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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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 = 0.2). 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. © 2019 Association for Dental Sciences of the Republic of China. Publishing services by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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. The lag screw technique in maxillofacial surgery was first advocated by Brons and Boering in 1970 and was later reintroduced by Niederfellmann et al., 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. The 3-dimensional (3D) plating system for mandibular fracture treatment is relatively new. The 3D plates can be considered a 2-plate system, with 2 miniplates joined by interconnecting crossbars. Their shape is based on the principle of a quadrilateral as a geometrically stable configuration for support. 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.

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.

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.clinicalconnection.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.
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, the Strengthening the Reporting of Observational Studies in Epidemiology statement and the Preferred Reporting Items for Systematic Reviews and Meta-analyses 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.

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 one 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).
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 dehiscence 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 ($\chi^2 = 16.77$, df = 16, $P = .4$; $I^2 = 5\%$), as well as the test for subgroup differences (inconsistency across the subgroups) ($\chi^2 = 1.16$, 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 dehiscence and occlusional 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

Fig. 1  Study screening process. MF, mandibular fracture.
| Study                        | Year published | Study design | Gender(M/F) | Mean Age(Range) (y) | Patients(n) | Follow-UpPeriod | MF Fixation Methods | Mean Length of Operation (min) | MFs Region of MFs |
|------------------------------|----------------|--------------|-------------|---------------------|-------------|----------------|---------------------|------------------------------|-------------------|
| Jain, Manjunhet al.          | 2010           | RCT          | (G1): 17/3  | (G1): 48            | (G1): 20    | 1, 2, 4 6wk 2 month | G1: two 2.0-mm miniplates | G1: 45                        | (G1):13 symphyseal and parasymphyseal 5 body, 2 angle (G2):13 symphyseal and parasymphyseal 5 body, 2 angle |
|                             |                |              | (G2): 18/2  | (G2): 47            | (G2): 20    |                  | G2: 3D 2-mm stainless steel plates | G2: 33                        |
| Kumar P et al.               | 2012           | RCT          | (G1, G2): 20/0 | (G1, G2): 33.9(19−63) | (G1, G2): 10 | 1, 2, 4 8wk 3 month | G1: one 2-mm stainless steel plates | G1: 10.2                      | (G1, G2):10 (symphyseal and parasymphyseal) (G1, G2): 2 body, 4 angle (G2): Bicondyle |
|                             |                |              |             |                     |             |                  | G2: 3D 2-mm stainless steel plates | G2: 6.3                      |
| Khalifa et al.               | 2012           | CCT          | (G1, G2): 14/6 | (G1, G2): 32.5(15−50) | (G1, G2): 10 | Up to 6 month   | G1: two 2.0-mm titanium miniplates | G1: 19.4                     | (G1):10 (symphyseal and parasymphyseal) (G1, G2): 2 body, 4 angle (G2): Bicondyle |
|                             |                |              |             |                     |             |                  | G2: 3D rectangular miniplates   | G2: 10.8                     |
| Malhotra et al.              | 2012           | RCT          | (G1, G2): 20/5 | (G1, G2): 33.9(19−63) | (G1, G2): 10 | 1, 3 6 wk 3 month | G1: two 2.0-mm miniplate | NM                          | (G1):10 (symphyseal and parasymphyseal) (G1, G2): 11 (symphyseal and parasymphyseal) (G1, G2): 1 body, 2 angle |
|                             |                |              |             |                     |             |                  | G2: 3D 2-mm stainless steel plates | NM                          |
| Singh et al.                 | 2012           | RCT          | (G1, G2): 37/3 | (G1, G2): 26.62(24.72) | (G1, G2): 40 | 1, 3 6 wk 3 month | G1: two 2.0-mm miniplates | G1: 38                        | (G1, G2):10 (symphyseal and parasymphyseal) (G2): 11 (symphyseal and parasymphyseal) (G1, G2): 1 body, 2 angle |
|                             |                |              | (G2): 39/1  |                     | (G2): 40    |                  | G2: 3D 2-mm stainless steel plates | G2: 49                        |
| Sadhwani et al.              | 2013           | CCT          | (G1, G2): 18/10 | (G1, G2): 18-60 | (G1, G2): 14 | 1 day 1 week 3 months | G1: two 2.0-mm titanium miniplates | NM                          | (G1, G2):9 (symphyseal and parasymphyseal) (G2): 9 (symphyseal and parasymphyseal) (G1): 3 body, 2 angle (G2): 3 body, 2 angle |
|                             |                |              |             |                     | (G2): 14    |                  | G2: 3D rectangular miniplates   | NM                          |
| Barde et al.                 | 2014           | CCT          | (G1, G2): 34/6 | (G1, G2): 35(20−50) | (G1, G2): 20 | 1, 2, 3, 4, 6, 12, 24 wk | G1: two 2.0-mm miniplates | G1: 59.40                     | (G1, G2):20 (symphyseal and parasymphyseal) (G1, G2): 20 (symphyseal and parasymphyseal) |
|                             |                |              |             |                     | (G2): 20    |                  | G2: 3D rectangular miniplates   | G2: 50.60                     |
| Vineeth et al.               | 2012           | RCT          | (G1, G2): 16−60 | (G1, G2): 10 | (G1, G2): 10 | 1, 2, 4, 6WK and 2 months | G1: Single 2.0-mm 4-hole miniplate at the external oblique line on the mental foramina region | G1: 49.57                     | (G1, G2):20 (symphyseal and parasymphyseal) (G1): 3 body, 2 angle (G2): 3 body, 2 angle |
|                             |                |              |             |                     |             |                  | (n = 10) | G2: Single rectangular 2.0-mm 6-hole 3D miniplate (n = 10) | G2: 43                        |
| Xue et al.                   | 2013           | RCT          | (G1, G2): 19−51 | (G1, G2): 1 | (G1, G2): 1 | 1 day 1 week 1 month 3 months | G1: Single 2.0-mm 4-hole miniplate at the external oblique line on the mental foramina region | G1: 42                        | (G1, G2):20 (symphyseal and parasymphyseal) (G2): 10 (symphyseal and parasymphyseal) |
|                             |                |              |             |                     |             |                  | (n = 10) | G2: Single rectangular 2.0-mm 6- or 8-hole 3D miniplate (n = 10) | G2: 102                       |
| Hober et al.                 | 2012           | RS           | (G1, G2): 52/8 | (G1, G2): 31.1 | (G1, G2): 30 | 1−2 weeks 4−6 weeks 6 months | G1: Single 2.0-mm 4-hole miniplate at the external oblique line on the mental foramina region | G1: 89 (G1, G2): 81 | (G1, G2):20 (symphyseal and parasymphyseal) (G2): 10 (symphyseal and parasymphyseal) |
|                             |                |              |             |                     |             |                  | (n = 7) | G2: Singlecurved 2.0-mm 10-hole 3D miniplate (n = 5) | G2: 10 |
|                             |                |              |             |                     |             |                  | (n = 5) | G1: Single 2.0-mm 6-hole miniplate at the external oblique line on the mental foramina region | (n = 30) |
|                             |                |              |             |                     |             |                  | (n = 30) | G2: Single rectangular 2.0-mm 4-hole 3D miniplate (n = 30) | (n = 25) |

