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ARTHROSCOPIC-ASSISTED REDUCTION INTERNAL FIXATION *VS.* OPEN REDUCTION INTERNAL FIXATION OF TIBIAL PLATEAU FRACTURES: A SYSTEMATIC REVIEW OF THE LAST TEN YEARS

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ABSTRACT – *Objective:* Tibial plateau fractures involve the articular surface and metaphysis of the proximal tibia, and they can result from high-energy trauma in young individuals or minor injuries in elderly patients with osteoporosis. Arthroscopy-assisted reduction internal fixation (ARIF) has emerged as a recent alternative to open reduction internal fixation (ORIF).

Materials and Methods: A systematic review of scientific articles indexed in medical databases (such as PubMed and Scopus) was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. Inclusion criteria encompassed clinical studies comparing ARIF *vs.* ORIF for tibial plateau fracture management, published within the last decade. The review included randomized controlled trials, case-control studies, and cohort studies. Data extraction was performed *via* an electronic form, with authors independently extracting information from the selected studies.

Results: Of the 146 articles identified through literature research, 127 were deemed ineligible and were subsequently excluded. Following a full-text review of 18 articles, only 5 studies met the criteria for inclusion in the systematic review. All included studies were assessed to be of high quality. Comparative retrospective designs were employed in four studies, while one study utilized a prospective design. Various assessment tools were utilized across the studies, including Rasmussen scores, the Knee Society Score (KSS), the International Knee Documentation Committee (IKDC), and the Hospital for Special Surgery (HSS). Radiographic data comparison was conducted in three studies. Common complications included infection, knee stiffness, deep vein thrombosis, and intolerance to plates and screws. Finally, the findings suggest that the ARIF technique may contribute to shorter hospital stays following tibial fracture treatment.

Conclusions: Both ARIF and ORIF procedures have demonstrated favorable clinical and radiological outcomes in managing tibial plateau fractures. However, ARIF procedures have exhibited superior results in specific tibial plateau fracture cases, along with a reduction in hospitalization duration.

KEYWORDS: Arthroscopy, Open, Tibia, Tibial plateau, Fracture, Orthopedics, Surgery.

ABBREVIATIONS: ARIF: Arthroscopy-assisted reduction internal fixation; ORIF: Open reduction internal fixation; MCL: Medial collateral ligament; LCL: Lateral collateral ligament; ACL: Anterior cruciate ligament; PCL: Posterior cruciate ligament; KSS: Knee Society Score; IKDC: International Knee Documentation Committee; HSS: Hospital for Special Surgery; NOS: Newcastle-Ottawa Scale; PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analysis; MRI: Magnetic resonance imaging; OTA: Orthopedic Trauma Association

INTRODUCTION

Arthroscopy-assisted reduction internal fixation (ARIF) has recently emerged as an alternative method to open reduction internal fixation (ORIF)[1-3]. This procedure has the advantage of achieving less surgical invasiveness through percutaneous fixation, better diagnosis of fracture patterns, anatomic reduction of the joint surface, and treatment of additional intra-articular lesions[4,5]. The arthroscopic-assisted procedure has also been associated with decreased length of hospital stays, faster weight bearing, and a shorter postoperative rehabilitation time[5-7]. Disadvantages of the ARIF procedure include longer operative times, fluid extravasation into the limb, higher cost, and less rigid fixation with percutaneous techniques[8-10]. ARIF may be more effective in Schatzker types I, II, and III fractures or fractures with significant soft tissue injury, while comminuted fractures and Schatzker types IV to VI are generally not recommended for arthroscopic treatment due to an increased risk of compartment syndrome, operation time, loss of detached cartilage fragments due to joint distension, and incidence of infection[11]. Some authors[5] believe arthroscopic-assisted reduction with plate fixation may improve the quality of articular fracture reduction and offer a good alternative to large open arthrotomy incisions required with ORIF for treating Schatzker type IV, V, and VI fractures.

