Arthroscopy-Assisted Reduction Percutaneous Internal Fixation Versus Open Reduction Internal Fixation for Tibial Plateau Fracture

A Systematic Review and Meta-analysis

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Background: Arthroscopy-assisted reduction percutaneous internal fixation (ARIF) has emerged recently as an alternative treatment method in treating lower-energy tibial plateau fractures. To date, the comparison of clinical efficacy between ARIF and open reduction internal fixation (ORIF) is limited, with divergent conclusions.

Purpose: To review studies on the clinical efficacy of ARIF and ORIF in the treatment of tibial plateau fracture.

Study Design: Systematic review; Level of evidence, 3.

Methods: A search was conducted using the PubMed, Web of Science, Cochrane Library, and EMBASE databases between inception and August 20, 2020, for retrospective and prospective studies evaluating ARIF versus ORIF in the treatment of tibial plateau fracture. We identified 6 clinical studies that met the inclusion criteria, with 231 patients treated with ARIF and 386 patients treated with ORIF. The risk of bias and the quality of evidence of the included studies were assessed. The 2 treatment types were compared in terms of clinical results and complications by using odds ratios (ORs), mean differences (MDs), or standardized mean differences (SMDs), with 95% confidence intervals (CIs). Heterogeneity among studies was quantified using the I^2 statistic.

Results: The quality of the studies was high. Compared with ORIF, treatment with ARIF led to better clinical function (SMD = 0.31; 95% CI, 0.14 to 0.48; $I^2 = 15\%$; $P = .0005$), shorter hospital stay (MD = –2.37; 95% CI, –2.92 to –1.81; $I^2 = 0\%$; $P < .001$), and more intra-articular lesions found intraoperatively (OR = 3.76; 95% CI, 1.49 to 9.49; $I^2 = 66\%$; $P = .005$). There were no complications or significant differences between the techniques in the radiological evaluation of reduction.

Conclusion: Compared with ORIF, the ARIF technique for tibial plateau fractures led to faster postoperative recovery and better clinical function and the ability to find and treat more intra-articular lesions during the operation. However, the radiological evaluation of reduction and complications were not significantly different between the 2 groups.

Keywords: arthroscopy-assisted reduction percutaneous internal fixation (ARIF); open reduction internal fixation (ORIF); tibial plateau fracture; clinical function; faster recovery; intra-articular lesions; meta-analysis

Tibial plateau fractures, which are typically caused by high-energy trauma or osteoporosis in older adults, comprise approximately 1% of all fractures,[2,4,5] and many different surgical techniques and approaches have been described for the management of tibial plateau fractures.[18,42] There are 2 principles in the treatment of tibial plateau fractures: one is the anatomic reduction of the articular surface and reconstruction of the mechanical axis of the lower limb, and the other is to reconstruct the stability of the injured knee joint. Tibial plateau fractures are usually classified using Schatzker type (I-VI) or the 3-column system.[25,33] Traditionally, although displaced tibial plateau fractures are treated with open reduction internal

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fixation (ORIF), many surgical approaches and techniques have been developed,[37] such as the anterolateral approach and posteromedial inverted L-shape approach. However, complications after ORIF, such as infections, hematoma formation, surgical wound dehiscence, and knee stiffness, are common.[12,13]

Recently, arthroscopy-assisted reduction percutaneous internal fixation (ARIF) has emerged as an alternative treatment method in treating lower-energy tibial plateau fractures. ARIF was first reported by Caspari et al[3] and Jennings[17] in patients with fractures of Schatzker types I to III. This method has the advantage of the minimally invasive operation damage without violating the intra-articular structures and the treatment of additional intra-articular lesions. A large number of studies have reported the satisfactory clinical and radiological results of ARIF in treating tibial plateau fracture.[6,31,34] Thus, it seems ARIF has advantages in the treatment of tibial plateau fracture; however, there has been little published meta-analysis of the comparison between ARIF and ORIF in tibial plateau fracture.[40]

Since the differences between ARIF and ORIF in tibial plateau fracture were not very clear, this up-to-date meta-analysis study aimed to compare functional and radiological results, complication rates, and other clinical measurements of ARIF with those of traditional ORIF in the treatment of tibial plateau fractures. We hypothesized that ARIF would have a lower complication rate, faster postoperative recovery, and better functional and radiological results.