**Table 1**: Comparison between fixation methods (Lag Screw, 3d Plate, two conventional miniplates) in mandibular fractures.
| Study                        | Year | Study Design | Group 1 | Group 2 | Follow-up | Fixation Method 1 | Fixation Method 2 | Duration | Angle 1 | Angle 2 | Reference Details |
|------------------------------|------|--------------|---------|---------|-----------|------------------|------------------|----------|---------|---------|-----------------|
| Guy et al.                   | 2013 | RS (G1):20/2 (G2):64/4 | G1:22   | G2:68   | G1:47 days G2:55 days | G1: One or two 2.0-mm 4-hole miniplate (n = 22) G2: Singlecurved 2.0-mm 8-hole miniplate (n = 68) | NM | 161 | Angle (n = 96) parasympysis (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-or 6-hole miniplate at the external oblique line (n = 33) (G2) Singlecurved 2.0-mm 8-hole miniplate (n = 73) | NM | 168 | Angle (n = 106), parasympysis (n = 51) body (n = 11) |
| Moraissi et al.              | 2014 | RCT (G1, G2):16/4 | G1:23   | G2:68   | G1:28 G2:23 | G1:39.7 ± 9.1 G2:33 ± 4.6 | NM | NM |
| Tarir et al.                 | 2015 | RS (G1):6/2(G2):6/2 | G1:25   | G2:24   | G1:1 week, 1, 2, 3 and 6 month G2: 1, 3, 6 months | G1: Single2.0-mm standard miniplate G2: 1.0-mm miniplate (n = 73) | G1: Two miniplates fixation G2: 3D miniplate | NM | 16 | Mandibular angle (16) |
| Mittal et al.                | 2016 | RCT (G1, G2):24/6 | G1:15   | G2:15   | G1:1,3,6 months G2: 1,3,6 months | G1: Two miniplates fixation G2: 3D miniplate | G1: Single 2.0-mm locking miniplate G2: single rigid 2.3-mm plate | G1:33.3 ± 2.44 G2:42.0 ± 2.32 |
| Elsayed et al.               | 2015 | RS (G1):7/3(G2):7/3 | G1:26.1 ± 2.34 G2:27 ± 0.9 | G1:10 G2:10 | 1week, 1, 2, 3 and 6 month | 36 | G1: (n = 2) angle G2: (n = 3) angle | 36 | |
| Ellis et al.                 | 2011 | Rs (G3):374/30 (G4):430/46 | G1:27.9 | G3:411 G4:476 | G1:142.2d G4:147.3d | G1: 2.7- or 2.4-mm lag screw (G4): two 2.0-mm miniplates (n = 3) | G1: G2: Two 2.0-mm miniplates G3: 2.4-mm cortical lag screw G4: 2.0-mm miniplates | NM | 660 | G3: 193 angle, 117 condyle (G4): 223 angle, 127 condyle |
| Goyal et al.                 | 2012 | RCT (G3, G4):9/1 | G3:27.9 | G4:24 | G3:411 G4:476 | G1: G2: Two 2.0-mm miniplates G3: 2.4-mm cortical lag screw G4: 2.0-mm miniplates | G1: G2: Two 2.0-mm miniplates | G1: 2.7- or 2.4-mm lag screw (G4): two 2.0-mm miniplates (n = 3) | G1: (n = 4) G2: (n = 3) G3: 120–180 G4: 60–120 |
| Bhatnar et al.               | 2013 | RCT NM | NM | NM | NM | NM | NM | NM |
| Agnihri et al.               | 2014 | RCT NM | (G3,G4):33.7 (18–70) | G1:40 G2:40 | (G3): 25.1 G4: 21 | (G3): 25.1 G4: 21 | (G3): 25.1 G4: 21 | (G3): 25.1 G4: 21 | (G3): 25.1 G4: 21 | (G3): 25.1 G4: 21 |
| Schaaf et al.                | 2011 | Rs (G3):19/2 (G4):22/2 | G3:27 | G4:23 | G3:27 | G3:27 | G3:27 | G3:27 | 16 | Angle (n = 1) parasympysis (n = 1) body (n = 1) condyle (n = 1) coronoid (n = 1) ramus (n = 1) |

