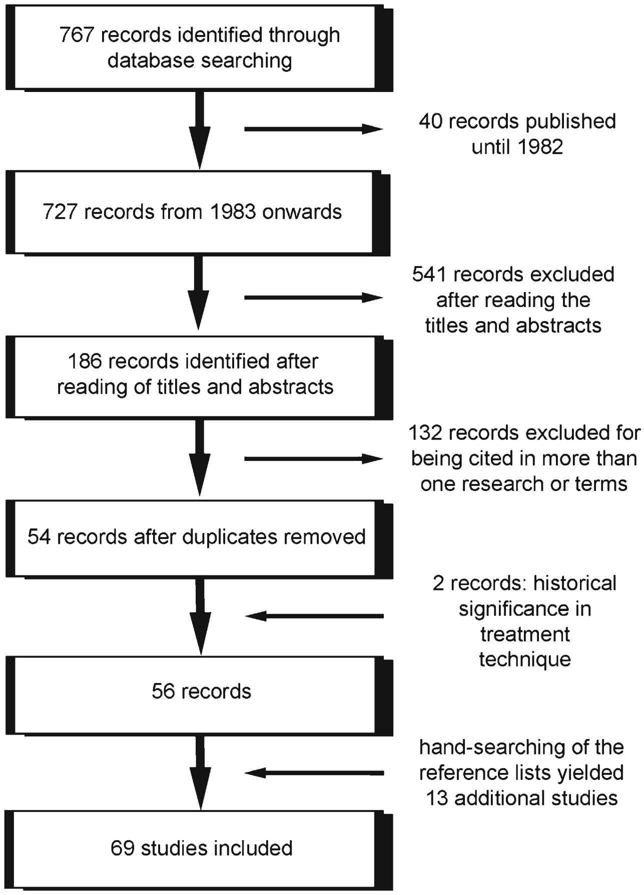

Fig. 1 Study screening process

1.5 mm. The miniplates were not made of titanium, but of Vitallium, an alloy containing 60 % of cobalt, 20 % of chromium, 5 % of molybdenum, and other elements. The authors were probably the first ones to suggest that the plate must be slightly curved to fit the sulcus of the external oblique line for the fixation of MAFs. The authors suggested that the MMF could be either shortened or suppressed. The authors did not consider MAFs in separate, but stated that "the analysis of 300 cases (500 plates) shows the excellent results and the major advantage of this method."

Champy's [13] biomechanical studies resulted in the concept of an ideal line of osteosynthesis. They used blocks made of a photoelastic resin (araldite) to represent the mandible. A plate was then secured to the lateral surface of the blocks along the superior border, and the complex was subjected to simple cantilever loading. The test showed that the pattern of stress distribution created in the plated blocks was similar to the uncut blocks. This study was instrumental in establishing the concept of tension band plating for the treatment of MFs. Taking into account torsional tensile, and compressive forces at all points of the mandible, the ideal lines of osteosynthesis were described. Moreover, the authors also reviewed 183 cases of MFs using a modification of Michelet's osteosynthesis method [19]. They used what they called of "monocortical juxta-alveolar and sub-apical osteosynthesis without compression". In the paper, the authors stressed that all 183 patients were able to eat soft food on the first postoperative day, and that they could eat normal food from the tenth postoperative day. Moreover, infection was found in only 3.8 % of the cases, malunion occurred in 0.5 %, delayed union in 0.5 %, and in 4.8 %, grinding was needed to adjust the occlusion. The patients were followed up for periods up to 5 years. Although not considering the complications of MAFs in separate, the study is important because Champy et al. [13] were the first to report low rates of complications when effectively using mandibular fixation without the use of postoperative MMF. The concept of an ideal line of osteosynthesis was also a cornerstone of the internal fixation of MFs with miniplates. In the case of MAFs, their biomechanical results demonstrated that the best site for the plating is the vestibular osseous flat part located in the third molar region. Stabilization of the fracture with a miniplate positioned along this tension band will negate the muscular forces that naturally act to distract the fragments. They also stated that an osteosynthesis located lower, on the outer surface of the mandible, is solid enough to support the strain developed by the masticatory forces in this region.

Gerlach et al. [20] conducted a large study evaluating the treatment of patients with MFs, in a time span of 7 years in Strasbourg and 5 years in Cologne. The study reports the treatment of 1,187 patients with MFs treated with different methods (298 with MMF, 6 with wire osteosynthesis, 21 with compression plates, and 862 with miniplates), but focuses on the 1,277 MFs in 862 patients treated with miniplate osteosynthesis. Although the study has not distinguished the incidence of fractures and the postoperative complications by mandibular region, the study is important because it showed, in a large population of patients with a wide variety of fracture types, that the proportion of serious complications was relatively low when the MFs were fixed with miniplates using monocortical screws.

Chuong et al. [7] reported 227 patients with 372 MFs, of which 109 were MAFs, all treated by CTR or ORIF with wire osteosynthesis. Considering the low rate of complications in MAFs, the authors stated that a 4-week guideline for MMFs of MFs is appropriate and that routine application of longer periods of immobilization is not necessary.

Cawood [21] prospectively reviewed 50 successive patients with 86 MFs (27 MAFs) treated with plating alone were compared with a control group of 50 successive patients with 90 MFs (21 MAFs) treated by wire fixation and MMF. Separate complication data for MAFs in the control group was not provided, but considering MFs from all regions, the test group had more complications than the control group. The test group lost, in average, less weight

Table 1 Clinical series of MAFs

Authors	Published	Study design	Patients (n)	Patients' age range (average) (years)	Follow-up period range (average)	Mandibular fractures	MAFs	Teeth in the line of MAFs	Teeth retained/removed (in MAFs)	Antibiotics/chlorhexidine rinses (days)	MAF fixation method
Chuong et al. [7]	1983	RA	227	NM (NM)	1 week–38 months (10.4 months)	372	109	88	50/38, 21 (edentulous)	2 IV+5 oral/0	MMF (n=37), wire (n=72)
Cawood [21]	1985	PCCT	50 (test), 50 (control)	10–79 (NM)	NM (NM)	86 (test), 90 (control)	27 (test), 21 (control)	NM	NM/NM	"Were routinely prescribed"/NM	Miniplate (test), wire+6 weeks MMF (control)
Mommaerts and Engelke [22]	1986	RA	41	15–40 (NM)	3 months (3 months)	42	15	NM	NM/NM	7/0	One 4-hole, 2.0-mm miniplate (external oblique line)+MMF (in 76 % of the cases)
Niederdellmann and Shetty [23]	1987	RA	50	NM (NM)	NM/NM	50	50	NM	NM/NM	NM/NM	Solitary lag screw
Theriot et al. [24]	1987	PS-NCG	75	14–53 (26.9)	1 week–6 months (NM)	126	43	NM	NM/NM	2 IV + 5 oral/0	DCP, wire+4–6 weeks MMF
Wald et al. [25]	1988	PS-NCG	54	16–42 (NM)	2–13 months (NM)	85	36	NM	NM/NM	IV preoperatively/0	1 miniplate 2.0 mm (external oblique line or superior lateral surface)
Ardary et al. [8]	1989	PS-NCG	72	NM (28)	2–22 months (NM)	102	32	NM	NM/NM	7/0	DCPs
Takenoshita et al. [26]	1989	RA	20	14–33 (NM)	NM (NM)	22	22	21	0/21	"Prophylactic antibiotic was ordered after the operation"/NM	1 (n=15) or 2 miniplates, or wire+1 miniplate, all cases: MMF (mean, 12.7 days)
Rubin et al. [27]	1990	RA	105	NM (NM)	NM (NM)	105	105	105	NM/NM	At least 5/0	Wire+MMF, MMF
Ellis and Ghali [28]	1991	RA	30	17–49 (NM)	8–52 weeks (11)	30	30	28	0/28	NM/NM	Solitary lag screw
Levy et al. [29]	1991	RA	61	18–47 (28.6)	NM (19)	63	63	63	51/12	IV pre- and postoperatively/preoperatively	One or two 2.0-mm miniplates, with or without MMF
Ellis and Karas [30]	1992	RA	30	15–39 (25.5)	6–36 weeks (16)	31	31	29	3/26	NM/NM	Two 2.0-mm mini DCPs (1 superior, 1 inferior)
Farris and Dierks [31]	1992	RA	34	19–36 (NM)	1 week–1 year (NM)	49 (34 MAFs, 15 associated fractures)	34	NM	NM/NM	NM/NM	Solitary lag screw (n=13), other methods (n=21)
Spaić et al. [32]	1992	RA	47 (only MAFs)	NM (NM)	NM (NM)	227	47	37	NM/NM	NM/NM	Wire osteosynthesis+MMF
Ellis [33]	1993	RA	52	16–63 (29)	9–104 weeks (18)	?[a]	52	40	7/33	NM/NM	Reconstruction plate 2.7 mm
Ellis and Sinn [34]	1993	RA	65	16–49 (29.7)	7–28 weeks (13)	94	65	55	9/46	NM/NM	Two 2.4-mm DCPs
Iizuka and Lindqvist [35]	1993	RA	113	16–77 (31)	8–28 months (13.9)	121	121	71	14/57	7/0	Lag screw (n=3), DCPs (n=22), or reconstruction plates 2.7 mm (n=96)
Passeri et al. [36]	1993	RA	96	3.5–49 (26.5)	21–252 days (75)	?[a]	99	80	36/44	NM/NM	MMF alone (n=59), wiring+MMF (n=35), small plates+MMF (n=5)

Table 1 (continued)

Authors	Published	Study design	Patients (n)	Patients' age range (average) (years)	Follow-up period range (average)	Mandibular fractures	MAFs	Teeth in the line of MAFs	Teeth retained/ removed (in MAFs)	Antibiotics/ chlorhexidine rinses (days)	MAF fixation method
Ellis and Walker [37]	1994	RA	67	13–65 (28.1)	6–59 weeks (22)	110	69	NM	NM/NM	NM/NM	Two 2.0-mm miniplates
Marciani et al. [12]	1994	RA	23	17–41 (22.6)	NM (NM)	29	24	24	0/24	NM/NM	Superiorly positioned wire fixation+MMF
Marker et al. [38]	1994	RA	57	10–41 (24.6)	1 year (1 year)	90	57	57	57/0	7/±42	MMF
Valentino et al. [40]	1994	RA	246	NM (NM)	4 weeks–6 months (2.7 months)	432	107			7–10/21	1 miniplate 2.0 mm (external oblique line)
Choi et al. [41]	1995	RA	40	18–66 (NM)	11 weeks–10 months (5 months)	54	40	39	39/0	5/0	Two 2.0-mm miniplates
Barthélémy et al. [42]	1996	RA	109	16–87 (27)	NM (NM)	157	114	NM	NM/NM	8/0	One 4-hole miniplate 2.0 mm (external oblique line)
Ellis and Walker [43]	1996	RA	81	12–52 (27.2)	6–64 weeks (19)	120	81	65	26/39	NM/NM	One 4-hole miniplate 2.0 mm (external oblique line)
Kallela et al.[44]	1996	PRS	7 (23)[b]	15–48 (29)	3 months (3 months)	11	7	5	5/0	7/0	Solitary lag screw
Kuriakose et al. [9]	1996	RA	168	2–89 (NM)	3–18 months (NM)	266	92	NM	NM/NM	IV preop+oral postop/NM	2.0-mm miniplates (n=58), 2.7 mm plates (n=34)
Schierle et al. [14]	1997	PRS	31	19–52 (NM)	Minimum of 6 months	45	38	5	0/5	NM/NM	One 2.0-mm miniplate (n=16), two 2.0-mm miniplates (n=15)
Potter and Ellis [45]	1999	PS-NCG	46	14–52 (27.6)	6–52 weeks (11.9)	77[c]	51	43	9/34	NM/NM	One 1.3-mm miniplate (external oblique line)
Quereshy et al. [46]	2000	Canine model	6 Beagle dogs	–	The dogs were killed at 6 months	6	6	–	–	Preop/postop doses intramuscular penicillin	One 2.0-mm biodegradable (n=4) or titanium (n=2) miniplate
Zhang [47]	2000	RA	27 (tension band), 19 (inferior)	NM (NM)	36 weeks (tension band), 31 weeks (inferior)	48	28 (tension band), 20 (inferior)	NM	NM/NM	NM/NM	One superior 2.0-mm miniplate (n=28), inferior border plating (n=20)
Ellis [48]	2002	PS-NCG	402	12–56 (28)	6–208 weeks (17.5)	402	402	345	87/258	Preoperatively/ NM	2.0-mm miniplate (32.6 %), 1.3-mm miniplate (12.4 %), 2.0-mm locking miniplate (8.2 %), two mini-DCPs (7.7 %), two 2.0-mm miniplates (22.4 %), or two 2.4-mm DCPs (16.7 %)
Cabrini Gabrielli et al. [10]	2003	RA	191	6–87 (30.3)	6 months–8 years (22 months)	280	79	56	35/21	7/7	6-hole 2.0 mm miniplate (inferior border), 4-hole 2.0 mm miniplate (upper border)
Feller et al. [49]	2003	RA	277	8–82 (30, men; 38 women)	NM (NM)	NM	293	NM	NM/NM	NM/NM	One 2.0-mm miniplate (external oblique line, n=175), MMF (n=72), 2 miniplates or lag screws (n=30)

Table 1 (continued)

Authors	Published	Study design	Patients (n)	Patients' age range (average) (years)	Follow-up period range (average)	Mandibular fractures	MAFs	Teeth in the line of MAFs	Teeth retained/removed (in MAFs)	Antibiotics/chlorhexidine rinses (days)	MAF fixation method
Fox and Kellman [50]	2003	RA	68	16–54 (28.2)	6–83 weeks (13.6)	119	70	39	38/1	7–10/7–10	Two 2.0-mm miniplates
Feledy et al. [52]	2004	RA	22	16–68 (20.2)	Minimum of 6 months	36	22	NM	NM/NM	Preoperatively IV/0	3D grid 2.0-mm miniplate (curved 8-hole)
Chritah et al. [53]	2005	PS-NCG	34	12–48 (21.4)	At least 6 weeks	50	31	?	"Extraction of impacted third molars in the line of fracture, was performed if indicated"	7/NM	2.0-mm locking miniplate+1 week MMF
Guimond et al. [54]	2005	RA	37	15–62 (28.6)	4–40 weeks (10)	60	37	29	5/24	7/preoperatively	One curved 3D grid 8-hole 2.0-mm miniplate
Razukevicius et al. [55]	2005	RA	425	15–44 (NM)	NM (NM)	425	425	NM	NM/NM	NM/NM	MMF (n=115), Kirschner wire (n=246), miniplate (n=59), Zes Pol plate (n=5)
Soriano et al. [56]	2005	RA	69	12–69 (29)	1–11 months (6.6; with molar in the line of fracture), 1–9 months (4.8; without molar)	111	72	30	25/5	NM/NM	Miniplate+6 days (average) of MMF
Barry and Kearns [57]	2007	RA	50	16–42 (22.4)	1–84 months (34)	50	50	47	5/42	10/0	One 2.0-mm miniplate (external oblique line)
Siddiqui et al. [58]	2007	PRS	62	17–57 (NM)	Until 12 weeks	62	62	NM	NM/NM	IV periop, continued for 24 h postop/0	One (n=36) or two 2.0-mm miniplates (n=26)
Zix et al. [59]	2007	PS-NCG	20	18–59 (33.9)	At least 6 months	34	20	14	14/0	6–7/until removal of the arch bars	3D grid 2.0-mm miniplate (straight 8-hole or curved 10-hole)
Bell and Wilson [60]	2008	RA	75	13–61 (28.2)	At least 6 weeks	129	83	60	37/23	Number of days NM/0	One 2.0-mm miniplate (external oblique line)
Mehra and Murad [61]	2008	RA	133	17–55 (24.8)	8–64 weeks (12.3)	163	163	163	0/163	7/14	Rigid fixation via extraoral approach+1 weeks MMF (65 fractures 57 patients), semirigid fixation via intraoral approach+2 weeks MMF (98 fractures, 76 patients)
Paza et al. [62]	2008	RA	114	16–62 (27)	NM (NM)	175	115	63	55/8	7/7	One miniplate superior border (n=40), two miniplates (n=36), one 2.4-mm bicortical plate inferior border (n=12), one superior miniplate (n=6), and one 2.4-mm inferior plate, or MMF (n=3)