METHODS

Search Strategy and Article Selection

A systematic search of the literature was performed on August 20, 2020, in the PubMed, Web of Science, Cochrane Library, and EMBASE databases with the following search string: ((tibial plateau fracture OR tibial platform fracture) AND (arthroscopy OR arthroscopic OR ARIF) AND (open OR operation OR surgery OR ORIF)). We supplemented the electronic database examination by searching the reference lists of selected articles manually. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed.[26] The article selection process was performed independently by 2 authors (L.J., E.C.). Any disagreement in the selection was resolved by consensus or by the intervention of a third author (L.H.).

Eligibility Criteria

The inclusion criteria were the following: (1) clinical studies comparing ARIF versus ORIF in treating acute tibial plateau fracture (3 weeks from injury to surgery), including randomized controlled trials (RCTs), cohort studies, and case-control studies; (2) published in English; (3) included functional outcomes; (4) follow-up time >12 months; and (5) full text of studies available. The exclusion criteria were the following: (1) letters, comments, case reports, reviews, animal studies, cadaveric studies, biomechanical studies, and study protocols; (2) only abstract available; (3) chronic tibial plateau fracture (3 weeks after trauma); and (4) duplicated studies and data.

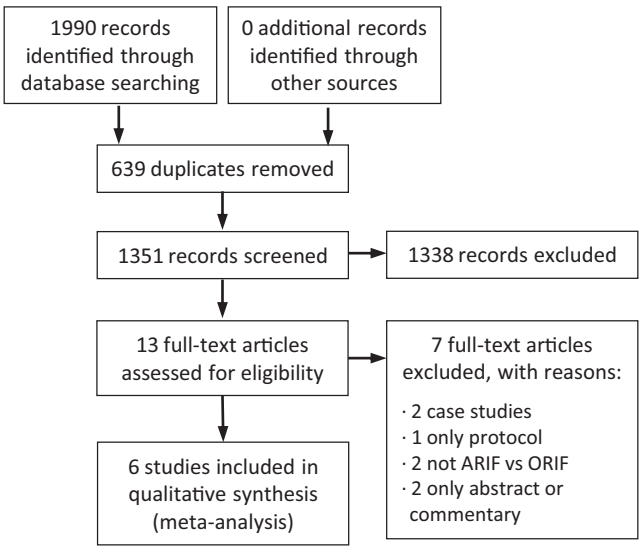

Figure 1. Flow diagram based on the PRISMA (Preferred Reporting Items for Systematic Meta-Analyses) guidelines outlining the literature search, screening, and review. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; ORIF, open reduction internal fixation.

The database search resulted in 1990 records, 639 of which were duplicates. Of the remaining 1351 articles, after the title and abstract screening, 13 articles remained eligible for full-text screening. From these studies, 5 retrospective case-control studies and 1 prospective RCT met the inclusion criteria.[8,11,22,27,39,41] Figure 1 shows the flowchart of study inclusion.

Data Assessment

An electronic piloted form was created for data extraction. Data including study design, sample size, length of follow-up, patient sex and age at surgery, Schatzker tibial plateau fracture classification, hospital stay, and functional outcome parameters were extracted. The functional outcomes were evaluated in terms of the Rasmussen clinical score,[30] Knee Society Score (KSS),[16] Hohl and Delamarter scoring system, and Hospital for Special Surgery (HSS) score.[29] In addition, associated intra-articular injuries and complications as defined in each study were collected. Radiological outcomes were evaluated using the Rasmussen radiological score (excellent = 18, good = 12-17, fair = 6-11, and poor = 0-5),[30] in which the comparison was made using either the point score or the percentage of cases graded as excellent/good versus fair/poor, as provided.