NM, not mentioned; NP, not performed; RCT, randomized controlled trials; CCT, controlled clinical trials; RA, retrospective analysis; G1, group 1 (standard miniplates); G2, group 2 (3D miniplates); G3, lag screw; G4, miniplate; MMF, maxillomandibular fixation.
| Study                  | Year published | Study period | Study design | Gender (M/F) | Mean Age (Range) (y) | Patients (n) | Follow-Up Period | MF Fixation Methods                                                                 | 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 | (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 | (G5): 6 parasymphyseal, 13 angle, 13 body (G6): 10 parasymphyseal, 13 angle, 15 body |
| 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 | (G5): 68 (G6): 128 parasymphyseal, 24 body, 44 angle, 20 parasymphyseal |
| 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 3 month | (G5): 2.0-mm locking plates (G6): non-locking 2-mm plates | (G5): 59 parasymphyseal, 5 symphysis, 6 angle, 5 body; (G6): 60 parasymphyseal, 3 symphysis, 5 angle, 13 body |
| 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 plates (G6): standard miniplates | (G5): 4 parasymphyseal (G5): 7 angle (G6): 4 body, 10 angle, 2 multiple fractures |
| 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 mm standard stainless steel miniplates | (G5): 5 symphysis (G6): 4 symphysis (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, 6 wk | (G5): 2-mm locking miniplate (G6): 2-mm non-locking miniplate | (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 ± 7.3 | 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 parasympysis, 1 symphysis, and 1 angle] and six patients had multiple fractures (4 parasympysis, 2 body) (G6): [2 parasympysis, 1 symphysis, 1 body, and 2 angle] and multiple fractures (3 parasympysis, 1 symphysis) 1 symphysis, 12 parasympysis, 10 body, 4 angle, 4 subcondyle |
| 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 mm miniplates | (G5): 31 parasymphyseal, 12 parasympysis, 10 body, 4 angle, 4 subcondyle |

NM, not mentioned; NP, not performed; RCT, randomized controlled trials; CCT, controlled clinical trials; RA, retrospective analysis; G5, group 1 (locking miniplates); G6, group 2 (standard miniplate); MMF, maxillomandibular fixation.
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

Table 3
Results of the quality assessment.

