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Original Article

Three-dimensional versus standard miniplate, lag screws versus miniplates, locking plate versus non-locking miniplates: Management of mandibular fractures, a systematic review and meta-analysis

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KEYWORDS
3-Dimensional versus standard miniplate;
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Meta-analysis

Abstract *Background/purpose:* The aims of the present study were to 1) evaluate the clinical outcomes between different fixation methods in the management of mandibular fractures (MFs) and 2) determine which fixation method is the best option for the treatment of mandibular fractures.
Materials and methods: A systematic review was conducted according to PRISMA guidelines, examining Medline-Ovid, Embase, and Pubmed databases. Inclusion criteria were studied in humans, including randomized controlled trials, controlled clinical trials, and retrospective studies, with the aim of comparing the two techniques. In addition, the incidence of complications was evaluated.
Results: Thirty-two publications were included: 20 randomized controlled trials, 4 controlled clinical trials, and 8 retrospective studies. There were statistically significant advantages for 3-dimensional miniplate and lag screws. There was no statistically significant difference between locking plates and standard miniplates ($P = 0\ 0.2$). The cumulative odds ratio was 0.64, meaning that the use of locking miniplate in the fixation of MFs decreases the risk for postoperative complications by 36% over the use of standard miniplates.
Conclusion: The results of the *three-Dimensional Versus Standard miniplate* showed that 3-dimensional miniplate is the best option for mandibular fractures. Regarding *Lag Screws Versus Miniplates* results of the meta-analysis found that the use of lag screws is superior

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to using miniplates in reducing the incidence of postoperative complications. And in regards to locking miniplates versus non-locking miniplate, the analysis indicates that the 2.0-mm locking miniplate is a prospective fixation system in the treatment of maxillofacial fractures.

Introduction

The treatment of mandibular fractures has evolved during the past several decades, especially in regards to fixation management. However, debate continues regarding the best treatment method. Various types of miniplating systems have been developed to provide stable fixation for mandibular fractures. Internal fixation of mandibular fractures with miniplates (in conformity with the tension band principle) was first introduced by Michelet in 1973 and was later modified by Champy et al.[1] The lag screw technique in maxillofacial surgery was first advocated by Brons and Boering[2] in 1970 and was later reintroduced by Niederdellmann et al.,[3] who stated that at least two screws were necessary to prevent rotational movement of the fragments in oblique fractures of the mandible.

A majority of MFs are treated by using the standard Champy miniplate fixation.[4,5] The 3-dimensional (3D) plating system for mandibular fracture treatment is relatively new.[6] The 3D plates can be considered a 2-plate system, with 2 miniplates joined by interconnecting crossbars.[7] Their shape is based on the principle of a quadrilateral as a geometrically stable configuration for support.[8] 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 of the long axis of the plate.[9]

Locking 2.0 miniplates utilize double threaded screws which lock to the bone and the plate, creating a mini-internal fixator. This results in a more rigid construction with less distortion of the fracture or osteotomy, less screw loosening and less interference with bone circulation since the plate is not too tightly pressed against the bone.[10]

The aim of this study was to answer the following question: what fixation method has the fewest complications in the treatment of MFs? The study also provides clinical database to determine which fixation method is the best option in treatment of MFs.

Materials and methods

Data sources for identification of studies

A systematic review was conducted according to PRISMA guidelines, examining Medline-Ovid, Embase, and Pubmed databases, the Cumulative Index to Nursing and Allied Health Literature, and the Electronic Journal Center. The keywords and combinations of the following search terms were included:

"3-dimensional versus standard miniplate", "conventional versus 3-dimensional miniplate", "standard miniplate versus AND 3-dimensional AND fixation AND mandibular fracture", "Champy technique versus 3-dimensional miniplate AND fixation AND mandibular fracture", "mandibular fracture", "three-dimensional, standard or conventional", "rigid fixation","osteosynthesis", "grid miniplate", "matrix miniplate", "3D strut miniplate AND Champy", "locking miniplate versus standard miniplate", "locking, standard or unlocking miniplate", "conventional versus locking miniplate", "lagscrew versus miniplate", "lagscrew" and "miniplate". A manual search of oral and maxillofacial surgery-related journals including *International Journal of Oral and Maxillofacial Surgery; British Journal of Oral and Maxillofacial Surgery; Journal of Oral and Maxillofacial Surgery; Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology; Journal of Cranio-Maxillo-Facial Surgery; Journal of Craniofacial Surgery; and Journal of Maxillofacial and Oral Surgery* was also performed. Relevant reviews on the subject and the reference lists of the studies identified were also scanned for possible additional studies. Moreover, the following online databases providing information on clinical trials in progress were checked: http://clinical-trials.gov http://www.centerwatch.com/clinicaltrials http://www.clinicalconnec-tion.com.

Inclusion and exclusion criteria

We reviewed abstracts of all citations and reviewed all of the relevant studies. The following criteria were used to accept published studies:

(a) Only the controlled trials that compared the efficacy of the 3-dimensional miniplating system with the standard miniplating system, locking miniplate versus standard miniplate, and lag screw versus miniplate in treatment of mandibular fractures were included.
(b) The studies were included regardless of whether they were randomized or quasi-randomized controlled trials, controlled clinical trials, or retrospective studies.
(c) The studies had to contain sufficient raw data for odds ratio (OR) with 95% confidence intervals (CIs).

We excluded the articles according to the following criteria:

(a) Case reports, technical reports, animal studies, in vitro studies, review papers, uncontrolled clinical studies, studies with the use of bioabsorbable materials, and studies that included infected and/or comminuted MFs and fractures in edentulous mandibles.

(b) Without raw data available or duplicate publications.
(c) No usable data reported.

Selection of relevant studies

We carefully assessed the eligibility of all studies retrieved from the databases. From the included studies in the final analysis, the following data were extracted (when available): authors, year of publication, study design, number of patients, gender, mean age in years, follow-up period, number of MFs, region of MFs, fixation methods, length of operation, use of antibiotics and/or chlorhexidine, mouth opening, postoperative complications (infection, postoperative occlusion, hardware failure, malunion, trismus, wound dehiscence and paresthesia). Authors were contacted for possible missing data.

Risk for bias in individual studies

A methodological approach quality rating was performed by combining the proposed criteria of the Meta-Analysis of Observational Studies in Epidemiology statement,[11] the Strengthening the Reporting of Observational Studies in Epidemiology statement[12] and the Preferred Reporting Items for Systematic Reviews and Meta-analyses[13] to verify the strength of scientific evidence in clinical decision making. The classification of the risk for bias potential for each study was based on the following five criteria: random selection in the population, definition of inclusion and exclusion criteria, report of losses to follow-up, validated measurements, and statistical analysis. A study that included all these criteria was classified as having a low risk for bias, and a study that did not include one of these criteria was classified as having a moderate risk for bias. When two or more criteria were missing, a study was considered to have a high risk for bias.

Meta-analysis

Meta-analyses were conducted only if there were studies of similar comparisons and they reported the same outcome measures. For binary outcomes, we calculated a standard estimation of the odds ratio (OR) by the random-effects model if heterogeneity was detected; otherwise, a fixed-effect model with a 95% confidence interval (CI) was used. Weighted mean differences were used to construct forest plots of continuous data. The data were analyzed using Review Manager version 5.2.6 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

Assessment of heterogeneity

The significance of any discrepancies in the estimates of the treatment effects of the different trials was assessed by means of the Cochrane test for heterogeneity. Heterogeneity was considered statistically significant if $P < .10$. A rough guide to the interpretation of I2, given in the Cochrane handbook (http://www.cochranehandbook.org) is as follows:

1) 0%—40% heterogeneity might not be important
2) 30%—60% may represent moderate heterogeneity
3) 50%—90% may represent substantial heterogeneity
4) 75%—100%, there is considerable heterogeneity

Investigation of publication bias

A funnel plot (plot of effect size versus standard error) was constructed. Asymmetry of a funnel plot may indicate publication bias and other biases related to sample size, although the asymmetry may also represent a true relationship between trial size and effect size.