Assessment of Risk of Bias and Quality of Evidence

The risk of bias for RCTs was assessed using the revised Cochrane risk-of-bias tool for randomized trials (RoB 2.0).[36] The overall quality of evidence for retrospective case-control

TABLE 1
Study Characteristics[a]

First Author (year)	Study Design	Sample Size, ARIF/ORIF	Sex, M/F	Age, y	Follow-up, mo	Schatzker Classification, I/II/III/IV/V/VI	Quality Score[b]
Verona (2019)[39]	Case-control	19/21	21/19	48 ± 16	41.95 ± 28.85	5/16/19/0/0/0	9 (good)
Elabjer (2017)[11]	RCT	40/35	58/17	47	13.5	19/33/23/0/0/0	Low risk of bias
Ohdera (2003)[27]	Case-control	19/9	9/19	48	31.5	0/15/13/0/0/0	7 (good)
Dall'oca (2012)[8]	Case-control	50/50	54/46	51	73 ± 27	14/12/44/8/0/0	9 (good)
Wang (2017)[41]	Case-control	26/31	36/21	46	44 ± 11.8	9/28/12/8/12/10	8 (good)
Le Baron (2019)[22]	Case-control	77/240	186/131	48 ± 14	38 ± 23	76/173/68/0/0/0	9 (good)

[a]Data are presented in M ± SD. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; ORIF, open reduction internal fixation; RCT, randomized controlled trial.

[b]Study quality was assessed with the Newcastle-Ottawa Scale for case-control studies (good, fair, or poor) and the revised Cochrane risk-of-bias tool for randomized trials (low or high risk of bias).

studies or prospective cohort studies was graded according to the Newcastle-Ottawa Scale (NOS) guidelines.[24] All assessments were checked by 2 reviewers (L.J., C.W.), and any disagreements were resolved via discussion or the involvement of a third author (E.C.).

Statistical Analysis

Statistical analysis was performed using RevMan Version 5.3.5 (Cochrane Community) for outcome measurements. Estimations of the overall results are shown as forest plots. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for dichotomous outcomes, and mean differences (MDs) with 95% CIs were used for continuous outcomes. When the same outcome was measured using different scales or the same data were calculated with either dichotomous or continuous outcomes, the standardized mean difference (SMD) was calculated. Heterogeneity among studies was quantified using the I^2 statistic, and substantial heterogeneity was represented by an I^2 value >50%. Random-effects models were used when significant heterogeneity was detected in the meta-analysis; otherwise, fixed-effects models were used. $P < .05$ was considered statistically significant.

RESULTS

Study Characteristics

The quality of evidence for the 5 case-control studies was considered good according to the NOS, and the risk of bias of the RCT was considered low according to RoB 2.0. All studies were of high quality. Individual study characteristics are provided in Table 1. Among the 6 studies, a total of 617 patients participated (231 in the ARIF group, 386 in the ORIF group) with a follow-up rate of 100% and a frequency weighted mean follow-up time of 41.4 months (range, 12-116 months). The frequency-weighted mean age of participants was 48.4 years (range, 13-77 years); 364 were male and 253 were female. According to the Schatzker tibial plateau fracture classification, there were 123 cases of type I, 277 of type II, 179 of type III, 16 of type IV, 12 of type V, and 10 of type VI. The interval from injury to surgery was <3 weeks.

Functional Outcomes

The Rasmussen clinical assessment score was used in 3 studies[8,11,41]; the HSS score, in 1 study[22]; the Hohl and Delamarter score, in 1 study[27]; and the KSS, in 1 study.[39] The results indicated statistically significantly better postoperative functional outcomes for patients treated with ARIF compared with ORIF (SMD = 0.31; 95% CI, 0.14-0.48; $I^2 = 15\%$; $P = .0005$) (Figure 2).