| Authors                  | Published Year | 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.   | 2010           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Kumar P et al.           | 2012           | Yes                           | No                                  | Yes               | No                    | Yes                  | High                             |
| Khalifa et al.           | 2012           | Yes                           | No                                  | Yes               | Yes                   | No                   | High                             |
| Mahathota et al.         | 2013           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Agarwal et al.           | 2012           | Yes                           | Yes                                 | No                | Yes                   | Yes                  | Moderate                         |
| Sadhwaani et al.         | 2012           | Yes                           | No                                  | Yes               | Yes                   | Yes                  | Low                              |
| Barde et al.             | 2014           | No                            | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Singh et al.             | 2012           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Jain, Sankar et al.      | 2013           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Vineeth et al.           | 2013           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Xue et al.               | 2013           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Höffner et al.           | 2012           | No                            | Yes                                 | Yes               | Yes                   | Yes                  | Moderate                         |
| Guy et al.               | 2013           | No                            | Yes                                 | No                | No                    | Yes                  | Moderate                         |
| Moore et al.             | 2013           | Yes                           | No                                  | No                | No                    | Yes                  | High                             |
| Moraisi et al.           | 2014           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Mittal et al.            | 2016           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Tai et al.               | 2015           | No                            | Yes                                 | Yes               | Yes                   | Yes                  | Moderate                         |
| Elsayed et al.           | 2015           | No                            | No                                  | Yes               | Yes                   | Yes                  | High                             |
| Collins et al.           | 2004           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Agarwal et al.           | 2011           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Singh et al.             | 2011           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Kumar I et al.           | 2013           | No                            | No                                  | Yes               | Yes                   | Yes                  | High                             |
| Saikrishna et al.        | 2013           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Shai et al.              | 2014           | No                            | Yes                                 | Yes               | No                    | Yes                  | Low                              |
| Giri et al.              | 2015           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Kumar BP et al.          | 2015           | Yes                           | No                                  | Yes               | Yes                   | Yes                  | Moderate                         |
| Rastogi et al.           | 2016           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Goyal et al.             | 2012           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Bhatnagar et al.         | 2013           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Ellis et al.             | 2012           | No                            | Yes                                 | Yes               | Yes                   | Yes                  | Moderate                         |
| Agnihotri et al.         | 2014           | Yes                           | Yes                                 | Yes               | Yes                   | Yes                  | Low                              |
| Schaaf et al.            | 2011           | No                            | Yes                                 | Yes               | Yes                   | Yes                  | Moderate                         |
Fig. 2  Forest plots, 3D miniplate versus standard miniplate in MAFs (postoperative complications). CI, confidence interval; M-H, the Mantel-Haenszel.
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 = 0.003). 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 = 0.22). 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 = 0.04). No statistically significant difference in the incidence of paresthesia was observed between the two techniques (P = 0.29). 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 = 0.004). 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, 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.

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. 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 = 0.0003), 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 = 0.0001). 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 < 0.0001). 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. The locking plate/screw system has only minor additions to the instrument armamentarium. This system requires perpendicular placement of the plate...
Fig. 5   Forest plots, lag-screw versus miniplates in MFs (postoperative complications). CI, confidence interval; M-H, the Mantel-Haenszel.

| Study or Subgroup | lag screw | miniplate | Odds Ratio IV, Fixed, 95% CI |
|-------------------|-----------|-----------|-----------------------------|
|                   | Events    | Total     | Weight                      | Odds Ratio IV, Fixed, 95% CI |
| infection         |           |           |                             |                            |
| Agnihotri et al   | 1         | 40        | 4.6%                        | 0.23 [0.02, 2.16]           |
| Bhathnar et al    | 4         | 15        | 8.9%                        | 1.00 [0.20, 5.04]           |
| Edward et al      | 6         | 411       | 28.6%                       | 0.27 [0.11, 0.66]           |
| Goyal et al       | 0         | 15        | 2.2%                        | 0.31 [0.01, 8.28]           |
| Schaaf et al      | 1         | 21        | 2.2%                        | 3.59 [0.14, 92.83]          |
| Subtotal (95% CI) | 502       | 570       | 46.5%                       | 0.39 [0.19, 0.78]           |
| Total events      | 12        | 34        |                              |                            |
| Heterogeneity: Ch² = 3.99, df = 4 (P = 0.41), I² = 0% |
| Test for overall effect: Z = 2.64 (P = 0.009) |