Table 1 (continued)

Authors	Published	Study design	Patients (*n*)	Patients' age range (average) (years)	Follow-up period range (average)	Mandibular fractures	MAFs	Teeth in the line of MAFs	Teeth retained/removed (in MAFs)	Antibiotics/chlorhexidine rinses (days)	MAF fixation method
Scolozzi and Jaques [63]	2008	PS-NCG	7	17–29 (22.3)	12 months (12 months)	7	7	7	7/0	3/0	One 6-hole reconstruction plate (inferior border)
Bui et al. [64]	2009	RA	49	15–52 (26)	4–24 weeks (NM)	49	49	32	13/19	7/0	One curved 3D grid 8-hole 2.0-mm miniplate
Ramakrishnan et al. [65]	2009	RA	83	17–62 (32)	1–12 months (2.5)	140	85	52	NM/NM	Yes/yes (the days of use were not informed)	One 2.0-mm, 4-hole miniplate (external oblique line), superior 2.0-mm and inferior 2.0-mm bicortical, two monocortical miniplates, or a 2.0-mm biplanar curved-angle strut plate
Sugar et al. [66]	2009	PRS	140	16–68 (25)	1 week (first review), 1 month (second), 3 months (third)	140	140	NM	NM/NM	"Patients received the same antibiotic regime"/0	One 2.0-mm, 4-hole miniplate (external oblique line or lateral mandibular aspect)
Bayat et al. [67]	2010	PS-NCG	19	15–41 (27.4)	1–24 weeks (NM)	19	19	15	6/9	7/7	One 6-hole, 2.5 mm biodegradable plate (lateral mandibular aspect)+MMF
Boffano and Roccia [68]	2010	RA	8 (only bilateral MAFs)	20–41 (29)	6 months (6 months)	16	16	16	14/2	7/0	One 4-hole, 2.0 mm miniplate (external oblique line or lateral mandibular aspect)+7 days of MMF
Danda [69]	2010	PRS	54	18–43 (32, G1), 21–49 (29, G2)	1–6 weeks (NM)	54	54	NM	NM/NM	3/0	One (G1, n=27) or two (G2, n=27) 2.0-mm miniplates+2 weeks of MMF
Ellis [70]	2010	PS-NCG	185	13–54 (28)	At least 6 weeks (162 days)	185	185	167	17/150	5–7/"chlorhexidine mouth rinse was provided"	Wire+5–6 weeks of MMF (G1, n=60), one miniplate (superior border, G2, n=62), two miniplates (G3, n=63)
Seemann et al. [71]	2010	RA	322	NM (29.7, men), NM (29.1, women)	NM (NM)	?	335	NM	NM	NM/NM	1 miniplate (n=95), 2 miniplates (n=170), 1 lag screw (n=27), 2 biodegradable plates (n=17), other (n=26)
Hochuli-Vieira et al. [72]	2011	RA	45	15–64 (29)	6 months (6)	66	45	NM	NM/NM	NM/NM	One rectangular 3D grid 4-hole, 2.0-mm miniplate
Kumar et al. [73]	2011	RA	80	16–62 (26.6)	3 months (3 months)	80	80	73	NM/NM	NM/NM	One (external oblique line; intraoral approach: n=35; combined approach: n=15) or two (inferior border; extraoral: n=30) 4-hole, 2.0-mm miniplates

Table 1 (continued)

Authors	Published	Study design	Patients (*n*)	Patients' age range (average) (years)	Follow-up period range (average)	Mandibular fractures	MAFs	Teeth in the line of MAFs	Teeth retained/removed (in MAFs)	Antibiotics/chlorhexidine rinses (days)	MAF fixation method
Schaaf et al. [17]	2011	RA	45	17–70 (27, G1), 13–78 (23, G2)	NM (NM)	45	45	NM	NM/NM	NM/NM	2.0-mm lag screw (G1, *n*=21) or one or two 2.0-mm miniplates (G2, *n*=24)
Singh et al. [74]	2011	PS-NCG	52	NM (NM)	NM (NM)	84	54	NM	NM/NM	NM/NM	One 4-hole, 2.0 mm miniplate (inferior border)
Singh et al. [75]	2011	RA	51	NM (NM)	NM (NM)	87	51	NM	NM/NM	NM/NM	One 4-hole, 2.0 mm miniplate (external oblique line)+MMF (7–14 days)
Höfer et al. [76]	2012	RA	60	15–73 (31.1)	At least 1 year (NM)	90	60	NM	NM/NM	4 (mean)/0	One 4-hole, 2.0 mm miniplate (external oblique line, G1, *n*=30) or 3D grid 4-hole 2.0-mm miniplate (vestibular cortex, G2, *n*=30)
Laverick et al. [77]	2012	PRS	250	NM (NM)	1–40 weeks (6.7)	261	261	219	NM/NM	"A standard peri- and postoperative antibiotic regimen"/NM	One 4-hole, 2.0 mm miniplate (intraoral approach, external oblique line, G1, *n*=137; or extraoral approach, lateral mandibular aspect, G2, *n*=124)
Perry et al. [78]	2012	RA	9	NM (NM)	NM (NM)	9	9	NM	NM/NM	NM/NM	One 4-hole, 2.0-mm locking miniplate (Kirschner wires were used to assist in the fixation)
Vineeth et al. [16]	2012	PRS	20	19–51 (NM)	90 days (90 days)	29	20	20	19/1	5–7/?	One 4-hole, 2.0-mm miniplate (G1; *n*=10), 3D grid 4- or 6-hole, 2.0 mm miniplate (G2; *n*=10), both applied at the external oblique line

NM not mentioned, *IV* intravenous application (parenteral), *DCP* dynamic compression plate, *RA* retrospective analysis, *PS-NCG* prospective study with no control group, *PCCT* prospective controlled clinical trial, *PRS* prospective randomized study

[a] Although associated mandibular fractures were present, the exact number was not reported

[b] Among the 23 patients with parasymphyseal and angle fractures of the study, seven had MAFs

[c] Twenty-six patients had at least one other fracture of the mandible, indicating that 77 was the minimum number of mandibular fractures. The exact number was not reported

Table 2 Clinical series of MAFs: treatment complications

Authors	Published	Treatment complications									
		Infection	Wound dehiscence	Plate fracture	Osteomyelitis[a]	Malocclusion	Delayed union/malunion[b]	Nonunion[b]	Facial nerve injury	Alveolar inferior nerve injury	Other
Chuong et al. [7]	1983	4	2	0	NM	1	5/0	NM	1	0	0
Cawood [21]	1985	1 (test) NM (control)[c]	3 (test) NM (control)[c]	0 (test) 0 (control)[c]	0 (test) NM (control)[c]	1 (test) NM (control)[c]	0 (test) NM (control)[c]	0 (test) NM (control)[c]	1 (test) NM (control)[c]	0 (test) NM (control)[c]	0 (test) (control)[c]
Mommaerts and Engelke [22]	1986	–[d]	0	0	–[d]	–[d]	0	0	0	–[d]	0
Niederdellmann and Shetty [23]	1987	1	0	0	1	3	2	0	0	3	0
Theriot et al. [24]	1987	4 (DCP) 0 (wire)	0	0	0	? (2)[e]	0	? (1)[e]	0	0[e]	0
Wald et al. [25]	1988	3	0	0	0	0	0	0	0	0	1 patient complained of intermittent pain 5 months postoperatively
Ardary et al. [8]	1989	5	0	0	0	? (2)[f]	0	? (2)[f]	0	? (1)[f]	0
Takenoshita et al. [26]	1989	0	0	0	0	0	0	0	0	0	0
Rubin et al. [27]	1990	–[g]	–[g]	–[g]	–[g]	–[g]	–[g]	–[g]	–[g]	–[g]	–[g]
Ellis and Ghali [28]	1991	7	0	0	0	2	0	0	0	0	8 patients with slight mobility of the fracture, necessitating supplemental methods of fixation (1 DCP, 7 MMF)
Levy et al. [29]	1991	3 (1 plate), 1 (2 plates)	0	0	0	1 (1 plate), 0 (2 plates)	1 (1 plate), 0 (2 plates)	0	0	0	0
Ellis and Karas [30]	1992	3	0	0	1	0	0	1	0	0	5 postoperative swellings that necessitated hardware removal
Farris and Dierks [31]	1992	2	0	0	0	2	0	0	0	0	Tap used to thread the proximal fracture fragment sheared off in 1 patient; 1 with profuse bleeding; 1 with suboptimal fracture reduction
Spaić et al. [32]	1992	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Ellis [33]	1993	4	0	0	0	4	0	0	0	0	0
Ellis and Sinn [34]	1993	21	0	0	0	1	13	0	0	0	0
Iizuka and Lindqvist [35]	1993	8	0	0	0	17	0	0	1	3	7 hypertrophic scars, 2 joint pain, 30 cold sensation/feeling of foreign body
Passeri et al. [36]	1993	17	0	0	0	4	4	0	0	0	0
Ellis and Walker [37]	1994	17	1	0	0	0	5	1	0	0	Hardware removal in 16 of the 17 infected fractures
Marciani et al. [12]	1994	3	0	0	0	2	0	1	0	0	0

Table 2 (continued)

Authors	Published	Treatment complications									
		Infection	Wound dehiscence	Plate fracture	Osteomyelitis[a]	Malocclusion	Delayed union/ malunion[b]	Nonunion[b]	Facial nerve injury	Alveolar inferior nerve injury	Other
Marker et al. [38]	1994	2	0	0	0	5	0	0	0	0	0
Valentino et al. [40]	1994	7	1	0	0	0	7	2	0	0	0
Choi et al. [41]	1995	2	0	0	0	2	0	0	0	0	0
Barthélémy et al. [42]	1996	1	0	0	0	0	0	1	0	2	2 postoperative hematomas
Ellis and Walker [43]	1996	6	0	0	0	3	0	1	0	0	4 swelling without discharge, 3 complaints of pain in the area of the bone plate
Kallela et al.[44]	1996	1	0	0	0	0	0	0	0	1	1 lag screw did not provide adequate stability in relation to the fracture line, 1 lag screw had broken, 1 with angular pain 4 months after surgery
Kuriakose et al. [9]	1996	6 (2.0 mm), 1 (2.7 mm)	0	0	0	6 (2.0 mm), 2 (2.7 mm)	0	0	0 (2.0 mm) 4 (2.7 mm)	0	6 plate removal (2.0 mm), 3 plate removal (2.7 mm)
Schierle et al. [14]	1997	1 (1 m), 1 (2 m)	0	0	0	0	0	0	0	0	0
Potter and Ellis [45]	1999	3	0	5	0	0	2	0	0	0	0
Quereshy et al. [46]	2000	0	1 (titanium)	0	0	0	0	0	0	0	0
Zhang [47]	2000	3 (tension band), 1 (inferior)	0	0	0	2 (tension band), 1 (inferior)	0	0	0	0	6 healing gap at lower border (tension band)
Ellis [48]	2002	75	NM	NM	NM	NM	NM	NM	NM	NM	Removal of hardware in 75 cases
Cabrini Gabrielli et al. [10]	2003	15	0	0	0	? (4)[h]	1	3	3	0	2 discreet facial asymmetry due to medial or lateral dislocation of the mandibular ramus
Feller et al. [49]	2003	1 (MMF)	12 (1 miniplate)	1 (1 miniplate)	2 (2 miniplates)	2 (MMF), 3 (1 miniplate)	0	2 (1 miniplate), 3 (2 miniplates)	0	10 (1 miniplate)	0
Fox and Kellman [50]	2003	2	4	0	0	4	0	0	0	3	0
Feledy et al. [52]	2004	2	0	0	0	0	0	0	0	0	0
Chritah et al. [53]	2005	0	0	0	0	1	0	0	0	0	0
Guimond et al. [54]	2005	2	1	0	0	0	0	0	0	3	Hardware removal in 2 patients
Razukevicius et al. [55]	2005	Infections were included in the “osteomyelitis” classification	NM	NM	28 (5.3 % in CTR methods, 15.3 % in ORIF)	NM	NM	NM	0	–[i]	0

Table 2 (continued)

Authors	Published	Treatment complications									
		Infection	Wound dehiscence	Plate fracture	Osteomyelitis[a]	Malocclusion	Delayed union/ malunion[b]	Nonunion[b]	Facial nerve injury	Alveolar inferior nerve injury	Other
Soriano et al. [56]	2005	5 (with molar), 4 (without)	NM	NM	NM	NM	NM	NM	NM	NM	NM
Barry and Kearns [57]	2007	4	1	1	0	4	0	0	0	4	1 patient with lingual nerve deficit
Siddiqui et al. [58]	2007	4 (1 plate), 4 (2 plates)	0	0	0	4 (1 plate), 2 (2 plates)	0	0	0 (1 plate), 2 (2 plates)	–[j]	0
Zix et al. [59]	2007	0	2	1	0	4	0	0	0	2	0
Bell and Wilson [60]	2008	4	1	0	0	0	1	1	0	0	16 cases of loose/ symptomatic hardware
Mehra and Murad [61]	2008	2 (intraoral), 1 (extraoral)	5 (intraoral), 0 (extraoral)	0	0	0	0	0	0 (intraoral), 13 (extraoral)	0	4 objectionable scarring requiring further surgery (extraoral)
Paza et al. [62]	2008	10	0	0	0	2	0	0	0	2	0
Scolozzi and Jaques [63]	2008	0	0	0	0	0	0	0	0	0	0
Bui et al. [64]	2009	4	0	0	0	0	0	0	0	0	0
Ramakrishnan et al. [65]	2009	8	NM	NM	NM	NM	NM	NM	NM	NM	NM
Sugar et al. [66]	2009	7 (first review), 26 (second), 19 (third)	19 (first), 27 (second), 20 (third)	0	0	4 (first), 4 (second), 2 (third)	0	5	0	0	Plate exposure: 5 (first), 4 (second), 8 (third); dry socket: 3 (first), 2 (second), 0 (third). Five plate removals after nonunion and use of reconstruction plates
Bayat et al. [67]	2010	2	0	0	0	1	0	0	0	0	5 screw heads fractured during screw placement
Boffano and Roccia [68]	2010	1	0	0	0	0	0	0	0	0	0
Danda [69]	2010	1 (G1), 2 (G2)	3 (G1), 2 (G2)	NM	NM	0	NM	NM	NM	NM	Scar developed in 5 cases of G2. Plate removal: 1(G1), 1 (G2)
Ellis [70]	2010	8 (G1), 2 (G2), 14 (G3)[k]	5 (G1), 0 (G2), 8 (G3)	0	NM	4 (G1), 0 (G2), 3 (G3)	0	14 (G1), 5 (G2), 3 (G3)	NM	3 (G1), 1 (G2), 3 (G3)	Plate/wire exposure: 3 (G1), 0 (G2), 5 (G3)
Seemann et al. [71]	2010	33	51	19 (including screws loosening)	0	2	0	16	5	0	18 functional impairment (pathologically limited TMJ range of motion or joint affection)
Hochuli-Vieira et al. [72]	2011	3	0	0	0	3	0	0	0	4	0