Regarding the Rasmussen radiological evaluation, the point score was reported in 4 studies comprising 135 patients with ARIF and 137 patients with ORIF[8,11,39,41] and ranged from 10 to 18. The mean score was 12.04 in the ARIF group and 11.79 in the ORIF group, with no statistically significant difference between groups (MD = 0.18; 95% CI, –0.30 to 0.66; $I^2 = 46\%$; $P = .46$) (Figure 3). The Rasmussen evaluation was reported as a grade in 5 studies comprising 181 patients with ARIF and 336 patients with ORIF.[11,22,27,39,41] The percentage of fracture reductions graded as excellent/good was 86.2% in the ARIF and 81.3% in the ORIF group, with no significant between-group difference (OR = 1.38; 95% CI, 0.81 to 2.34; $I^2 = 0\%$; $P = .23$) (Figure 4).

Other Clinical Results

Associated intra-articular injuries found intraoperatively were reported in 5 studies,[8,11,27,39,41] of which 154 cases were patients with ARIF and 146 cases were patients with ORIF. Intra-articular injuries included meniscal tear, chondral damage, and ligament rupture. The rate of intra-articular injuries found was 65.6% in the ARIF group and 37.7% in the ORIF group, which was statistically significantly higher in favor of the ARIF technique (OR = 3.76; 95% CI, 1.49-9.49; $I^2 = 66\%$; $P = .005$) (Figure 5). The intra-articular injuries were treated simultaneously using fracture management in all reports.

Hospital stay was reported in 2 studies comprising 59 patients with ARIF and 56 patients with ORIF.[11,39] The mean hospital stay in the ARIF group was 3.37 days as

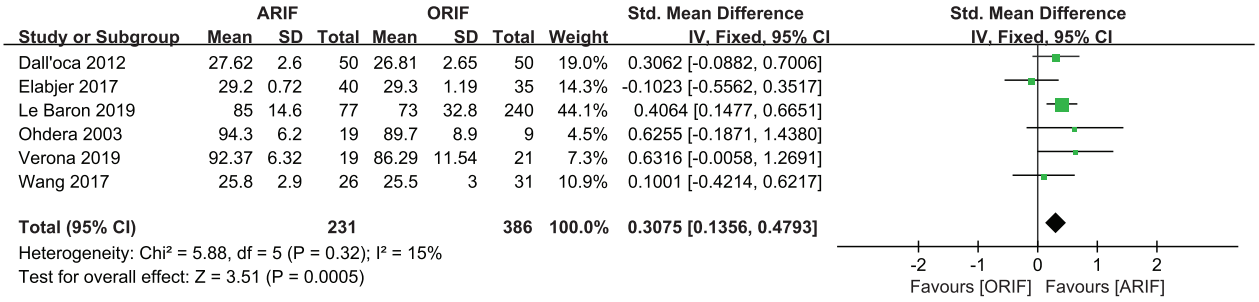

Figure 2. Forest plot of postoperative patients' clinical functional score. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; IV, inverse variance; ORIF, open reduction internal fixation. Std., standard deviation.

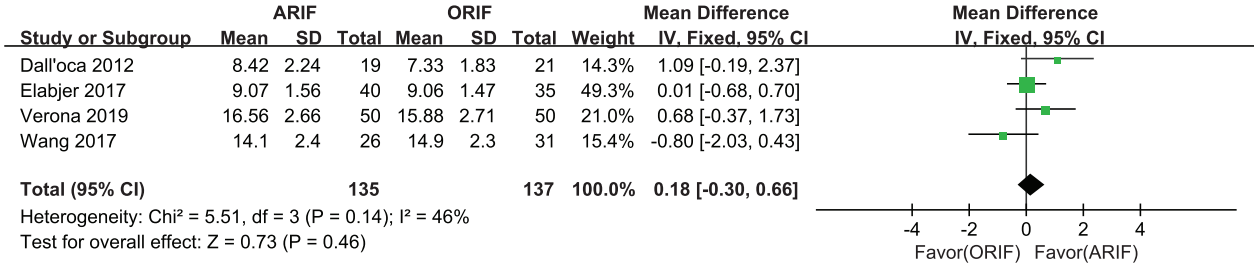

Figure 3. Forest plot of postoperative patients' Rasmussen radiological score. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; IV, inverse variance; ORIF, open reduction internal fixation.

