Comparative clinical efficacy of anatomic plate and Kirschner wire internal fixation in midshaft clavicle fractures: A meta-analysis

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Abstract. Midshaft (mid)-clavicle fractures are the most common type of clavicle fractures. The Kirschner wire (KW) and anatomic plate (AP) are two commonly used surgical treatment methods for mid-clavicle fractures, of which the use of an AP appears to be a more effective option. The present study performed a meta-analysis of a number of published studies on the treatment of mid-clavicle fractures with APs and KWs, in order to compare the advantages and disadvantages of the two treatments, so as to select a more effective treatment approach. The articles were obtained from several databases, including Cochrane Library, PubMed, Embase, CNKI, Wanfang, VIP and Chinese Biomedical Literature Database. The search period was from database establishment to June, 2021. Research was obtained by two authors who individually searched the aforementioned databases. For controversial studies, decisions were made by two authors (JZ and LW). A total of 20 studies involving 1,739 patients were included in the meta-analysis, including eight randomized controlled studies and 12 cohort trials. The results of the meta-analysis suggested that: Compared with the KW group, the AP group exhibited significant differences in incision length [standardized mean difference (SMD)=2.40; 95% confidence interval (CI), 1.93-2.86], constant function score (6 months; SMD=1.59; 95% CI, 1.29-1.89) and fracture healing time (SMD=-1.48; 95% CI, -2.09 to -0.87) (P<0.05). However, no significant differences were observed in the duration of the surgery (SMD=1.19; 95% CI, -0.19-2.57) and intraoperative blood loss (SMD=0.10; 95% CI, -3.13-3.32) (P>0.05). Compared with the KW group, significant differences were observed in post-operative efficacy (OR, 4.81; 95% CI, 3.10-7.46) and the incidence of post-operative complications (OR, 0.16; 95% CI, 0.05-0.55) in the AP group (P<0.05). On the whole, the AP and KW are two common materials for the clinical surgical treatment of mid-clavicle fractures. The present study confirmed that there was no significant difference between the two treatments as regards the duration of surgery and intraoperative blood loss; however, for post-operative shoulder joint function recovery, fracture healing state and healing time, the AP was significantly more effective than the KW. The post-operative complication rate of the AP group was significantly lower than that of the KW group. However, further prospective, large-sample randomized controlled studies are required to provide more concrete evidence for verification.

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Key words: bone, fracture, clavicle fracture, midshaft clavicle fracture, anatomic plate, Kirschner wire, fixation

Introduction

Clavicle fractures are a common type of fracture observed in clinical practice, accounting for ~2.6-10% of total body fractures; 80% of clavicle fractures occur in the midshaft clavicle, while distal and proximal clavicle fractures have a low incidence (1,2). Previous studies have reported that the incidence of mid-clavicle fractures is ~29-64 cases per 100,000 individuals each year; in addition, the incidence of such fractures in children is significantly higher than that in adults (3,4). The traditional non-operative treatment used is usually a sling or figure-of-eight bandage, even if the clavicle fracture is displaced (5). If patients with a clavicle fracture are not treated in a timely and effective manner, their limb function and quality of life is severely affected. It has been reported that the rate of bone non-union following the conservative treatment of comminuted fractures can amount to 15% (6). Compared with conservative (non-surgical) treatments, early surgical treatment can significantly improve the prognosis of fractures and can reduce the incidence of non-unions and malunions (7). Traditional surgical treatment with Kirschner wire (KW) fixation is more common; however, the associated risk of fracture end displacement and malunion is prohibitive, and for patients with comminuted or severely unstable clavicle fractures, it is difficult to achieve satisfactory results with traditional treatments (8). It has been reported that >50% of clinical clavicle fractures are displaced, and the risk of fracture malunion and discontinuity is relatively high; in addition, improper treatment can lead to the development of severe complications (9).

With the continuous exploration and development of treatment methods and the continuous improvement of patient requirements, the treatment of clavicle fractures with an anatomic plate (AP) has been widely used in clinical practice. At present, AP and KW fixation are widely used in clinical practice for the treatment of clavicle fractures. KW wire fixation requires a smaller incision, and less soft tissue and periosteum dissection; however, it is associated with a high possibility of fracture displacement and re-operation. Although AP requires a long surgical incision, it has a good stability, fewer complications and a higher post-operative fracture healing rate, particularly for comminuted and severely unstable fractures. Despite the fact that a variety of fixation methods have been described in the published literature to date, the optimal treatment of mid-clavicle fractures remains controversial (10,11). However, to date, the available evidence is not sufficient to confirm the advantages and disadvantages for the use of the AP and KW in mid-clavicle fractures. Therefore, the present study aimed to further explore the treatment of mid-clavicle fractures by analyzing available clinical studies on the treatment of such fractures with an AP and KW, in order to select a more suitable clinical treatment method.