Table 2 (continued)

Authors	Published	Treatment complications									
		Infection	Wound dehiscence	Plate fracture	Osteomyelitis[a]	Malocclusion	Delayed union/malunion[b]	Nonunion[b]	Facial nerve injury	Alveolar inferior nerve injury	Other
Kumar et al. [73]	2011	5 (intraoral), 5 (extraoral)	1 (combined intra-/extraoral)	0	0	1 (intraoral), 1 (combined intra-/extraoral)	0	0	0	0	0
Schaaf et al. [17]	2011	1 (G1), 0 (G2)	0	0	0	0 (G1), 2 (G2)	0	0	0	0	2 loosening of screws (G1), 1 instability owing to noncompliance (G1), 3 loosening of plates (G2)
Singh et al. [74]	2011	2	0	0	0	2	0	0	1	0	0
Singh et al. [75]	2011	8	6	0	0	4	4	0	0	5	12 “cosmetic disfigurements” at the lower border
Höfer et al. [76]	2012	3 (G1), 0 (G2)	3 (G1), 0 (G2)	0	0	0	0	0	0	0	Plate loosening: 2 (G1), 0 (G2)
Laverick et al. [77]	2012	28 (G1), 6 (G2)	NM	NM	NM	26 (G1), 16 (G2)	0	6	0	60 (G1), 51 (G2)	Hardware removal in 34 fractures
Perry et al. [78]	2012	0	0	0	0	0	0	0	0	0	0
Vineeth et al. [16]	2012	2 (G1), 0 (G2)	0	0	0	0	0	0	0	1 (G1), 2 (G2)	0

NM not mentioned

[a] Many studies do not mention osteomyelitis as a complication, probably including it in the “infection” category of complication

[b] The definitions of several types of osseous unions may vary from study to study. The main definitions described in the literature are the following: (1) *delayed union*: a union is considered delayed when healing has not advanced at the specific rate for the location and type of fracture. Others defined as a fracture in which healing was delayed beyond 8 weeks but successfully treated with minimal intervention and a longer time of fixation. It is also defined as mobility at the fracture site after a certain number of weeks of treatment. The number of weeks depends on the definition of each study; (2) *malunion*: any fracture site that exhibited deformity or anomaly because accurate apposition of fractured bone ends was not achieved during fracture healing. Virtually, malunion is “bony union,” and the fractured bone ends are united by normal bony image in radiograph. However, the normal anatomic structure is not restored because of the unsatisfactory reduction; (3) *nonunion*: a diagnosis of nonunion is unjustified until there is evidence, either clinical or radiographic, that healing has ceased and that union is highly improbable. There is also the definition of (4) *fibrous union*: any fracture site that exhibited mobility after 8 weeks of surgical management or after 4 weeks without treatment

[c] Separate complication data for MAFs in the control group was not provided, but considering mandibular fractures from all regions, the test group had more complications than the control group

[d] There were six complications in 42 mandibular fractures: five local infections and one osteomyelitis. Four of these complications developed in four of the 15 patients with MAFs (26.6 %), but delineation of the specific problems in these individuals was not available. However, the authors also reported three patients with malocclusion, 15 patients with disturbance of inferior alveolar nerve (most hypoesthesias and two cases of paresthesia), and four anesthesias of the inferior alveolar nerve

[e] In the group treated with DCPs, there were two malocclusions and one nonunion. However, the authors did not inform the location of the fractures in these patients with these complications. In addition, the authors did not inform exactly how many nerve injuries occurred; they commented only that “there was no difference in neurosensory disturbance of the inferior alveolar nerve between the bone plate and wire osteosynthesis groups”

[f] It was not specified the location of the fractures in the patients with these complications

[g] Delineation of the specific problems in the patients was not available. The authors reported the complications by intervention: open reductions (25 %), closed reductions (20 %), extraction of the tooth in the line of fracture (19 %), and retention of the tooth (23 %)

[h] Four patients among the 100 who were dentate or partially edentulous presented with malocclusion related to the treatment. However, the number of patients with MAFs between these four was not reported

[i] The authors studied the changes in the pain threshold of the damaged nerve after the therapeutic procedure: the degree of the alveolar inferior nerve damage was classified as mild (n=31), moderate (n=168), and severe (n=89)

[j] The term “lip numbness” (subjective and objective) was used to probably characterize alveolar inferior nerve injury (one miniplate, n=31; two miniplates, n=18)

[k] Considering together the occurrences of cellulitis, purulence, and granulation tissue

than the control group. The patients from the test group also restored the normal weight faster than the control group. The same occurred with the postoperative mouth opening.

Mommaerts and Engelke [22] described the results of miniplate fixation of 42 mandible fractures at all locations. For MAFs, they applied one 2.0-mm noncompression miniplate to the external oblique line. Four (out of six) complications developed in four of the 15 patients with MAFs (26.6 %), but delineation of the specific problems in these individuals was not available.

Niederdellmann and Shetty [23] conducted a retrospective study evaluating MAFs treated with solitary lag screw osteosynthesis. Their intraoral method featured a 16.0 % complication rate and required reoperation for screw removal at 6 months. The authors stated that 96 % of patients showed “uneventful” healing. They recommended leaving teeth in the line of fracture unless they were grossly mobile or involved with pathology, and, if necessary, removing them later at the time of screw removal. The authors concluded that this is an effective and predictable modality of treatment with a low rate of morbidity.

Theriot et al. [24] prospectively compared fracture healing and complication rates using mini dynamic compression plates (DCPs) osteosynthesis and wire osteosynthesis with 4 to 6 weeks of MMF. There was no statistical difference in infection rates between the two groups ($P<0.05$) and in the infection rate in rigidly fixed fractures with or without compression ($P<0.05$). There was no significant difference between the amount of time it took to reduce mandible fractures with transosseous wiring and plating, although this was not considered separately for MAFs.

Wald et al. [25] conducted a prospective study to evaluate the efficacy of noncompression miniplates without MMF in the fixation of MFs by transoral approach. Of the four occurrences of infections, three were in the angle (8.3 % rate of infection in 36 MAFs). The authors concluded that mandibular osteosynthesis using miniature malleable plates is a useful and effective method for the repair of selected mandible fractures.

Ardary [8] prospectively evaluated MFs treated with compression plates. Of the nine infected fracture sites, five were located in the angle region (four had plates placed extraorally and one was placed intraorally). Of the extraorally managed MAFs that developed infections, all were associated with the presence of a third molar that was extracted at the time the plate was placed (a total of seven MAFs were managed extraorally with simultaneous extraction of a third molar). Five of the six plates associated with infection that were removed were located in the angle region.

Takenoshita et al. [26] evaluated patients with MAFs treated with one or two 2.0-mm miniplates, or with wiring and one miniplate. All third molars were removed from the line of fracture. No plate exposure or nonunion was observed. The authors did not report cases of postoperative infections.

Rubin et al. [27] conducted a retrospective analysis of MAFs associated with impacted or partially erupted third molars. Morbidity was analyzed according to retention versus extraction of the third molar tooth at the time of fracture reduction and closed versus extraoral open reduction with internal fixation using wire osteosynthesis. When comparing open and closed reduction of the MAF associated with an impacted or partially erupted third molar tooth, the incidence of complications in the open reduction group was 25 % and in the closed reduction group was 20 %, with no statistical significance. When comparing extraction of the tooth and retention of the tooth, the complication rate was 19 % and 23 %, respectively, with no statistical significance. In those who were treated with retention of the tooth combined with open reduction, however, there seems to be a trend toward an increased incidence of complications (44 %), being higher when compared with 20 % for retention of the third molar with closed reduction, 20 % for extraction of the third molar with closed reduction, and 19 % for extraction of the third molar with open reduction.

Ellis and Ghali [28] retrospectively evaluated 30 patients with MAFs treated with a single lag screw. All teeth in the line of fracture were removed during the surgery. Following application of the lag screw, eight patients had slight mobility of the fracture, necessitating supplemental methods of fixation. The authors stressed that the infections in the patients were all very mild. They also stated that this is an extremely useful, but technique-sensitive, method of providing rigid internal fixation for MAFs.

Levy et al. [29] conducted a retrospective study including non-infected and noncomminuted MAFs treated with miniplates. Only two patients had their miniplates removed. The patients were distributed in the following groups: (1) one miniplate/no MMF, (2) one miniplate/MMF, (3) two miniplates/no MMF, and (4) two miniplates/MMF. Statistical evidence indicated that the higher number of complications observed in the one-miniplate group was significant.

Ellis and Karas [30] evaluated patients who had MAFs treated with two 2.0-mm mini DCPs. Nine fractures (29 %) required further surgical intervention to solve problems. The authors stated that the use of two mini DCPs to treat MAFs in the manner described is associated with a significant incidence of postsurgical complications.

Farris and Dierks [31] compared 13 patients with MAFs treated with a solitary lag screw with 21 patients with at least one MAFs treated with other methods. In the lag screw group, six patients had multiple fracture sites. Complications occurred with two (15.4 %) of the patients, but only one (7.7 %) directly related with the use of a lag screw. In the group not using lag screws, complications were seen in five (24 %) of the patients. The authors stated that equipment costs are decreased by this technique, which is "conceptually straightforward."

Spaić et al. [32] evaluated 47 patients presenting MAFs treated with wire osteosynthesis, and showed no unsuccessfully treated cases. In their technique, the wire is located just beneath the mucoperiosteum and can be easily removed if necessary. They stated that the buccal mandibular cortex in the molar region is thick enough to accept a wire ligature, which has to ensure the immobility of the fragments and prevent any displacement of the distal fragment.

Ellis [33] retrospectively evaluated 52 patients with unilateral MAFs treated with reconstruction bone plate (2.7 mm). The occlusal relationships were judged as normal in all but four of the dentulous patients at 1 week following surgery. All four of these patients had concomitant fractures of the mandible in the tooth-bearing region, making it difficult to determine which fracture(s) was not perfectly reduced. Four fractures (7.5 %) required further surgical intervention for postsurgical infections. Three of these patients had a third molar removed at the time of surgery; the other patient did not have a tooth associated with the fracture. The author concluded that the use of the reconstruction bone plate for MAFs was found to be very predictable and was associated with a low rate of complications.

Ellis and Sinn [34] evaluated 65 patients with 65 MAFs treated with two 2.4-mm DCPs. Twenty-one MAFs (32 %) developed infections requiring secondary surgical intervention for bone plate removal. During the surgery, bony sequestra were commonly found. A separate analysis of the first 20 patients, where the screws were inserted as self-threading screws, found that eight required plate removal and sequestrectomy (40 %). An analysis of the 45 patients whose screw holes were tapped found that 13 required further intervention (29 %). The authors concluded that the use of two dynamic compression plates was found to be relatively easy, but resulted in an unacceptable rate of infection.

Iizuka and Lindqvist [35] evaluated the outcome in patients with MAFs treated with either lag screw fixation, compression plates, or neutral reconstruction plates. A postoperative infection was identified in eight cases (6.6 %). Malocclusion was more frequent when two separate osteosynthesis were performed compared with one osteosynthesis (26.2 % vs. 8.5 %; global rate of 14 %). There was an association with infection and the use of compression plates at the angle after tooth extraction in the fracture line. The authors suggested that if a molar tooth in the fracture line has to be extracted, this should be done after fracture stabilization. Moreover, they also stated that because of the relatively small cross-section of bone surface and particular anatomic features of the angular region, well-adjusted interfragmentary compression is often not possible. Thus, a neutral reconstruction plate is considered optimal for rigid osteosynthesis.

Passeri et al. [36] retrospectively analyzed complications in 96 patients with 99 MAFs treated with MMF and/or open reduction with nonrigid means of intraosseous fixation, such as transosseous wires, circummandibular wires, or small positional bone plates. Every one of the 17 cases that developed postoperative infection had a tooth initially associated with the fracture. The authors concluded that MAFs are associated with a significant number of postsurgical complications, regardless of the method of treatment.

Ellis and Walker [37] evaluated patients with MAFs treated with two noncompression miniplates. Nineteen patients (28 %) developed complications that required further surgical intervention, of which 17 became infected (25 %). Twelve of the 14 infected fractures associated with a tooth occurred in fractures where the tooth was removed during surgery. The authors concluded that the fixation technique was found to be relatively easy, but resulted in an unacceptable rate of infection.

Marciani et al. [12] evaluated patients with MAFs with either impacted or erupted third molars in the line of fracture, treated with one superiorly positioned transosseous wire fixation and MMF. Treatment of the fractures involved removal of the third molar. Complications developed in four fractures (17 %), of which three were infections. Two patients were noncompliant and removed their MMF multiple times following fracture repair. One noncompliant patient developed a nonunion requiring reconstruction. The authors stated that transosseous wire placement is relatively easy, inexpensive, and can be quickly executed using simple armamentarium in an ambulatory care setting.

Marker et al. [38] retrospectively evaluated patients with MAFs where a completely or partially impacted third molar was present in the line of fracture. Infection was diagnosed in three patients (5 %), of which two were MAFs. The authors concluded that in cases of MAF, when a completely or partially impacted third molar is present in the line of fracture, the tooth can be retained and the fracture treated with CTR using MMF with low rate of infection. The prerequisites for this treatment are that there is no pericoronal infection around the tooth, that the tooth itself is not fractured, that the tooth is not displaced with an exposed apex, and finally that the tooth does not cause difficulty in reducing the fracture.

Tate et al. [39] evaluated the ability of patients with MAFs to generate bite forces after surgical treatment. Bite forces were recorded at varying periods in 35 males treated with ORIF using two miniplates for MAFs and compared with bite forces obtained in 29 male controls. Seventeen patients had isolated MAFs, one patient had bilateral angle fractures, all others had an angle fracture combined with a contralateral symphysis or body fracture. Bite forces were measured at the incisor and right and left molar regions, on as many postoperative visits as possible. A statistically significant reduction in incisor and molar bite force was found in the first 6 weeks after surgery when compared with either the patients after the sixth postoperative week or the controls. There was no significant difference between controls and patients after the sixth postoperative week for incisor bite force. The same did not occur for the molar bite force.

Valentino et al. [40] retrospectively reviewed 246 patients with 432 MFs, of which 107 were MAFs. When individual fractures were examined for incidence of any complication, the rates were 10 %, 14 %, 14 %, and 18 % for fractures at the symphysis, body, parasymphysis, and angle, respectively. Wound infection and malunions were most frequently found at the MAF.

Choi et al. [41] evaluated a sample of 40 patients who had MAFs treated with the two-miniplate fixation technique. Bone healing took place in all cases without evidence of osteomyelitis. None of the 32 plates that were removed 6 to 10 months postoperatively showed signs of screws loosening. Two patients (5 %) had postoperative infection. The authors indicated the fixation technique in the case of MAFs to achieve early mobility of the jaw with accurate reduction and stable fixation of the fractures. The authors also performed an in vitro study.

Barthélémy et al. [42] evaluated 109 patients with 114 MAFs treated with one miniplate at the external oblique line, with a 94.5 % healing success rate. The authors advocated the intraoral approach with the use of a transbuccal trocar in order to decrease the morbidity.

