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Open versus closed treatment for unilateral mandibular extra-capsular condylar fractures: A meta-analysis

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ABSTRACT

Purpose: To compare the functional outcomes between open reduction and internal fixation (ORIF) and closed reduction (CR) for unilateral mandibular extra-capsular condylar fractures in patients over 12 years old.

Materials and methods: A comprehensive electronic search of PubMed, Embase and the Cochrane Library databases was conducted up to October 31, 2018. The evaluated functional outcomes included malocclusion, temporomandibular joint (TMJ) pain, protrusion, laterotrusion, maximum inter-incisal opening and lateral deviation during maximum inter-incisal opening.

Results: Fourteen studies appeared to meet the inclusion criteria. Statistically significant differences between ORIF and CR treatment were observed for the outcomes of malocclusion ($P = 0.001$), maximum inter-incisal opening ($P = 0.0008$), lateral deviation during maximum inter-incisal opening ($P = 0.007$) and laterotrusion ($P < 0.0001$), but not for the outcomes of protrusion ($P = 0.33$) and TMJ pain ($P = 0.29$).

Conclusions: ORIF treatment of unilateral mandibular extra-capsular condylar fractures provides better functional outcomes in comparison to CR treatment with regard to occlusion, maximum inter-incisal opening, lateral deviation during maximum inter-incisal opening and laterotrusion, whereas there was no statistically significant difference between ORIF and CR group with regard to protrusion and TMJ pain.

1. Introduction

Condylar process fractures are prevalent in maxillofacial injuries and represent 25%~40% of all mandibular fractures (Marker et al., 2000; De Riu et al., 2001; Ellis and Throckmorton, 2005). The current treatment protocol for condylar fractures remains controversial. Some (Brandt and Haug, 2003; Ellis et al., 2012) advocated that closed reduction (CR), which was easy to operate without invasive procedures, might be suitable for all the unilateral displaced or dislocated condylar fractures only if patients' occlusal relationships were good enough. Nevertheless, CR appears to be associated with a high risk of temporomandibular joint (TMJ) pain, and maxillomandibular fixation (MMF) needs extended therapeutic periods (Singh et al., 2018). With the development of surgical techniques and improvement of internal fixation materials, open reduction and internal fixation (ORIF), which could be used to anatomically restore fractured condyle, has been gradually accepted and widely applied (Schneider et al., 2008; Danda et al., 2010; Bhagol et al., 2011; Chrcanovic, 2015).

According to the location of mandibular condyle, its fracture is divided into head, neck and base fracture, the latter two are also known as extra-capsular fractures. Previous meta-analyses (Duan and Zhang, 2006; Nussbaum et al., 2008; Kyzas et al., 2012; Liu et al., 2013; Yao et al., 2014; Al-Moraissi and Ellis, 2015; Berner et al., 2015; Chrcanovic, 2015) have already compared the functional outcomes between ORIF and CR treatment for mandibular condylar fractures. Unfortunately, none of the studies elaborated the level and side of condylar fractures, furthermore, patients' age was also overlooked all the while. Actually, the selection of treatment options and functional outcomes of either treatment varied with the above factors (Hovinga et al., 1999; Yang et al., 2002; Schneider et al., 2008).

Therefore, we updated our research for related articles and designed a novel meta-analysis about comparison between ORIF and CR treatment for unilateral mandibular extra-capsular condylar fractures in patients over 12 years old.

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2. Materials and methods

This review fully complied with the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Moher et al., 2009). Three reviewers participated in the whole work.

2.1. Literature search

We considered all the studies that had compared functional outcomes between ORIF and CR treatment for unilateral mandibular extra-capsular condylar fractures in patients over 12 years old. A comprehensive electronic search of PubMed, Embase and the Cochrane Library databases was performed to identify relevant studies available up to October 31, 2018. The following terms were used in the search strategy: (surgical treatment OR anatomical reduction OR open reduction) AND (closed reduction OR nonsurgical treatment OR functional treatment OR conservative treatment) AND (condylar fracture OR subcondylar fracture). Moreover, references in the eligible studies or textbooks were also reviewed to check through manual searches to find other potentially eligible studies.

2.2. Inclusion and exclusion criteria

We selected randomized controlled studies (RCT), retrospective cohort studies (RCS) and prospective cohort studies (PCS) to compare the clinical functional outcomes between ORIF and CR treatment for unilateral mandibular extra-capsular condylar fractures. The included studies had to meet all the following criteria: 1) patients older than 12 years; 2) unilateral condylar neck or base fractures, displaced or no-displaced; 3) complete functional outcomes of ORIF and CR, such as malocclusion, protrusion, laterotrusion, maximum inter-incisal opening, lateral deviation during maximum inter-incisal opening and TMJ pain. Studies were excluded when they were: 1) with regard to mandibular condylar head fractures (including sagittal condylar fractures), bilateral condylar fractures or concomitant midface fractures; 2) without sufficient follow-up period (<3 months); 3) animal studies, case reports, comments, letters, conference abstracts or reviews.

2.3. Data extraction

Using a standardized form, data from included studies were extracted independently by two reviewers to fill in necessary information. The information extracted from included studies consisted of study design, aetiology, patients' information (age, volume and gender), type of condylar fracture and concomitant mandibular fracture, procedure of ORIF and CR treatment, postoperative complication of ORIF treatment and follow-up period. Authors were contacted for missing information. In case of conflicting evaluations, a final agreement was reached following a discussion with a third reviewer.

