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Systematic Review and Meta-Analysis
Trauma

Complications of locking and non-locking plate systems in mandibular fractures

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Abstract. This systematic review and meta-analysis was performed to critically assess the methodological quality of the existing systematic reviews, and to evaluate the postoperative complications of the mandibular fractures treated with locking and non-locking plate systems. An electronic search was conducted in PubMed, Embase, Web of Science, Cochrane library's electronic databases and grey literate using a combination of Medical Subject Heading terms and key words, until September 2018. No restrictions were applied to the search strategy. In total, three relevant systematic reviews were included, and the quality of these studies was low. A total of 33 studies (20 randomized studies and 13 non-randomized studies) were included in this systematic review, and 16 of them were included in meta-analysis. Most of the included randomized studies had an unclear risk of bias (Cochrane Collaboration); the quality of non-randomized studies ranged between 6 and 17 (Methodological Index for Non-Randomized Studies – MINORS). Based on the results of our meta-analysis, we conclude that locking plates are superior only with respect to the need for mandibulomaxillary fixation (MMF) in the early postoperative period.

Key words: mandibular fractures; bone plates; locking plate; conventional plate; postoperative complications; meta-analysis.

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Postoperative complications after surgical treatment of the mandibular fractures occur in 20–26% of patients[1–3]. A wide variety of complications may occur after surgical treatment of mandibular fractures. Yet, infection is one of the most common complications resulting in abscesses, non-union, osteomyelitis and wound dehiscence[4]. Hardware failures such as screw loosening and plate fractures, is another commonly occurring complication[2]. These complications are associated with patient's general health condition, and fracture type and location[3,5,6]. In particular, comminuted and angle region fractures and a poor oral hygiene are associated with complications[3,5,7].

To reduce the postoperative complications after surgical treatment of mandibular fractures, locking plate systems have been introduced[8]. Theoretically, the locking plate system has the advantages of less screw loosening and greater stability while less accuracy is required in plate adaption compared to non-locking Plates [9].Clinical studies have shown that locking plates give a more rigid fixation than non-locking Plates [10,11]. But other clinical studies did not show differences between locking and non-locking plate systems regarding postoperative complication rates[12,13].

Systematic reviews and meta-analyses are powerful tools for clinical decision making and management of the hospital, and are used to develop clinical guidelines or for making policy decisions. Therefore, these reviews should be unbiased, and the most recent studies should have been included. Currently, three systematic reviews and meta-analyses have been published comparing postoperative complications in locking and non-locking plate systems for mandibular fracture treatment[14–16]. However, these reviews all have several methodological weaknesses, such as unreported inter-rater reliability and absence of a flow chart, but so far no critical appraisal of these reviews has been published.

The aim of this systematic review is to critically assess the methodological quality of the existing systematic reviews, and to synthesize the primary studies available in the literature comparing locking plate and non-locking plate systems in the treatment of patients with mandibular fractures regarding postoperative complications, including infection, occlusal disturbance, and hardware failure.

Materials and methods

This systematic review was reported according to the PRISMA statement[17].

Search strategy and selection criteria

A systematic literature search was conducted to identify studies comparing postoperative complications in locking and non-locking plate systems in the treatment of mandibular fractures. The search strategy was developed with help of biomedical information specialist (Sjoukje Van der Werf). We searched in PubMed, Embase, Web of Science, Cochrane library's electronic databases and grey literate with a combination of Medical Subject Heading (MeSH) terms and key words (Appendix 1) until September 2018. No restrictions were applied to the search strategy. References of the included studies were screened to identify additional relevant studies missed in the database search.

Included were systematic reviews and primary studies comparing locking and non-locking plates for treatment of mandibular fractures in humans regarding complications including infection, occlusal disturbance, and hardware failure. Excluded were animal studies, in vitro or biomechanical studies, expert opinions and case series that included less than 10 patients in each group. Two observers (E.O.B and P.U.D) independently assessed titles and abstracts using a pre-developed screening form (Appendix 2). After title and abstract assessment, the same form was used to assess full-text of the selected studies by two observers (E.O.B and B.v.M) independently. Inter-observer agreement was calculated (Cohen's Kappa and absolute agreement), and disagreement between observers was resolved by discussion.

Quality assessment and data extraction

The methodological quality was assessed by two observers (E.O.B and P.U.D). Systematic reviews were assessed using AMSTAR-2 (A MeaSurement Tool to Assess systematic Reviews)[18]. Quality of included randomized control trials was assessed using the Risk of Bias tool of the Cochrane Collaboration[19], and non-randomized (observational) studies were assessed using the MINORS (Methodological Index for Non-Randomized Studies) tool[20]. Data was extracted by two observers (E.O.B and R.R.M.B) independently using a pre-developed form (Appendix 2), and inter-observer reliability was calculated.

The postoperative complications described in the studies were categorized because studies reported complications in different ways. Occlusal-related complications included occlusal disturbances, mobility of fractures, step deformity, and loss of reduction and need for mandibulomaxillary fixation (MMF) which was used to solve problems such as mobility of a fracture and occlusal disturbances. Infection-related complications included soft tissue infection, plate infection, hardware removal due to infection, and plate removal due to infection, wound dehiscence due to infection. The category hardware failure not related to infection included plate and screw loosening or plate fracture. If any other complications occurred, we categorized them as other complications. Additionally, the following information was extracted from the included studies: conflict of interest, informed consent, plate design and dimensions, and fracture fixation principles.

Statistical analysis

The observed complications were analysed in the following postoperative timeframes: 1st–4th week (early), 1–3 months or 5th–12th week (intermediate), more than 3 months or 13th week and further (late). If more than one complication occurred in the same patient and the cause was the same, they were counted as one complication (for instance, in a case where a patient had infection and hardware removal due to infection, this was counted as one complication). Inter-observer agreement was calculated with IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). Meta-analysis was performed if studies compared differences in complication rates in locking and nonlocking plates and they compared the same types of plates regarding diameter, design and number of plates. Meta-analysis was performed using Comprehensive Meta-Analysis software (CMA, Biostat, Englewood, NJ, USA) with random effects model. Separate meta-analyses were conducted for randomized and non-randomized studies. Clinical heterogeneity was assessed by studying study methodology and patient characteristics. Statistical heterogeneity was assessed using I^2 and Tau^2. As a result of all these assessments, a random-effects model was applied. Contrary to fixed-effects analyses, in which it is assumed that there is one true effect and that differences between studies are based on sampling variation, in a random-effects model it is assumed that there are several effects which may vary based on, for instance, study population and study methodology.