Ellis and Walker [43] evaluated dentate patients with noncomminuted MAFs treated with a four-hole noncompression titanium miniplate adapted along the external oblique ridge. Postsurgical MMF was not used in any patient. Thirteen patients (16 %) developed complications that required further surgical intervention (minor complications in 11 patients and major infections in two patients). The authors concluded that the fixation technique is a simple, reliable technique with a relatively small number of major complications.

Kallela et al. [44] prospectively evaluated 23 adult patients with a parasymphyseal fracture, a MAF, or both, all treated with lag screws. Five complications occurred with MAFs. In two patients, the lag screw did not provide adequate stability, and it was removed and the fracture also fixated with a miniplate along the external oblique ridge. Another patient had local infection, requiring lag screw removal, and the fracture was restabilized with a 2.7-mm reconstruction plate. The authors concluded that in MAFs, the lag screw fixation is likely to be too technique-sensitive to allow its extensive use.

Kuriakose et al. [9] evaluated patients with MFs, of which 92 were MAFs. The group of MAFs treated with miniplates had 27 complications, whereas the group treated with 2.7 mm plates had ten complications. Almost 40 % of all plates removed were from the angle. Most of the infected fractures in this series belonged to the angle region. The authors concluded that a better treatment outcome for MAFs was noted with rigid plates.

Schierle et al. [14] conducted a prospective randomized study, in which 31 consecutive patients with 38 MAFs were treated with 2.0 mm miniplates. One group was treated with one plate, the other one with two plates. In the one-miniplate category, one of 16 cases (6.3 %) and, in the two-miniplate category, one of 15 cases (6.7 %) showed complications consisting of infection of the fracture site. The authors concluded that the two-plate fixation may not offer advantages over single-plate fixation in general. An in vitro study was also conducted.

Potter and Ellis [45] prospectively evaluated the use of a thin, malleable miniplate and 1.3-mm screws for stabilization of MAFs. No patient was placed into postsurgical MMF. Seven patients (15.2 %) developed complications postoperatively, and five patients developed fractured plates (10.8 %). The authors concluded that the use of the 1.3-mm bone plate for MAFs provided adequate fixation in most cases but was associated with an unacceptable incidence of plate fracture.

Quereshy et al. [46] compared the treatment of MAFs by using a 2.0-mm biodegradable fixation system with a conventional 2.0-mm titanium system in an in vivo canine model. All operated animals were allowed to function immediately. After the animals were killed, all biodegradable plates were clinically absent after 6 months and associated with adequate fixation and healing. One animal with titanium fixation showed signs of intraoral wound dehiscence, with the metallic fixation being visible and palpable. In the biodegradable group, there was no clinical evidence of wound infection, malocclusion, palpability of the device, mobility of the fractured segments on manual manipulation, or malunion as visualized at the time of sacrifice. The authors concluded that the biodegradable fixation system used in the study was efficacious in the treatment of MAFs in the dog model.

Zhang [47] compared the use of a superior 2.0-mm miniplate to fixate MAFs with other types of MAF fixation at the inferior border of the mandible. The author concluded that the augmentation of fixation at lower border is necessary for unfavorable and seriously displaced fractures.

Ellis [48] determined whether teeth in the line of a MAF, or the teeth retention or removal, increase the incidence of a postoperative infection or the need for removal of the bone plate(s). The 402 MAFs were treated by six different fixation techniques. The incidence of hardware removal in patients who had no tooth associated with the angle fracture was 17.5 % compared with 18.8 % in those who did. The incidence of infection in patients who had no tooth associated with the MAF was 15.8 % compared with 19.1 % in those who did (19.5 % when the tooth was retained, 19.0 % when removed). There was a significant difference in the rates of infection with respect to the type of treatment provided.

Cabrini Gabrielli et al. [10] retrospectively evaluated 191 patients with 280 MFs, of which 79 were MAFs, treated most of the time with a six-hole, 2.0-mm miniplate at the inferior border and bicortical screws combined with an upper border four-hole, 2.0-mm miniplate and bicortical screws wherever possible. Twenty-one patients (11 %) presented a total of 22 (7.85 %) infected fractures, of which 15 (of 79 MAFs, 19 %) were MAF. The most common region for removal of hardware was the angle region with nine fractures (53 %) of all infected cases. In the MAFs group, three patients presented nonunion and one malunion. The authors concluded that the overall incidence of complications, including infections, was similar to those described for more rigid methods of fixation.

Feller et al. [49] conducted a finite element analysis study and a clinical study. In the clinical study, the data of 277 patients with 293 MAF were evaluated retrospectively. The authors concluded that in comminuted MAFs and in noncompliant patients, the use of a stronger osteosynthesis material should be considered, while in all other cases, application of a single 1.0 mm of thickness (2.0 mm screws) miniplate was regarded as sufficient for fixation using ORIF.

Fox and Kellman [50] evaluated 68 patients with 70 MAFs treated with two noncompression 2.0-mm miniplates. Thirty-six had miniplates placed in a monoplanar distribution (lateral buccal cortex), 30 had plates placed along the oblique line and superior buccal cortex, and four had plates placed along the oblique line and inferior border. No association was found between each of the possible biplanar plate orientations and the postoperative complications. There was also no statistically significant association between biplanar (n=34) vs. monoplanar (n=36) plate orientation and postoperative complications.

Gerlach and Schwarz [51] compared the extent of the maximum jaw closing forces in 22 completely dentate patients with MAFs treated with one miniplate at the external oblique ridge and 15 controls without MFs. An electric test procedure for the determination of the load resistance between the incisors, canines, and molars was carried out from 1 to 6 weeks after treatment. The patients with MAFs recorded 31 % and 58 % of the maximal vertical load at 1 and 6 weeks postoperatively, respectively, in comparison with the controls. Since the maximum voluntary bite forces were not registered during the time of healing, the authors concluded that the one-miniplate fixation according to Champy's method ensures a sufficient stability for an undisturbed fragment consolidation for fully dentate patients with MAFs.

Besides an in vitro biomechanical study, Feledy et al. [52] also followed up 22 patients with MAFs treated with 3D miniplates. No cases of nonunion, malunion, or plate failure were reported. Two patients had infection (9 %). The authors stated that their results compare very favorably to previously published series using one or two miniplates.

In a prospective study, Chritah et al. [53] evaluated transoral 2.0-mm locking miniplate fixation of MFs plus 1 week of MMF in 34 patients. There were 31 MAFs and 19 fractures in other regions of the mandible (patients with condylar fractures were excluded from the study). Primary bone healing was achieved in 98 % of cases. Three complications (6 %) were noted, but only one with a MAF (a posterior open bite). The authors concluded that the method of fixation used is a reliable and effective treatment modality for MFs.

Guimond et al. [54] retrospectively evaluated 37 patients with MAFs treated with a curved 3D grid eight-hole, 2.0-mm miniplate. The authors stated that this plate is low in profile, strong yet malleable, facilitating reduction and stabilization at both the superior and inferior borders, and that the method of fixation used was predictable. Moreover, they also stated that the infection rate of 5.4 % found in their study compares favorably with that seen with reconstruction plates.

Razukevicius et al. [55] evaluated the treatment of 425 patients with MAFs. Relative computerized densitometry showed that closed fixation methods result in a faster fracture healing. The findings of the pain threshold test showed that open fixation methods more severely damage the function of the lower alveolar nerve. Infection occurred in 5.3 % of cases when using closed fixation methods, and in 15.3 % of cases while using open fixation methods. The authors stated that in the presence of suitable conditions, closed fixation methods should be preferred applied in MAFs.

Soriano et al. [56] compared the complication rates in patients with MAFs divided in two groups: with a third molar in the line of fracture and without. In the third molar group, 16.6 % of patients developed infectious complications versus 9.5 % in the without third molar group. The authors concluded that the angular localization of a MF increases the risk of infectious complications especially if the wisdom tooth is in the fracture.

Barry and Kearns [57] evaluated 50 patients with isolated MAFs treated with one miniplate at the superior border. Six patients (12 %) experienced complications requiring bone plate removal. The authors suggested that adherence to a strict protocol in the management of isolated MAFs results in a relatively low complication rate.

Siddiqui et al. [58] conducted a prospective randomized study, in which 62 patients with noncomminuted MAFs were randomly treated with one or two miniplates. There were no significant differences between the groups in total morbidity or for individual complications. There was a reported 11 % and 15 % incidence of infection in the one- and two-miniplate groups, respectively. The authors concluded that two miniplates seem to confer no extra benefit to patients. However, they also stated that a much larger trial would be required to show this conclusively.

Zix et al. [59] prospectively evaluated 20 patients with noncomminuted MAFs treated with 3D grid 2.0-mm (straight eight-hole and curved ten-hole) miniplates. The authors stated that its application should be limited to cases where the fracture site has sufficient interfragmentary stability. Moreover, the curved 3D plate can be considered more stable and possibly more safe for fracture fixation than the straight plate, taking the possible mechanical weakness of the lengthwise bars into account.

Bell and Wilson [60] retrospectively analyzed the complications associated with 83 MAFs in 75 patients treated with a single 2.0-mm miniplate using standard Champy technique. The patients were divided into three groups based upon the type of intraoperative MMF used: Erich arch bars, 24-gauge interdental “Stout” wires, and manual reduction alone. All patients eventually achieved successful bony union with an acceptable occlusion. There was no statistical difference in individual complications based on the type of MMF or in complications (when pooled together) between the three groups.

Mehra and Murad [61] retrospectively compared treatment outcomes between rigid fixation via extraoral approach and semirigid fixation via intraoral approach for the management of isolated MAFs. None of the patients in either group required further surgical intervention in the operating room during follow-up and healing. The authors stated that there seemed to be no statistically significant difference in the incidence of major postsurgical complications between these two techniques.

Paza et al. [62] retrospectively evaluated 114 patients with 115 MAFs. They also evaluated the influence of drug and alcohol use on the postoperative complications. Complications occurred in 19 patients (17 %), in which ten (9 %) were infections. They concluded that severity of the trauma and social risk, which included alcohol abuse, smoking, and intravenous and nonintravenous drug abuse, were factors that contributed to the development of postoperative infection.

Scolozzi and Jaques [63] prospectively evaluated seven patients with isolated MAFs, reduced with a compression forceps, and fixated with a six-hole reconstruction plate at the inferior border of the mandible. Wisdom teeth were present in the fracture area in all of the patients, and in no case were wisdom teeth in MAFs removed. No complications were reported. The authors concluded that the reduction and fixation technique used resulted in a high rate of success.

Bui et al. [64] retrospectively evaluated 49 patients with MAFs treated with a 3D grid 2.0-mm curved eight-hole miniplate. Four patients (8.2 %) developed infections. The authors concluded that this fixation system is associated with a low infection and complication rate.

Ramakrishnan et al. [65] evaluated 83 patients with MAFs treated with ORIF by several fixation techniques. The rate of postoperative infection was 9.6 % and 9.7 % for patients with and without tooth involvement, respectively. Among the patients with a tooth in the fracture line, 28.9 % (15 out of 52 patients) developed a major postoperative complication necessitating a second surgery, while this rate was 12.9 % (4 out of 31 patients) for patients without teeth involvement. The authors concluded that third molar involvement in MAFs and selective removal of the involved tooth based on commonly used guidelines may not change the rate of minor complications responsive to conservative measures or major complications necessitating revision surgery.

In a prospective randomized clinical trial, Sugar et al. [66] compared outcomes following fixation of 140 simple noncomminuted MAFs with a combined transbuccal and intraoral technique in which a single 2.0-mm, four-hole miniplate is fixed to the lateral aspect of the mandible, with the standard intraoral technique in which a single miniplate is fixed to the anterior aspect of the mandibular external oblique ridge. Fewer plates were removed in the combined transbuccal intervention group (20 %) than in the intraoral control group (36 %), being the only comparison between groups with a statistical significant difference ($P=0.042$). The combined transbuccal/intraoral procedure was safer and more effective than the standard intraoral technique in terms of complications requiring further surgery.

In a prospective study, Bayat et al. [67] evaluated the treatment of 19 unilateral noncomminuted MAFs via a single six-hole noncompression 2.5-mm biodegradable plate adapted along the lateral border of the external oblique ridge. Three (15.7 %) patients had minor complications. No cases of nonunion or dehiscence were reported. The authors concluded that the use of a single biodegradable plate for unilateral MAFs is a reliable fixation technique with minor complications.

Boffano and Roccia [68] evaluated the surgical outcomes of a group of eight patients with bilateral MAFs. The fractures were fixated with one 2.0-mm, four-hole miniplate (external oblique line or lateral mandibular aspect) plus 7 days of guiding elastics. Only one complication was observed (one infection 5 months after surgery).

In the prospective study of Danda [69], 54 patients with noncomminuted unilateral MAFs were divided into two groups with 27 individuals. Group I was treated with a single noncompression miniplate fixed according to the method of Champy et al. [13]. Group II was treated with two noncompression miniplates (one superior and one inferior). MMF was used for 2 weeks in all cases. None of the comparisons of the incidence of complications between the two groups were statistically significant.

Ellis [70] prospectively evaluated 185 patients with isolated noncomminuted MAFs. Patients were sequentially assigned to one of three treatment groups (see Tables 1 and 2 for details). There were significant differences in treatment outcomes for several variables, including the amount of time it took to perform the surgery, postoperative wound problems, malocclusion, neurosensory deficits, radiographic interpretation of fracture alignment, and maximum interincisal dimension at last follow-up. Group 1 (wire +MMF) had the largest number of cases of nonunions (14 of 22). The author concluded that the use of a single miniplate was associated with fewer complications than if two plates were used or if an interosseous wire and MMF were employed.

Seemann et al. [71] evaluated the complications in 322 patients presenting at least one MAF fixated with several methods. Wound-healing disturbances accounted for most complications, followed by infections. No significant differences were found between MAFs treated with one miniplate or two miniplates.

In a study comprising patients from two countries (Brazil and Germany), Hochuli-Vieira et al. [72] evaluated the clinical outcome of 45 patients with MAFs treated by intraoral access and a rectangular 3D grid 2.0-mm miniplate with four holes. The authors concluded that the type of miniplate used was stable for the treatment of simple MAFs through intraoral access, with low complication rates.

Kumar et al. [73] retrospectively evaluated 80 patients with MAFs treated by ORIF (intraoral single miniplate, extraoral two-miniplate approach, or combined transbuccal/intraoral approach using a single miniplate). There was no significant difference in complication rate between the three techniques.

Schaaf et al. [17] compared different methods for the treatment of MAFs using one or two miniplates or 2.0-mm lag screw. The decision whether to use one method of fixation or the other was made by the surgeon. The main parameters for the outcome analysis were fracture gaps at four defined measuring points on postoperative radiography. Lag screw fixation demonstrated smaller fracture gaps compared with miniplate fixation. The mean duration of the surgical intervention suggested that the lag screw method was faster than the miniplate method. The lag screw-treated group had a 14 % overall complication rate. If an additional miniplate was placed, a higher complication rate was observed.

Singh et al. [74] prospectively studied the efficacy of using a single noncompression miniplate at the inferior border in the management of MAFs. The displacement of fracture was assessed on panoramic radiography by measuring the displacement of the inferior alveolar canal. Fractures with displacement greater than 2 mm were included in the study. Five patients (9.5 %) experienced complications. The authors concluded that "the outcomes were acceptable in their patients."

Singh et al. [75] evaluated 51 patients with MAFs and treated with a single miniplate at the superior border and MMF for 7–14 days. Due to the considerable number of complications, the authors concluded that the single miniplate fixation technique in unfavorable MAFs is questionable, and hence, these fracture require some alternative method for fixation.