Various studies[1,12-14] have reported satisfactory clinical and radiological outcomes of ARIF in the treatment of tibial plateau fracture. This study hypothesizes that treatment with the ARIF procedure would yield better functional and radiological results and a lower complication rate than ORIF[10]. The aim of this study is to provide a thorough comparison of the ARIF and ORIF techniques to help guide surgeons in their clinical practice when facing tibial plateau fractures[4].

MATERIALS AND METHODS

Search Strategy

A systematic review of scientific articles listed in medical databases (PubMed, Scopus) was performed following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines[15] (Figure 1) from January to May 2024. Search terms were utilized and adapted for each database to obtain the most accurate results. The search for relevant articles was conducted using the following keywords: [“Tibial plateau fracture” OR “Tibial platform fracture”] AND [“arthroscopy” OR “arthroscopic procedure” OR “Arthroscopy-assisted reduction internal fixation” OR “ARIF”] OR [“Osteosynthesis” OR “Open surgery” OR “Open reduction and internal fixation” OR “ORIF”]. Articles were identified by combining two concepts with the operator “AND”. A manual search, using references of included manuscripts, was conducted to identify additional articles. Authors (FRE and RC) screened titles and abstracts according to our inclusion and exclusion criteria. Any disagreement was resolved by the intervention of a third author (PR). The search was restricted to English language literature.

Inclusion and Exclusion Criteria

The inclusion criteria were clinical studies comparing ARIF *vs.* ORIF for the treatment of tibial plateau fractures published in the last ten years, considering the fast development of techniques for tibial plateau fracture reduction and fixation. The research included randomized controlled trials, case-control studies, and cohort studies. Original scientific articles were included if they reported the functional evaluation of the treatment of tibial plateau fractures and at least one of the following outcome variables: radiological results, complications and adverse events, failure of the procedure, and associated intra-articular injuries. Original articles with only the abstract available, duplicated data, studies on patients with previous tibial plateau fractures, patients with significant pre-existing degenerative joint disease or