Results

Study identification and selection

The database searches resulted in 503 records (Fig. 1), and after duplicate removal 182 titles and abstracts were assessed. Fifty-six studies were included for full-text assessment. Cohen's kappa and agreement (%) for the title and abstract assessment was 0.71 [95% confidence interval (CI) 0.60–0.82] (88%). After full-text reading of three systematic reviews (Table 1), 33 studies (Tables 2 and 3) were selected, and Cohen's kappa and agreement (%) was 0.61 [95% CI 0.40–0.82] (77%) for this selection. Consensus was reached for all studies by discussion among the observers.

Characteristics and quality of existing systematic reviews

Three relevant systematic reviews were included (Table 1). These systematic reviews were published between 2014 and 2017, and the authors conducted meta-analyses. The reviews included ran-

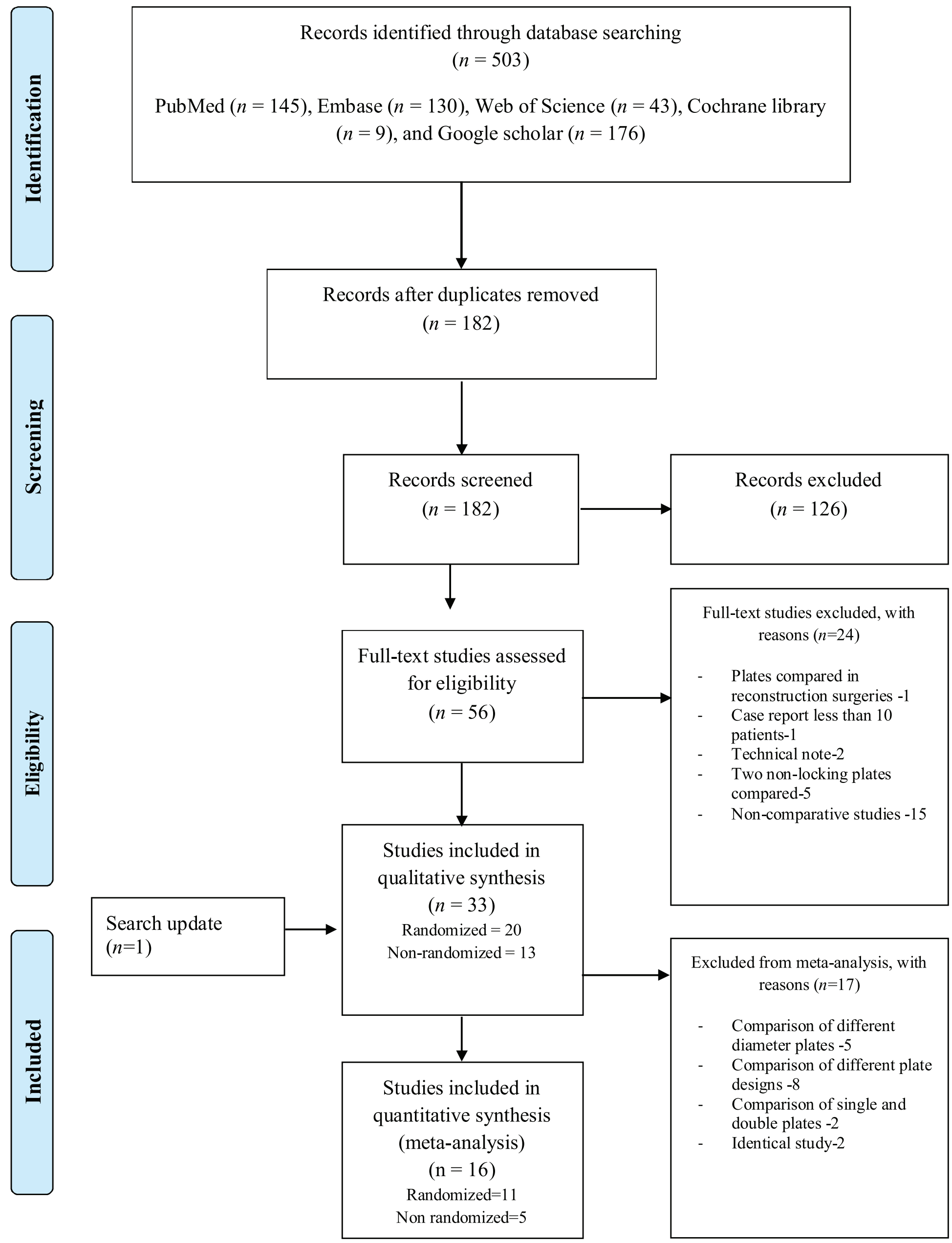

Fig. 1. Flowchart of study selection.

domized studies as well as non-randomized (observational) studies. The methodological qualities of the included studies in the systematic reviews were assessed using the Jadad tool[21] and Cochrane risk of bias tool[19]. Two of these reviews compared 2.0-mm locking and 2.0-mm non-locking Plates[15,16], and one compared various types of locking and non-locking Plates[14]. All three reviews did not report a list of excluded studies and did not calculate kappa values as measures for inter-observer agreement for study selection. Moreover, the review by Wusiman et al.[16] did not report a flowchart of the study selection process, and that review is almost identical to the review by Zhan et al.[15]. The quality of published systematic reviews was low (Appendix 3). Cohen's kappa and agreement was 0.51 [95% CI 0.33–0.69] (68%) for AMSTER-2 criteria. Consensus was reached by discussion.

Characteristics and quality of included primary studies

There were two identical studies[22,23], and two studies[13,24] seemed to include the same patient data. Therefore, we included the earliest studies in this review[13,22]. Of the 33 included studies, 20 were randomized studies (Table 2), 13 were non-randomized studies (Table 3). Thirteen of those 33 studies had been included in one or more of the previously published systematic reviews (Fig. 2).