Höfer et al. [76] evaluated 60 patients with MAFs, divided in two groups: 30 were treated with an external oblique plate and compared to 30 patients treated with a 3D grid four-hole, 2.0-mm miniplate on the vestibular cortex. Complications occurred significantly more often in the external oblique group (13.3 %; n=8) than in the grid plate group (0 %; n=0). The authors concluded that isolated MAFs can be more effectively treated using grid plates than using other osteosynthesis techniques. However, there is a disadvantage of the technique: an angulated burr and screwdriver has to be used to put on the plate laterally.

In a prospective randomized clinical trial, Laverick et al. [77] investigated the null hypothesis that there is no difference in the incidence of postoperative removal of an infected plate between miniplates placed through two different approaches (intraorally placed at external oblique line or transbuccally miniplate placed on the buccal surface of the mandible). It was proposed that the three-dimensional bends placed in a ridge plate to contour it to the external oblique ridge may reduce its rigidity. The ridge plate's superficial placement on the ridge may also make it prone to exposure and consequent infection from wound breakdown. In contrast, the transbuccal plate is placed deeper within the tissues and flat on the mandible with no dimensional changes. The transbuccal plate had a significantly lower postoperative infection rate (5 %) compared with (20 %) external oblique line plates. There were no significant differences between the groups in the incidence of damage to the inferior dental and facial nerves, occlusion after reduction of the fracture, or method of reduction. The greater the preoperative displacement of the fracture on radiographs, the higher the rate of infection, injury to the inferior dental nerve, and the rate of plate removal. Smoking had a highly significant effect (P=0.000), showing that it adversely affects the healing of MAFs. There was no significant effect of alcohol consumption alone on plate removal, although the analysis suggested a close association ($P=0.06$). If the effect of smoking was added to that of alcohol, the combination was significant ($P=0.001$). Neither the presence of a wisdom tooth in the line of the fracture on removal of the plate, nor its removal, or the delay between the injury and operation had any significant effect on the rate of removal. There was a highly significant difference between the postoperative occlusal outcome and the rate of removal of the plate.

Perry et al. [78] presented a technique using Kirschner wires to provide stable reduction of unfavorable MAFs and easy plate fixation in nine patients. There were no injuries to the facial nerve, postoperative infections, or exposed hardware. All patients were restored to their premorbid occlusion. The authors suggested placing Kirschner wires percutaneously in the outer plate holes. Then, one bicortical screw on either side of the fracture line in the inner plate holes is percutaneously placed. The wires are then removed, and screws are placed percutaneously through the outer plate holes. The authors stated that this technique maintains plate position without assistance, allowing a single operating surgeon to maintain reduction while placing percutaneous screws.

Vineeth et al. [16] conducted a prospective randomized study with 20 patients with 20 MAFs in order to compare the efficacy between two methods of fixation: one four-hole, 2.0-mm miniplate, or 3D grid four- or six-hole, 2.0-mm miniplate, both applied at the external oblique line. The authors observed that the 3D miniplates showed more favorable results compared to single conventional titanium miniplate with respect to initial interfragmentary stability and complications.

Discussion

A MAF is termed favorable or unfavorable, depending on the direction of the fracture line in the horizontal and vertical plane and the consequent potential for displacement. Most MAFs extend from the surgical angle downward and backward [23]. An upward, forward, and medial displacement of the ramus occurs due to the pull of the elevator group of muscles (masseter, medial and lateral pterygoids, and temporalis). At the same time, the anterior fragment is displaced downward and inward by the depressor group of muscles (geniohyoid, genioglossus, mylohyoid, and digastric). The resulting forces are tensile at the upper border and compressive at the lower border of the mandibular angle [29]. Thus, it appears that biomechanically, the forces exerted by the muscles of mastication have a greater influence at the angle than in other regions of the mandible. Moreover, MAFs are biomechanically complex because all the major stress-dissipating trajectories of the mandible are disrupted [79]. Thus, it is important to correctly reduce and fixate MAFs.

Five types of fixations for the treatment of MAFs have been proposed. The first consists of wire osteosynthesis of bone fragments and/or 4 to 8 weeks of MMF. The second, known as rigid fixation, is based on the use of plates and large-diameter screws to provide sufficient rigidity and resist displacement of the bone fragments during mandibular function. In the third, known as stable or semirigid fixation, the mandibular osteosynthesis is achieved by malleable miniature non-compressive plates fixed with monocortical screws via a buccal approach [13, 19, 73]. The fourth is known as external pin fixation, although the external splinting of the mandible with pin fixation or with an external fixator appliance is nowadays an unusual modality in fracture treatment with an indication confined to a few problematic cases beyond routine [80]. The fifth uses the lag screw principle.

The traditional method of MAFs treatment consists of wire osteosynthesis and/or MMF. Transosseous wire placement is relatively easy, inexpensive, and can be quickly executed using simple armamentarium in an ambulatory care setting [12]. Some authors think that postsurgical MMF is beneficial in all MAF patients [61]. Mehra and Murad [61] believe that the MMF (1) helps form an oral mucosal epithelial seal and allows undisturbed healing of incisions intraorally, (2) helps initially to stabilize the occlusion, particularly in cases treated with nonrigid fixation, (3) trains the patient to become accustomed to a liquid diet, and (4) for those patients who are unreliable, arch bars and short-term fixation in place seem to encourage patients to return for follow-up examination.

Although considered as a nonrigid osteosynthesis, when treating MAFs with wire+MMF, only one study [70] observed a high rate of bone union problems (14 of 60 cases). Four other studies showed good clinical results. Marciani et al. [12] reported only one case (in a total of 23 patients) which developed a nonunion requiring reconstruction, and yet this one patient removed their MMF multiple times following fracture repair. Treating with the same method, Chuong et al. [7] reported only five cases of delayed union in 109 MAFs. Cawood [21] did not mention malunion or nonunion in their 21 patients treated with wire+6 weeks of MMF. Applying only MMF, Marker et al. [38] observed no problems with bone union in 57 MAFs. Other studies [27, 32] also applied the same method of fixation, but delineation of the specific problems in the patients was not available.

However, some believe that the MAF is generally posterior to the dentition, preventing adequate stabilization by MMF [50]. Moreover, the potential problems include compromised oral airway, inadequate nutritional intake with weight loss, social inconvenience, temporomandibular joint (TMJ) articular cartilage thinning or ankylosis, and patient noncompliance with frequent removal of arch bars [73]. In the study of Cawood [21], patients treated with ORIF (test group) lost, in average, less weight than the control group of patients treated with wire osteosynthesis+MMF. The patients from the test group also restored the normal weight faster than the control group. The same occurred with the postoperative mouth opening. Critics of prolonged MMF have noted patient complaints of panic, insomnia, social inconvenience, phonetic disturbance, loss of effective work time, physical discomfort, and difficulty recovering a normal range of jaw movement [21]. The prolonged MMF (4–8 weeks) can be problematic in patients with psychiatric disorders or patients at risk for aspiration such as alcoholics or patients with altered mental status. Prolonged MMF can also lead to atrophy of mastication muscles [64].

Some authors even state that the use of MMF is not necessary. Based on the results of their study, Bell and Wilson [60] stated that Erich arch bars, interdental “Stout wires,” and manual reduction alone all have efficacy for achieving favorable bony union in the ORIF of MAFs using the Champy technique [13]. Furthermore, the use of Erich arch bars or interdental wire fixation to assist with MMF during surgery is not always necessary for successful outcome in selected patients [60]. According to Paza et al. [62], MAFs can rarely be treated by MMF alone. The retrospective study of Kumar et al. [73] showed no significant differences in treating isolated mandible fractures with ORIF and immediate release versus ORIF with 5–7 days of MMF.

Plating is another well-known method to fixate MAFs. In general, this can be divided into those techniques that use large bone plates (with or without compression) secured near the inferior border of the mandible, or miniplates (without compression) applied to the superiolateral border or to the inferior border of the mandible [28], or a combination of two miniplates.

The first type of plating uses large plates (2.4 and 2.7 mm plates) for rigid fixation. This kind of plate provides sufficient rigidity to the fragments to prevent interfragmentary mobility during active use of the mandible [43]. The plate is three-dimensionally bendable, allowing accurate contouring to the surface of the mandible. Each screw hole allows for placement of compression in either direction or no compression, depending on where one drills the hole within the confines of the screw hole slot. The use of three screws on each side of the fracture with this bone plate is claimed to provide adequate neutralization of functional forces in the absence of compression [33]. Plating has considerable advantages of early recovery of normal jaw opening and body weight [21]. Some authors claim that a reconstructive plate is recommended for use in patients who the surgeons anticipate will be noncompliant with instructions, oral hygiene, and follow-up because of the frequent self-removal of MMF [33]. In cases of MAFs with comminution or with continuity defect, surgeons may consider reconstruction plates that are thicker and therefore provide greater strength that would resist functional load better [81].

However, the large bone plates are more difficult than miniplates to place in the mandibular angle region through a transoral approach. Access is often extremely limited, especially when edema is present, which makes soft tissue retraction difficult [28]. An extraoral approach creates a facial scar and has the possibility of injury to the marginal mandibular branch of the facial nerve [33, 37]. Adapting the plate to the unique contour of the lateral mandible is a procedure that takes a considerable amount of time and skill [28, 37]. Schwimmer [82] recommended that when placing a reconstruction plate at the angle of the mandible, a prebent plate is preferable to avoid overbending that may result in hole deformation or weakening of the plate; if bends over 15° are required, a prebent plate should be used. Moreover, instrumentation for drilling and screw placement through a transbuccal trocar is difficult, and more than one transbuccal puncture is necessary in the majority of instances. Because of these difficulties with large bone plates, miniplate systems have become quite popular [28].

Concerning the use of compression plates, the defense of its use is based on the fact that compression plating has been shown to be associated with improved stability at the fracture site by producing tight approximation of the fragments, which is accomplished as a result of larger contact surfaces generated by the compressive forces [83]. When rigid fixation is produced at the fracture site so that the functional dynamic forces of mastication are neutralized by the static force generated by the compression plate, functional healing will occur without the need for MMF [8]. However, the successful and predictable use of compression plates and screws in the management of mandible fractures is dependent upon adherence to specific technical details and appropriate case selection [8]. Moreover, proper application of compression plates is technically more demanding. Iizuka and Lindqvist [35] suggested that compression plates should be only used to fixate MAFs where there is adequate bony buttressing and noncompression plates when there is not. Two studies [30, 34] reported high complication rates with the use of compression plates to fixate MAFs. The mandibular angle is a region with little buccal-lingual width, and even less interface when extraction of a tooth in the fracture line is performed [34]. Thus, Ellis and Sinn [34] suggested that it is possible that the compressive force used with these plates is too great for the bone in this region.

The second type of plating uses thinner plates (1.3 or 2.0 mm miniplates) for semirigid fixation. The use of miniplates also obviates the need for MMF [13, 29]. Early mobilization of the jaws by reducing or eliminating the period of MMF is of significant benefit to patients since the potential adverse effects of prolonged immobilization are removed [19, 21, 24]. Using miniplates for osteosynthesis has also several advantages over rigid fixation systems: (1) sensory disturbance caused by screw placement in the inferior alveolar nerve bundle can be avoided with use of monocortical screws [29], (2) the intraoral incisions eliminate the risk of a large hypertrophic cutaneous scar and the risk of damage to the marginal mandibular nerve [19, 29, 61], (3) simultaneous observation of fracture line reduction and occlusal relationships is possible [19, 21, 29], (4) miniplates are less palpable and less thermal sensitive by the patient, (5) the smaller dimensions of these plates enable them to be adapted with greater ease to the contours of bone [13], and (6) miniplates are less costly than reconstruction and compression plates. A striking difference in the application of semirigid miniplates, when compared with rigid systems of osteosynthesis, is the use of monocortical versus bicortical screws. Monocortical screws engage only one cortex and, being self-tapping, eliminate the need for using a screw tap in the drilled hole, but their reduced anchorage also makes fixation less capable than bicortical screws of resisting muscle forces especially if principles of fixation are not respected [84]. This reduced mechanical strength and consequent lack of rigidity makes it important for the surgeon to respect Champy's lines of ideal osteosynthesis when planning the location of bone plates [84]. Champy et al. [13] stated that the strong and thick outer cortex of the mandible provides osteosynthesis screws with good anchorage due to the compact bone. Even though the thickness of cortex may be as little as 3 mm, its strength offers sufficient monocortical anchorage to screws. It is important to mention here that the studies of Michelet et al. [19], Champy et al. [13], and Gerlach et al. [20] were very important to change the surgeons' beliefs until that time, that the use of bicortical screws and rigid fixation was the only effective method to fixate MFs. These three studies, specially the study of Gerlach et al. [20] that presented a large number of patients with a wide variety of MFs types, showed that MFs can be treated in a highly effective way and with a relatively low rate of complications with monocortical miniplate fixation.

Concerning the use of thinner miniplates (1.3 mm), the plate is extremely malleable and does not require adaptation to the underlying bone, and therefore it is very fast to insert. Thus, there is less trauma and bleeding with shorter procedures and less complications, since minimum disruption of the periosteum and improved vascularity enhance the opportunity for healing at the fracture site and decrease the chances of an infection or nonunion to occur [37]. Moreover, because of its small size and the small hole diameter for the screws, the plate could be placed on top of the external oblique ridge [45]. However, Potter and Ellis [45] observed in their study that the use of the 1.3-mm bone plate for MAFs was associated with an unacceptable incidence of plate fracture. Therefore, the plate cannot be recommended for routine use for MAFs.

Miniplates are not recommended for comminuted and infected fractures because more torsional movements are expected in the less rigid miniplates than the reconstruction plates [29]. In cases where ORIF of the comminuted MAF is indicated, stabilization by compression or any other form of load-sharing osteosynthesis is obviously contraindicated because small fragments cannot be compressed and are not capable of sharing loads [81]. Moreover, the nonrigidity of this technique has prompted some surgeons [22, 26, 28, 53, 56, 68, 69, 75] to use varying periods of MMF following surgery and to limit the diet to very soft foods, even in no comminuted MAFs.

Three studies [48, 53, 78] used locking miniplates to treat MAFs. The locking miniplate system has conical threaded holes that lock the corresponding threaded screw to the plate. The screws, plate, and bone form a solid framework with higher stability than the traditional miniplate system [53]. Locking miniplates have been shown to overcome some disadvantages of conventional miniplates, such as difficulty in adaptation to the underlying bone, alterations in the alignment of the segments, infections, and changes in the occlusal relationship and in the TMJs [85]. Chritah et al. [53] observed that a single locking miniplate placed along the external oblique line for osteosynthesis with 8-mm long monocortical locking screws plus 1 week of MMF was a reliable and effective treatment for MAFs. The use of locking miniplates may also decrease what was observed in the study of Ellis and Karas [30]: a high incidence of infection due to loosening of fixation hardware.

It is generally accepted that during function of the lower jaw, tension will occur at the level of the dentition, whereas an effect of compression will be observed along the lower border. In the chin area, torsional forces produce a combination of tension and compression [86]. From orthopedic studies, it is known that osteosyntheses are most effective if they are carried out in the zone of tension. In the mandible, however, the presence of teeth and alveolar nerves limit the surgeon from extending fixation materials into some zones [87, 88]. A MAF can be stabilized with the plate being placed superiorly (called tension bone plating) and inferiorly (called stabilization bone plating). Superiorly, it can be placed in two ways: extending from the mandibular lateral border near the external oblique ridge to a point posterior to the second molar in the area of the retromolar trigone (external oblique line), or along the superior lateral face. These are the two possible regions to fixate a miniplate according to the "ideal line of osteosynthesis" established by Champy et al. [13]. Many other authors have introduced the use of the two-miniplate fixation, with the second miniplate being fixated in the inferior lateral face of the mandible (Fig. 2).