Sensitivity analysis

If there were sufficient studies included, we conducted a sensitivity analysis to assess the robustness of the review results by repeating the analysis and excluding those studies with a high risk of bias.

Results

Description of studies

The study selection process is summarized in Fig. 1. The electronic search resulted in 1564 entries and four additional articles were identified by hand-searching. After the initial screening of the titles and abstracts, 615 articles were excluded because they were cited in more than 1 search of terms. Of the resulting 953 studies, 886 were excluded for not being related to the topic. The full-text reports of the remaining 67 articles led to the exclusion of 35, because they did not meet the inclusion criteria. Thus, a total of 32 publications were included in the review. Detailed characteristics of the included studies are shown in Table 1 and Table 2.

Quality assessment

With respect to the quality assessment of the included studies, 18 studies showed a low risk for bias, 7 studies showed a moderate risk for bias, and 7 studies showed a high risk for bias. The scores are summarized in Table 3.

Results of individual studies

Three-dimensional versus standard miniplate

18 studies compared the 3D plate with the standard 2-miniplate technique at varying follow-up periods. There were no statistically significant differences regarding infection or wound dehiscence, however, they were statistically significant in regards to hardware failure, malocclusion and paresthesia/trismus. The cumulative analysis showed that there were advantages of the 3D miniplate over the standard 2-miniplates technique in the fixation of MFs and this advantage did reach statistical significance ($OR = 0.66$; 95% CI, 0.47 to 0.92; $P = .003$) (Fig. 2).

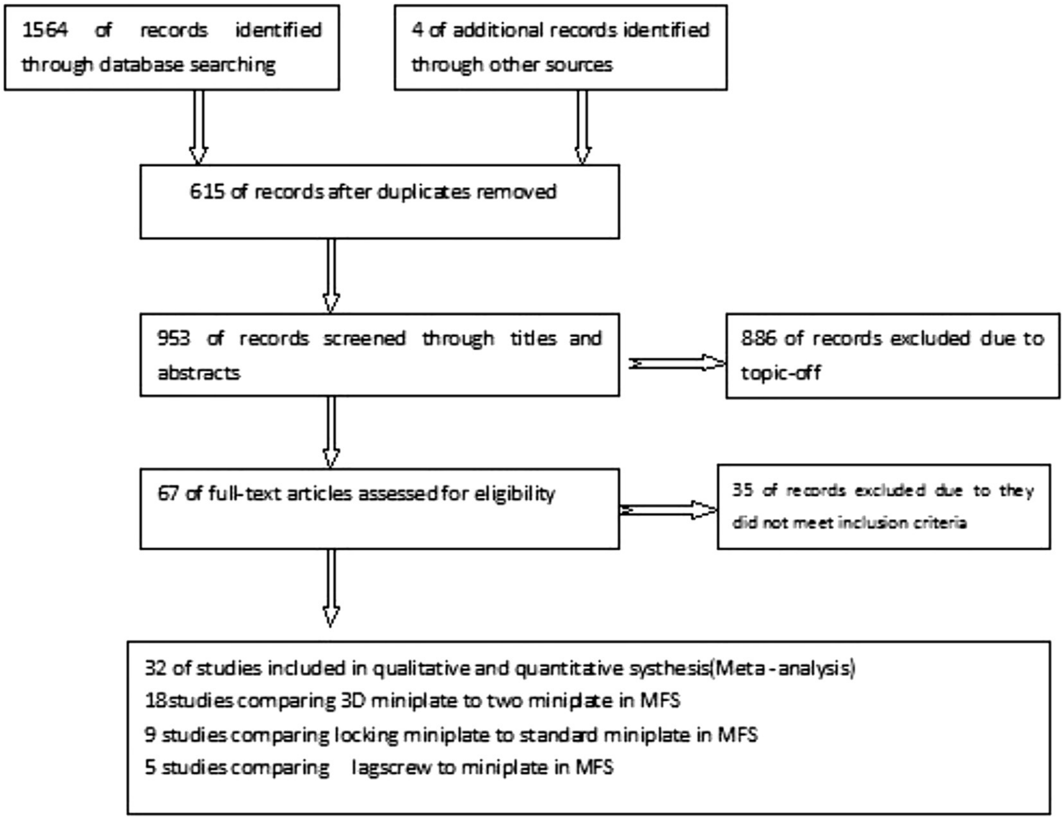

Fig. 1 Study screening process. MF, mandibular fracture.

Operative time

12 studies reported operative times but only 5 studies provided standard deviations. There were shorter operative times in the 3D plate groups over the standard 2-miniplate groups in anterior mandibular fractures (Fig. 3). The 3D plate technique showed a significant benefit in time ($P < .00001$). There were shorter operative times in the standard miniplate groups over the 3D plate in the mandibular angle fractures (Fig. 4). Therefore, comparing length of operation between these studies was not possible.

Lag screws versus miniplates

Five studies comparing lag screws and miniplates assessed the incidence of postoperative complications. There were significant differences with regard to postoperative infection and hardware failure, but no significant differences with respect to malocclusion, wound dehisence and paresthesia. The overall analysis of all complications revealed a statistically significant advantage for the lag-screw technique when the incidence of all postoperative complications was considered (OR = 0.32; 95% CI, 0.21 to 0.5; P = .0003). The test of heterogeneity among all studies showed homogeneity ($\chi2 = 16.77$, df = 16, P = .4; $I^2 = 5\%$), as well as the test for subgroup differences (inconsistency across the subgroups) ($\chi2 = 1.16$, df = 5, P = .95; $I^2 = 0\%$). The cumulative OR was 0.32, meaning that the use of lag screws in the fixation of MFs decreases the risk for postoperative complications by 67% compared with using 2 mini-plates (Fig. 5).

Operative time

Three studies reported the operating times, however, only 1 study mentioned the standard deviation to compute continuous outcomes. The lag screw technique showed a significant benefit in time ($P < .0001$) compared with the application of 2 miniplates (Fig. 6).

Locking plate versus non-locking miniplates

Seven studies reported the incidence of postoperative complications when using locking plates compared with the application of standard miniplates. There were no significant differences concerning infection, paresthesia, wound dehisence and occlusian discrepancy. The cumulative analysis revealed an advantage for the use of a locking miniplate over standard miniplates, although this difference did not reach statistical significance (OR = 0.64; 95% CI, 0.34 to 1.22; P = .2). The test of heterogeneity among all studies showed homogeneity ($\chi^2 = 4.43$, df = 14, P = .99; $I^2 = 0\%$), as well as the test for subgroup differences (inconsistency across the subgroups) ($\chi^2 = 0.58$, df = 3, P = .9; $I^2 = 0\%$) (Fig. 7).

Maxillomandibular fixation (MMF)

The low postoperative MMF rate suggests that the specific plate system has an enormous potential in the future application in treatment of mandibular fractures. When comparing the MMF rate, there was a statistical difference between 2 groups (OR = 0.43; 95% CI, 0.22–0.83; $P < .0001$) (Fig. 8), that revealed that the 2.0-mm locking miniplate

Table 1 Comparison between fixation methods (Lag Screw, 3d Plate, two conventional miniplates) in mandibular fractures.