In 16 studies[10–13,22,24–34], 2.0-mm locking plates were compared with a 2.0-mm non-locking plate system. In two studies, a 2.0-mm locking plate, and three-dimensional (3D) locking plate were compared with double 2.0-mm non-locking Plates[35,36]. Other studies[35,37–48] compared various types of locking and non-locking

Table 1. General description of existing meta-analyses.

Author (year)	Journal	Date of last search	Number of included studies and study type	Total number of patients reviewed	Plate types compared	Quality (AMSTAR-2)
Chrcanovic (2014)[14]	Int J Oral Maxillofac Surg	December 2013	10 (8 RCT, 2 non-RCT)	471	Various types	Low quality
Zhan et al. (2014)[15]	J Craniofac Surg	?	4 (3 RCT, 1 non-RCT)	220	Only 2.0 mm vs. 2.0 mm	Low quality
Wusiman et al. (2017)[16]	J Craniofac Surg	?	9 (7 RCT, 1CCT, 1 non-RCT)	380	Only 2.0 mm vs. 2.0 mm	Low quality

CCT, controlled clinical trials; RCT, randomized controlled trials.

plates (Tables 2 and 3). In two studies, locking plates, non-locking plates, lag screws and biodegradable plates were compared[28,45].

Whereas Champy principle was used in 14 studies[11–13,24,26–28,30,32,34–36,41,42] in both locking and non-locking groups, AO/ASIF (Arbeitsgemeinschaft fuer Osteosynthesefragen/Association for the Study of Internal Fixation) principle was used in one study[45] in both groups. Four studies[10,22,31,48] did not report which fixation principle was used, but reported that the surgical technique was standardized, or was the same for the two groups except the drilling. In four studies, the mandibular fractures were fixated according to Champy principle, and in the non-locking group according to AO/ASIF principles[38,43,47,49]. In two studies[37,44], only condylar fractures were treated and fixated with double plates in each. In the remaining seven studies[23,29,33,39,40,46], the fixation principle was not reported.

Mandibular fractures concomitant with condylar fractures were included in eight studies, and in two[43,45] of them the condylar fractures were treated closed. In two studies[33,39], the condylar fractures were treated with open reduction and internal fixation (ORIF), and four studies[13,23,28,41] did not report whether the condylar fractures were treated with ORIF or closed. In 10 studies[10–12,22,26,30,32,34,38,46], condylar fractures were excluded and 10 studies[25,27,29,35,36,40,42,47–49] did not report whether these fractures were included or not. In the studies that included mandibular fractures concomitant with another mandibular fracture (bilateral or double unilateral), the concomitant fracture was fixated with non-locking 2.0-mm plates.

Conflict of interest was not reported in 12 studies[12,25–27,32,33,37,39,41,42,46]. In 18 studies informed consent was reported[11,13,22,23,27,29,31,35–38,43–45,48–51].

From most of the included randomized studies risk of bias could not be assessed because of unclear reporting (Tables 2 and 3), and Cohen's kappa and agreement (%) was 0.66 [95% CI 0.54–0.77] (79.4%). The quality of the non-randomized studies ranged between 6 and 17 (median (interquartile range) 10.0 (8.2; 15.0) (Table 4). (Cohen's kappa (% agreement) was 0.58 [95% CI 0.47–0.68] (73.6%). Table 5 shows the quality of the non-randomized observational studies (MINORS tool).

Meta-analysis

In total, 16 studies were selected for the meta-analysis. Reasons for not being included in the meta-analysis were: comparison of different diameter plates $n = 5$[38,39,41,44,45] (e.g., 2.0-mm locking vs. 2.3-mm non-locking), comparison of different plate designs $n = 8$[35,37,40,42,43,48,50,51] (i.e. 3D vs. 2.0 mm), comparison of single and double plates $n = 2$[36,47], identical study $n = 1$[23] and duplicated study $n = 1$[24]. Cohen's kappa (% agreement) for data extraction was kappa 0.72 [95% CI 0.62–0.81] (89%), and consensus was reached.

The study of Bhatt et al.[28] compared more than two plate systems. We pooled only the data of locking and non-locking plates. In postoperative early results (1–4 weeks) (Fig. 3), the need for MMF was significantly lower in the locking plate group compared to non-locking group in randomized studies (odds ratio (OR) = 0.2, $p = 0.001$). In the intermediate results (1–3 months) (Fig. 4) this difference remained and the need for MMF was significantly lower in the locking groups in both randomized (OR = 0.3) and non-randomized (OR = 0.1) studies. The last results (after 3 months or more) (Fig. 5) showed no difference between locking and non-locking groups regarding the need for MMF in both randomized and non-randomized studies.

We were unable to perform a meta-analysis regarding infection that occurred in the first 4 weeks postoperatively due to an insufficient number of reported data. The infection-related complications did not differ significantly between the groups postoperatively after 1–3 months and more than 3 months but with a tendency towards less infection-related complications in the locking group in the randomized studies for the intermediate results (OR = 0.5, $p = 0.089$) (Figs. 6 and 7). A meta-analysis of hardware failure (not related to infection) was only applicable for the intermediate follow-up in one study and there was no difference between the groups found (OR = 0.1, $p = 0.286$). We were unable to perform a meta-analysis regarding other complications because the author did not report the complication in detail (reported as minor complications)[27].

Discussion

Based on the results of this review, mandibular fractures fixated with locking plate systems have less need for postoperative MMF in the short and intermediate terms. No difference between the two plate systems was found regarding the postoperative infection-related complications. These outcomes are based on 33 included studies evaluating locking and non-locking plates for mandibular fracture fixation. Despite this number of studies, this review provides low quality of evidence due to the overall poor quality of the included studies.

Prior to this systematic review, three systematic reviews and meta-analyses were published comparing postoperative complications in locking and non-locking plate systems for mandibular fracture treatment. According to AMSTER-2 cri-

Table 2. Characteristics of the included primary studies (randomized studies).