2.4. Quality assessment of included studies

Two reviewers independently assessed the quality of included studies according to the Newcastle–Ottawa Scale (NOS) (Wells et al., 2014). Eight assessment items associated with the methodological quality appraisal were used in this meta-analysis, scores ranging from 0 to 9. Scores of 0–3, 4–6, 7–9 were defined as low, moderate and high quality, respectively. Disagreement was resolved by discussion with the third reviewer.

2.5. Statistical analysis

Meta-analysis was performed using Review Manager Version 5.3 (provided by the Cochrane Collaboration, available at: http://ims.cochrane.org/revman/download). The evaluated functional outcomes of ORIF and CR treatments included dichotomous data (malocclusion and TMJ pain) and continuous data (protrusion, laterotrusion, maximum inter-incisal opening and lateral deviation during maximum inter-incisal opening). The dichotomous data were analyzed using risk ratio (RR) as the effect size, the continuous data were analyzed using mean difference (MD) in millimeters as the effect size, and both statistics were assessed with 95% confidence interval (CI).

The heterogeneities of the included studies were estimated using Cochrane's Q-statistic, while $P < 0.05$ was considered as a manifestation of statistically significant heterogeneity. The effect of heterogeneity was quantified using the I^2 test. When a significant Q-test ($P < 0.05$) or I^2>50% indicated that heterogeneity among studies existed obviously, the random-effects model was employed for the meta-analysis. Otherwise, the fixed-effects model was used. Sensitivity analysis was conducted after exclusion of PCS and RCS. Publication bias was examined from funnel plots. Asymmetry in funnel plots might indicate publication bias and other biases associated with sample size.

To ensure the reliability and accuracy of the results, two reviewers populated the data in the statistical software programs independently and obtained identical results.

3. Results

3.1. Literature search

Subsequent to the initial screening, a total of nine hundred and twenty relevant publications were identified. Fourteen studies (Worsaae and Thorn, 1994; Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015) appeared to meet the inclusion criteria and were subjected to further examination. The flow chart of study selection is summarized in Fig. 1.

3.2. Characteristics of included studies

The included studies (Worsaae and Thorn, 1994; Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015) consisted of five RCTs, six RCSs and three PCSs. Patients' age ranged from twelve to eighty years old, and male patients were in the majority. Five studies (Throckmorton and Ellis, 2000; Danda et al., 2010; Singh et al., 2010, 2018; Leiser et al., 2013) mentioned the causes of condylar fractures, involving fall, road traffic accident and assault. Seven studies (Worsaae and Thorn, 1994; Yang et al., 2002; Singh et al., 2010, 2018; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015) reported condylar base fractures only, one study (Kokemueller et al., 2012) reported condylar neck fractures only, and six studies (Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Danda et al., 2010; Rasheed et al., 2010; Vesnaver et al., 2012) reported both. The ORIF surgeries were performed via preauricular, submandibular, transmasseteric anterior parotid, retromandibular approach or endoscope-assisted intraoral approach, with or without maxillomandibular fixation