A consecutive series of studies has indicated that, up to a point, the incidence of major complications after MAFs are

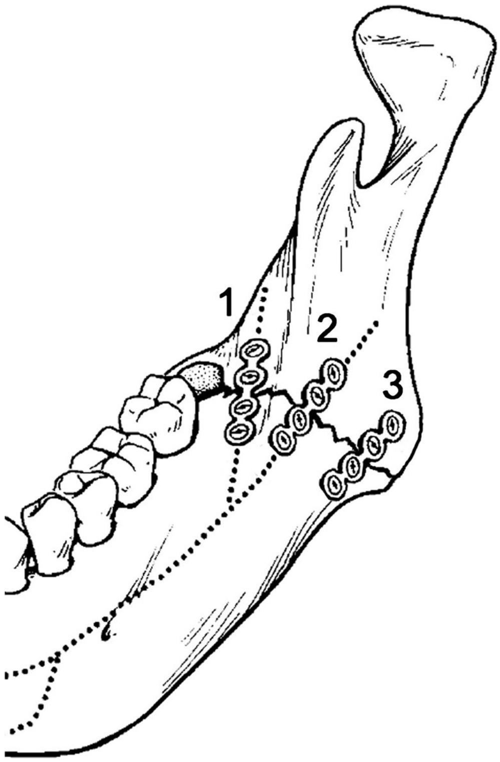

Fig. 2 Possible regions to fixate MAFs with miniplates: (*1*) external oblique line, (*2*) along the superior lateral face, and (*3*) inferior lateral face of the mandible. Positions (*1*) and (*2*) are the two possible regions to fixate a miniplate according to the "ideal line of osteosynthesis" established by Champy et al. [13]. Miniplates placed at positions (*2*) and (*3*) constitute a monoplanar fixation. Miniplates placed at positions (*1*) and (*3*) constitute a biplanar fixation

inversely proportional to the rigidity of the fixation applied, i.e., whenever two points of fixation were used for MAFs, the complication rate was much higher than when one point of fixation was applied. This fact was observed by Ellis and colleagues using various treatment schemes for MAFs performed on a consecutive series of patients in the same hospital over the course of several years [28, 30, 33, 34, 36, 37, 43, 48, 70]. However, three studies conducting prospective randomized clinical trials [14, 58, 69] concluded that no significant differences were found between the use of one or two miniplates in terms of postoperative infection and occlusal disturbances. Moreover, two other studies [29, 49] have shown that the use of the two-miniplate technique provides a lower rate of postoperative complications than the use of only one miniplate. In the meantime, the results of several studies [14, 29, 37, 40, 50] indicate that the use of the two-miniplate fixation technique to treat MAFs provides better stability compared with Champy's method [13]. During function of the lower jaw, tension will occur at the level of the dentition, whereas an effect of compression will be observed along the lower border. In the chin area, torsional forces produce a combination of tension and compression [86]. The zones of tension and compression may reverse when forces are generated along the posterior teeth. The closer the load is applied to the MAF, the more there is a tendency for separation of the bony cortices at the inferior border [86]. In effect, the inferior border, which usually is the zone of compression, becomes a zone of tension, and the superior surface of the mandible becomes the zone of compression [30]. The use of two miniplates avoids lateral displacement of the lower mandibular border and opening of the inferior fracture gap, suspected to contribute to the occurrence of complications [41]. However, whether this gap is important to the clinical outcome remains to be seen [58].

The two-miniplate technique has also some disadvantages. When using an intraoral approach, two-miniplate fixation technique necessitates reflection of all soft tissues from the mandible, increasing intraoperative trauma. When using an extraoral approach to place the second miniplate on the inferior border, it increases the risk of bacterial contamination, scarring, postoperative edema, hematoma, and marginal mandibular nerve damage. The use of the two-miniplate fixation also prolongs the operation time. Some studies showed a high complication rate with the two-miniplate method. Ellis and Karas [30] observed a 29 % complication rate when two mini DCPs were used to treat MAFs. The authors stated that the method used in their study proved to be an unpredictable treatment for MAFs. A complication rate of 28 % has been reported by Ellis and Walker [37] when two miniplates were used at the mandibular angle. In a comparative study, a 16 % complication rate was reported for the one-miniplate method and 28 % for two miniplates for MAFs [43]. In a more recent study, Ellis [70] showed that the use of a single miniplate was associated with fewer complications than if two plates were used. In the study of Schaaf et al. [17], the use of this method showed a 30 % complication rate.

There is another important point to consider when two miniplates are used. There are two modes of fixation concerning the planes of placement of the miniplates: the monoplanar (plates positioned in one plane, in the lateral aspect of the mandible) and the biplanar (plates positioned in two planes: oblique lines and superior or inferior buccal cortex; Fig. 2). Only one study clinically evaluated the difference in stability between the two techniques. Fox and Kellman [50] found no association between each of the possible biplanar plate orientations and the postoperative complications. There was also no statistically significant association between biplanar (n=34) vs. monoplanar (n=36) plate orientation and postoperative complications.

There is a growing number of clinical studies evaluating the use of 3D plates for the treatment of MAFs [16, 52, 54, 59, 64, 72, 76], all with good results. The 3D plates can be considered a two-plate system, with two miniplates joined by interconnecting crossbars [89]. Their shape is based on the principle of the quadrilateral as a geometrically stable configuration for support [16]. Because the screws are arranged in the configuration of a box on both sides of the fracture, a broadband platform is created, increasing the resistance to twisting and bending to the long axis of the plate [54]. This stability represents the gain achieved by distributional force sharing by means of the adjoining strut bars [52]. One of the advantages of the technique is the simultaneous stabilization of the tension and compression zones, making the 3D plates a time-saving alternative to conventional miniplates. Moreover, this system is simple to apply because of its malleability, low profile (reduced palpability), and ease of application (requires little or no additional contouring) [64]. Zix et al. [59] and Hochuli-Vieira et al. [72] had low complication rates in their clinical studies. Höfer et al. [76] concluded that isolated MAFs can be more effectively treated using grid plates than using other osteosynthesis techniques. Vineeth et al. [16] compared the 3D plates with the 2.0-mm miniplates and observed that the 3D miniplates showed more favorable results compared to single conventional titanium miniplate with respect to initial interfragmentary stability and complications. The system may be contraindicated in patients in whom insufficient interfragmentary bone contact causes minor stability of the fracture [59].

The less common described method of fixation of MAFs is the external pin fixation. Cornelius et al. [80] stated that the external method of fixation still is a valuable treatment option to bridge localized comminuted fracture areas or defects that are associated with compromised bone quality and/or a critical soft tissue situation (large amount of periosteal, muscle, or mucosal damage). In those cases, an increased incidence of nonunion and infections can be expected. External pin fixation can be used in most cases with a tenuous blood supply to the residual mandibular fragments when there are inadequate teeth on either side of the comminuted fracture to control the spatial relationship of the remaining mandibular fragments with MMF [90].

In 1981, Niederdellmann described a method of internal fixation of MAFs using lag screws [91]. The technique provides internal fixation with a minimum of implant material [23]. The principle of the lag screw is based on axial compression of the bone fragments. The screw glides through the fragment located near the screw head (gliding hole) and seizes the fragment distant from the screw head (threaded hole) [17]. The lag screw is considered to function analogous to a tension band that neutralizes and converts the distracting forces at the superior border into compressive forces, thereby equitably distributing interfragmentary compression across the fracture line [79]. Experimental data corroborated the clinical impression of MAFs line stability following solitary lag screw fixation [79], against an axiom of lag screw fixation of fragments that a minimum of two lag screws are required to ensure the integrity of fixation. Since the loads are axial and not rotatory, only one screw needs to be placed, unlike what is required with other lag screw techniques [31]. Lag screw fixation has a number of advantages over plate osteosynthesis. Besides supplying compression between the fragments to support healing (resulting in primary bone healing), fracture stabilization is firm, and tissue exposure is reduced [28]. An advantage of lag screw over one-plate fixation is that it can be easier applied and more rapidly [17, 28]. The miniplate must be contoured individually to the linea obliqua [13]. An intraoral access is possible for lag screw fixation, with a minimal transbuccal approach for correct screw angulation, whereas several monocortical holes have to be drilled for miniplate fixation [17, 28]. It is also less costly than a bone miniplate [31].

According to Ellis and Ghali [28], the use of the lag screw technique in MAFs requires more attention to detail than any other technique of internal fixation because it is an extremely technique-sensitive method of fixation. Because of its technique sensitivity, it occasionally requires supplementary MMF [79]. The two most common errors made in lag screw fixation of MAFs are the improper countersinking the screw hole and the angulation of the screw [28]. A fundamental difficulty with the lag screw is that pressure is exerted on a very small area of bone. The screw placement technique must consider the dense cortical bone on the lingual aspect of the ramus, so the insertion path should be approximately 10° to 20° from the buccal corridor [28] (Fig. 3).

Some studies used lag screws to fixate MAFs. In the study of Niederdellmann and Shetty [23] with 50 patients,

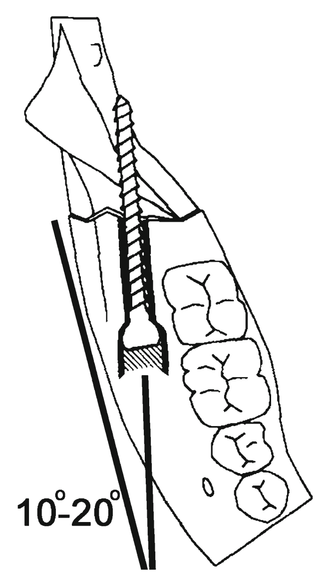

Fig. 3 The lag screw insertion path to fixate MAFs should be approximately 10° to 20° from the buccal corridor (after Ellis and Ghali [28])

the complication rate for solitary lag screw osteosynthesis of MAFs was reported to be 4 % infection, 2 % occlusal disturbances, and 4 % malposition of fragments. Ellis and Ghali [28] reported an overall postsurgical infection of 23 %, and 13 % required further intervention. Two patients had very minor occlusal discrepancies. Eight (of 30) patients had slight mobility of the fracture, necessitating supplemental methods of fixation. In contrast to Niederdellmann and Shetty [23] recommendations, Ellis and Ghali [28] routinely removed teeth in the line of fracture, as most of them had visible exposure of the apices, mobility, and/or pericoronitis. Ellis and Ghali [28] stated that this may have been the reason why they reported higher rates of infection. It may be that the removal of teeth reduced the rigidity of the repaired skeletal unit, leading to postoperative mobility and resultant infection. Farris and Dierks [31] observed a complication rate of 7.7 %. Schaaf et al. [17] reported an overall complication rate of 14 % in the lag screw group in the treatment of MAFs. However, this study also demonstrated good results. The radiographic analysis of the postoperative fracture gap demonstrated a significant reduction in fracture gap with lag screw fixation when compared with the miniplate. There is a direct correlation between the fracture gap width and the healing process. A good reduction of a fracture with small interfragmentary gaps is important for its revascularization and healing. If the fracture gap width is larger than 2 mm, then bone healing is delayed [92].

Choice of the solitary lag screw technique depends not only on the nature and location of the fracture but also on the surgeon's familiarity with the technique and the availability of specific instrumentation [79]. In addition, despite all the advantages of the lag screw fixation, there are circumstances where the use of lag screws is contraindicated. There is an obvious disadvantage of lag screw fixation that is its primary reliance on an adequate bony buttress and fracture interface. The shape and strength of the fragments should be such that they can absorb and transmit the functional stresses. MAFs with severe disruption of the reinforcing bony buttresses, as in comminuted fractures and/or bone loss in the fracture gap, are unsuitable for fixation by this technique. In such situations, the indication is to apply a bone plate without compression across this gap [28].

This current practice of the use of titanium plates to treat MAFs certainly has unknown biomechanical consequences because the fixation device forever shields the surrounding bone from normal anatomic stresses. Some of these devices require removal because of infection, thermal sensitivity, or psychologic considerations. In addition, titanium poses long-term biocompatibility risks and can be problematic during future radiologic examination [93]. Biodegradable (resorbable) materials were eventually developed for fixation plates to definitively eliminate the need for retrieval [94]. Clinical application of biodegradable polymers, such as polyglycolic acid, polylevolactic acid, and polydioxanone sulfate, for fixation of fractures is well established and supported by numerous studies. Concerns about compatibility with future imaging needs and radiation treatment, as well as corrosion and allergy, migration of the material, growth restriction, long-term palpability, and thermal sensitivity, can be reduced by biodegradable materials [67], and there is no need for a second surgical procedure for removal.

However, the use of a biodegradable plate system for MFs is still not a generally accepted method. Their limited mechanical properties continue to give rise to the question of whether such MF fixation will result in excessive fracture mobility or premature implant failure [67]. There are more disadvantages. These plates can be bent to match the curve of the bone, but they cannot be bent to change vertical orientation [67]. The costs are still high when compared with titanium plates, there is a local foreign body reaction, there is the absence of a self-tapping feature, the system has greater dimensions than the similar titanium system, and there is a need to place the screws vertically into the place, in order to avoid screw breakage [95]. Furthermore, when using absorbable materials in bones that are exposed lateral and torsional forces like the mandible during the mastication, it can be a necessary additional effort intended for increase of stability (increasing the number of plates or screws, using of postsurgical MMF) [95].

Only two studies performed clinical studies exclusively using biodegradable plates to fixate MAFs. In the first one, Quereshy et al. [46] compared the treatment of MAFs by using a 2.0-mm biodegradable fixation system with a conventional 2.0-mm titanium system in an in vivo canine model. Although the number of individuals were small in the biodegradable group (n=4), there was no clinical evidence of wound infection, malocclusion, palpability of the device, mobility of the fractured segments on manual manipulation, or malunion as visualized at the time of sacrifice. In the second study, Bayat et al. [67] evaluated the treatment of 19 unilateral MAFs in humans using a single six-hole, 2.5-mm biodegradable plate. Three (15.7 %) patients had minor complications (two infections and one malocclusion). No cases of nonunion or dehiscence were reported. The authors reported a 4 % incidence of technical problems (five screw heads fractured during screw placement). Further clinical studies are needed to draw better conclusions concerning the use of biodegradable plates to fixate MAFs.

Although several authors do not leave the patient in MMF after bone plating (or after use of lag screws) to fixate MAFs [8–10, 13, 14, 17, 21, 24, 25, 28, 30, 33–35, 37, 40, 42, 43, 45, 48–50, 52, 54, 57–66, 71–73, 76, 77], Ellis and Walker [43] recommended to leave arch bars on in every dentate case for many reasons, especially to encourage the patient to return for follow-up. They also suggest to not remove the arch bars until the patient's mandibular function is rehabilitated, generally a minimum of 6 weeks after surgery. The preservation of arch bars after the surgery may also be useful in cases where there is slight mobility of the fracture or when the hardware must be prematurely removed due to infection, necessitating supplemental methods of fixation, and when there are minor occlusal discrepancies, which might be corrected it by postsurgical slight elastic traction.