Authors	Country/ patient consent	Mean age ± SD (range)	Total number of patients (fractures) (*n*)	Locking plate				Non-locking plate				Fracture location	Follow-up (weeks)	Evaluation/ funding
				Age ± SD (range)	Patients (*n*)	Fractures (*n*)	Plate(s), material (company)	Age ± SD (range)	Patients (*n*)	Fractures (*n*)	Plate(s), material (company)			
Wakeel et al. (2018)[30]	India/ -	- (–)	30 (–)	29.1 ± 9.1 (–)	15	-	2.0 mm - (–)	27.7 ± 8.3 (–)	15	-	2.0 mm - (–)	Symphysis Parasymphysis Body Angle Ramus	24	Complications -
Aggarwal et al. (2017)[50]	India/ +	- (–)	40 (–)	- (–)	20	-	3D Titanium (–)	- (–)	20	-	1.8 mm Titanium (–)	Symphysis Parasymphysis Body Angle	8	Complication +
Camino Jr et al. (2017)[38]	Brazil/ +	- (–)	87 (112)	35.4 (–)	45	-	2.0 mm Titanium (Synthesis)	25.6 (–)	42	-	2.0 mm and 2.4 mm Titanium (Synthesis)	Parasymphysis Body Angle	26	Complications +
Vashistha et al. (2017)[36]	India/ +	- (–)	40 (–)	36.8 ± 9.5 (–)	20	-	2.0 mm Titanium (–)	37.0 ± 10.4 (–)	20	-	2 × 2.0 mm Titanium (–)	Inter-foraminal	8	Complications -
Kumar et al. (2017)[39]	India/ -	30.6 ± 10.2 (18–53)	20 (30)	- (–)	10	-	1.8 mm along with 2.3 mm Titanium (–)	- (–)	10	-	2.0 mm Titanium (–)	Symphysis Parasymhysis Body Angle Condyle	13	Complications -
Ali et al. (2016)[29]	India +	- (12–54)	30 (–)	- (–)	15	-	2.0 mm Titanium (–)	- (–)	15	-	2.0 mm Titanium (–)	Symphysis Parasymphysis Body	26	Complications +
George et al. (2016)[48]	India +	- (–)	20 (–)	- (22–45)	10	-	3D Titanium (–)	- (21–41)	10	-	2.0 mm Titanium (–)	Inter-foraminal	13	Bite force +
Rastogi et al. (2016)[23]*	India +	- (11–40)	20 (31)	- (–)	10	-	2.0 mm - (–)	- (–)	10	-	2.0 mm - (–)	Any	6	Bite force -
Giri et al. (2015)[22]*	India -	- (11–40)	20 (31)	- (–)	10	-	2.0 mm - (–)	- (–)	10	-	2.0 mm - (–)	Any	6	Bite-force -
Kumar BP et al. (2015)[25]	India -	29 ± 7.5 (17–45)	20 (–)	- (–)	10	-	2.0 mm Titanium (–)	- (–)	10	-	2.0 mm Titanium (–)	Symphysis Parasymphysis Body Angle	12	Complications -
Saha et al. (2015)[27]	India +	26 (12–43)	20 (–)	- (–)	10	14	2.0 mm - (–)	- (–)	10	12	2.0 mm - (–)	Parasymphysis Body Angle	6	Complications -
Yang and Patil (2015)[11]	China +	- (18–60)	60 (–)	35.4 (–)	30	30	2.0 mm - (Orthomax)	37.3 (–)	30	30	2.0 mm - (Orthomax)	Angle	26	Complications -

Table 2 (*Continued*)

Authors	Country/ patient consent	Mean age ± SD (range)	Total number of patients (fractures) (*n*)	Locking plate: Age ± SD (range)	Locking plate: Patients (*n*)	Locking plate: Fractures (*n*)	Locking plate: Plate(s), material (company)	Non-locking plate: Age ± SD (range)	Non-locking plate: Patients (*n*)	Non-locking plate: Fractures (*n*)	Non-locking plate: Plate(s), material (company)	Fracture location	Follow-up (weeks)	Evaluation/ funding
Kumar et al. (2014)[34]	India -	27.2 (14–56)	20 (–)	- (–)	10	-	2.0 mm Stainless still (SK Surgicals)	- (–)	10	-	2.0 mm Stainless still (SK Surgicals)	Parasymphysis Angle	6	Bite force +
Jain et al. (2012)[35]	India +	- (16–30)	20 (20)	- (–)	10	10	3D 2.0 mm Titanium (–)	- (–)	10	10	2 × 2.0 mm Titanium (–)	Symphysis Parasymphysis	9	Complications +
Agarwal et al. (2011)[31]	India +	- (46–60)	20 (32)	- (–)	10	18	2.0 mm Titanium (Synthes)	- (–)	10	14	2.0 mm Titanium (Synthes)	Any	13	Bite force -
Goyal et al. (2011)[42]	India -	- (16–60)	30 (45)	- (–)	15	-	3D Titanium (–)	- (–)	15	-	2.0 mm Titanium (–)	Symphysis Parasymphysis Body Angle	13–26	Complications -
Singh et al. (2011)[13]	India +	30.0 ± 8.5 (16–52)	50 (76)	- (–)	25	36	2.0 mm Titanium (Synthes)	- (–)	25	40	2.0 mm Titanium (Synthes)	Parasymphysis Body Angle Condyle	12	Complications +
Saikrishna et al. (2009)[10]	India -	-	40 (59)	- (–)	20	-	2.0 mm - (–)	- (–)	20	-	2.0 mm - (–)	Any	6	Complications +
Seemann et al. (2009)[37]	Germany, Austria -	37.2 ± 17.5 (–)	129 (146)	- (–)	-	72	Trilock condyle plate Titanium (–)	- (–)	-	74	Modus condyle plate Titanium - (–)	Condyle	21–30	Complications -
Collins et al. (2004)[12]	USA -	25.9 ± 6.7 (14–58)	90 (122)	- (–)	-	64	2.0 mm Titanium (Synthes)	- (–)	-	58	2.0 mm Titanium (Synthes)	Any	6	Complications -

-, Not reported; +, reported; 3D, three-dimensional; SD, standard deviation.
*Study populations interventions and outcomes are (almost) identical.