Data and methods

Literature search and inclusion criteria. The inclusion criteria were as follows: Randomized controlled studies or cohort trials on mid-clavicle fractures, the exclusion of pathological fractures, the inclusion of at least one evaluation index and the inclusion of a full text. The exclusion criteria were the following: No mid-clavicle fractures, multiple injuries, no mean values. For contradictory articles and data, any issues were resolved by the corresponding author (JZ). Two researchers (DY and LW) searched the database and randomly searched the literature on AP and KW fixation for mid-clavicle fractures. The databases used included the Cochrane Library (https://www.cochrane.org), PubMed (https://www.ncbi.nlm.nih.gov/), Embase (https://www.embase.com), CNKI (http://www.cnki.net/),Wanfang (http://www.wanfangdata.com.cn/index.html), VIP (http://www.cqvip.com/) and CBM (sinomed.ac.cn). The retrieval time used was from the establishment of the database to June, 2021. The key words used for the search were the following: Clavicle fracture, anatomical plate and Kirschner wire, and finally, the articles included at least one evaluation index to evaluate the effectiveness of the treatment for mid-clavicular fractures. They included mean incision length, mean surgical duration, blood loss, constant function score (6 months), fracture healing time, post-operative efficacy and complication rate. The retrieval strategies for PubMed and CBM are presented in Fig. 1 (each # symbol and number in the figure represent a retrieval step).

Data extraction and quality evaluation. The basic features of the included studies, including the number of cases in the AP and KW groups, mean age, fracture type, duration of follow-up, and randomized controlled studies or cohort trials, were obtained by two researchers (DY and LW) by reading the title, abstract, key words and finally, the full article. RevMan 5.0 software Cochrane bias risk assessment (https://training.cochrane.org/handbook) was used for randomized controlled studies and the Newcastle-Ottawa Scale (NOS) was used for cohort trials, in order to evaluate the quality. The scale total score is nine points, and a score of ≥6 is considered high-quality research (12).

Statistical analysis. For continuous data obtained, the standardized mean difference (SMD) and 95% confidence intervals (CIs) were used to estimate validity. For dichotomous data, the odds ratios (ORs) were calculated. A meta-analysis was carried out using RevMan 5.0 software and the I^2 index for the heterogeneity of the studies. When the I^2 was >50%, indicating a high heterogeneity (13,14), the random effects model was used for data analysis. When the I^2 ≤50%, the fixed effects model was used for data analysis. A value of $P<0.05$ was considered to indicate a statistically significant difference.

Results

Features of the included articles. The Cochrane Library, PubMed, Embase, CNKI, Wanfang, VIP and CBM databases were searched. A total of 734 studies were retrieved, and 156 duplicate studies were found. After reading the titles and abstracts, 516 articles were excluded, including: 439 unrelated articles, 25 review articles, 23 conference articles and 29 case reports; remaining 62 articles. After reading the full articles, 41 articles were found to include no mid-clavicle fractures, and one article had no mean values. Finally, 20 articles containing at least one research index were obtained. Among these 20 articles, 17 included dichotomous variables and 8 included continuous variables. A flow chart of the included studies is presented in Fig. 2. In total, eight randomized controlled studies (8,15-21) and 12 cohort trials (22-33) were included. The basic characteristics of the studies are listed in Table I.

Qualitative evaluation and bias risk assessment of the included studies. There were 20 studies, including eight randomized controlled studies (8,15-21) and 12 cohort trials (22-33). Participants were treated for mid-clavicular fractures within a certain period of time, and not all studies provided criteria for inclusion. The evaluation criteria for a post-operative good rate were not consistent. All the studies covered mid-clavicle fractures and provided specific surgical procedures. For the included studies, it was not suggested that all treatments were treated using the blind method, and the sample size of each study was not arranged in advance, and the end point of evaluation of the post-operative rehabilitation status of the patients was also randomly determined. The bias risk assessment of the included randomized controlled studies is illustrated in Fig. 3, and the quality assessment of the cohort studies is presented in Table II.

Average incision length. Of the 20 studies included, there were three studies (8,22,25) that included the average incision length, as shown in Fig. 4. The results revealed that the incision length of the AP group was higher than that of the KW group (SMD=2.40; 95% CI, 1.93-2.86; $P<0.00001$).