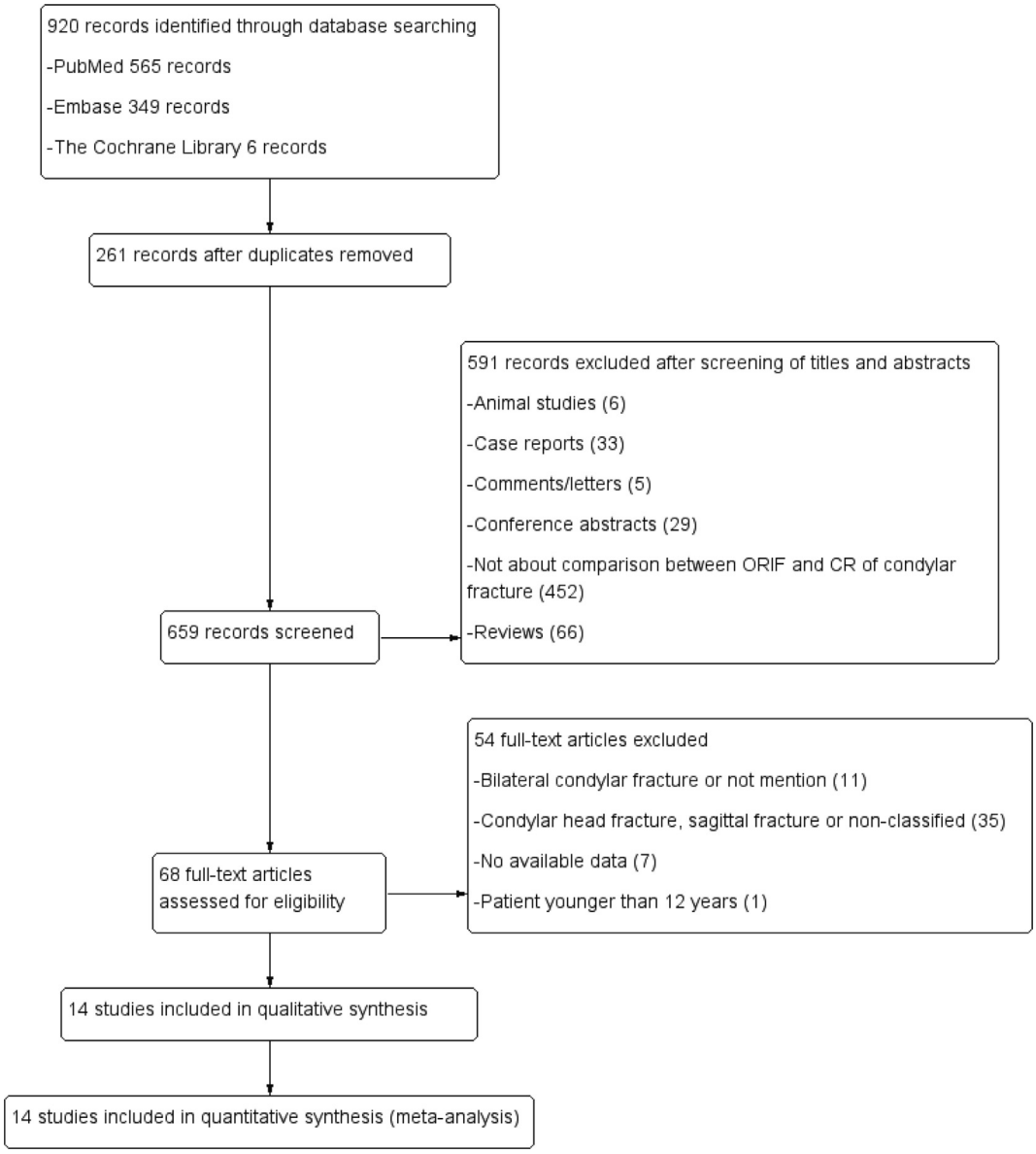

Fig. 1. The flow chart of study selection.

(MMF) (Worsaae and Thorn, 1994; Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015). The implementation of MMF was not consistent. Most ORIF surgeries were accomplished with fracture plates and screws (Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015), while Worsaae and Thorn (1994) adopted stainless steel wires. The most common postoperative complication of ORIF was facial nerve damage, accompanied with salivary fistula, paraesthesia, Frey's syndrome, malposition of fragments, implant breakage, infection and hypertrophic scar (Yang et al., 2002; Danda et al., 2010; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Khiabani et al., 2015). Concomitant mandibular fractures other than condylar fractures were treated with ORIF in proper occlusal relationships (Ellis et al., 2000; Khiabani et al., 2015). Follow-up period was not less than three months. Quality scores of the included studies (Worsaae and Thorn, 1994; Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015) ranged from 6 to 9. The characteristics and methodological quality of the included studies are shown in Table 1.

3.3. Main results of meta-analysis

Occlusal disturbances induced by unilateral condylar fractures mainly contain ipsilateral premature contact and contralateral open bite. Eleven studies (Worsaae and Thorn, 1994; Ellis et al., 2000; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Khiabani et al., 2015) reported malocclusion after ORIF and CR treatments. The heterogeneity test showed that $P = 0.43$, $I^2 = 2\%$, and a fixed-effects model was

Table 1
Characteristics and qualities of included studies.

Authors and Year	Study design	Aetiology	Patient age (years)	Patient volume	Type of condylar fracture	Concomitant mandibular fracture	Therapeutic method		Postoperative complication of ORIF	Follow-up period (months)	NOS score
							ORIF	CR			
Worsaae and Thorn (1994)	RCS	NM	18–71	52 (M,37; F,15; G1,24; G2,28)	base	NM	submandibular approach, double 0.3 mm stainless steel wires; rigid MMF for 6 weeks, then elastic MMF for 1 week	rigid MMF for 6 weeks, then elastic MMF for 1 week	none	6–64	7
Ellis et al. (2000)	PCS	NM	16–70	62 (G1,33; G2, 29)	base, neck	symphysis, body, angle or none	retromandibular approach, mini dynamic compression plates, 2 mm screws; no MMF	no MMF	NM	12	7
Throckmorton and Ellis (2000)	PCS	most assault	16–70	69 (M,55; F,14; G1,32; G2,37)	base, neck	NM	retromandibular approach, mini dynamic compression plates, 2 mm screws; no MMF	no MMF	NM	12	7
Ling and Chu (2001)	RCS	NM	16–60	34 (M,42; F,7; G1,16; G2,18)	base, neck	NM	preauricular, submandibular, or retromandibular approach, mini-plates; elastic MMF for 1 week	elastic MMF for 4–6 weeks	NM	12	6
Yang et al. (2002)	RCS	NM	17–70	36 (G1,22; G2,14)	base	NM	endoscope-assisted intraoral approach, mini-plates; MMF for 1 week	rigid MMF for 3 weeks	transient facial paralysis	12–63	6
Danda et al. (2010)	RCT	road traffic accident, assault or fall	>18	32 (M,27; F,5; G1,16; G2,16)	base, neck	NM	preauricular, submandibular, transmasseteric anterior parotid or retromandibular approach, mini-plates; elastic MMF for 2 weeks	rigid MMF for 2 weeks, then elastic MMF for 2 weeks	transient facial paralysis	4–42	8
Rasheed et al. (2010)	RCS	NM	>12	49 (M,38; F,22; G1,24; G2,25)	base, neck	NM	preauricular approach, mini-plates	MMF for 4–6 weeks	NM	12	6
Singh et al. (2010)	RCT	motor vehicle, assault or others	an average of 30.6	40 (M,33; F,7; G1,18; G2,22)	base	NM	retromandibular approach, 2.0 mm titanium mini-plates; elastic MMF for 3–5 days	elastic MMF for 1–5 weeks	NM	6	9