Table 3. Characteristics of the included primary studies (non-randomized studies).

Authors	Country/ informed consent	Mean age ± SD (range)	Total number of patients (fractures) (*n*)	Locking plate				Non-locking plate				Locations	Follow-ups (weeks)	Evaluation/ funding
				Age ± SD (range)	Patients (*n*)	Fractures (*n*)	Plate(s), material (company)	Age ± SD (range)	Patients (*n*)	Fractures (*n*)	Plate(s), material (company)			
Budhraja et al. (2018)[51]	India +	(18–50)	30 (–)	-	15	-	3D Stainless steel (S.K Surgical)	- (–)	15	-	2.0 mm Stainless steel (S.K Surgical)	Inter-foraminal	13	Complications +
Passi et al. (2017)[40]	India -	32.5 (15–50)	40 (–)	-	20	-	2 × 2.0 mm Titanium (–)	- (–)	20	-	3D Titanium (–)	Inter-foraminal	26	Complications +
Singh and Arunkumar (2016)[46]	India -	- (–)	20 (27)	25.5 ± 7.79 (–)	10	12	3D Titanium (–)	27.2 ± 11.35 (–)	10	15	3D Titanium (–)	Any	13	Complications -
Strasz et al. (2016)[47]	Austria -	- (–)	193 (–)	26.4 ± 12.6, (16–72)	88	-	Modus Trillock angle, Titanium (Medartis)	31.0 ± 15.5, (16–90)	70/35	-	2.00 mm and 2 × 2.0 mm Titanium (Synthesis, KLSMartin, Medartis)	Angle	26	Complications -
Bhatt et al. (2015)[28]	India -	27.4 ± 9.7 (15–56)	36 (–)	29.5 ± 10.9	16	-	2.0 mm Titanium (Synthes)	26.4 ± 10.1	20	-	2.0 mm Titanium (Synthes)	Angle	26	Complications +
Elsayed et al. (2015)[45]	Egypt +	- (–)	20 (–)	26.1 ± 2.3 (–)	10	-	2.0 mm - (Synthes)	26.3 ± 2.4 (–)	10	-	2.3 mm - (Leibinger)	Angle	26	Complications +
Zhang et al. (2015)[44]	China +	- (–)	101 (101)	35.8 (18–56)	51	51	L shaped 2.3 mm - (Orthomax)	37.3 (19–60)	50	50	L-shaped 2.0 mm - (Orthomax)	Condyle	26	Complications +
Shaik et al. (2014)[26]	India -	- (15–60)	60 (64)	- (–)	30	34	2.0 mm Stainless still (–)	- (–)	30	30	2.0 mm Stainless still (–)	Symphysis Parasymphysis Body Angle	13	Complications -
Singh et al. (2013)[43]	India +	- (–)	50 (–)	- (–)	25	-	2.0 mm - (–)	- (–)	25	-	3D - (–)	Angle	13	Complications +
Kumar et al. (2013)[24]*	India -	- (–)	60 (88)	28.4 (–)	30	44	2.0 mm Titanium (–)	27.6 (–)	30	44	2.0 mm Titanium (–)	Parasymphysis Body Angle	6	Complications -
Baig et al. (2011)[41]	India -	- (20–40)	20 (–)	- (–)	10	-	2.0 mm Stainless steel (–)	- (–)	10	-	2.5 mm Stainless steel (–)	Inter-foraminal	6	Complications -

Table 3 (*Continued*)

Authors	Country/ informed consent	Mean age ± SD (range)	Total number of patients (fractures) (*n*)	Locking plate: Age ± SD (range)	Locking plate: Patients (*n*)	Locking plate: Fractures (*n*)	Locking plate: Plate(s), material (company)	Non-locking plate: Age ± SD (range)	Non-locking plate: Patients (*n*)	Non-locking plate: Fractures (*n*)	Non-locking plate: Plate(s), material (company)	Locations	Follow-ups (weeks)	Evaluation/ funding
Ramesh et al. (2011)[32]	India -	35 ± 11 (20–55)	20 (27)	- (–)	10	14	2.0 mm - (–)	- (–)	10	13	2.0 mm - (–)	Symphysis Parasymphysis Body Angle Ramus	13	Complications -
Verma et al. (2011)[33]	India -	20–65 (–)	43 (43)	- (–)	21	21	2.0 mm - (–)	- (–)	22	22	2.0 mm - (–)	Symphysis Parasymphysis Body Angle Condylar	12	Complications -

-, Not reported; +, Reported; 3D, three-dimensional; SD, standard deviation.
*Study possibly included overlapped patients with the study of Singh et al., 2011.

teria, all three were of low quality. None of the reviews reported inter-rater reliability for the title and abstract selection, the full-text selection and quality assessment. All three reviews included both randomized control trials and observational studies but did not perform separate meta-analyses for each study design. For quality assessment two reviews used the Risk of bias tools (Cochrane), and one used a Jadad score. However, these quality-assessment tools are intended for randomized controlled trials[19,21]. Observational studies which were included in the reviews should have been assessed using an assessment tool for observational studies[52].

The systematic review by Chranovic[14] was conducted and written by one author. Logically no kappa value could be reported. In that review, several types of locking and non-locking plates were compared. The review by Zhan et al.[15] compared only 2.0-mm locking and non-locking plates. However, their electronic search was completed using two online databases, and it is preferable to search from at least three sources[18]. Lastly, in the systematic review by Wusiman et al. (2017)[16] the sentences that report the conclusions of the abstract, inclusion and exclusion criteria, statistical analysis in the methods section, some paragraphs of the results and discussion section, and the conclusions of the full-text paper are identical to sentences in the review of Zhan et al. (2014)[15]. Moreover, a flowchart of the study-selection process is missing in the study of Wusiman et al.[16].