Study	Year published	Study design	Gender(M/F)	Mean Age(Range) (y)	Patients(n)	Follow-UpPeriod	MF FixationMethods	Mean Length of Operation (min)	MFs	Region of MFs
Jain, Manjunhet al	2010	RCT	(G1): 17/3 (G2): 18/2	(G1): 48 (G2): 47	(G1): 20 (G2): 20	1, 2, 4 6 wk 2 month	G1: two 2.0-mm miniplates G2: 3D 2-mm stainless steel plates	G1: 45 G2: 33	40	(G1):13symphysealand parasymphyseal 5 body,2 angle (G2):13symphysealand parasymphyseal 5 body,2 angle
Kumar P et al.	2012	RCT	(G1, G2): 20/0	(G1, G2): 33.9(19—63)	(G1):10 (G2): 10	1, 2, 4 8 wk 3 month	(G1): one 2-mm stainless steel (G2): 3D 2-mm stainless steel	(G1): 10.2 (G2): 6.3	34	G1:10(symphysealand parasymphyseal) G2:10(symphysealand parasymphyseal)(G1, G2): 2 body,4 angle, 8condyle
Khalifa et al.	2012	CCT	(G1, G2): 14/6	(G1, G2): 32.5(15—50)	(G1): 10 (G2): 10	Up to 6 month	(G1): two 2.0-mm titanium miniplates (G2): 3D rectangular miniplates	(G1): 19.4 (G2): 10.8	30	(G1): 10(symphysealand parasymphyseal)(G2):10(symphysealand parasymphyseal)(G1, G2): 4 angle,6 condyle
Malhotra et al.	2012	RCT	(G1, G2): 20/5	(G1, G2): 29	(G1): 10 (G2): 10	1, 3 6 wk 3month	(G1): two 2.0-mm miniplate (G2): 3D 2-mm stainless steel plates	NM	25	(G1):10(symphysealand parasymphyseal) (G2):11(symphysealand parasymphyseal)(G1, G2):1body,2angle
Agarwal et al.	2013	RCT	(G1): 37/3 (G2): 39/1	(G1): 26.62(G2): 24.72	(G1): 40 (G2): 40	1, 3 6 wk 3 month	(G1): two 2.0-mm miniplates (G2): 3D 2-mm stainless steel plates	(G1): 38 (G2): 49	NM	NM
Sadhwani et al.	2013	CCT	(G1, G2): 18/10	(G1, G2): 18-60	(G1): 14 (G2): 14	NM	(G1): two 2.0-mm titanium miniplates (G2): 3D rectangular miniplates	NM	28	(G1):9 (symphysealand parasymphyseal)(G2): 9 (symphysealand parasymphyseal)(G1): 3 body, 2 angle(G2): 3 body, 2angle
Barde et al.	2014	CCT	(G1, G2): 34/6	(G1, G2): 35(20—50)	(G1): 20 (G2): 20	1, 2, 3, 4,6, 12, 24 wk	(G1): two 2.0-mm miniplates (G2): 3D rectangular miniplates	(G1): 59.40 (G2): 50.60	40	(G1): 20(symphyseal and parasymphyseal)(G2): 20(symphyseal and parasymphyseal
Singh et al.	2012	RCT	(G1, G2):4/46	(G1, G2):30.4	G1:25 G2:25	1,4,8,12WK	(G1) Single2.0-mm 4-hole miniplateatthe externaloblique line oronthelateralcortex (n = 10) (G2) Single rectangular 2.0-mm 6-hole 3Dminiplate (n = 10)	G1:49.57 G2:43	56	Angle (n = 20) parasymphysis(n = 35) symphysis(n = 1)
Jain, Sankar et al.	2012	RCT	NM	(G1, G2):16—60	G1:10 G2:10	1,2,4, 6WK and 2 months	G1:2 mm titanium locking miniplates G2:2 mm 4 holed 3-dimensional (3D) locking titanium miniplates	G1:38 G2:17	20	inter mental foramina region:20
Vineeth et al.	2012	RCT	NM	(G1, G2):19—51	G1:10 G2:10	1 day 1 week 1month 3 months	(G1) Single2.0-mm 4-hole miniplateatthe externaloblique line (n = 10) (G2) Single rectangular 2.0-mm 6- or 8-hole3D miniplate (n = 10)	NM	29	Angle(n = 20)additional fractures (n = 9; G1,n = 5; G2,n = 4)
Xue et al.	2013	RCT	(G1, G2):18/0	(G1): 28 (G2): 28	G1:6 G2:7	1—2 weeks 4—6 weeks 6 months	(G1) Single2.0-mm 4-hole miniplateat the externaloblique line (n = 7) (G2) Singlecurved 2.0-mm 10-hole3Dminiplate (n = 6)	(G1):42 (G2):102	22	Angle (n = 13)parasymphysis (n = 8) subcondylar (n = 1)
Höfer et al.	2012	RS	(G1, G2):52/8	(G1,G2): (31.1)	G1:30 G2:30	7,14,28 days, 3,6,12 months	(G1) Single2.0-mm 6-hole miniplateatthe externaloblique line (n = 30) (G2) Single rectangular 2.0-mm 4-hole 3Dminiplate (n = 30)	89(G1) 81 (G2)	90	Angle(n = 60)(G1, G2):body(n = 25) ascending ramus (n = 5)

Guy et al.	2013	RS	(G1):20/2 (G2):64/4	(G1, G2): 28	G1:22 G2:68	G1:47 days G2:55 days	(G1) One or two 2.0-mm 4-holeminiplate (n = 22) (G2) Singlecurved 2.0-mm 8-hole3Dminiplate (n = 68)	G1:232.2 G2:219.5	161	Angle (n = 96)parasymphysis (n = 41) body (n = 11) condyle (n = 5)coronoid (n = 2) ramus(n = 6)
Moore et al.	2013	RS	(G1):27/5 (G2):59/13	NM(31)	G1:32 G2:72	NM	(G1) Single2.0-mm 4- or6-hole miniplate at the external obliqueline (n = 33) (G2) Singlecurved 2.0-mm 8-hole3D miniplate (n = 73)	NM	168	Angle (n = 106),parasymphysis (n = 51) body (n = 11)
Moraissi et al.	2014	RCT	(G1, G2):16/4	G1:25.5 ± 6.8 G2:27 ± 0.9	G1:10 G2:10	1week,1,2, 3 and 6 month	G1: Single2.0-mm standard miniplate G2: 1.0-mm miniplate (n = 73)	G1:39.7 ± 9.1 G2:33 ± 4.6	NM	NM
Tairi et al.	2015	RS	(G1): 6/2(G2): 6/2	G1: 25 G2: 24	G1:8 G2:8	1, 3, 6 months	G1: two miniplates fixation G2: 3D miniplate	NM	16	Mandibular angle (16)
Mittal et al.	2016	RCT	(G1, G2): 24/6	(G1, G2):16-60	G1:15 G2:15	1,3,6months	G1:two miniplatesfixation G2:3D miniplate	NM	30	parasymphysis
Elsayed et al.	2015	RS	(G1): 7/3(G2): 7/3	G1:26.1 ± 2.34 G2:27 ± 0.9	G1:10 G2:10	1,2,3,4week 3,6month	G1: single 2.0-mm locking miniplate G2:single rigid 2.3-mm plate	G1:33.20 ± 2.44 G2:42.0 ± 2.32	36	G1:(n = 2)angle G2: (n = 3)angle 【Symphyseal + angle G1:(n = 1) G2: (n = 1)】【Parasymphyseal + angle G1: (n = 4) G2: (n = 3)】【Body + angle G1: (n = 3) G2: (n = 3)】【 subcondylar G1: (n = 1) G2:(n = 1) 】
Ellis et al.	2011	Rs	(G3): 374/30 (G4): 430/46	(G3): 27.9 (G4): 27.4	(G3): 411 (G4): 476	G3:142.2d G4:147.3d	(G3): 2.7- or 2.4-mm lag screw (G4): two 2.0-mmminiplates	NM	660	(G3): 193 angle, 117 condyle(G4): 223 angle, 127 condyle
Goyal et al.	2012	RCT	(G3, G4): 9/1	(G3, G4): 15-25	(G3):15 (G4):15	3, 6, 12, and 24wk	(G3): 2.4-mmcortical lag screw (G4): 2 2.0-mm miniplates	(G3): 75.6 (G4): 118.2	NM	mandibular symphysis parasymphysis region
Bhatnar et al.	2013	RCT	NM	NM	(G3): 15 (G4): 15	2nd, 4th, 6th, and 8th weeks	(G3): two 2.5-mm lag screws (G4): two 2.5-mm miniplates	NM	NM	symphysis or parasymphysis mandibular fracture
Agnihri et al.	2014	RCT	NM	(G3,G4):33.7 (18—70)	(G3): 40 (G4): 40	Immediate, 1, 3, and 6 month	(G3): two 2.5-mm cortical screws (G4): two 2.0-mm miniplates	(G3): 120—180 (G4): 60 -120	NM	mandibular symphysis/parasymphysis region
Schaaf et al.	2011	Rs	(G3): 19/2 (G4): 22/2	(G3): 27 (G4): 23	(G3): 21 (G4): 24	NM	(G3):0.56 mmlag-screw (G4): 0.85 mm 1miniplate, 1.40 mm 2miniplates	(G3): 50.08 (G4): 69.09	45	(G3):21 angle (G4):24angle