Average duration of surgery. Of all the studies that were subjected to the meta-analysis, there were seven studies (8,18,19,22,24,25,28) that demonstrated the results of

PubMed		CBM
#1 Clavicle	#19 Spiral fracture	#1 Clavicle fracture common
#2 Clavicles	#20 Torsion fractures	files: intelligence
#3 Collar bone	#21 Fracture, torsion	#2 Anatomic plate common
#4 Bone, collar	#22 Fractures, torsion	files: intelligence
#5 Bones, collar	#23 Torsion fracture	#5 Kirschner wire common
#6 Collar bones	#24 #8 or #9 or #10 or #11 or	files: intelligence
#7 #1 or #2 or #3 or #4	#12 or #13 or #14 or #15 or #16	#4 #1 and #2 and #3
or #5 or #6	or #17 or #18 or #19 or #20 or	
#8 Fractures, bone	#21 or #22 or #23	
#9 Broken bones	#25 Anatomic plates	
#10 Bone, broken	#26 Anatomic plates	
#11 Bones, broken	#27 Anatomic plates	
#12 Broken bone	#28 #25 or #26 or #27	
#13 Bone fractures	#29 Kirschner pin	
#14 Bone fracture	#30 Kirschner pins	
#15 Fracture, bone	#31 Kirschner wires	
#16 Spiral fractures	#32 Kirschner wires	
#17 Fracture, spiral	#33 #29 or #30 or #31 or #32	
#18 Fractures, spiral	#34 #7 and #24 and #28 and	
	#33	

Figure 1. PubMed and CBM search strategy. CBM, Chinese Biomedical Literature Database. Each # symbol and number in the figure represent a retrieval step.

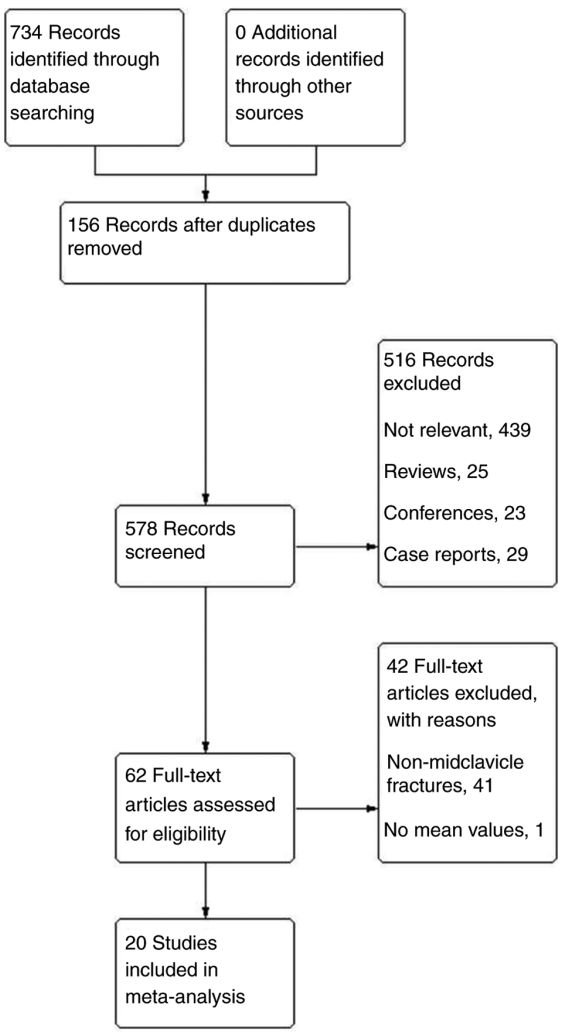

Figure 2. Flow chart of the included studies.