The quality of included primary studies was moderate to low in both randomized and non-randomized studies. Furthermore, half of the included studies could not be included in the quantitative synthesis because they compared several types of locking and non-locking plates. Some of these studies compared a 2.0-mm locking plate with a 2.3-mm or a 2.4-mm non-locking plate, and a single locking plate with double non-locking plates. Also, other studies compared a 3D locking plate with 2.0-mm plates or vice versa. When studying the effects of the locking and non-locking plates, the following confounding variables should be taken in to account: size or dimensions of the plates and screws, fracture fixation principles, number of plates and plate design. Furthermore, factors such as dental status (periodontitis, number of teeth/occlusal units), smoking habits, concomitant fractures, and medical comorbities should be taken into account as well. Firstly, it has been shown that a load-bearing plate (2.3 mm or bigger diameter) is stronger

Table 4. Quality assessment of the randomized studies (Risk of Bias Tool).

Studies	Items					
	1	2	3	4	5	6
Wakeel et al. (2018)[30]	?	?	-	?	?	+
Budhraja et al. (2018)[51]	+	?	-	+	?	-
Camino Jr et al. (2017)[38]	+	?	-	?	-	+
Aggarwal et al. (2017)[50]	?	?	-	?	?	+
Vashistha et al. (2017)[36]	?	?	-	?	?	+
Kumar et al. (2017)[39]	?	?	-	?	?	+
George et al. (2016)[48]	?	?	-	?	?	+
Ali et al. (2016)[29]	?	?	-	?	?	?
Rastogi et al. (2016)[23]	+	?	?	?	?	+
Giri et al. (2015)[22]	+	+	-	?	?	+
Kumar et al. (2015)[25]	?	?	-	?	?	+
Saha et al. (2015)[27]	?	?	-	?	?	+
Yang and Patil (2015)[11]	?	?	-	-	?	+
Kumar et al. (2014)[34]	?	?	-	?	?	+
Jain et al. (2012)[35]	?	?	-	+	?	+
Agarwal et al. (2011)[31]	?	?	-	?	?	+
Goyal et al. (2011)[42]	?	?	-	?	?	+
Singh et al. (2011)[13]	+	?	-	?	?	+
Saikrishna et al. (2009)[10]	?	?	-	?	?	+
Seemann et al. (2009)[37]	+	?	-	?	?	+
Collins et al. (2004)[12]	+	?	-	?	+	+

+, Low risk; −, high risk;? unclear.
1: Random sequence generation. 2: Allocation concealment. 3: Blinding of participants and personnel. 4: Blinding of outcome assessment. 5: Incomplete outcome data (attrition bias). 6: Selective reporting.

and can bear more mechanical load than a load-sharing plate (2.0 mm diameter)[53]. Secondly, fracture fixation principles differ according the biomechanics of the mandible. When Champy's principle is followed, plates are fixated in the tensile zone of the mandible (upper border), and when the AO principle is followed, plates are fixated in the compression zone of the mandible (lower border)[53]. Thirdly, the number of plates that has been applied in mandibular fractures can influence the postoperative complications[54,55]. Lastly, the plate designs (i.e. 3D) must be comparable regarding their biomechanics. Therefore, besides the locking or non-locking characteristics, the aforementioned other characteristics of the plates must be similar when comparing the outcome of the locking plate systems with non-locking plate systems in mandibular fractures.

This meta-analysis was conducted only for those studies that compared plates that have the same dimensions, fixation principles, and design. A significant difference was found regarding the need for MMF in postoperative early and intermediate results in the locking-plate group compared with the non-locking-plate group. Early and intermediate postoperative evaluations showed that mandibular fractures fixated with locking plates are more stable than non-locking plates. These findings indicate that fewer occlusal deformities, fracture mobility, or loss of reduction occurred in the locking plate group. However, after 3 months of follow-up, the difference was no longer observed, probably because most cases had already been treated with MMF. In this review, we considered the need for MMF as a complication only if MMF was used to treat a complication such as occlusal disturbance and fracture mobility. In most of the in-

Table 5. Quality assessment of the non-randomized (observational studies MINORS tool).

Studies	Items												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Passi et al. (2017)[40]	1	0	0	1	0	2	0	0	2	0	0	0	6
Singh A and Arunkumar (2016)[46]	1	0	0	0	0	2	0	0	2	0	1	0	6
Strasz et al. (2016)[47]	2	2	1	2	0	2	1	0	2	2	1	1	16
Bhatt et al. (2015)[28]	2	2	1	2	0	2	0	0	2	2	1	1	15
Elsayed et al. (2015)[45]	2	0	1	2	1	2	0	0	2	2	2	1	15
Zhang et al. (2015)[44]	2	2	1	2	1	2	0	0	2	2	2	1	17
Shaik et al. (2014)[26]	1	2	0	2	0	2	0	0	2	0	1	0	10
Kumar et al. (2013)[24]	1	0	1	2	0	2	0	0	2	2	1	1	12
Singh et al. (2013)[43]	1	1	0	2	0	2	0	0	2	0	0	0	8
Baig et al. (2011)[41]	2	0	0	2	0	1	0	0	2	2	1	0	10
Verma et al. (2011)[33]	1	0	0	2	0	2	0	0	2	2	0	0	9
Ramesh et al. (2011)[32]	1	0	0	2	0	2	0	0	2	2	0	0	9

The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The highest possible score for a study is 24.
1: A clearly stated aim. 2: Inclusion of consecutive patients. 3: Prospective collection of data. 4: Endpoint appropriate to the study aim. 5: Unbiased evaluation of endpoints. 6: Follow-up period appropriate to the major endpoint. 7: Loss to follow up not exceeding 5%. 8: A control group having the gold standard intervention. 9: Contemporary groups. 10: Baseline equivalence of groups. 11: Prospective calculation of the sample size. 12: Statistical analyses adapted to the study design.