NM,notmentioned; NP, not performed; RCT, randomized controlled trials; CCT, controlled clinical trials; RA,retrospectiveanalysis; G1, group1(standardminiplates); G2, group 2(3Dminiplates); G3, lag screw; G4,miniplate; MMF, maxillomandibularfixation.

Table 2 Comparison between fixation methods (3d Plate, two conventional miniplates) in mandibular fractures.

Study	Year published	Study period	Study design	Gender (M/F)	Mean Age(Range) (y)	Patients(n)	Follow-UpPeriod	MF FixationMethods	MFs	Region of MFs
Collins et al.	2004	2002.1–2003.2	RCT	(G5, G6): 82/8	(G5, G6) = 25.9 ± 6.7	(G5): 45 (G6): 45	6 wk	G5:locking 2.0-mm miniplates G6:non-locking 2-mm plates	122	(G5):26 parasymphyseal body, 29 angle (G6):30 parasymphyseal 7 body, 21 angle
Agerwal et al.	2011	2007.1–2008.2	RCT	(G5, G6): 19/1	(G5, G6): 1–60	(G5):10 (G6): 10	1, 3, 6 wk 3 month	(G5): 2-mm locking titanium miniplates (G6): 2-mm non-locking titanium miniplates	34	NM
Singh et al.	2011	2007.11–2009.6	RCT	(G5, G6): 46/4	(G5, G6):30.04 ± 8.75	(G5): 25 (G6): 25	4, 6 wk 2,3 month	(G5): 2.0-mm locking plates (G6): non-locking plates	76	(G5): 6parasymphyseal, 13 angle, 13 body (G6):10 parasymphyseal, 13 angle, 15 body
Kumar I et al.	2013	2007.6–2009.9	RS	(G5): 26/4 (G6): 28/2	(G5): 28.4(G6): 27.6	(G5): 30 (G6): 30	6 wk,2 3month	(G5): 2.0-mm locking plates (G6): non-locking 2-mm plates	88	(G5, G6):24body,44angle,20 parasymphyseal
Saikrishna et al.	2009	2006.7–2008.8	RCT	(G5): 19/1 (G6): 18/2	(G5, G6): 15–60	(G5): 20 (G6): 20	6 wk	(G5): 2.0-mm locking miniplates (G6): standard miniplates	59	(G5): 12 parasymphyseal,5symphysis,6 angle,5 body; (G6):10 parasymphyseal,3symphysis,5 angle,13body
ShaiK et al.	2014	NM	CCT	NM	NM	(G5): 30 (G6): 30	1,3,6 weeks	(G5): 2.0 mm locking stainless steel miniplates (G6): 2.0 mm standard stainless steel miniplates	NM	(G5):5 symphysis (G6): 4symphysis (G5): 4 body, 7 angle (G6): 4 body, 10 angle,2 multiple fractures
Giri et al.	2015	2012.6–2014.8	RCT	(G5, G6): 17/3	(G5, G6): 11–40	(G5): 10 (G6): 10	1, 3, 6wk	(G5): 2-mm locking titanium miniplate (G6): 2-mm non-locking titanium miniplate	31	(G5): 20 (symphyseal and parasymphyseal) (G6): 20(symphyseal and parasymphyseal
Kumar BP et al.	2015	2010.9–2012.8	RCT	(G5, G6): 14/6	(G5, G6):29 ± 7.53	G5:10 G6:10	1 WK and 1,2,3 months	G5:2.0-mm locking miniplates G6:2 mm standard champy's titanium miniplates	NM	G5:[(2 parasymphysis, 1 symphysis, and 1angle) and six patients had multiple fractures (4parasymphysis, 2 body)] G6:[(2 parasymphysis, 1 symphysis,1 body, and 2 angle) and multiple fractures (3 parasymphysis, 1 symphysis)]
Rastogi et al.	2016	2012.8–2014.8	RCT	(G5, G6): 17/3	(G5, G6):11–40	G5:10 G6:10	1,3,6 weeks	G5:2.0 mm locking miniplates G6:standard 2.0 mmminiplates	31	1sysphysis, 12 parasysphysis, 10 body,4 angle,4 subcondyle

NM, not mentioned; NP, not performed; RCT, randomized controlled trials; CCT, controlled clinical trials; RA, retrospectiveanalysis; G5,group1(locking miniplates); G6, group 2(standard miniplate); MMF,maxillomandibularfixation.

Table 3 Results of the quality assessment.

Authors	Published	Random selection in population	Defined inclusion/exclusion criteria	Loss of follow-up	Validated measurement	Statistical analysis	Estimated potential risk of bias
Jain, Manjunath et al.[33]	2010	Yes	Yes	Yes	Yes	Yes	Low
Kumar P et al.[36]	2012	Yes	No	Yes	No	Yes	High
Khalifa et al.[37]	2012	Yes	No	Yes	Yes	No	High
Malhotra et al.[38]	2012	Yes	Yes	Yes	Yes	Yes	Low
Agarwal et al.[23]	2013	Yes	Yes	Yes	Yes	Yes	Low
Sadhwani et al.[40]	2013	Yes	No	Yes	Yes	Yes	Moderate
Barde et al.[25]	2014	No	No	Yes	Yes	Yes	High
Singh et al.[19]	2012	Yes	Yes	Yes	Yes	Yes	Low
Jain, Sankar et al.[34]	2012	Yes	Yes	Yes	Yes	Yes	Low
Vineeth et al.[8]	2013	Yes	Yes	Yes	Yes	Yes	Low
Xue et al.[46]	2013	Yes	Yes	Yes	Yes	Yes	Low
Höfer et al.[32]	2012	No	Yes	Yes	Yes	Yes	Moderate
Guy et al.[31]	2013	No	Yes	No	Yes	Yes	Moderate
Moore et al.[47]	2013	No	Yes	No	No	Yes	High
Moraissi et al.[14]	2014	Yes	Yes	Yes	Yes	Yes	Low
Mittal et al.[15]	2016	Yes	Yes	Yes	Yes	Yes	Low
Tairi et al.[45]	2015	No	Yes	Yes	Yes	Yes	Moderate
Elsayed et al.[29]	2015	No	No	Yes	Yes	Yes	High
Collins et al.[27]	2004	Yes	Yes	Yes	Yes	Yes	Low
Agarwal et al.[24]	2011	Yes	Yes	Yes	Yes	Yes	Low
Singh et al.[44]	2011	Yes	Yes	Yes	Yes	Yes	Low
Kumar I et al.[35]	2013	No	No	Yes	Yes	Yes	High
Saikrishna et al.[41]	2013	Yes	Yes	Yes	Yes	Yes	Low
Shai et al.[43]	2014	No	Yes	Yes	No	No	High
Giri et al.[21]	2015	Yes	Yes	Yes	Yes	Yes	Low
Kumar BP et al.[22]	2015	Yes	No	Yes	Yes	Yes	Moderate
Rastogi et al.[39]	2016	Yes	Yes	Yes	Yes	Yes	Low
Goyal et al.[30]	2012	Yes	Yes	Yes	Yes	Yes	Low
Bhatnagar et al.[26]	2013	Yes	Yes	Yes	Yes	Yes	Low
Ellis et al.[28]	2012	No	Yes	Yes	Yes	Yes	Moderate
Agnihotri et al.[20]	2014	Yes	Yes	Yes	Yes	Yes	Low
Schaaf et al.[42]	2011	No	Yes	Yes	Yes	Yes	Moderate

system had an overall advantage in treating mandible fractures compared with the 2.0-mm standard miniplate system.