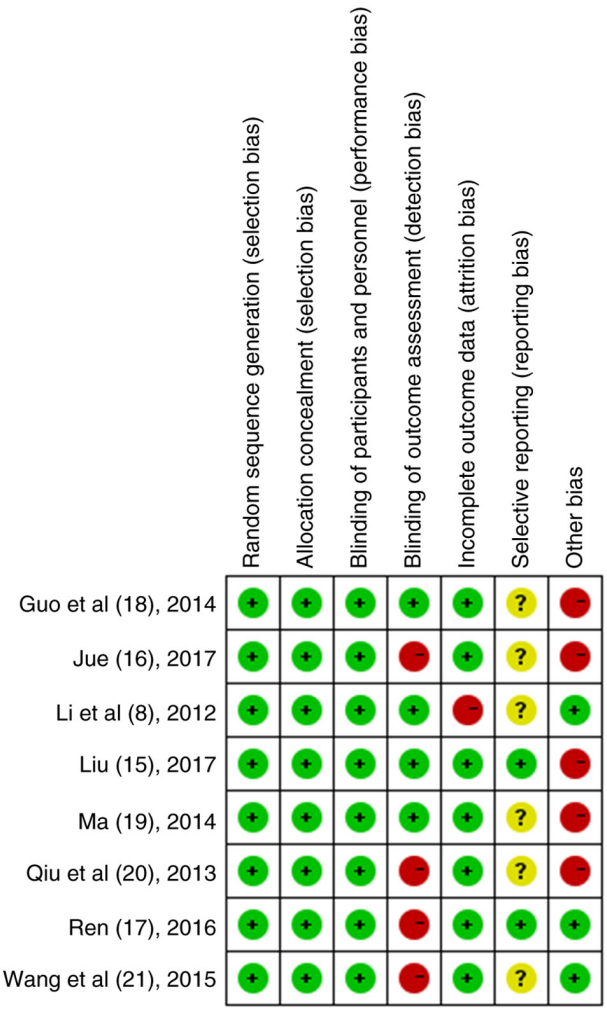

Figure 3. Quality evaluation of the randomized controlled studies, all of which were grade B or above.

Table I. The characteristics of the included studies.

Author	Year of publication	No. of cases AP/KW	Characteristics of cases (average age, ratio of male to female)	Fracture types open/closed	Research type	Follow-up time (months)	(Refs.)
Li	2014	28/28	AP: 38.6±5.7 years old, 19/9 KW: 39.6±4.7 years old, 17/11	AP: 8/20 KW: 9/19	Cohort trial	12	(25)
Tian	2013	37/7	5-68 years old	Open 2, closed 56	Cohort trial	6 to 18	(26)
Guo *et al*	2014	20/20	AP: 22.4±15.9 years old, 13/7 KW: 23.8±13.5 years old, 14/6	Not mentioned	Randomized controlled study	6	(18)
Yang	2017	36/34	AP: 40.58±2.43 years old, 22/14 KW: 39.76.8±2.58 years old, 21/13	All are closed	Cohort trial	6	(22)
Liu	2017	35/35	AP: 44.57±12.24 years old, 18/17 KW: 44.63±12.12 years old, 20/15	Not mentioned	Randomized controlled study	6	(15)
Li *et al*	2012	58/50	AP: Average age 36, 39/19 KW: average 34.5 years old, 32/18	All are closed	Randomized controlled study	6	(8)
Lv and Du	2010	24/37	13-65 years old	All are closed	Cohort trial	9-24	(31)
Wang *et al*	2011	35/33	AP: 37±5 years old, 19/16 KW: 37±5 years old, 17/16	AP: 2/33 KW: 3/30	Cohort trial	12 to 41 (28±5)	(28)
Ma	2014	44/44	37.45 ± 5.44 years old, 48/40	All are comminuted	Randomized controlled study	Not mentioned	(19)
Jue	2017	38/38	AP: 42.48±3.27 years old, 23/15 KW: 43.17±3.34 years old, 22/16	Not mentioned	Randomized controlled study	Not mentioned	(16)
Cheng	2015	30/30	AP: 42.3±22.69 years old, 18/12 KW: 41.78±21.53 years old, 20/10	Not mentioned	Cohort trial	Not mentioned	(24)
Bu *et al*	2006	24/60	15-65 years old	Not mentioned	Cohort trial	7 to 18	(33)
Qiu and Xiao	2013	41/33	16-73 years old	All are closed	Randomized controlled study	3 to 24 (average 15)	(20)
Wang *et al*	2015	100/100	AP: 45.8 years old, 51/49 KW: average 45.5 years old, 50/50	Not mentioned	Randomized controlled study	Not mentioned	(21)
Zhang *et al*	2012	75/33	5-68 years old	Open 2, closed 114	Cohort trial	6 to 18	(27)
Chen *et al*	2015	30/10	22 to 25 years old	Not mentioned	Cohort trial	5 to 12	(23)
Zhang	2010	128/33	15-76 years old	Not mentioned	Cohort trial	6 to 18	(30)
Yang *et al*	2009	102/97	6-73 years old	Open 9	Cohort trial	6 to 12	(32)
Ji *et al*	2010	53/79	25 to 67 years old	Not mentioned	Cohort trial	24	(29)
Ren	2016	53/76	27-76 years old	Not mentioned	Randomized controlled study		(17)

Mid-clavicle fractures were noted in each study. AP, anatomic plate; KW, Kirschner wire.

Table II. Quality evaluation of the cohort studies, all of which were >6 points.