(*continued on next page*)

Table 1 (*continued*)

Authors and Year	Study design	Aetiology	Patient age (years)	Patient volume	Type of condylar fracture	Concomitant mandibular fracture	Therapeutic method		Postoperative complication of ORIF	Follow-up period (months)	NOS score
							ORIF	CR			
Kokemueller et al. (2012)	PCS	NM	>18	71 (M,60; F,11; G1,30; G2,41)	neck	NM	endoscope-assisted intraoral approach; elastic MMF for 1–2 weeks	elastic MMF for 2–8 weeks	technique problem, facial nerve damage, implant breakage	10–14	8
Vesnaver et al. (2012)	RCS	NM	14–80	62 (M,39; F,23; G1,42; G2,20)	base, neck	NM	periauricular or retromandibular approach; elastic MMF for 1–2 weeks	rigid MMF for 2–3 weeks, then elastic MMF for 1–4 weeks	transient facial paralysis, transient salivary fistula, paraesthesia, Frey's syndrome, malposition of fragments, implant breakage, infection, hypertrophic scar	>24	7
Kotrashetti et al. (2013)	RCT	NM	20–40	22 (G1,10; G2,12)	base	NM	retromandibular approach, 2.0 mm titanium mini-plates	elastic MMF for 2–3 days, then rigid MMF for 3–4 weeks	facial paralysis	6	8
Leiser et al. (2013)	RCS	fall, road traffic accident, interpersonal violence	13–66	30 (M,24; F,6; G1,8; G2,22)	base	none	retromandibular approach, mini-plates	rigid MMF for an average of 2 weeks	none	11–60	6
Khiabani et al. (2015)	RCT	NM	17–59	40 (M,30; F,10; G1,20; G2,20)	base	symphysis, body, angle or none	endoscope-assisted intraoral approach, 2.0 mm titanium mini-plates; elastic MMF for 1 week	elastic MMF for 4 weeks	transient facial paralysis, edema	3	9
Singh et al. (2018)	RCT	road traffic accident, assault or others	19–60	20 (M,16; F,4; G1,10; G2,10)	base	none	retromandibular approach, 2.0 mm titanium mini-plates; elastic MMF for 3–5 days	elastic MMF for 1–6 weeks	NM	6	9

ORIF, open reduction and internal fixation; CR, closed reduction; RCT, randomized controlled trial; RCS, retrospective cohort study; PCS, prospective cohort study; M, male; F, female; G1, ORIF group; G2, CR group; MMF, maxillomandibular fixation; NM, not mention.

conducted. The incidence of malocclusion was much higher in the CR group, and the difference was statistically significant (RR = 0.46, 95% CI [0.29, 0.73], $P = 0.001$; Fig. 2).

Seven studies (Throckmorton and Ellis, 2000; Ling and Chu, 2001; Rasheed et al., 2010; Singh et al., 2010, 2018; Vesnaver et al., 2012; Khiabani et al., 2015) reported maximum inter-incisal opening after ORIF and CR treatments. The heterogeneity test showed that $P = 0.0001$, $I^2 = 78\%$, and a random-effects model was conducted. There was a statistically significant effect on the outcome of maximum inter-incisal opening favoring the ORIF group (MD = 3.78, 95% CI [1.58, 5.98], $P = 0.0008$; Fig. 3).

Four studies (Throckmorton and Ellis, 2000; Singh et al., 2010; Vesnaver et al., 2012; Khiabani et al., 2015) reported lateral deviation during maximum inter-incisal opening after ORIF and CR treatment. The heterogeneity test showed that $P = 0.0006$, $I^2 = 83\%$, and a random-effects model was conducted. Lateral deviation during maximum inter-incisal opening was greater in the CR group, and the difference was statistically significant (MD = −2.02, 95% CI [−3.48, −0.57], $P = 0.007$; Fig. 4).

Only three studies (Throckmorton and Ellis, 2000; Singh et al., 2010, 2018) reported laterotrusion and protrusion after ORIF and CR treatment. The heterogeneity test showed that $P = 0.08$, $I^2 = 61\%$ and $P < 0.0001$, $I^2 = 89\%$, respectively. Therefore, random-effects models were conducted. There was a statistically significant effect on the outcome of laterotrusion in favor of the ORIF group (MD = 1.91, 95% CI [1.00, 2.83], $P < 0.0001$; Fig. 5), but not on the outcome of protrusion (MD = 0.80, 95% CI [−0.81, 2.42], $P = 0.33$; Fig. 6).

Five studies (Worsaae and Thorn, 1994; Yang et al., 2002; Danda et al., 2010; Kotrashetti et al., 2013; Leiser et al., 2013) reported TMJ pain after ORIF and CR treatments. The heterogeneity test showed that $P = 0.07$, $I^2 = 53\%$, and a random-effects model was conducted. There was no statistically significant difference between the ORIF and CR group in regard to TMJ pain (RR = 0.52, 95% CI [0.16, 1.72], $P = 0.29$; Fig. 7).