Sensitivity analysis and publication bias

The cumulative analysis after the exclusion of studies with a high risk of bias did not change the overall main results (Fig. 9). The funnel plot did not show any noticeable asymmetry, indicating the absence of publication bias (Fig. 10).

Discussion

With increasing industrialization, mandibular fractures are more common in facial trauma. The fixation method of mandibular fractures has become an increasingly important decision for the maxillofacial surgeon. The key to successful management of these fractures is to understand the principles of accurate re-establishment of occlusion, fracture reduction, and stable internal fixation.[14]

The geometry of 3D plates conceptually allows for stability in three dimensions, and resistance against torque forces while maintaining a low profile and malleability.[15] The major advantages of the lag-screw technique are that it can be applied more rapidly without decreasing rigidity and that it allows a more anatomically accurate reduction.[16] The locking screw plate system reduces compressive forces between the undersurface of the plate and lateral bony cortex compared to a conventional mandibular plate. In a locking screw plate system, forces are generated between the threaded portion of the plate and the screw. This limits stress shielding and creates a more stable fixation over time.[17]

In general, the results of the present meta-analysis show statistically higher complication rates when 2 miniplates are used, and this observation not only has statistical significance but also has important clinical implications. It was observed that MFs repaired with lag screws have one-third the risk, with standard miniplate having two-fifths the risk for postoperative complications compared with patients with MFs fixed with miniplates, locking plate system. Successful treatment of mandible fractures depends on undisturbed healing in the correct anatomical position under stable conditions. Failure to achieve this leads to infection, malocclusion, or non-union.[8]

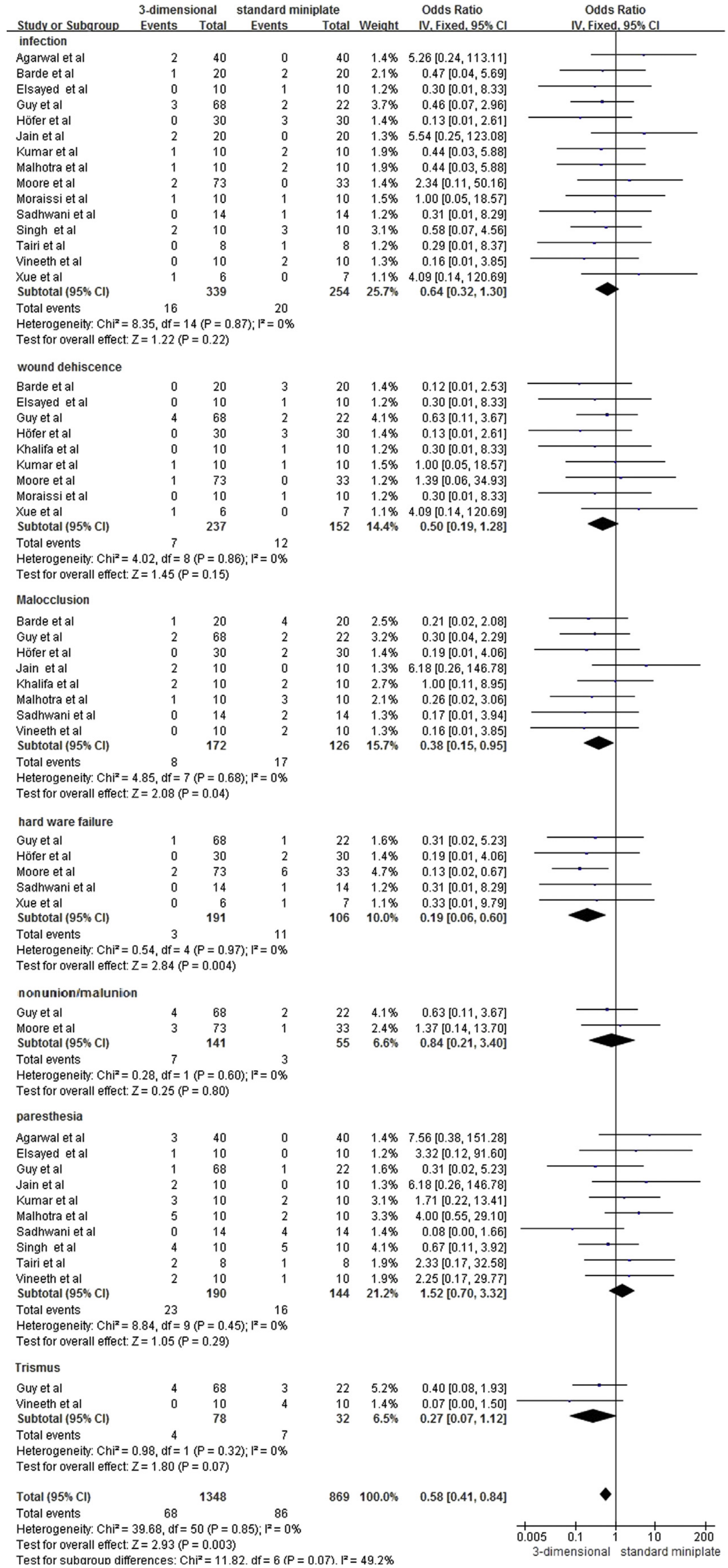

Fig. 2 Forest plots, 3D miniplate versus standard miniplate in MAFs (postoperative complications). CI, confidence interval; M-H, the Mantel-Haenszel.

	3-dimensional			standard miniplate				Mean Difference	
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI	Year
Jain et al	33	0	10	45	0	10		Not estimable	2010
Jain et al	17	0	10	38	0	10		Not estimable	2012
Kumar et al	6.3	1.33	10	10.2	0	10		Not estimable	2012
Khalifa et al	10.8	1.93	10	19.4	2.75	10	66.1%	-8.60 [-10.68, -6.52]	2012
Agarwal et al	38	0	40	49	0	40		Not estimable	2013
Barde et al	50.6	3.83	20	59.4	5.42	20	33.9%	-8.80 [-11.71, -5.89]	2014
Total (95% CI)			**100**			**100**	**100.0%**	**-8.67 [-10.36, -6.97]**	

Heterogeneity: Chi² = 0.01, df = 1 (P = 0.91); I² = 0%
Test for overall effect: Z = 10.03 (P < 0.00001)

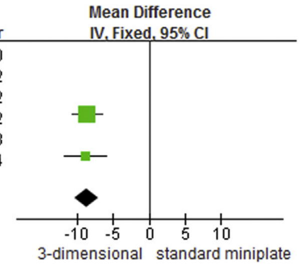

Fig. 3 Forest plots, 3D plate versus miniplate in AMFs (operative time). CI, confidence interval; IV, inverse variance.