Author/(Refs.)	Year of publication	Case selection				Comparability	Outcome measure			Score
		1	2	3	4		A	B	C	
Li (25)	2014	*	*	*	*	**		*	*	8
Tian (26)	2013		*	*	*	*		*	*	6
Yang (22)	2017	*	*	*	*	**		*		7
Lu and Du (31)	2010		*	*	*	*		*	*	6
Wang *et al* (28)	2011	*	*	*	*	**		*		7
Cheng (24)	2015	*	*	*	*	**	*			7
Bu *et al* (33)	2006	*	*	*	*	**		*		7
Zhang *et al* (27)	2012		*	*	*	*		*	*	6
Chen *et al* (23)	2015	*	*	*	*	*	*	*	*	8
Zhang (30)	2010	*	*	*	*	*		*		6
Yang *et al* (32)	2009		*	*	*	*	*	*	*	7
Ji *et al* (29)	2010	*	*	*	*	*		*		6

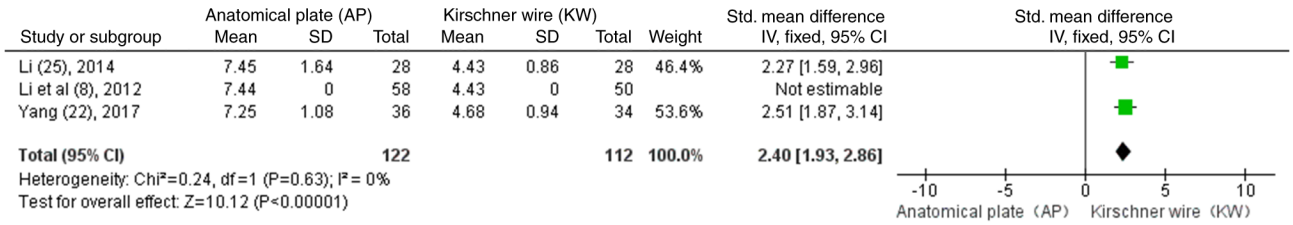

Figure 4. Comparison of the average incision length between the AP and KW group in the treatment of mid-clavicle fractures. The diamond shapes represent the results of statistical analysis. The squares represent the weight of each study, and the horizontal lines represent the 95% confidence intervals for each study. The results revealed that the incision length of the KW group was comparatively shorter than that of the AP group. AP, anatomic plate; KW, Kirschner wire.

duration of surgery, as shown in Fig. 5. The results revealed that there were no significant differences (P>0.05) in the duration of surgery between the AP and KW group in the treatment of mid-clavicle fractures (SMD=1.19; 95% CI, -0.19-2.57; P=0.09).

Bleeding/blood loss. At the time of the meta-analysis, there were four studies (18,22,24,28) that included the findings of any bleeding associated with the treatments, as shown in Fig. 6. The results revealed that there were no significant differences (P>0.05) in blood loss between the AP and KW group in the treatment of mid-clavicle fractures (SMD=0.10; 95% CI, -3.13-3.32; P=0.95).

Constant function score (6 months). There were three studies found for the comparison of the constant function scores (8,22,25), as shown in Fig. 7. The SMD from the three studies was 1.59 (95% CI, 1.29-1.89; P<0.00001). These results revealed that compared with the KW group, the AP group had a better recovery of function following surgery (P<0.05).

Fracture healing time (weeks). There were five studies available for the comparison of the fracture healing time (16,19,22,24,28), as shown in Fig. 8. The SMD obtained from the analysis of the data from these five studies was -1.48 (95% CI, -2.09 to -0.87; P<0.00001). These results revealed that the AP group had a shorter fracture healing time than the KW group (P<0.05).

Post-operative efficacy assessment. There were nine studies available for the assessment of the post-operative efficacy of the two surgical methods (16,17,20,21,24,28,29,31,33), as shown in Fig. 9. The results revealed that compared with the KW group, the AP group had a better post-operative recovery rate (OR, 4.81; 95% CI, 3.10-7.46; P<0.00001; P<0.05).

Complications. There were 12 studies available on the incidence of post-operative complications between the two surgical methods (8,17-19,22,23,26-28,30-32), as shown in Fig. 10. The results revealed that compared with the KW group, the AP group had a relatively lower incidence of post-operative complications (OR 0.16; 95% CI, 0.05-0.55; P=0.004; P<0.05).