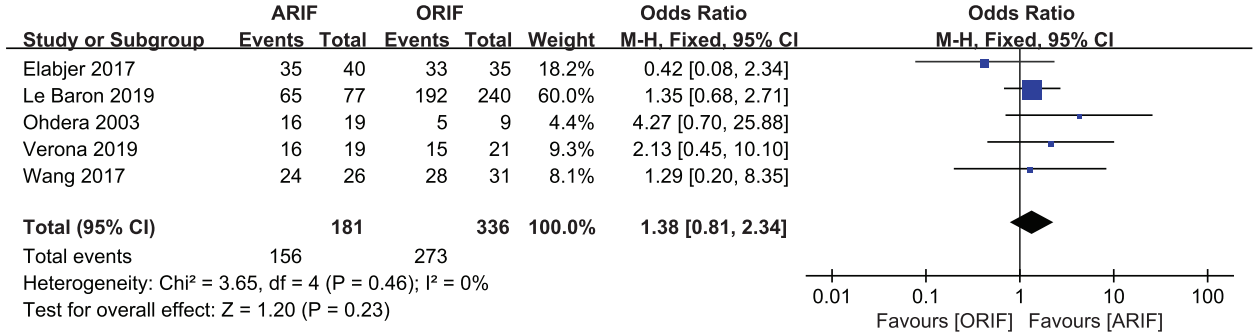

Figure 4. Forest plot of postoperative patients' Rasmussen radiological evaluation. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; M-H, Mantel-Haenszel; ORIF, open reduction internal fixation.

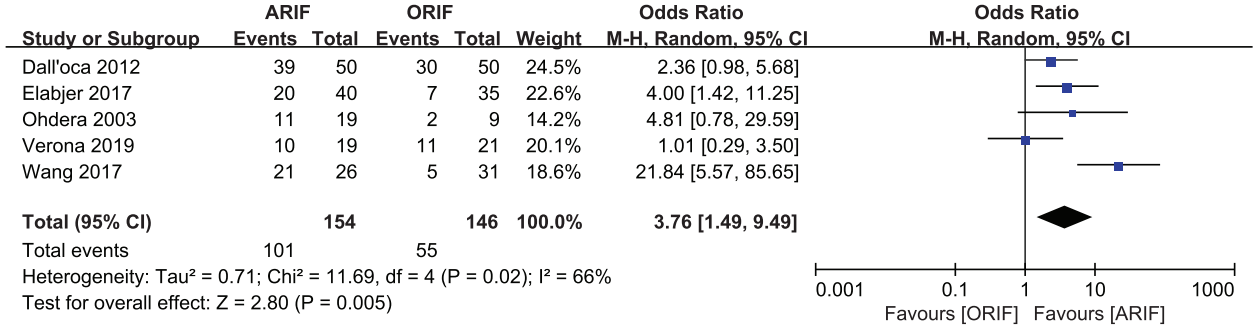

Figure 5. Forest plot of rate of associated intra-articular injuries found intraoperatively. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; M-H, Mantel-Haenszel; ORIF, open reduction internal fixation.

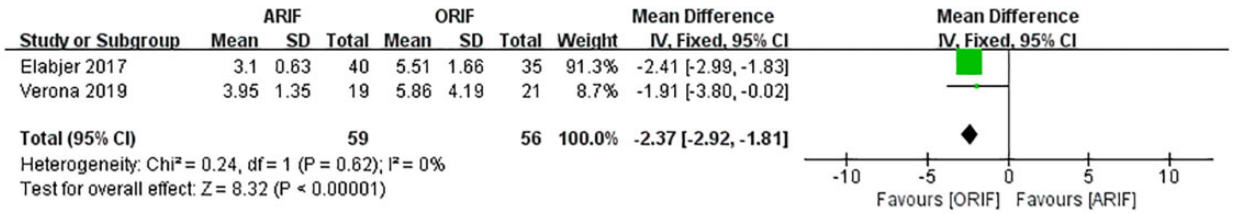

Figure 6. Forest plot of postoperative patients' hospital stay. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; IV, inverse variance; ORIF, open reduction internal fixation.