3.4. Sensitivity analysis and publication bias

The sensitivity analysis results after exclusion of PCS and RCS revealed that the functional outcomes did not change significantly. The funnel plot for the outcome of malocclusion showed symmetry (Fig. 8A). Nevertheless, the funnel plot for the outcomes of maximum inter-incisal opening, lateral deviation during maximum inter-incisal opening, laterotrusion, protrusion and TMJ pain showed asymmetry, indicating possible publication biases (Fig. 8B–F).

4. Discussion

At present, the rational treatment regimen of condylar fractures remains controversial. A general consensus is that non-displaced condylar fractures should be treated conservatively, while displaced or dislocated condylar fractures should be treated surgically (Khelemsky et al., 2016). The specific regimen still needs to be selected in combination with patients' age, the type of condylar fractures and general condition.

Several classifications have been provided for mandibular condylar fractures. Loukota et al. (2005) sorted mandibular condylar fracture into three types, including condylar head fracture (diacapitular fracture), neck fracture and base fracture, the latter two were also called extra-capsular fractures. Kozakiewicz et al. (Kozakiewicz, 2018) further divided condylar neck fracture into high neck fracture and low neck fracture separated by the head anterior border point.

Actually, the side and level of bone fractures play indispensable roles in the selection of treatment options and functional outcomes of either treatment (Yang et al., 2002; Schneider et al., 2008). Fractured condylar head may be too small to be treated with ORIF and most surgeons advocate to remove the fragments (Takenoshita et al., 1990; Chakranarayan and Mukherjee, 2012). Bilateral condylar fractures lead to more serious functional defects of mandible (Zachariades et al., 2006; Gupta et al., 2012). Singh et al. (2012) considered that ORIF treatment was superior in all subjective and objective function parameters of bilateral condylar fractures. It is recommended that ORIF should be avoided in children younger than 12 years old owing to mandibular growth disturbance (Norholt et al., 1993; Hovinga et al., 1999). However, previous meta-analyses did not consider the level and side of condylar fractures and patients' age as limited factors, which further increased confounding bias. Therefore, we eliminated studies about condylar head fractures, bilateral condylar fractures and fractures in which patients were younger than 12 years old, and made a further discussion about comparison between ORIF and CR treatment for unilateral mandibular extra-capsular condylar fractures.

In essence, the results of this meta-analysis reveal that the ORIF treatment of unilateral mandibular extra-capsular condylar fractures provides better clinical results compared with CR treatment in regard to occlusion (RR = 0.46, 95% CI [0.29, 0.73], $P = 0.001$), maximum inter-incisal opening (MD = 3.78, 95% CI [1.58, 5.98],

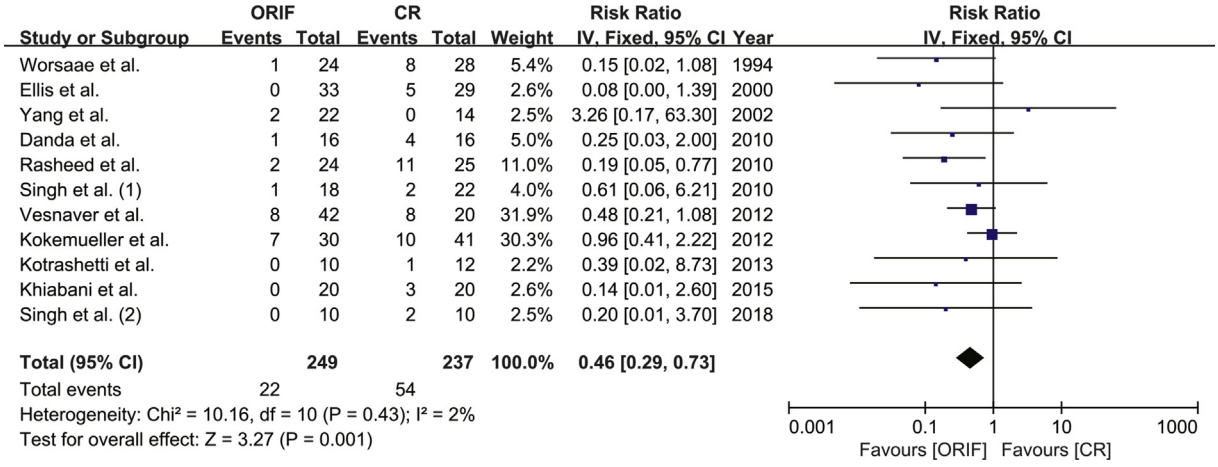

Fig. 2. Forest plot for malocclusion (dichotomous data).