Discussion

Mid-clavicle fractures are the most common fractures of the clavicle. For the treatment of mid-clavicle fractures,

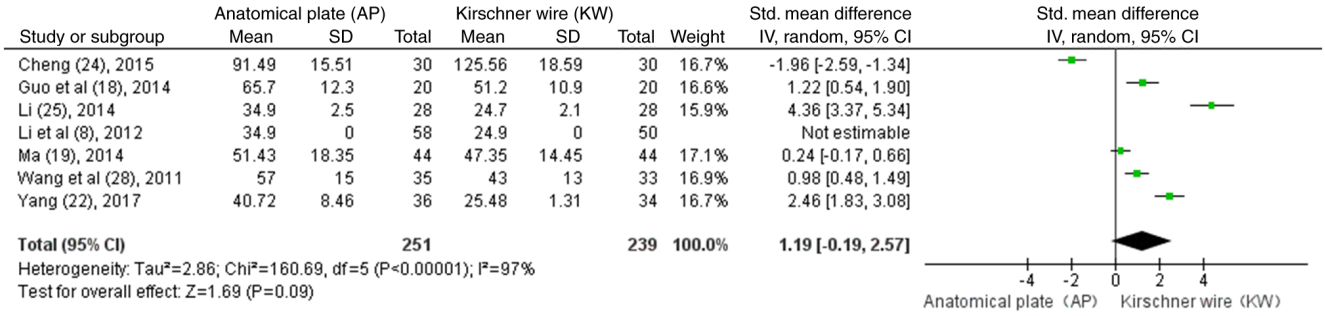

Figure 5. Comparison of duration of surgery between the AP and KW group. The diamond shapes represent the results of statistical analysis. The squares represent the weight of each study, and the horizontal lines represent the 95% confidence intervals for each study. The results revealed that the AP group had no significant advantage over the KW group in the duration of surgery for mid-clavicle fractures. AP, anatomic plate; KW, Kirschner wire.

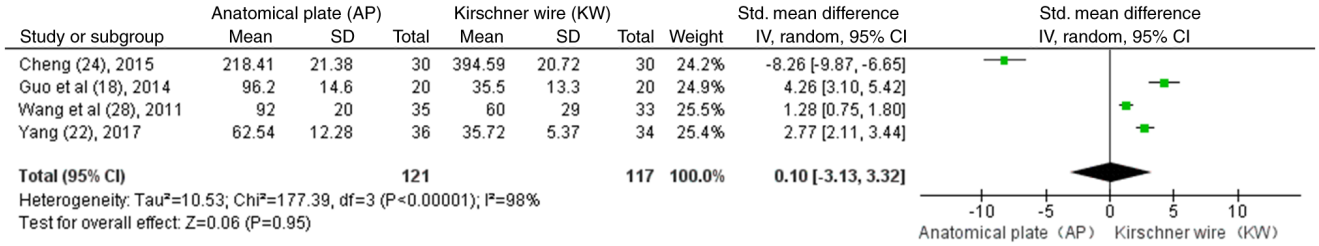

Figure 6. Comparison of blood loss between the AP and KW group. The diamond shapes represent the results of statistical analysis. The squares represent the weight of each study, and the horizontal lines represent the 95% confidence intervals for each study. The results revealed that surgical bleeding was not reduced in the AP group compared with the KW group. AP, anatomic plate; KW, Kirschner wire.

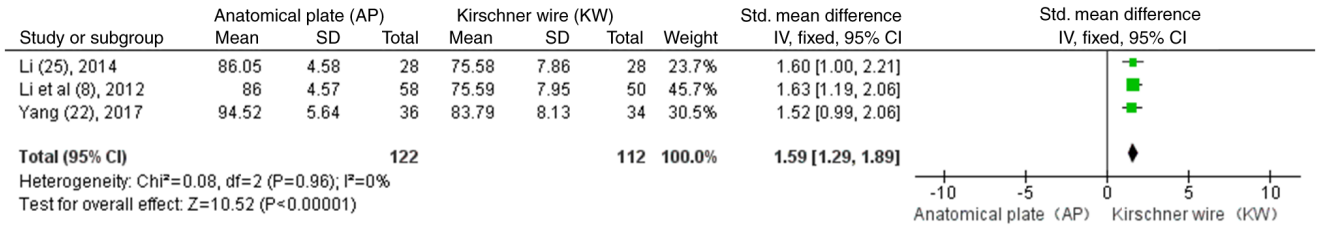

Figure 7. Comparison of constant function scores between the AP and KW group. The diamond shapes represent the results of statistical analysis. The squares represent the weight of each study, and the horizontal lines represent the 95% confidence intervals for each study. The results revealed that the AP group had a better recovery of function than the KW group. AP, anatomic plate; KW, Kirschner wire.