With respect to the 3D plate versus 2 miniplates, it was observed that MF fixation with 3D miniplates decreases the risk of postoperative complications by 34% compared with standard miniplates (OR = 0.66; 95% CI, 0.47 to 0.92; P = .003). When comparing differences between the techniques concerning the incidence of infection (4.7% in the 3D miniplate group, 7.9% in the standard miniplate group), the incidence of infection did not reach statistical significance (P = .22). With respect to the 3D miniplate versus standard miniplate considering the incidence of malocclusion (4.7% in the 3D miniplate group, 13.5% in the standard miniplate group), the incidence of malocclusion reached statistical significance (P = .04). No statistically significant difference in the incidence of paresthesia was observed between the two techniques (P = .29). With regard to the incidence of hardware failure (1.6% in the 3D miniplate group, 10.4% in the standard miniplate group) there was a statistically significant difference in the incidence of hardware failure observed between the two techniques (P = .004). 3-dimensional miniplate has a better inter-fragmentary stability, thus it was shown that significant differences in the incidence of complications exist between the 3D plate system and two miniplate techniques. Nine studies showed the operating time using the 3D plating system to be shorter, whereas three others showed that the standard plating system had a shorter operating time. One might expect the operating time to be shorter with the 3D plating system because the surgeon needs to place only one plate instead of two separate conventional miniplates,[18] however, due to the broad size of the plate and because more screws are needed (6—10 holes), fixation of 3D plates in the angle region usually takes more time. Intraoral placement of the 6 to 10-hole 3D miniplate is also more difficult.[19]

Internal fixation surgery should meet four basic conditions: (1) anatomic reduction of the bone fragments; (2) functionally stable fixation of the fragments; (3) preservation of the blood supply to the fragments by atraumatic operating technique; (4) early, active, pain-free mobilization. All the above requirements are met by miniplates as well as lag screws. Lag screws have the added advantage of achieving inter-fragmentary compression and stability with a minimum of implant material.20 Our observations suggest that there was a statistical advantage of lag screw over miniplate (OR = 0.32; 95% CI, 0.21 to 0.5; P = .0003), meaning that the use of 1 strong plate in the fixation of MFs decreases the risk for postoperative complications by 69.1% over the use of miniplates. With respect to operating time, 3 studies reported the time required to perform fixation with lag screws or miniplates but only one study mentioned the standard deviation. The lag screws took significantly less operative time (P = .0001). This clinical database showed that the lag-screw fixation is a time-saving method and simultaneously reduces postoperative complications, making it the best option for both surgeons and patients.

With respect to the locking plate versus standard miniplates, we found that MFs treated with 2.0-mm locking miniplates and 2.0-mm standard miniplates presented similar short-term complication rates. Furtherly, the use of 2.0-mm locking miniplates had a lower postoperative MMF rate compared with 2.0-mm non-locking miniplates and this differentiation has statistically significance (P < .0001). This new design of Mini-Locking plate provided locking of the screws on both the plate and bone interface, on either side of the fracture. Thus a frame construct was achieved on either side of the fracture fragments. This provided better stability of the fracture fragments and allowed for a better healing environment when compared to the conventional plates, while still retaining the same miniature dimensions. [29] The locking plate/screw system has only minor additions to the instrument armamentarium. This system requires perpendicular placement of the plate

	3-dimensional			standard miniplate				Mean Difference	
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI	Year
Höfer et al	81	38	30	89	42	30	0.9%	-8.00 [-28.27, 12.27]	2012
Singh et al	43	0	10	49.57	0	10		Not estimable	2012
Guy et al	219.5	0	68	232.2	0	22		Not estimable	2013
Xue et al	102	0	6	42	0	7		Not estimable	2013
Moraissi et al	39.7	9.1	10	33	4.6	10	9.7%	6.70 [0.38, 13.02]	2014
Elsayed et al	42	2.32	10	33.2	2.44	10	89.3%	8.80 [6.71, 10.89]	2015
Total (95% CI)			**134**			**89**	**100.0%**	**8.44 [6.46, 10.41]**	

Heterogeneity: Chi² = 2.93, df = 2 (P = 0.23); I² = 32%
Test for overall effect: Z = 8.38 (P < 0.00001)

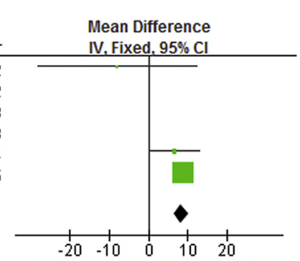

Fig. 4 Forest plots, 3D plate versus miniplate in MAFs (operative time). CI, confidence interval; IV, inverse variance.

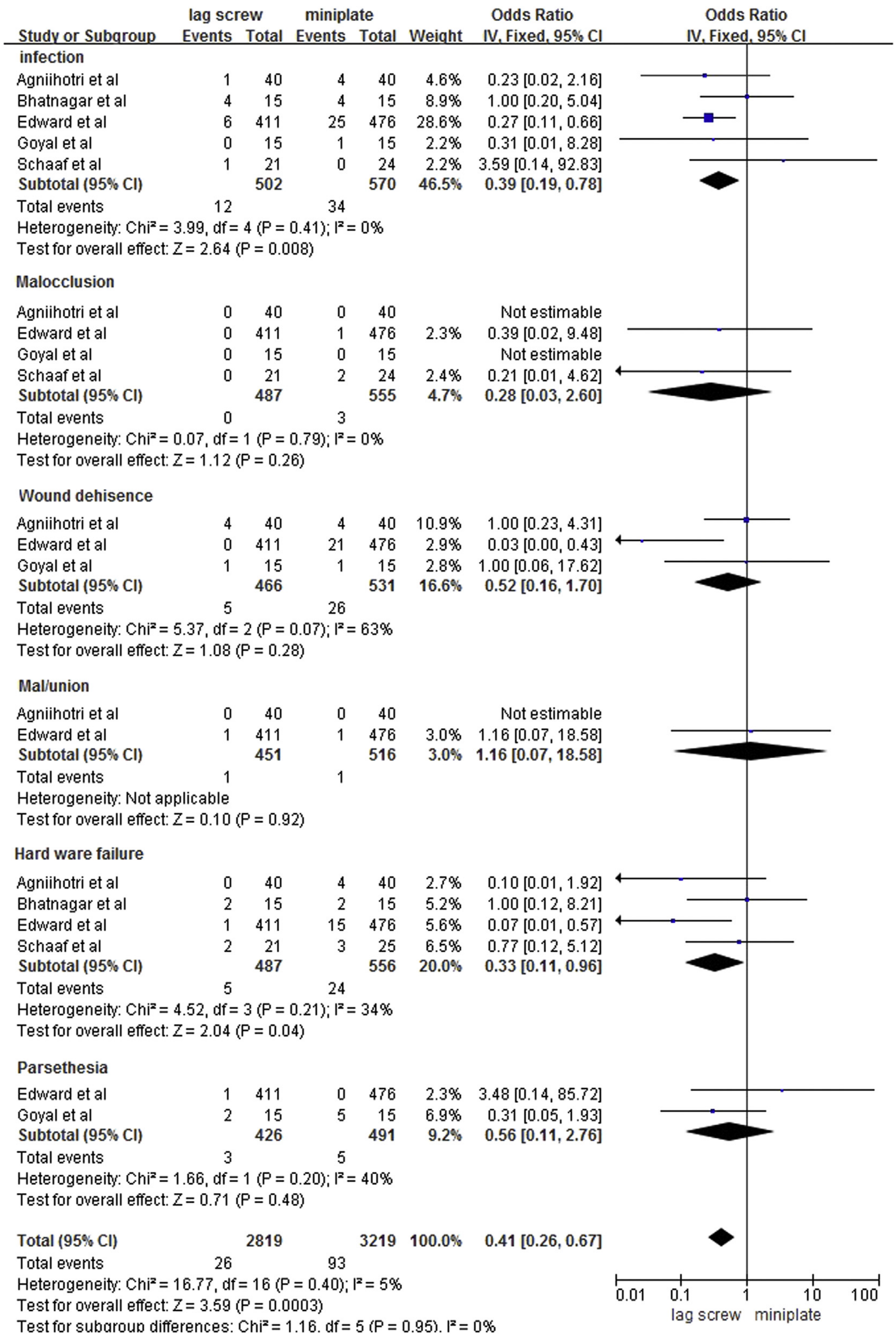

Fig. 5 Forest plots, lag-screw versus miniplates in MFs (postoperative complications). CI, confidence interval; M-H, the Mantel-Haenszel.