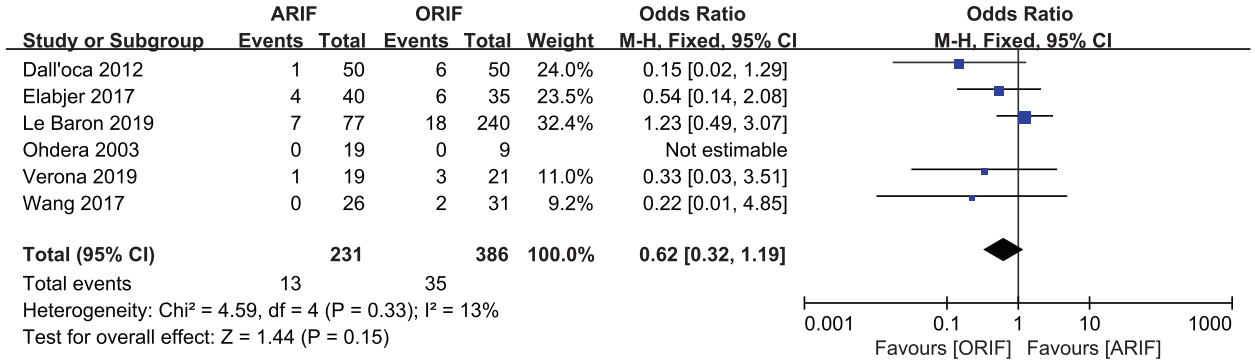

Figure 7. Forest plot of postoperative patients' complications. ARIF, arthroscopy-assisted reduction percutaneous internal fixation; M-H, Mantel-Haenszel; ORIF, open reduction internal fixation.

opposed to 5.64 days in the ORIF group. There was a statistically significant difference in favor of the ARIF technique (MD, –2.37; 95% CI, –2.92 to –1.81; $I^2 = 0\%$; $P < .001$) (Figure 6).

Complications

Complications were reported in all 6 studies.[8,11,22,27,39,41] The reported complication rate for the patients in the ARIF group was 5.6%, with 9.1% for the ORIF group. There was no statistically significant difference between the 2 groups (OR, 0.62; 95% CI, 0.32-1.19; $I^2 = 13\%$; $P = .15$), but the ARIF group showed lower complication rates compared with the ORIF group (Figure 7).

DISCUSSION

In this comprehensive meta-analysis, ARIF provided better clinical function and shorter hospital stays for patients and led to more intra-articular lesions found intraoperatively compared with ORIF. However, the fracture reduction evaluation and postoperative complication rate for ARIF and ORIF were similar.

There has been a limited number of published meta-analyses about ARIF compared with ORIF in treating tibial plateau fracture. Wang et al[40] reported their meta-analysis about ARIF and ORIF in 2018, but all trials included in their meta-analysis were conducted in China with small sample sizes, lacked diversity, and were written in Chinese. Thus, the results suggested in their meta-analysis, that the clinical function of ARIF is superior to that of ORIF and that the risk of perioperative complications in the ARIF group is statistically significantly lower than in the ORIF group, may not be conclusive. ARIF has features allowing minimally invasive operation damage without violating the intra-articular structures,[1,38] which could maintain the integrity of the lateral knee capsule. Further, avoidance of meniscal detachment preserves maximum function of the affected knees. According to the results of our meta-analysis, ARIF treatment in tibial plateau fracture could significantly shorten hospital stay, which means ARIF could promote patient recovery more than could the traditional ORIF technique. Although the radiological evaluation was similar between the 2 groups, patients in the ARIF group recovered from the operation more quickly and had better clinical function because of the minimally invasive damage during the operation.