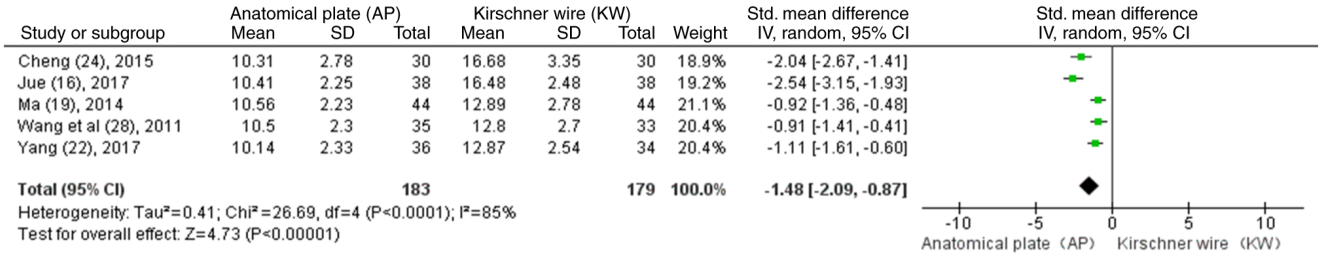

Figure 8. Comparison of fracture healing time between the AP and KW group. The diamond shapes represent the results of statistical analysis. The squares represent the weight of each study, and the horizontal lines represent the 95% confidence intervals for each study. The results revealed that the AP group had a shorter healing time and more rapid recovery than the KW group. AP, anatomic plate; KW, Kirschner wire.

particularly comminuted or unstable fractures, early surgical treatment is crucial for fracture healing and the avoidance of a second surgery. In the present study, through the analysis of the related studies of the treatment of mid-clavicle fractures with AP and KW fixation, it was found that the AP treatment of mid-clavicle fractures was associated with a better fracture healing, a shorter healing time, an improved post-operative function recovery, and the incidence of post-operative complications was significantly reduced compared with the KW group.

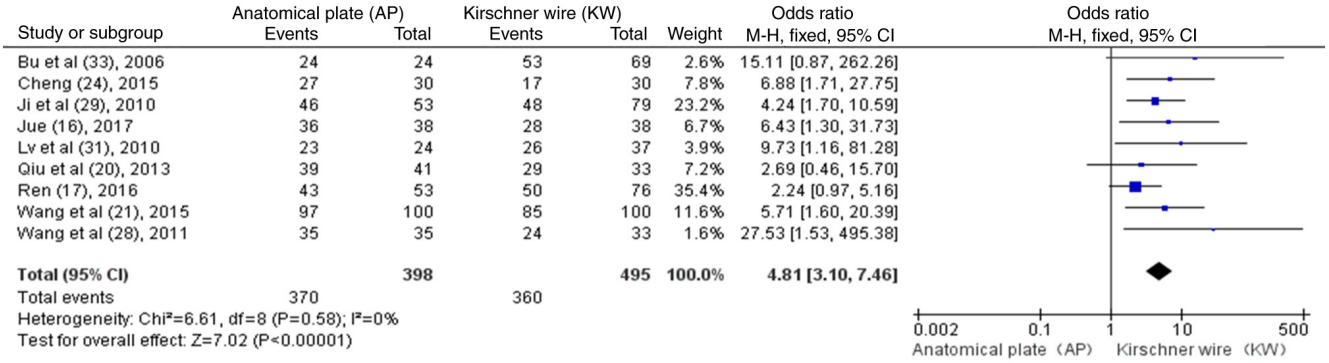

Figure 9. Comparison of post-operative curative effect between the AP and KW group. The diamond shapes represent the results of statistical analysis. The squares represent the weight of each study, and the horizontal lines represent the 95% confidence intervals for each study. The results revealed that the AP group had a better surgical prognosis than the KW group. AP, anatomic plate; KW, Kirschner wire.