Concerning the surgical approach to treat MAFs, the intraoral access is criticized because fractures are difficult to reduce, and the adaptation of the plate and insertion of the screws particularly at the inferior border of the mandible is said to be unsatisfactory or even impossible because of poor visibility. This applies to the rigid compression plates. However, the miniplates are thin and flexible and make adaptation very easy. Application is performed by using only monocortical screws set into the buccal compact bone. Thereby such plates are easier to apply with an intraoral approach than the rigid plates [41]. As compared with the extraoral access with preparation through various soft tissue layers, the intraoral access offers the advantages of rapid, time-saving exposure of the fracture with less trauma [41]. Moreover, facial scarring is minimized, and the likelihood of damage to the facial nerve and the inferior alveolar nerve is decreased. Authors advocating the one-miniplate technique state that limiting the dissection causes less periosteum reflection, which in turn leads to less interruption of the blood supply, and decreased postoperative swelling and pain [61]. The extraoral approach requires increased operating time and risks damage to the facial nerve, and hypertrophic scar formation may occur [43]. It appears that there is an inherent risk of infection when using an intraoral incision to treat MAFs regardless of the fixation method [12, 36].

A number of factors may play a role in the development of complications in MAFs, such as retention or extraction of the third molar, closed or open reduction, time from trauma to treatment, mobility after fixation, antibiotic treatment, and patient cooperation [38]. The main complications associated with treatment of MAFs include infection, malocclusion, delayed union, nonunion (pseudoathrosis), osteomyelitis, and facial and alveolar inferior nerve injury. It is important to note that the great majority of the studies reviewed here included patients with at least one MAF coexisting with other MF (or fractures) in the same individual, usually contralateral fractures of the body or of the parasymphysis. As well observed by Ellis [70] and Vineeth et al. [16], it is believed that a second fracture in the mandible can confound the outcome data because the fixation requirements of a double fracture are often different from those for an isolated fracture. Moreover, the real complication rates for the treatment of MAFs can be wrong. For example, if malocclusion is noted, it is not always possible to determine which of the fractures may be contributing to the malocclusion [70]. Only the isolated MAF allows us to establish the true complication rate for these fractures [57]. Another example concerns sensation alterations. The main cause for sensory nerve abnormalities in MAFs is the degree of displacement of the segments [54, 59], i.e., the trauma itself, which is observed previously to treatment. There is little information in the literature concerning the incidence and natural history of inferior alveolar sensory deficit as a consequence of the fracture or as a complication of fracture fixation, as postinjury/pretreatment sensory status is often not recorded [57]. Most studies of MAF are retrospective, and it is often difficult to obtain sufficient data from the patient records to allow analysis [57]. In addition, as the follow-up period was limited in many studies, it is unclear whether the sensory deficit is actually transient or permanent in these patients. During surgery, aggressive manipulation due to fracture replacement may cause additional nerve injury, and sometimes, drill-hole preparation near the mandibular canal may also cause permanent alterations [59]. A third example concerns the fixation hardware. Fracture of the plate or plate exposure due to soft tissue dehiscence may not be considered a complication in units where the fixation device is removed routinely after fracture healing [14]. Another important point is the period of follow-up because many studies report only short mean periods of follow-up (see Table 1), although it is difficult to judge what is a short and what is a long period of follow-up. Many minor complications such as fracture or exposure of the bone plate may occur months or even years after successful healing but must still be considered a complication as they result in a surgical intervention that would not otherwise have been necessary. The complication rate therefore may increase with the length of follow-up [57]. Moreover, many other factors may influence the incidence of complications in MFs, such as inadequate immobilization of the fracture segments, prolonged delay in obtaining treatment contributing to infection, inexperienced surgeons, no cooperation from patients, the severity of the trauma, smoking, and use of chronic abuse of alcohol and nonintravenous and intravenous drugs by the patients [62].

Of these complications, infection is one of the most problematic because it is an important contributing factor in the development of nonunion. The incidence of complications of five fixation systems reported in the literature has varied (see Table 2), although the absence of strict, standardized outcome criteria invites inaccurate interpretation. Moreover, it is unclear from many studies which kind of approach with antibiotics and chlorhexidine rinses was adopted. In most of these studies, the infection was treated by incision and drainage, oral antibiotics, irrigations, hardware removal, sequestrectomy, and extraction of the molar associated with the MAF. In general, all infections responded positively to plate removal. However, some authors are against it. Wald et al. [25] noted that soft-tissue infections often will resolve without removing the miniplates. Valentino et al. [40] believe that miniplates will often withstand a wound abscess. They stated that if the plates are providing mandibular stability, simple treatment of the infection will have no untoward effect on the ultimate bony union.

Some earlier studies on MAFs fixation reported higher rates of postoperative infection [7, 30, 34, 36, 37]. Some authors state that this high rate of infection may be reflected by the particular population studies, reporting that the vast majority of the patients were indigent and chronic substance abusers and neither extremely cooperative nor health care conscious [34, 36, 37]. Others state that the reason was fracture instability due to inadequate fixation [30], or that if routine removal of bone plates was performed at a specified time or when a complication developed, the complication rate in their studies would be smaller [30, 34, 37]. Another variable is the extraction of the tooth in the line of fracture, although this is a very difficult factor to evaluate due to the many confounding variables [7, 34, 36]. The use of compression plates was also considered as a cause of high infection rate [34]. Ellis and Sinn [34] hypothesized that the combination of the compressive force, the insertion force of the screws, and the vascular insult from elevating the periosteum and covering the bone with the plate inhibit diffusion of nutrients into the buccal bone, which may result in osteonecrosis. Becoming devitalized, the bone cannot maintain its integrity and will begin to sequester, which would cause loss of fracture fixation and mobility. The devitalized bone may also incite an inflammatory reaction on its own, causing an infection even in the absence of fracture instability. Another possible explanation for the increased incidence of infection in the angle region of the mandible is that in this region, greater forces are developed from mandibular function, which may overcome the rigidity of the compression plate. When this occurs, and sufficient bony callous has not formed, the resultant mobility at the fracture site may result in infection. This may be true especially if an intraoral communication is present, which will allow for percolation of bacteria into the fracture site. Additionally, when a third molar has been extracted, the cross-sectional surface area of the fracture site is decreased. In some cases, this decrease in surface area may not produce a satisfactory area of contact between the two segments so that even when plated, fracture site stability is not adequate to support immediate jaw function [8]. Some authors hypothesize the reasons for the fact that a high rate of infection has been found in some studies using two miniplates [34, 37], stating that the process of putting the second miniplate at the lower border also means increased periosteal stripping, bacterial contamination, and added metal work on the mandible, which theoretically increase the possibility of infection [58]. Thus, the rate of infection is not determined exclusively by the mobility of the fracture ends, but also to a considerable degree by the surgical trauma and the extent of bone exposure required [49].

Some authors state that leaving third molars in situ increases the risk of infection because presence of teeth in the fracture line classifies the fracture as a compound fracture due to intraoral communication through the periodontal ligament. This communication of the fracture and the oral cavity promotes ingress of bacteria-laden saliva into the fracture site in the postoperative healing period [61]. Others [28, 35] believe that the removal of teeth reduces the rigidity of the repaired skeletal unit, leading to postoperative mobility and resultant infection. Removal of the tooth may avoid the need to remove the third molar and bone plate at a later stage but may increase the risk of sensory deficit of the lip and/or tongue and may lead to increased fracture displacement [57]. It was also stated that the presence of a tooth in the line of fracture is more important than whether the tooth is removed or left in place during treatment [36]. Ellis and Walker [37] (using two noncompression plates) observed that the extraction of a tooth in the line of fracture seemed to increase the rate of infection, even though in a previous study, Ellis and Sinn [34] (using two compression plates) observed that extraction of a tooth in the line of fracture did not increase the rate of infection. Ellis [48] showed that the risk of infection and need for hardware increase when there is a tooth present in the fracture line, but the increase in risk is not statistically significant. He also found no difference in the rate of complications when teeth in the fracture line are removed or retained. Rubin et al. [27] observed that when partially erupted third molar teeth were found in the line of MAF, there was no difference in postoperative morbidity regardless of whether the tooth was extracted or retained. In addition, according to other studies, the keys to the low rate of infection appear to be the achievement of primary intraoperative anatomic alignment and stable fixation of the fracture with the two-miniplate fixation technique [41]. Moreover, the fact that there were no teeth in the fracture line in the cases of infections in the study of Schierle et al. [14] could suggest that there are obviously more important variables for the incidence of complications than the presence or absence of teeth and their removal. Other important result was observed by Marker et al. [38], who demonstrated that third molars in the line of fracture can safely be retained providing a few simple criteria are observed: the absence of pericoronal infection, no fracture of the tooth, no exposed apex, and no difficulty in reducing the fracture because of the presence of the tooth.

Conclusions

Prospective and at the same time randomized controlled studies of MAFs repair techniques that are scientifically rigorous by virtue of design, numbers of subjects, and the calibration of examiners to ensure reliability are scarce. Many studies reported that their study population comprises “all patients with MAFs” or “consecutive patients with MAFs” treated with a specific technique in their institution within a certain period of time. By performing these studies essentially serially, with all consecutive MAFs treated by only one technique, the best method for a particular fracture may not have been used. For the other studies here reviewed, it is not clear if patients selected were randomly selected or included all patients with MAFs treated in a determined center during a determined period of time. Based on this assumption, results with a specific technique may be even better in compliant patients who have a minimally displaced fracture, since many authors reported that their study population was formed by “not so cooperative” or “noncompliant” patients. Since direct comparison of studies from different units and countries is difficult as the etiology of fractures, socioeconomic status of patients, compliance of patients, quality of postsurgical care, and definition of complications may vary, and no single technique for the treatment of MAFs satisfies all of the objective criteria or subjective criticisms, it may be very difficult to come to specific conclusions as for the value of a single treatment form. However, some valuable observations can be drawn from the present review.

First of all, the available data at best predict that complications are associated with all kinds of fixation techniques. Second, the similar results of complications in studies using different methods of fixation indicate that biomechanics are only one factor to be considered when treating MAFs. Furthermore, a second fracture in the mandible (which was observed in the majority of the studies’ population) can confound the outcome data because the fixation requirements of a double fracture are often different from those for an isolated fracture. It is not known whether the complication at the mandibular angle is associated with the MAF alone or the influence of the associated MFs. Thus, it is difficult to say in general if the use of one technique (rigid, semirigid, or nonrigid fixation) is better than the other. Third, some retrospective studies have found that the complication rate is lower using a single miniplate to treat MAFs when compared with using two miniplates. Fourth, it can be necessary additional effort intended for increase of stability when using biodegradable plate system to fixate MAFs, which are exposed to lateral and torsional forces during the mastication. Fifth, the use of 1.3 mm malleable miniplates was associated with an unacceptable incidence of plate fracture, suggesting that this is not the most adequate system to treat MAFs. Sixth, the use of the 3D grid plates has shown good clinical results. Seventh, the efficiency of locking miniplate system is yet to be proven because there are few clinical studies with its use to fixate MAFs, although they have shown good results. Eighth, when considering the use of semirigid or rigid fixation systems, the use of two miniplates outweighs the advantages of the use of one reconstruction plate, although the use of miniplates is not recommended for displaced comminuted MAFs. In these cases, reconstruction plates (2.7 mm) should be used. Ninth, although it has been shown that absolute rigid fixation is not necessary for fracture healing, any system that provides superior stability without impacting negatively on other aspects of the procedure, i.e., time, exposure and cost, should be favored. Tenth, MAFs can be treated in a highly effective way and with a relatively low rate of complications with monocortical miniplate fixation. Moreover, if the surgical team is not well versed in the nuances of rigid internal fixation, or the necessary equipment is not available, it is far better to perform wire osteosynthesis+MMF, which may also be indicated in hospitals with high demand and limited facilities, or to refer the patient to a hospital that can provide means of ORIF. Last but not least, the large number of studies on the treatment of MAF reflects the fact that a consensus has not been reached for a single, ideal treatment method.

Acknowledgments This work was supported by CNPq, Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil. The author would like to thank Mr. Randi O’Gilvie for his help in providing Dr. Malcolm A. Lesavoy’s article, Mr. Lies Hermans for his help in providing Dr. Maurice Mommaerts’ article, Dr. Hajime Shudou for his help in providing Dr. Yasuharu Takenoshita’s article, and Dr. Eric Dierks, Dr. Emre Vural, Dr. Christian Lindqvist, and Dr. Isabelle Barthélémy for providing their articles.

Conflicts of interest The author declares that he has no conflict of interest.

References

1. Chrcanovic BR, Freire-Maia B, Souza LN, Araújo VO, Abreu MHNG (2004) Facial fractures: a 1-year retrospective study in a hospital in Belo Horizonte. Braz Oral Res 18:322–328
2. Chrcanovic BR, Abreu MH, Freire-Maia B, Souza LN (2010) Facial fractures in children and adolescents: a retrospective study of 3 years in a hospital in Belo Horizonte, Brazil. Dent Traumatol 26:262–270
3. Chrcanovic BR, Souza LN, Freire-Maia B, Abreu MH (2010) Facial fractures in the elderly: a retrospective study in a hospital in Belo Horizonte, Brazil. J Trauma 69:E73–E78
4. Zandi M, Khayati A, Lamei A, Zarei H (2011) Maxillofacial injuries in western Iran: a prospective study. Oral Maxillofac Surg 15:201–209
5. Chrcanovic BR (2012) Factors influencing the incidence of maxillofacial fractures. Oral Maxillofac Surg 16:3–17