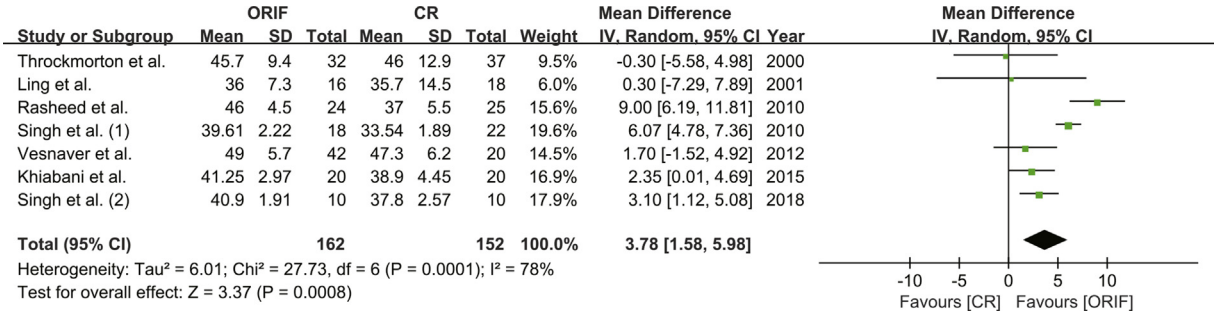

Fig. 3. Forest plot for maximum inter-incisal opening (continuous data).

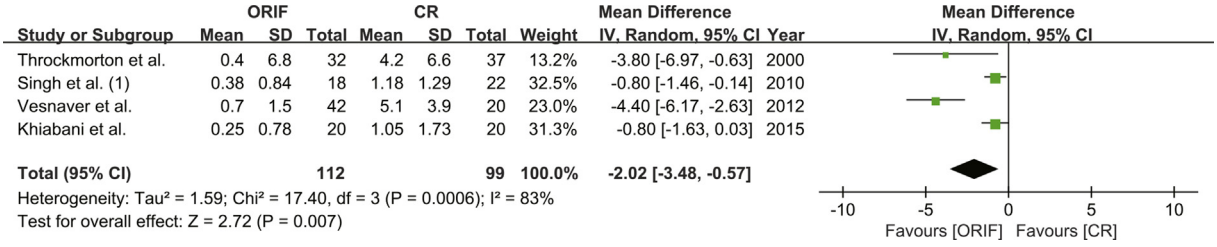

Fig. 4. Forest plot for lateral deviation during maximum inter-incisal opening (continuous data).

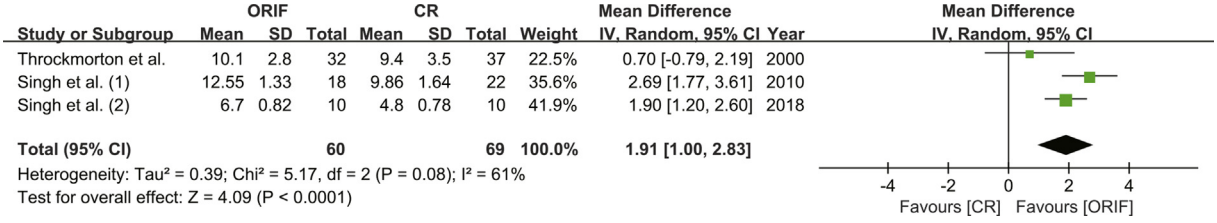

Fig. 5. Forest plot for laterotrusion (continuous data).

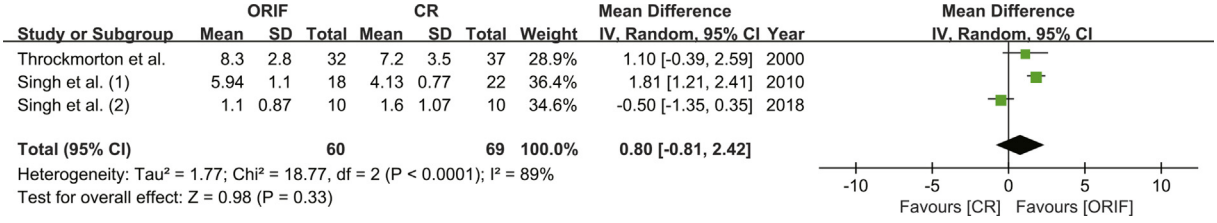

Fig. 6. Forest plot for protrusion (continuous data).

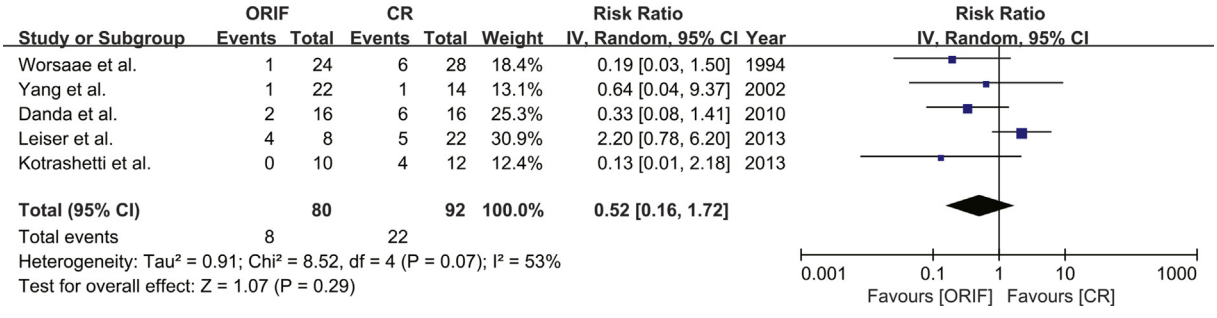

Fig. 7. Forest plot for TMJ pain (dichotomous data).