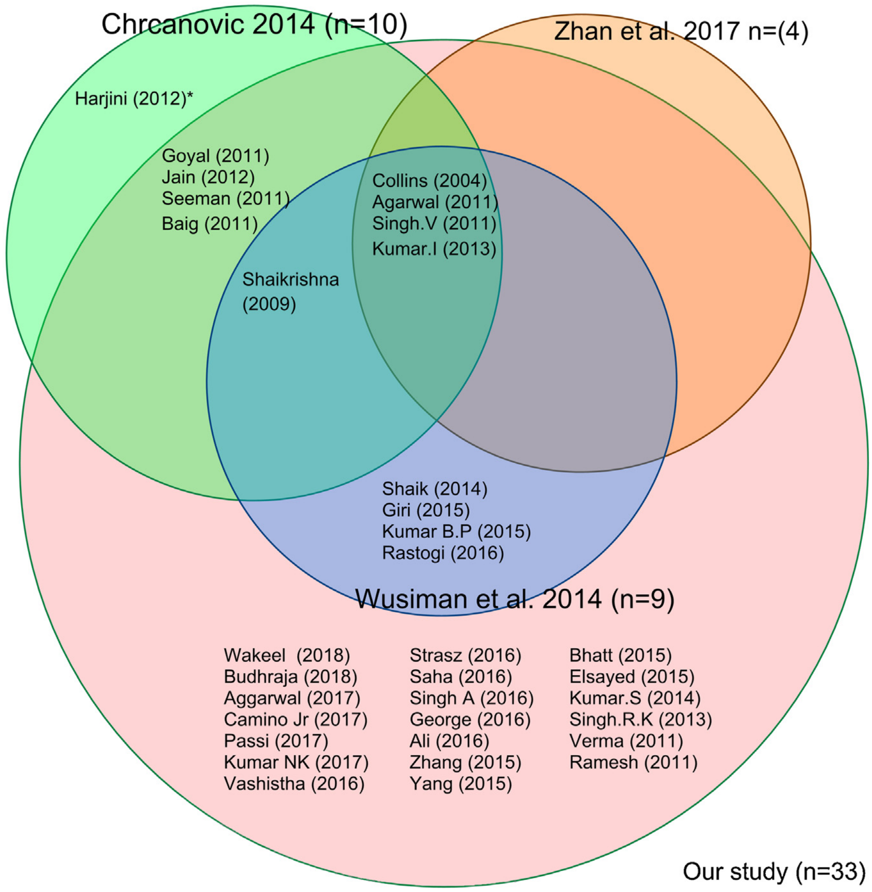

Fig. 2. A Venn diagram of the included studies in the existing systematic reviews and the current one.
*This study was not included in this review because a comparison was made between locking- and non-locking-plate systems in reconstruction surgery of the mandible.

cluded studies, however, MMF was not considered as a complication in the final comparison between the groups, maybe because MMF is considered as a standard procedure in the treatment of mandibular fractures by many surgeons and authors.

Furthermore, studies that included mandibular fractures concomitant with condylar fractures or other mandibular fractures did not report how they treated these concomitant fractures. It is not clear whether the concomitant condylar fractures were treated with ORIF or closed treatment, and there is substantial chance that the types of fractures affect the occlusal disturbances or need for MMF postoperatively. The incidence of postoperative infections was not different between locking and non-locking groups in the period of postoperative months.

The results of the previous meta-analyses were similar regarding the postoperative infection rate and need for MMF. However, their results were based on few studies[15,16], and on comparison of several types of plates besides the locking and non-locking characteristics. Additionally, those reviews did

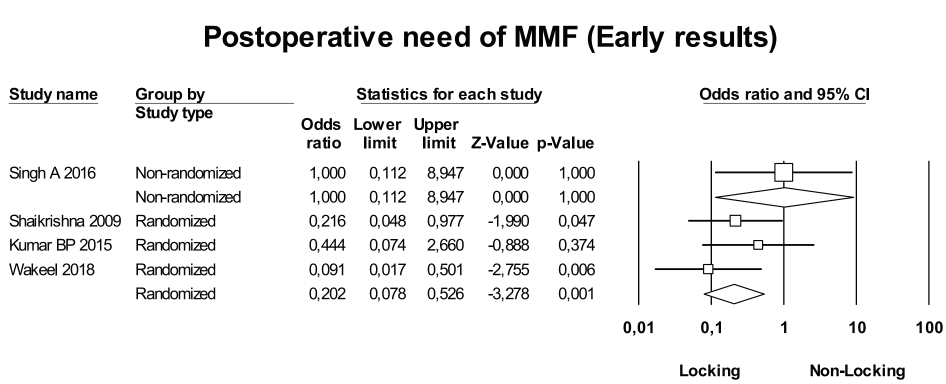

Fig. 3. Meta-analysis of need for mandibulomaxillary fixation (early results). Random effects model.
Randomized studies: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. Non-randomized study: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. CI, confidence interval.

Postoperative need of MMF (Intermediate results)

Study name	Group by Study type	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Verma 2011	Non randomized	0,105	0,020	0,565	-2,627	0,009
Ramesh 2011	Non randomized	0,162	0,007	3,847	-1,126	0,260
Shaik 2014	Non randomized	0,127	0,032	0,511	-2,906	0,004
Bhatt 2015	Non randomized	0,394	0,015	10,335	-0,559	0,576
	Non randomized	0,135	0,051	0,355	-4,051	0,000
Collins 2004	Randomized	2,764	0,110	69,190	0,619	0,536
Singh V 2011	Randomized	0,183	0,054	0,615	-2,747	0,006
Kumar BP 2015	Randomized	0,444	0,034	5,880	-0,615	0,538
Yang 2015	Randomized	0,196	0,038	1,020	-1,937	0,053
Ali 2016	Randomized	1,625	0,230	11,464	0,487	0,626
Wakeel 2018	Randomized	0,174	0,008	3,956	-1,097	0,273
	Randomized	0,353	0,149	0,839	-2,359	0,018

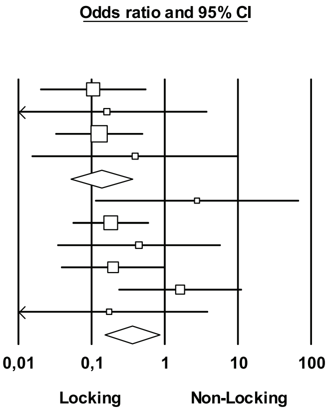

Fig. 4. Meta-analysis of need for mandibulomaxillary fixation (intermediate results). Random effects model. Randomized studies: $I^2 = 2.7\%$, $Tau^2 = 0.3\%$. Non-randomized studies: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. CI, confidence interval.