A number of studies have demonstrated satisfactory short-term functional and radiological results of ARIF in the treatment of tibial plateau fracture.[8,7,9,19,23,32] There was no need to perform arthrotomy—a process that may induce stiffness, proprioceptive disorder, severe postoperative pain, and scar-related complications—during the operation.[15,32] As ARIF could avoid these drawbacks, it might have advantages in the functional recovery of patients. Tibial plateau fractures are often associated with intra-articular lesions such as chondral damage, meniscal tear, and ligament rupture.[2,28,35] ARIF allows the surgeon to treat additional intra-articular lesions,[21] which are easy to miss during the operation according to our meta-analysis results (65.6% vs 37.7%). A significant difference

in intra-articular lesions between the ARIF and the ORIF group was found. Arthroscopy helped find and manage intra-articular injury during the operation. Finding intra-articular injuries during treatment for tibial plateau fracture is important. If a meniscal tear exists, we could perform a meniscal repair; if chondral damage exists, we could remove cartilage fragments from the articular space; and if anterior cruciate ligament or posterior cruciate ligament injury exists, the patient may need a brace and a second-stage operation. In ORIF, we may not recognize the details of these injuries and thus miss treatment opportunities. Thus, the advantages of ARIF in tibial plateau fracture are not only the minimally invasive damage during, and faster patient recovery after, the operation but also the treatment of additional intra-articular lesions during the operation.

The ARIF technique is used most commonly in the treatment of Schatzker types I to III tibial plateau fractures because complex tibial plateau fractures such as Schatzker types V to VI fracture are difficult to visualize using the arthroscopy monitor.[10] Schatzker types I to III fractures involve the lateral tibial plateau and have been treated traditionally with ORIF via an anterolateral approach.[37] Herbort et al[14] identified complex tibial plateau fracture as a contraindication for ARIF because of the high risk of iatrogenic compartment syndrome secondary to irrigation fluid extravasation. However, Krause et al[20] reported using "open fracturoscopy" compared with fluoroscopy to analyze the anatomic accuracy of fracture reduction in complex tibial plateau fractures (AO/OTA 41-C type fracture) during the operation. This latter study showed that subsequent "fracturoscopy" could find persistent fracture depression ($\geq$2 mm; fracturoscopy group) with the need for intraoperative correction in most cases, meaning that ARIF also could have value in the treatment of complex tibial plateau fracture by the method of open fracturoscopy. Our meta-analysis included a total of 617 patients; of these, only 38 were in the complex tibial fracture category (types IV-VI). Wang et al[41] reported 8 cases of type IV, 12 of type V, and 10 of type VI, and Dall'oca et al[8] reported 8 cases of type IV but used the ARIF technique only in selected cases where a low degree of comminution was present, which could be recognized as a simple fracture. Overall, ARIF is currently used mostly in simple tibial plateau fracture, and there are still difficulties with ARIF use in complex tibial plateau fracture; however, open fracturoscopy may offer a new method of arthroscopy in the treatment of tibial plateau fracture.

The present study has several limitations and potential biases. First, only 6 studies with 617 patients were included; the limited number of studies and small sample size might reduce the precision of the pooled results. Second, there was only 1 RCT, which might reduce the strength of evidence.[11] Most of the reviewed studies were retrospective, so there may be a selection bias, with ARIF being chosen for less comminuted or less displaced fractures. Third, different clinical functional scores were used in these studies; the most commonly used method was the Rasmussen radiological score, and it was only used in 5 studies.[8,11,22,39,41] Other clinical outcomes were only included in 2 to 4 studies. The comparison of these 2 groups needs more consistent measurement methods. Fourth, these studies did not pay much attention to the advantages of ARIF of a minimally invasive operation and fast patient recovery from surgery. Hospital stay was reported in 2 studies,[11,39] and full weightbearing was reported in only 1 study.[27] Finally, the follow-up duration of the included studies was varied, and more clinical studies with long-term follow-up are required.

CONCLUSION

This meta-analysis demonstrated that the most important value of ARIF might be the faster postoperative recovery and better clinical function for patients, as well as the ability to find and treat additional intra-articular lesions during the operation. There were also fewer complications with the ARIF technique compared with ORIF, although this difference was not statistically significant. Thus, the current literature supports the view that ARIF is a beneficial and safe treatment method in tibial plateau fracture. However, more high-level evidence research should be carried out, and ARIF use in complex tibial plateau fracture should be explored further.

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