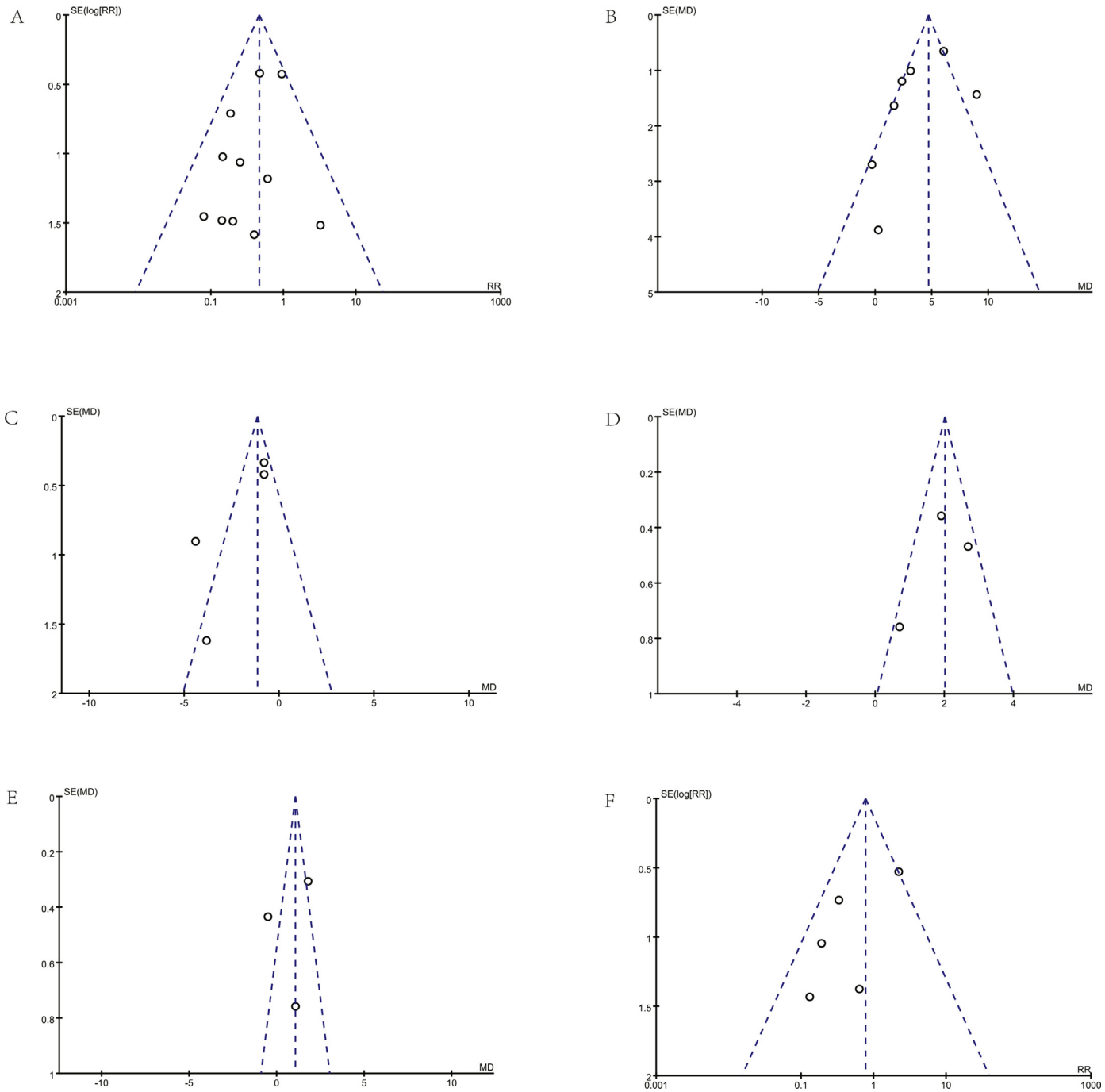

Fig. 8. Funnel plots ([A] malocclusion, [B] maximum inter-incisal opening, [C] lateral deviation during maximum inter-incisal opening, [D] laterotrusion, [E] protrusion, [F] TMJ pain).

$P = 0.0008$), lateral deviation during maximum inter-incisal opening (MD = −2.02, 95% CI [−3.48, −0.57], $P = 0.007$) and laterotrusion (MD = 1.91, 95% CI [1.00, 2.83], $P < 0.0001$), which is not exactly same as previous meta-analysis (Duan and Zhang, 2006; Nussbaum et al., 2008; Kyzas et al., 2012; Liu et al., 2013; Yao et al., 2014; Al-Moraissi and Ellis, 2015; Berner et al., 2015; Chrcanovic, 2015) without classification by the level and side of condylar fracture and patients' age. The preferable functional outcomes of ORIF group are attributed to increased ramus height and condyle replacement into articular fossa. On the contrary, there was no statistically significant difference between the ORIF and CR group in regard to protrusion (MD = 0.80, 95% CI [−0.81, 2.42], $P = 0.33$) and TMJ pain (RR = 0.52, 95% CI [0.16, 1.72], $P = 0.29$), which was probably related with insufficient follow-up period and sample size. Both muscle spasms induced by MMF and invasive operations could bring about residual pain, hence an extended follow-up period of ORIF and CR groups is necessary.