Malocclusion

| Study or Subgroup | lag screw | miniplate | Odds Ratio IV, Fixed, 95% CI |
|-------------------|-----------|-----------|-----------------------------|
|                   | Events    | Total     | Weight                      | Odds Ratio IV, Fixed, 95% CI |
| Agnihotri et al   | 0         | 40        | 40                           | Not estimable               |
| Edward et al      | 0         | 411       | 1476                        | 0.39 [0.02, 9.48]           |
| Goyal et al       | 0         | 15        | 15                           | Not estimable               |
| Schaaf et al      | 0         | 21        | 24                           | 0.21 [0.01, 4.62]           |
| Subtotal (95% CI) | 487       | 555       | 4.7%                        | 0.28 [0.03, 2.60]           |
| Total events      | 0         | 3         |                              |                            |
| Heterogeneity: Ch² = 0.07, df = 1 (P = 0.79), I² = 0% |
| Test for overall effect: Z = 1.12 (P = 0.26) |

Wound dehiscence

| Study or Subgroup | lag screw | miniplate | Odds Ratio IV, Fixed, 95% CI |
|-------------------|-----------|-----------|-----------------------------|
|                   | Events    | Total     | Weight                      | Odds Ratio IV, Fixed, 95% CI |
| Agnihotri et al   | 4         | 40        | 40                           | 10.9%                        |
| Edward et al      | 0         | 411       | 21                           | 2.9%                        |
| Goyal et al       | 1         | 15        | 15                           | 2.6%                        |
| Subtotal (95% CI) | 466       | 531       | 16.6%                       | 0.52 [0.16, 1.70]           |
| Total events      | 5         | 26        |                              |                            |
| Heterogeneity: Ch² = 5.37, df = 2 (P = 0.07), I² = 63% |
| Test for overall effect: Z = 1.08 (P = 0.28) |

Malunion

| Study or Subgroup | lag screw | miniplate | Odds Ratio IV, Fixed, 95% CI |
|-------------------|-----------|-----------|-----------------------------|
|                   | Events    | Total     | Weight                      | Odds Ratio IV, Fixed, 95% CI |
| Agnihotri et al   | 0         | 40        | 40                           | Not estimable               |
| Edward et al      | 1         | 411       | 1476                        | 3.0%                        |
| Subtotal (95% CI) | 451       | 516       | 3.0%                        | 1.16 [0.07, 18.58]          |
| Total events      | 1         | 1         |                              |                            |
| Heterogeneity: Not applicable |
| Test for overall effect: Z = 0.10 (P = 0.92) |

Hardware failure

| Study or Subgroup | lag screw | miniplate | Odds Ratio IV, Fixed, 95% CI |
|-------------------|-----------|-----------|-----------------------------|
|                   | Events    | Total     | Weight                      | Odds Ratio IV, Fixed, 95% CI |
| Agnihotri et al   | 0         | 40        | 40                           | 2.7%                        |
| Bhathnar et al    | 2         | 15        | 15                           | 5.2%                        |
| Edward et al      | 1         | 411       | 1476                        | 5.6%                        |
| Schaaf et al      | 2         | 21        | 25                           | 8.5%                        |
| Subtotal (95% CI) | 497       | 556       | 20.6%                       | 0.33 [0.11, 0.96]           |
| Total events      | 5         | 24        |                              |                            |
| Heterogeneity: Ch² = 4.52, df = 3 (P = 0.21), I² = 34% |
| Test for overall effect: Z = 2.04 (P = 0.04) |

Paresthesia

| Study or Subgroup | lag screw | miniplate | Odds Ratio IV, Fixed, 95% CI |
|-------------------|-----------|-----------|-----------------------------|
|                   | Events    | Total     | Weight                      | Odds Ratio IV, Fixed, 95% CI |
| Edward et al      | 1         | 411       | 0                             | 2.3%                        |
| Goyal et al       | 2         | 15        | 15                           | 8.9%                        |
| Subtotal (95% CI) | 426       | 491       | 9.2%                        | 0.56 [0.11, 2.76]           |
| Total events      | 3         | 5         |                              |                            |
| Heterogeneity: Ch² = 1.86, df = 1 (P = 0.20), I² = 40% |
| Test for overall effect: Z = 0.71 (P = 0.48) |

Total (95% CI) 2819 3219 100.0% 0.41 [0.26, 0.67]

Total events 26 93

Heterogeneity: Ch² = 16.77, df = 16 (P = 0.40), I² = 5% |
| Test for overall effect: Z = 3.59 (P = 0.0003) |
| Test for suborous differences: Ch² = 1.16, df = 5 (P = 0.95), I² = 0% |
**Comparative evaluation of different fixation system for mandibular fractures**

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

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. 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.  

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.
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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