Postoperative need of MMF (Late results)

Study name	Group by Study Type	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Verma 2011	Non-Randomized	0,333	0,013	8,648	-0,661	0,508
	Non-Randomized	0,333	0,013	8,648	-0,661	0,508
Ali 2016	Randomized	0,464	0,037	5,749	-0,598	0,550
Wakeel 2018	Randomized	0,174	0,008	3,956	-1,097	0,273
	Randomized	0,316	0,044	2,239	-1,154	0,249

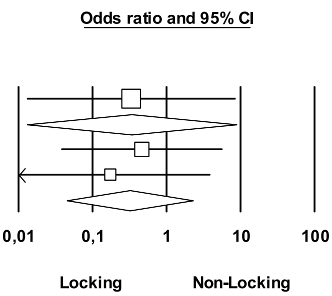

Fig. 5. Meta-analysis of need for mandibulomaxillary fixation (late results). Random effects model. Randomized studies: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. Non-randomized study: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. CI, confidence interval.

Postoperative infection (Intermediate results)

Study name	Group by Study type	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Verma 2011	Non randomized	0,317	0,030	3,316	-0,960	0,337
Ramesh 2011	Non randomized	3,316	0,120	91,601	0,708	0,479
Shaik 2014	Non randomized	1,556	0,241	10,049	0,464	0,643
	Non randomized	1,050	0,276	3,998	0,072	0,943
Collins 2004	Randomized	0,591	0,095	3,671	-0,564	0,573
Shaikrishna 2009	Randomized	0,474	0,039	5,688	-0,589	0,556
Singh V 2011	Randomized	0,457	0,076	2,755	-0,855	0,393
Agarwal 2011	Randomized	0,302	0,011	8,332	-0,708	0,479
Kumar S 2014	Randomized	1,000	0,112	8,947	0,000	1,000
Kumar BP 2015	Randomized	0,444	0,034	5,880	-0,615	0,538
Giri 2015	Randomized	0,162	0,007	3,847	-1,126	0,260
Yang 2015	Randomized	0,483	0,041	5,628	-0,581	0,561
Ali 2016	Randomized	3,207	0,121	85,203	0,696	0,486
Wakeel 2018	Randomized	0,174	0,008	3,956	-1,097	0,273
	Randomized	0,512	0,237	1,108	-1,700	0,089

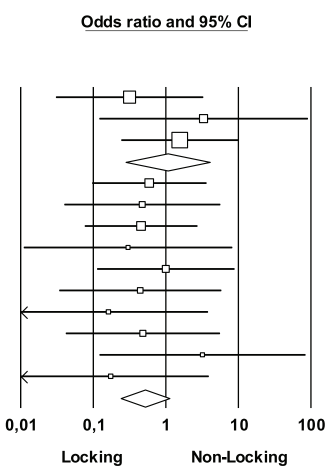

Fig. 6. Meta-analysis of infection (intermediate results). Random effects model. Randomized studies: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. Non-randomized study: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. CI, confidence interval.

Postoperative infection (Late results)

Study name	Group by Study Type	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Bhatt 2015	Non-randomized	4,385	0,410	46,931	1,222	0,222
	Non-randomized	4,385	0,410	46,931	1,222	0,222
Shaikrishna 2009	Randomized	0,122	0,006	2,527	-1,361	0,174
Agarwal 2011	Randomized	1,000	0,054	18,574	0,000	1,000
Wakeel 2018	Randomized	0,312	0,012	8,285	-0,696	0,486
	Randomized	0,347	0,059	2,040	-1,171	0,242

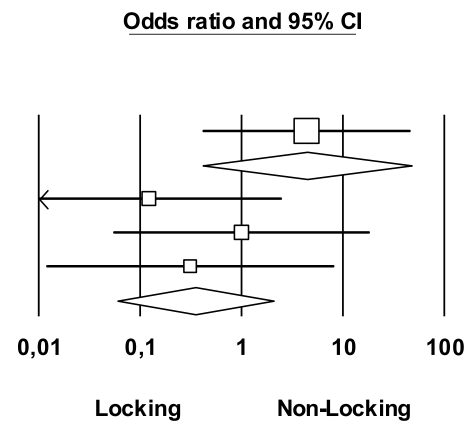

Fig. 7. Meta-analysis of infection (late results). Random effects model.
Randomized studies: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. Non-randomized study: $I^2 = 0.0\%$, $Tau^2 = 0.0\%$. CI, confidence interval.

not perform separate analysis for studies with different methodologies (randomized vs. observational studies).

The strength of our current meta-analysis is the extensive literature search without language restriction which also included grey literature. Moreover, all the review stages were assessed by two reviewers and inter-observer agreement was reported. However, inter-observer agreement was moderate in the quality-assessment stage, probably because included studies failed to report how they randomized participants, whether concealment of allocations was performed and whether participants and outcome assessors were blinded. Also, we used the relevant tools of the quality assessment based on the study types. A meta-analysis was conducted separately for the randomized and non-randomized studies. This study was limited by the quality of the included studies and the moderate inter-observer agreement in some stages of the review. Moreover, we did not register the review on PROSPERO before starting the systematic review.

We suggest that future studies should carefully consider the inclusion criteria for their studies, and try to compare locking or non-locking plates with otherwise (1) similar fracture locations and fixation principles between the groups, (2) identical dimensions of the plates to be compared, (3) identical number of plates and design of the plates to be compared. Furthermore, the treatment modalities of the concomitant fractures should be stated, and the timeframe in which complications occurred should also be stated.

Based on the results of our meta-analysis, we conclude that locking plates are superior only with respect to the need for MMF in the early postoperative period. However, due to the low quality of the included studies, properly designed studies are compulsory to evaluate the accurate effect on postoperative complications when treating mandibular fractures with locking plates, and with non-locking plates.

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Competing interests

The authors declare that they have no conflict of interest.

Ethical approval

Not required.

Patient consent

Not required.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ijom.2019.02.019.

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