For the occurrence of mouth-opening limitation and malocclusion, condylar fractures with significant displacement or dislocation, bilateral condylar fractures, or concomitant with maxillary (or mandibular) fractures, surgical treatment is superior to conservative treatment (Zide and Kent, 1983; Khelemsky et al., 2016). For the

above situations, the advantage of surgical treatment is that the functional movement of mandible and the pre-injury occlusal relationship can be restored more quickly, and a favorable reference for the reduction of the combined facial fractures is available.

Traditional surgical therapies include preauricular, submandibular and retromandibular approach, following with a period of MMF(Worsaae and Thorn, 1994; Ellis et al., 2000; Rasheed et al., 2010). Nevertheless, When one selects ORIF operation to treat with unilateral mandibular extra-capsular condylar fractures, one also needs to pay more attention to its corresponding complications, such as facial nerve paralysis, salivary fistula, Frey's syndrome, malposition of fragments, implant breakage, infection, hypertrophic scar, and so forth (Ellis, 1998). Latest surgical approaches, such as transmasseteric anterior parotid and endoscope-assisted intraoral approach, are used successfully to prevent parotid gland damage, or to solve the problem of facial nerve damage and scarring (Choi, 2015; Khiabani et al., 2015; Blumer et al., 2018).

A stress analysis using reflection photoelasticity implied that the ideal and stable ORIF plating position of condylar neck and base fractures runs parallel to the posterior border of ramus and below the sigmoid notch (Meyer et al., 2002). If the above two crucial positions are well fixed, we can effectively avoid malposition of fragments and breakage of internal fixators in the cases of mandibular extra-capsular condylar fractures. Other than conventional straight titanium plates or mini-plates, various kinds of geometric titanium plates have been designed for condylar neck and base fractures, such as trapezoidal plate, square plate, rhomboid plate, A-shaped plate, Y-shaped plate and Delta plate (Kozakiewicz and Swiniarski, 2014; Sikora et al., 2016; Bischoff et al., 2017). Resorbable plate is alternative to titanium plate in the use of condylar neck and base fractures, but operators should be vigilant about its decreased stability.

Occlusal relationship and TMJ pain were assessed by the examiners or patients themselves in related studies (Worsaae and Thorn, 1994; Ellis et al., 2000; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015). Singh et al. (2018) classified postoperative occlusion into being identical to pretraumatic, slight difference, functional malocclusion, requirement of occlusal adjustment and gross malocclusion, while the latter three were regarded as positive occlusal disturbance. No attempt to quantify malocclusion and TMJ pain made the results more subjective.

Most results of heterogeneity test were poor and influenced the validity of overall effects to some extent. Most funnel plots showed asymmetry, indicating possible publication biases. When formulating the criteria for inclusion and exclusion, we did not specify exposure or intervention, which could create inclusion criteria bias.

Measurement of condyle displacement and ramus height shortening is crucial in the selection of treatment options, while it was discrepant in included studies (Worsaae and Thorn, 1994; Ling and Chu, 2001; Yang et al., 2002; Singh et al., 2010, 2018; Vesnaver et al., 2012; Kotrashetti et al., 2013; Khiabani et al., 2015), which could result in somewhat confounding bias. As indicated by Chang et al. (2018), we had better utilize 3-dimensional perspective to accurately measure angulation of condyle displacement and shortening of ramus height rather than solely view panoramic radiograph or coronal CT, owing to both anteroposterior and mediolateral displacement of condylar fragment.

The incision approach, type of internal fixators and implementation of MMF were various in related studies (Worsaae and Thorn, 1994; Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kokemueller et al., 2012; Vesnaver et al., 2012; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015). The selection of incision approach immediately impacts on the sufficiency of operative field. How to select incision approach and prevent complications such as facial nerve damage is essential to every surgeon. Most ORIF surgeries were accomplished with fracture plates and screws (Ellis et al., 2000; Throckmorton and Ellis, 2000; Ling and Chu, 2001; Yang et al., 2002; Danda et al., 2010; Rasheed et al., 2010; Singh et al., 2010, 2018; Kotrashetti et al., 2013; Leiser et al., 2013; Khiabani et al., 2015), while Worsaae and Thorn (1994) adopted stainless steel wires. The rigid MMF has been basically abandoned, and the occlusal relationship is corrected by the method of elastic traction between the jaws, while patients can open mouth and bite during the traction process. The prognosis of bone fracture is basically time-dependent, and the functional outcomes of ORIF and CR varies with different follow-up time consequently.

Concomitant mandibular symphysis, body or angle fractures confound the functional outcomes of condylar neck and base fractures after ORIF and CR treatments. We considered to include the studies (Ellis et al., 2000; Khiabani et al., 2015) that elaborated on concomitant mandibular fractures because isolated unilateral mandibular condylar fractures are relatively infrequent.

5. Conclusion

In conclusion, our meta-analysis suggests that the ORIF treatment of unilateral mandibular extra-capsular condylar fractures provides better clinical and functional outcomes in comparison to CR treatment with regard to occlusion, maximum inter-incisal opening, lateral deviation during maximum inter-incisal opening and laterotrusion, whereas there was no statistically significant difference between the ORIF and CR group with regard to protrusion and TMJ pain. It is necessary to conduct more prospective randomized studies and properly control confounding factors to achieve effective results and gradually unify clinical guidelines.

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Conflicts of interest

The authors declare that there is no competing interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcms.2019.03.021.

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