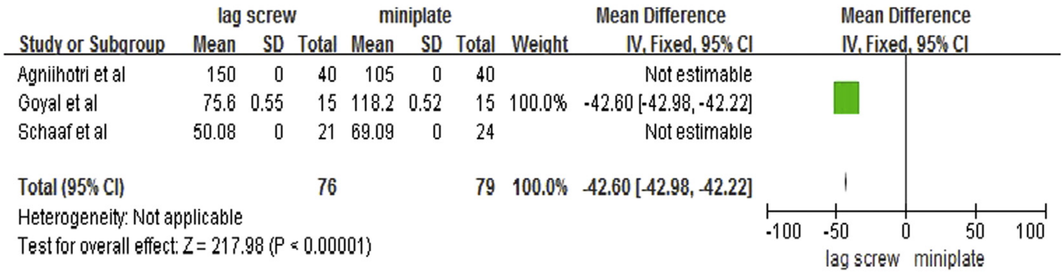

Fig. 6 Forest plots, lag-screw versus miniplates in MFs (operative time). CI, confidence interval; IV, inverse variance.

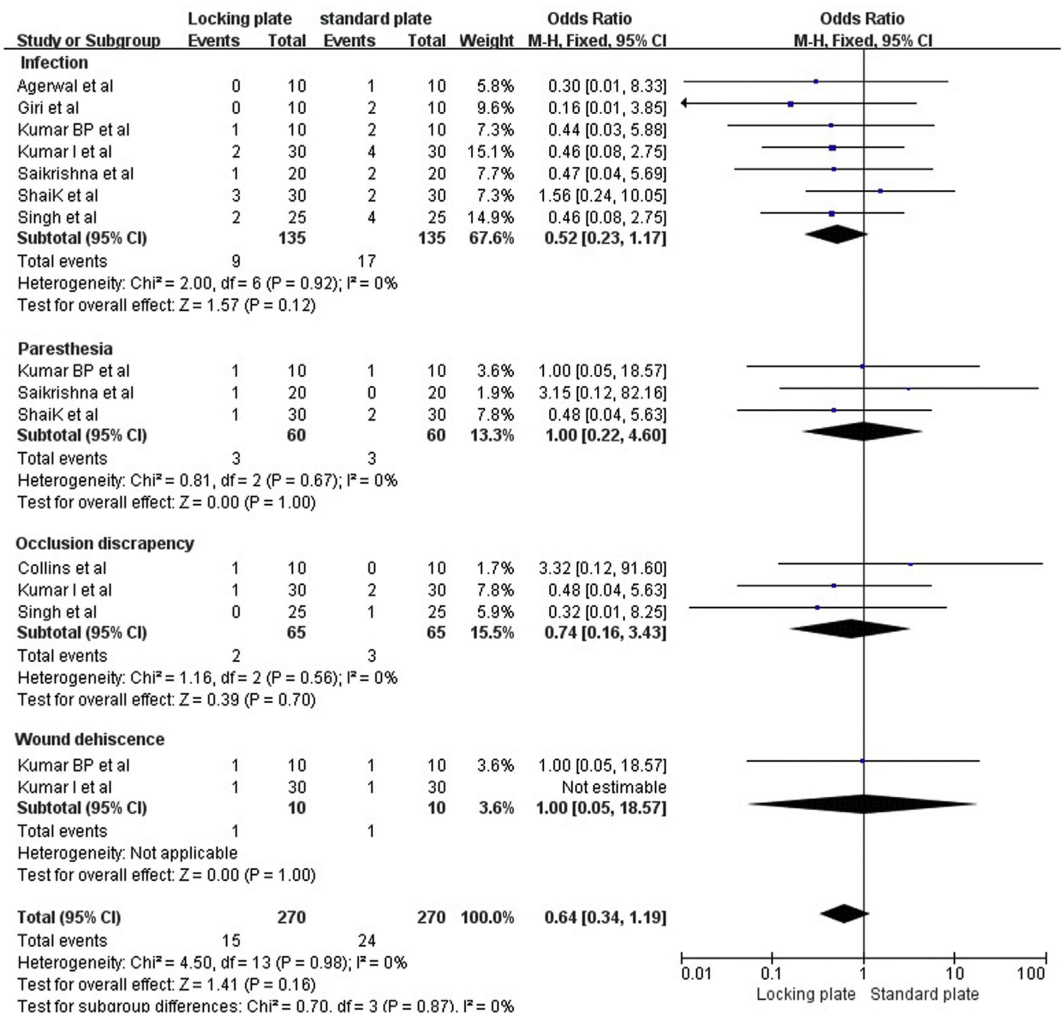

Fig. 7 Forest plots, locking miniplate versus standard miniplates in MFs (postoperative complications). CI, confidence interval; M-H, the Mantel-Haenszel.

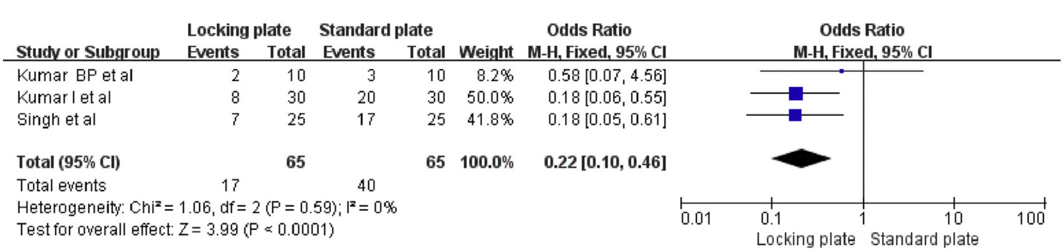

Fig. 8 Forest plots, Postoperative MMF. CI, confidence interval; IV, inverse variance.