6. Chrcanovic BR, Abreu MH, Freire-Maia B, Souza LN (2012) 1,454 mandibular fractures: a 3-year study in a hospital in Belo Horizonte, Brazil. J Craniomaxillofac Surg 40:116–123
7. Chuong R, Donoff RB, Guralnick WC (1983) A retrospective analysis of 327 mandibular fractures. J Oral Maxillofac Surg 41:305–309
8. Ardary WC (1989) Prospective clinical evaluation of the use of compression plates and screws in the management of mandible fractures. J Oral Maxillofac Surg 47:1150–1153
9. Kuriakose MA, Fardy M, Sirikumara M, Patton DW, Sugar AW (1996) A comparative review of 266 mandibular fractures with internal fixation using rigid (AO/ASIF) plates or mini-plates. Br J Oral Maxillofac Surg 34:315–321
10. Cabrini Gabrielli MA, Real Gabrielli MF, Marcantonio E, Hochuli-Vieira E (2003) Fixation of mandibular fractures with 2.0-mm miniplates: review of 191 cases. J Oral Maxillofac Surg 61:430–436
11. Chrcanovic BR, Custódio AL (2010) Considerations of mandibular angle fractures during and after surgery for removal of third molars: a review of the literature. Oral Maxillofac Surg 14:71–80
12. Marciani RD, Anderson GE, Gonty AA (1994) Treatment of mandibular angle fractures: transoral internal wire fixation. J Oral Maxillofac Surg 52:752–756
13. Champy M, Loddé JP, Schmitt R, Jaeger JH, Muster D (1978) Mandibular osteosynthesis by miniature screwed plates via a buccal approach. J Maxillofac Surg 6:14–21
14. Schierle HP, Schmelzeisen R, Rahn B, Pytlik C (1997) One- or two-plate fixation of mandibular angle fractures? J Cranio Maxillofac Surg 25:162–168
15. Perren SM, Rahn B, Cordey J (1975) Mechanik und Biologie der Frakturheilung. Fortschr Kiefer Gesichtschir 19:33–37
16. Vineeth K, Lalitha RM, Prasad K, Ranganath K, Shwetha V, Singh J (2012) A comparative evaluation between single noncompression titanium miniplate and three dimensional titanium miniplate in treatment of mandibular angle fracture—a randomized prospective study. J Craniomaxillofac Surg. doi:10.1016/j.jcms.2012.05.015
17. Schaaf H, Kaubruegge S, Streckbein P, Wilbrand JF, Kerkmann H, Howaldt HP (2011) Comparison of miniplate versus lag-screw osteosynthesis for fractures of the mandibular angle. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 111:34–40
18. Wittenberg J, Mukherjee D, Smith B, Kruse R (1997) Biomechanical evaluation of new fixation devices for mandibular angle fractures. Int J Oral Maxillofac Surg 26:68–73
19. Michelet FX, Deymes J, Dessus B (1973) Osteosynthesis with miniaturized screwed plates in maxillo-facial surgery. J Maxillofac Surg 1:79–84
20. Gerlach KL, Khouri M, Pape HD, Champy M (1983) Die Ergebnisse der Miniplattenosteosynthese bei 1000 Unterkieferfrakturen an der Kölner und Straßburger Klinik. Dtsch Zahnärztl Z 38:363–366
21. Cawood JI (1985) Small plate osteosynthesis of mandibular fractures. Br J Oral Maxillofac Surg 23:77–91
22. Mommaerts MY, Engelke W (1986) Erfahrungen mit der Osteosynthese-Platte nach Champy/Lodde bei Unterkieferfrakturen. Dtsch Z Mund Kiefer Gesichts Chir 10:94–101
23. Niederdellmann H, Shetty V (1987) Solitary lag screw osteosynthesis in the treatment of fractures of the angle of the mandible: a retrospective study. Plast Reconstr Surg 80:68–74
24. Theriot BA, Van Sickels JE, Triplett RG, Nishioka GJ (1987) Intraosseous wire fixation versus rigid osseous fixation of mandibular fractures. J Oral Maxillofac Surg 45:577–582
25. Wald RM Jr, Abemayor E, Zemplenyi J, Mannai C, Lesavoy MA (1988) The transoral treatment of mandibular fractures using noncompression miniplates: a prospective study. Ann Plast Surg 20:409–413
26. Takenoshita Y, Katsuyama H, Hirano H, Oka M (1989) Miniplate osteosynthesis for fractures of the mandibular angle. Fukuoka Igaku Zasshi 80:348–354
27. Rubin MM, Koll TJ, Sadoff RS (1990) Morbidity associated with incompletely erupted third molars in the line of mandibular fractures. J Oral Maxillofac Surg 48:1045–1047
28. Ellis E 3rd, Ghali GE (1991) Lag screw fixation of mandibular angle fractures. J Oral Maxillofac Surg 49:234–243
29. Levy FE, Smith RW, Odland RM, Marentette LJ (1991) Monocortical miniplate fixation of mandibular angle fractures. Arch Otolaryngol Head Neck Surg 117:149–154
30. Ellis E 3rd, Karas N (1992) Treatment of mandibular angle fractures using two mini dynamic compression plates. J Oral Maxillofac Surg 50:958–963
31. Farris PE, Dierks EJ (1992) Single oblique lag screw fixation of mandibular angle fractures. Laryngoscope 102:1070–1072
32. Spaić R, Jović N, Marjanović M (1992) Our experiences with monocortical wire osteosynthesis in the treatment of mandibular angle fractures. Br J Oral Maxillofac Surg 30:201–202
33. Ellis E 3rd (1993) Treatment of mandibular angle fractures using the AO reconstruction plate. J Oral Maxillofac Surg 51:250–254
34. Ellis E 3rd, Sinn DP (1993) Treatment of mandibular angle fractures using two 2.4 mm dynamic compression plates. J Oral Maxillofac Surg 51:969–973
35. Iizuka T, Lindqvist C (1993) Rigid internal fixation of fractures in the angular region of the mandible: an analysis of factors contributing to different complications. Plast Reconstr Surg 91:265–271
36. Passeri LA, Ellis E 3rd, Sinn DP (1993) Complications of nonrigid fixation of mandibular angle fractures. J Oral Maxillofac Surg 51:382–384
37. Ellis E 3rd, Walker LR (1994) Treatment of mandibular fractures using two non-compression miniplates. J Oral Maxillofac Surg 52:1032–1036
38. Marker P, Eckerdal A, Smith-Sivertsen C (1994) Incompletely erupted third molars in the line of mandibular fractures. A retrospective analysis of 57 cases. Oral Surg Oral Med Oral Pathol 78:426–431
39. Tate GS, Ellis E 3rd, Throckmorton G (1994) Bite forces in patients treated for mandibular angle fractures: implications for fixation recommendations. J Oral Maxillofac Surg 52:734–736
40. Valentino J, Levy FE, Marentette LJ (1994) Intraoral monocortical miniplating of mandible fractures. Arch Otolatyngol Head Neck Surg 120:605–612
41. Choi BH, Kim KN, Kang HS (1995) Clinical and in vitro evaluation of mandibular angle fracture fixation with two-miniplate system. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 79:692–695
42. Barthélémy I, Boutault F, Paoli JR, Dodard L, Gasquet F, Fabié M (1996) Traitement des fractures de l'angle mandibulaire par miniplaques vissées par voie transjugale. Rev Stomatol Chir Maxillofac 97:84–88
43. Ellis E 3rd, Walker LR (1996) Treatment of mandibular angle fractures using one noncompression miniplate. J Oral Maxillofac Surg 54:864–871
44. Kallela I, Ilzuka T, Laine P, Lindqvist C (1996) Lag-screw fixation of mandibular parasymphyseal and angle fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 82:510–526
45. Potter J, Ellis E 3rd (1999) Treatment of mandibular angle fractures with a malleable noncompression miniplate. J Oral Maxillofac Surg 57:288–292
46. Quereshy FA, Goldstein JA, Goldberg JS, Beg Z (2000) The efficacy of bioresorbable fixation in the repair of mandibular fractures: an animal study. J Oral Maxillofac Surg 58:1263–1269
47. Zhang Y (2000) A clinical investigation on miniplate fixation as tension band for mandibular angle fracture. Zhonghua Kou Qiang Yi Xue Za Zhi 35:340–342

48. Ellis E 3rd (2002) Outcomes of patients with teeth in the line of mandibular angle fractures treated with stable internal fixation. J Oral Maxillofac Surg 60:863–865
49. Feller KU, Schneider M, Hlawitschka M, Pfeifer G, Lauer G, Eckelt U (2003) Analysis of complications in fractures of the mandibular angle: a study with finite element computation and evaluation of data of 277 patients. J Craniomaxillofac Surg 31:290–295
50. Fox AJ, Kellman RM (2003) Mandibular angle fractures: two-miniplate fixation and complications. Arch Facial Plast Surg 5:464–469
51. Gerlach KL, Schwarz A (2003) Belastungsmessungen nach der Miniplattenosteosynthese von Unterkieferwinkelfrakturen. Mund Kiefer Gesichtschir 7:241–245
52. Feledy J, Caterson EJ, Steger S, Stal S, Hollier L (2004) Treatment of mandibular angle fractures with a matrix miniplate: a preliminary report. Plast Reconstr Surg 114:1711–1716
53. Chritah A, Lazow SK, Berger JR (2005) Transoral 2.0-mm locking miniplate fixation of mandibular fractures plus 1 week of maxillomandibular fixation: a prospective study. J Oral Maxillofac Surg 63:1737–1741
54. Guimond C, Johnson JV, Marchena JM (2005) Fixation of mandibular angle fractures with a 2.0-mm 3-dimensional curved angle strut plate. J Oral Maxillofac Surg 63:209–214
55. Razukevicius D, Sabalys G, Kubilius R (2005) Comparative analysis of the effectiveness of the mandibular angle fracture treatment methods. Stomatologija 7:35–39
56. Soriano E, Kankou V, Morand B, Sadek H, Raphaël B, Bettega G (2005) Fractures de l'angle mandibulaire: facteurs prédictifs des complications infectieuses. Rev Stomatol Chir Maxillofac 106:146–148
57. Barry CP, Kearns GJ (2007) Superior border plating technique in the management of isolated mandibular angle fractures: a retrospective study of 50 consecutive patients. J Oral Maxillofac Surg 65:1544–1549
58. Siddiqui A, Markose G, Moos KF, McMahon J, Ayoub AF (2007) One miniplate versus two in the management of mandibular angle fractures: a prospective randomised study. Br J Oral Maxillofac Surg 45:223–225
59. Zix J, Lieger O, Iizuka T (2007) Use of straight and curved 3-dimensional titanium miniplates for fracture fixation at the mandibular angle. J Oral Maxillofac Surg 65:1758–1763
60. Bell RB, Wilson DM (2008) Is the use of arch bars or interdental wire fixation necessary for successful outcomes in the open reduction and internal fixation of mandibular angle fractures? J Oral Maxillofac Surg 66:2116–2122
61. Mehra P, Murad H (2008) Internal fixation of mandibular angle fractures: a comparison of 2 techniques. J Oral Maxillofac Surg 66:2254–2260
62. Paza AO, Abuabara A, Passeri LA (2008) Analysis of 115 mandibular angle fractures. J Oral Maxillofac Surg 66:73–76
63. Scolozzi P, Jaques B (2008) Intraoral open reduction and internal fixation of displaced mandibular angle fractures using a specific ad hoc reduction-compression forceps: a preliminary study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 106:497–501
64. Bui P, Demian N, Beetar P (2009) Infection rate in mandibular angle fractures treated with a 2.0-mm 8-hole curved strut plate. J Oral Maxillofac Surg 67:804–808
65. Ramakrishnan J, Shingleton A, Reeves D, Key JM, Vural E (2009) The effects of molar tooth involvement in mandibular angle fractures treated with rigid fixation. Otolaryngol Head Neck Surg 140:845–848
66. Sugar AW, Gibbons AJ, Patton DW, Silvester KC, Hodder SC, Gray M, Snooks H, Watkins A (2009) A randomised controlled trial comparing fixation of mandibular angle fractures with a single miniplate placed either transbuccally and intra-orally, or intra-orally alone. Int J Oral Maxillofac Surg 38:241–245
67. Bayat M, Garajei A, Ghorbani K, Motamedi MH (2010) Treatment of mandibular angle fractures using a single bioresorbable miniplate. J Oral Maxillofac Surg 68:1573–1577
68. Boffano P, Roccia F (2010) Bilateral mandibular angle fractures: clinical considerations. J Craniofac Surg 21:328–331
69. Danda AK (2010) Comparison of a single noncompression miniplate versus 2 noncompression miniplates in the treatment of mandibular angle fractures: a prospective, randomized clinical trial. J Oral Maxillofac Surg 68:1565–1567
70. Ellis E 3rd (2010) A prospective study of 3 treatment methods for isolated fractures of the mandibular angle. J Oral Maxillofac Surg 68:2743–2754
71. Seemann R, Schicho K, Wutzl A, Koinig G, Poeschl WP, Krennmair G, Ewers R, Klug C (2010) Complication rates in the operative treatment of mandibular angle fractures: a 10-year retrospective. J Oral Maxillofac Surg 68:647–650
72. Hochuli-Vieira E, Ha TK, Pereira-Filho VA, Landes CA (2011) Use of rectangular grid miniplates for fracture fixation at the mandibular angle. J Oral Maxillofac Surg 69:1436–1441
73. Kumar S, Prabhakar V, Rao K, Brar R (2011) A comparative review of treatment of 80 mandibular angle fracture fixation with miniplates using three different techniques. Indian J Otolaryngol Head Neck Surg 63:190–192
74. Singh V, Gupta M, Bhagol A (2011) Is a single miniplate at the inferior border adequate in the management of an angle fracture of the mandible? Otolaryngol Head Neck Surg 145:213–216
75. Singh RK, Pal US, Agrawal A, Singh G (2011) Single miniplate osteosynthesis in angle fracture. Natl J Maxillofac Surg 2:47–50
76. Höfer SH, Ha L, Ballon A, Sader R, Landes C (2012) Treatment of mandibular angle fractures—linea obliqua plate versus grid plate. J Craniomaxillofac Surg 40:807–811
77. Laverick S, Siddappa P, Wong H, Patel P, Jones DC (2012) Intraoral external oblique ridge compared with transbuccal lateral cortical plate fixation for the treatment of fractures of the mandibular angle: prospective randomised trial. Br J Oral Maxillofac Surg 50:344–349
78. Perry AD, Wan DC, Shih H, Tanna N, Bradley JP (2012) Open reduction and internal fixation of mandibular angle fractures using temporary Kirschner wire fixation. Plast Reconstr Surg 129:192e–194e
79. Shetty V, Caputo A (1992) Biomechanical validation of the solitary lag screw technique for reduction mandibular angle fractures. J Oral Maxillofac Surg 50:603–607
80. Cornelius CP, Augustin JB, Sailer LK (2009) External pin fixation for stabilization of the mandible—comeback of a method: historical review and first experiences with the 'mandible external fixator'. Oral Maxillofac Surg 13:1–14
81. Chrcanovic BR (2012) Open versus closed reduction: comminuted mandibular fractures. Oral Maxillofac Surg. doi:10.1007/s10006-012-0349-2
82. Schwimmer A (1993) Discussion: treatment of mandibular angle fractures using the AO reconstruction plate. J Oral Maxillofac Surg 51:255
83. Perren S, Russenberger M, Steinemann S, Müller ME, Allgöwer M (1969) A dynamic compression plate. Acta Orthop Stand Suppl 125:31–41
84. Uppal N, Baliga M, Ramanathan A (2009) Improper reduction and fixation of bilateral anterior mandibular fractures: a case report. Oral Maxillofac Surg 13:177–179
85. Ellis E 3rd, Graham J (2002) Use of a 2.0-mm locking plate/screw system for mandibular fracture surgery. J Oral Maxillofac Surg 60:642–645
86. Kroon FHM, Mathisson M, Cordey JA, Rahn BA (1991) The use of miniplates in mandibular fractures. An in vitro study J Craniomaxillofac Surg 19:199–204

87. Schmoker R, Bronz G, Knutti D (1983) Die funktionsstabile Versorgung der Unterkieferfraktur: Indikation, Zugang, Osteosynthesemittel, Komplikationen. SSO Schweiz Monatsschr Zahnheilkd 93:513–522
88. Chrcanovic BR, Freire-Maia B (2012) Risk factors and prevention of bad splits during sagittal split osteotomy. Oral Maxillofac Surg 16:19–27
89. Kalfarentzos EF, Deligianni D, Mitros G, Tyllianakis M (2009) Biomechanical evaluation of plating techniques for fixing mandibular angle fractures: the introduction of a new 3D plate approach. Oral Maxillofac Surg 13:139–144
90. Ellis E 3rd, Muniz O, Anand K (2003) Treatment considerations for comminuted mandibular fractures. J Oral Maxillofac Surg 61:861–870
91. Niederdellmann H, Akuamoa-Boateng E, Uhlig G (1981) Lag-screw osteosynthesis: a new procedure for treating fractures of the mandibular angle. J Oral Surg 39:938–940
92. Claes L, Eckert-Hubner K, Augat P (2003) The fracture gap size influences the local vascularization and tissue differentiation in callus healing. Langenbecks Arch Surg 388:316–322
93. Cox T, Kohn MW, Impelluso T (2003) Computerized analysis of resorbable polymer plates and screws for the rigid fixation of mandibular angle fractures. J Oral Maxillofac Surg 61:481–487
94. Matsushita K, Inoue N, Totsuka Y (2011) In vitro biomechanical evaluation of the effect of an additional L-shaped plate on straight or box plate fixation in sagittal split ramus osteotomy using a bioabsorbable plate system. Oral Maxillofac Surg 15:139–146
95. Esen A, Ataoğlu H, Gemi L (2008) Comparison of stability of titanium and absorbable plate and screw fixation for mandibular angle fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 106:806–811