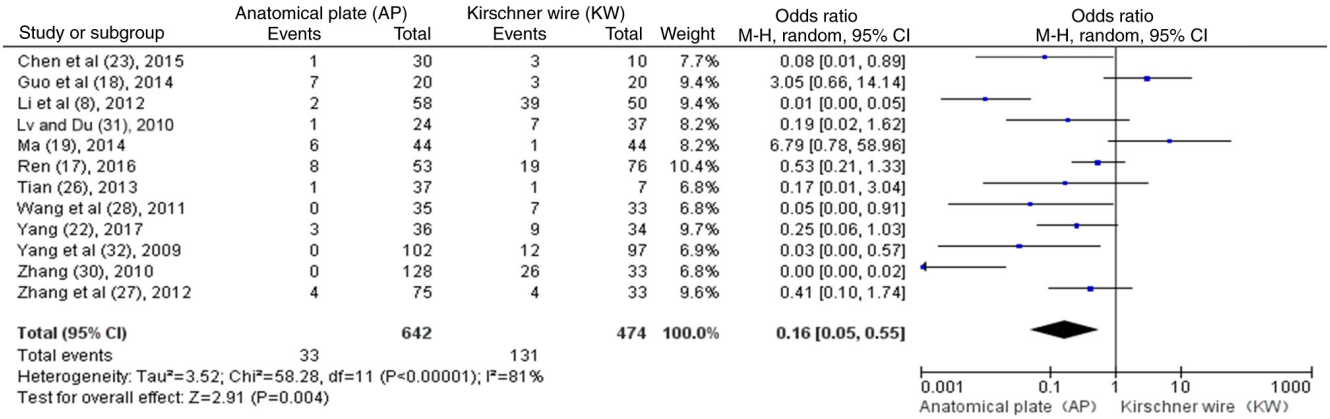

Figure 10. Comparison of the post-operative complication rate between the AP and KW group. The diamond shapes represent the results of statistical analysis. The squares represent the weight of each study, and the horizontal lines represent the 95% confidence intervals for each study. The results revealed that the AP group had fewer surgical complications than the KW group. AP, anatomic plate; KW, Kirschner wire.

The credibility of a meta-analysis is dependent upon the quality of each study included. In the present meta-analysis, 20 Chinese studies were retrieved from the databases searched. Of the included studies, only eight mentioned the randomization of patients, and only two of these mentioned randomizations by number (15,18). However, none of these randomized controlled studies mentioned that participants and treatments were assigned in a blinded manner. None of the studies was prospectively designed for sample size, and the end points of follow-up for each study case were randomized. Therefore, these deficiencies undermine the credibility of the study.

The KW is a commonly used means of internal fixation in clinical practice; however, it has no compression effect on the fracture end, and thus the displacement of the broken end and the occurrence of needle retreats are possible (8). The post-operative movement range of the KW is small, which often requires cervical wrist band fixation, severely affecting early movement. Although the present meta-analysis found that KW fixation had a smaller incision, the straightforward application of KW fixation was found to result in post-operative fracture end displacement, poor healing and a high rate of complications, which severely limit its clinical application. The AP has excellent adhesion and can be attached only with slight molding. It has a large post-operative mobility of the affected limbs and can be used for initial functional exercise and daily activities. However, excessive periosteum dissection can lead to delaying fracture union or bone non-union in order to achieve better adhesion.

The clavicle is the bone support structure connecting the scapula to the trunk. By attaching ligaments and muscles to the clavicle, the shoulder joint can be further stabilized. The state and time of clavicle healing severely affect the early functional movement of the shoulder joint. The present study found that compared with KW fixation, AP fixation has a wider force surface, stronger pressure effect, better resistance to bending stress and rotating force, and a higher biocompatibility. It not only reduces the slippage of internal fixation, but can also rapidly enter the functional training stage of the shoulder joint, which is in accordance with a previous study (29), further reducing the occurrence of periarthritis of the shoulder and joint stiffness.

The incidence of post-operative complications in the AP fixation group was significantly lower than that in the KW fixation group. Common post-operative complications include fixation loosening, Kirschner wire bending, fixation fracture, infection, needle withdrawal, malunion, and nonunion.

However, in the included studies, the studies on postoperative complications were often limited in some aspects, which lead to a certain deviation in the study of postoperative complications in the two groups, and thus reduces the credibility of the meta-analysis.

By this meta-analysis, it was concluded that AP fixation is significantly superior to KW fixation in a number of aspects; however, there are some limitations that should be taken into account. First of all, the time of fracture, age, screw type, operative years, post-operative bandage fixation time, time to start functional exercise and other factors for each study should be considered; in addition, the consideration of post-operative aesthetics and economic issues should also be considered. Despite these limitations, the present study, to the best of our knowledge, is the first to provide a comprehensive clinical basis for comparing AP and KW fixation for the treatment of mid-clavicle fractures, providing a more valuable theoretical basis for clinical practice. The present study also had some limitations; it could not independently analyze the use of the two materials for common and complex clavicle fractures. In future studies, the authors aim to separately perform the comparison of the two surgical methods (AP and KW) for closed or open clavicle fractures, so as to further reduce the errors caused by the complexity of the surgical methods, affecting the credibility of the study.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Authors' contributions

The title selection and design of the study were completed by DY and JZ. The retrieval, data extraction and analysis of the study were completed by all authors (DY, JZ and LW). The writing of the manuscript was completed by DY. The editing and revision of the manuscript was completed by JZ. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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