Study or Subgroup	3-dimensional miniplate Events	3-dimensional miniplate Total	Standard miniplate Events	Standard miniplate Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Postoperative complications						
Agarwal et al	3	10	0	10	0.3%	9.80 [0.44, 219.25]
Barde et al	3	20	7	20	5.0%	0.33 [0.07, 1.52]
Elsayed et al	1	10	3	10	2.3%	0.26 [0.02, 3.06]
Guy et al	19	68	13	22	11.9%	0.27 [0.10, 0.73]
Höfer et al	0	30	10	30	8.7%	0.03 [0.00, 0.58]
Jain, Manjunath et al	2	10	0	10	0.3%	6.18 [0.26, 146.78]
Jain,Sankar et al	2	10	0	10	0.3%	6.18 [0.26, 146.78]
Khalifa et al	2	10	3	10	2.0%	0.58 [0.07, 4.56]
Kumar P et al	4	10	4	10	2.0%	1.00 [0.17, 5.98]
Malhotra et al	5	10	2	10	0.8%	4.00 [0.55, 29.10]
Mittal et al	3	15	4	15	2.7%	0.69 [0.12, 3.79]
Moore et al	8	73	7	33	7.2%	0.46 [0.15, 1.39]
Moraissi et al	1	10	2	10	1.5%	0.44 [0.03, 5.88]
Sadhwani et al	0	14	4	14	3.7%	0.08 [0.00, 1.66]
Singh et al	6	10	8	10	2.7%	0.38 [0.05, 2.77]
Tairi et al	2	8	2	8	1.3%	1.00 [0.10, 9.61]
Vineeth et al	2	10	9	10	6.1%	0.03 [0.00, 0.37]
Xue et al	2	6	1	7	0.5%	3.00 [0.20, 45.24]
Subtotal (95% CI)		**334**		**249**	**59.3%**	**0.49 [0.33, 0.73]**
Total events	65		79			
Heterogeneity: Chi² = 27.19, df = 17 (P = 0.06); I² = 37%						
Test for overall effect: Z = 3.51 (P = 0.0004)						
Postoperative complication(Sensitivity analysis)						
Agarwal et al	3	10	0	10	0.3%	9.80 [0.44, 219.25]
Guy et al	19	68	13	22	11.9%	0.27 [0.10, 0.73]
Höfer et al	0	30	10	30	8.7%	0.03 [0.00, 0.58]
Jain, Manjunath et al	2	10	0	10	0.3%	6.18 [0.26, 146.78]
Jain,Sankar et al	2	10	0	10	0.3%	6.18 [0.26, 146.78]
Malhotra et al	5	10	2	10	0.8%	4.00 [0.55, 29.10]
Mittal et al	3	15	4	15	2.7%	0.69 [0.12, 3.79]
Moraissi et al	1	10	2	10	1.5%	0.44 [0.03, 5.88]
Sadhwani et al	0	14	4	14	3.7%	0.08 [0.00, 1.66]
Singh et al	6	10	8	10	2.7%	0.38 [0.05, 2.77]
Tairi et al	2	8	2	8	1.3%	1.00 [0.10, 9.61]
Vineeth et al	2	10	9	10	6.1%	0.03 [0.00, 0.37]
Xue et al	2	6	1	7	0.5%	3.00 [0.20, 45.24]
Subtotal (95% CI)		**211**		**166**	**40.7%**	**0.50 [0.31, 0.81]**
Total events	47		55			
Heterogeneity: Chi² = 25.99, df = 12 (P = 0.01); I² = 54%						
Test for overall effect: Z = 2.84 (P = 0.005)						
Total (95% CI)		**545**		**415**	**100.0%**	**0.50 [0.37, 0.67]**
Total events	112		134			
Heterogeneity: Chi² = 53.19, df = 30 (P = 0.006); I² = 44%						
Test for overall effect: Z = 4.51 (P < 0.00001)						
Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.95), I² = 0%						

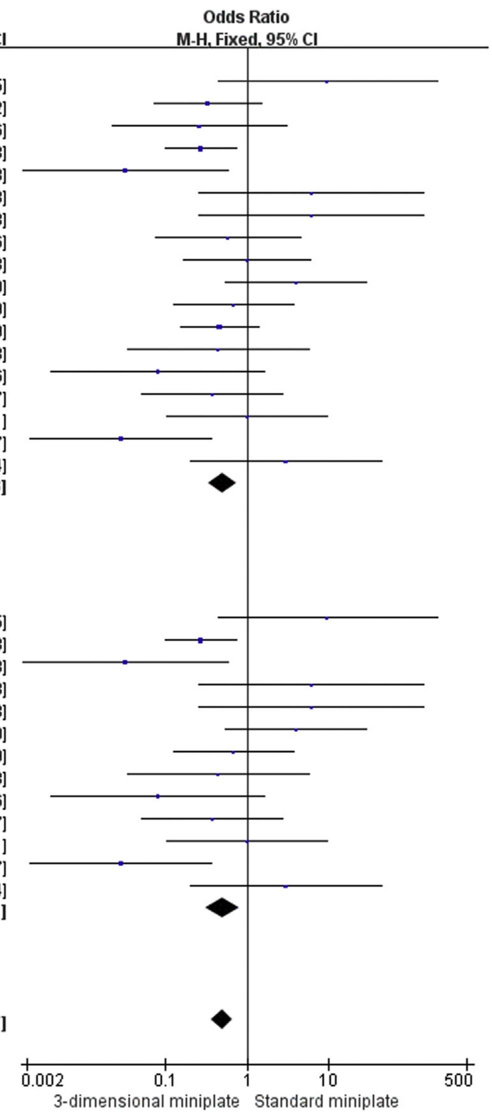

Fig. 9 Forest plots, 3D miniplate versus standard miniplate in MAFs (Sensitivity analysis). CI, confidence interval; M-H, the Mantel-Haenszel.

interface, thereby requiring a locking drill guide. The technical difficulty added to the case is fairly minor for even the inexperienced surgeon.[35]

The period of follow-up is also an important factor to be considered but three of the studies did not report the mean of follow-up periods. The maximum follow-up period in the included studies varied between 2 and 6 months. Many minor complications, such as fracture and exposure of the bone plate, may occur months or even years after successful healing but must still be considered complications as they result in surgical intervention that would not otherwise have been necessary. The complication rate, therefore, may increase with the length of follow-up.[18] A statistically and clinically significant difference in the incidence of complications was found after the meta-analyses, stressing the importance of meta-analyses to increase the sample size of individual trials to reach more precise estimates of the effects of interventions.[18]

There were several limitations in present meta-analysis. First, there is one general philosophy consensus that RCT (Randomized control trial) would provide more adequate and reliable data for meta-analysis, but present meta-analysis included both RCT and clinical control trials as well as retrospective studies. Second, follow-up period up to 3 months. This is short and acceptable follow-up period for studying mandible fractures when compared with the literature, however, a long-term follow-up is desirable. Third, the 4 included studies had small numbers of patients. Lastly, the difference in the age of patients, detailed surgical practice, and fracture sites will result in different bias. Therefore, there is a need for prospective, randomized studies comparing the two techniques. A large sample size of patients and a long follow-up period to evaluate whether one technique of fixation would result in lower postoperative complication rates than the other would be ideal.[21]

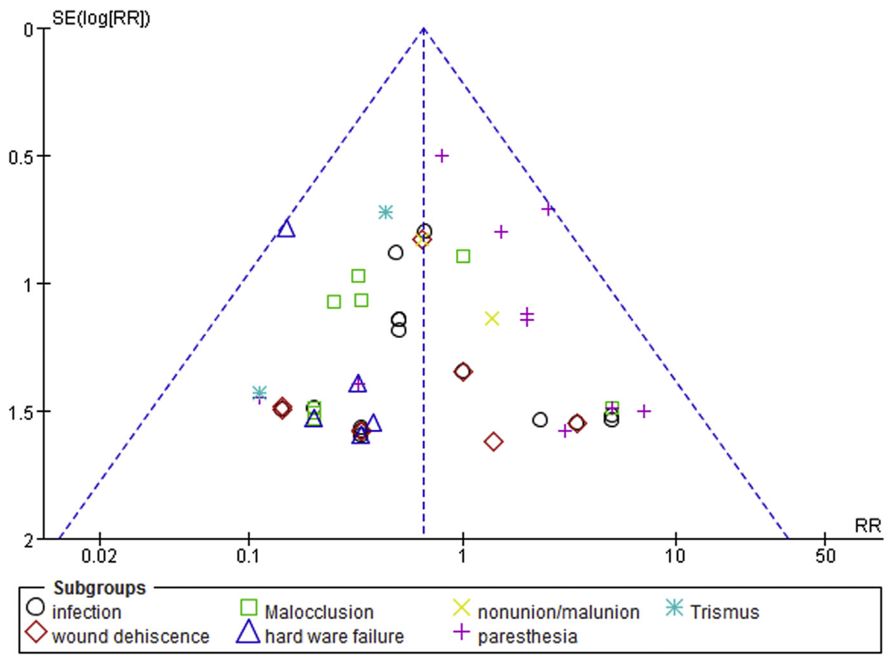

Fig. 10 Funnel plot — publication bias according to the reporte.

In conclusion, the results of the *Three-Dimensional Versus Standard Miniplate* showed that 3-dimensional miniplate is the best option for mandibular fractures. Regarding *Lag Screws Versus Miniplates* results of the meta-analysis found that the use of lag screws is superior to using miniplates in reducing the incidence of postoperative complications. And in regards to locking miniplates, the analysis indicates that the 2.0-mm locking miniplate is a prospective fixation system in the treatment of maxillofacial fractures.

Conflicts of interest

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