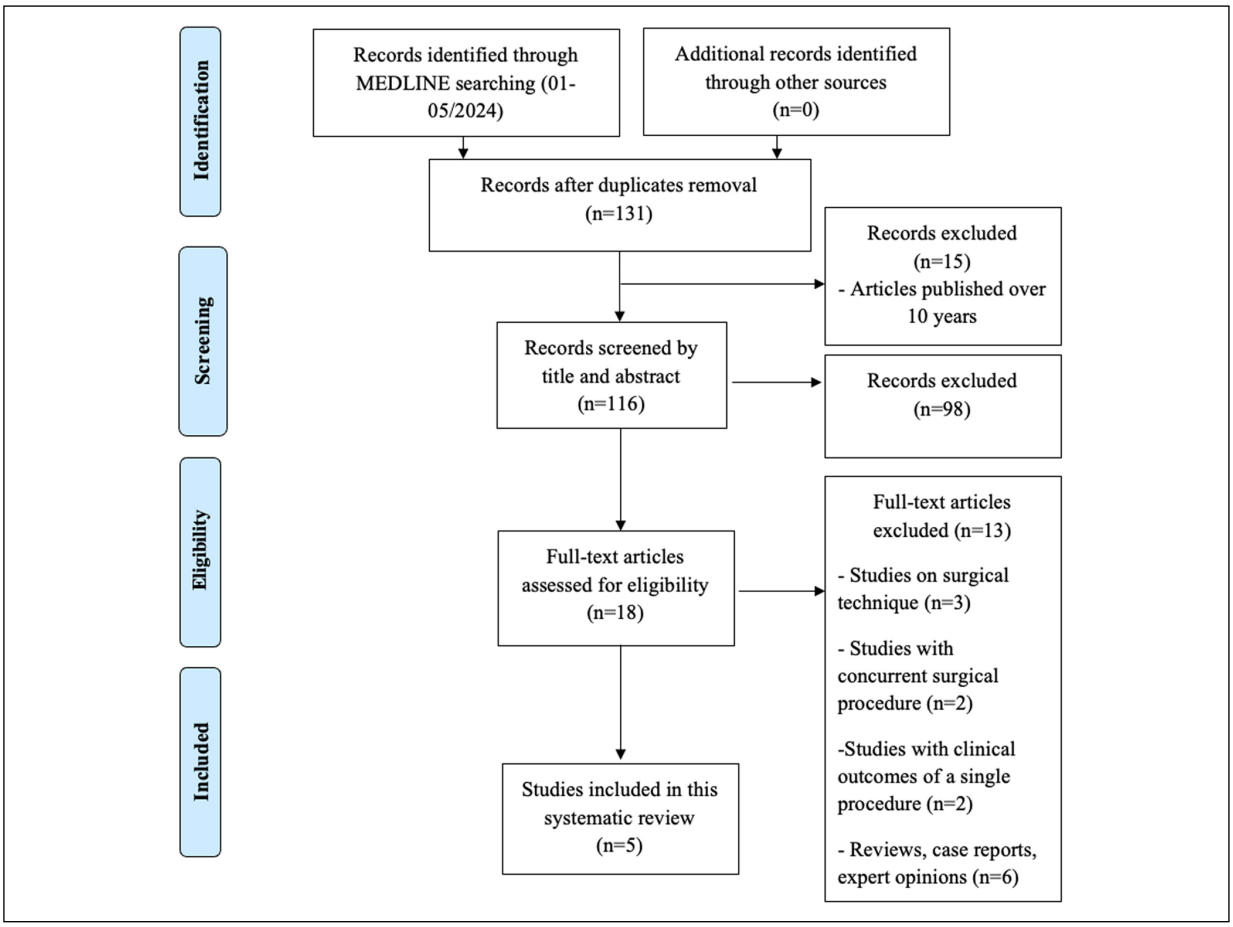

Figure 1. Flowchart of the studies' inclusion in the review.

severe neurological diseases, patients treated conservatively, patients unable to follow the post-surgery rehabilitation protocol, biomechanical or anatomical studies, studies on surgical technique, research on cadavers, reviews, letters, comments, case reports, study protocols, or other study designs were excluded. Studies with concurrent surgical procedures were excluded because these could affect the postoperative clinical scores. All full texts were independently reviewed by authors for the final decision.

Risk of Bias

Full-text articles were reviewed to identify clinical studies that met the inclusion criteria. Each article was assigned a level of evidence using the Oxford Centre for Evidence-Based Medicine guidelines[16] and was assessed using the Cochrane Collaboration's tool[17] for the risk of bias in randomized trials and according to the Newcastle-Ottawa Scale (NOS) guidelines[18] for case-control and cohort studies. The evaluation of any bias was performed by two authors (FRE and RC); if any disagreement occurred, both authors discussed them to reach the final decision.

Data Extraction

An electronic form was created for data extraction. The authors independently extracted data from the included studies in this research. Potentially duplicated data from the research were verified using authors' names and places of recruitment; only the study with the longest follow-up was considered to prevent the overlapping of patients. Any disagreement was resolved through discussion and consensus among authors. The information retrieved from the reports included the first author's name, study design, patient demographics, and clinical data (number of patients, mean age, sex, Schatzker classi-

fication, previous surgical procedures), type of treatment (ARIF or ORIF), fixation technique (screw or plate), use of bone graft, clinical and radiological evaluation scale used (Rasmussen clinical score, Knee Society Score – KSS, International Knee Documentation Committee score – IKDC, the Hospital for Special Surgery score – HSS), clinical results, range of motion (ROM) of the operated knee, radiological outcome, pre-operative arthritis (according to Kellgren-Lawrence criteria), post-operative complications or adverse events, length of follow-up, operative time, functional recovery of patients, failure cause and rate, patient's hospital length of stay, rate of associated intra-articular injuries found during the surgical procedure, prevalence of secondary arthritis. The primary outcome was to evaluate clinical results using the knee function scale. Secondary outcomes were to compare complications and failure rates, radiological assessment of osteoarthritis, the rate of associated intra-articular injuries found intraoperatively, and the patient's mean hospital stay.

RESULTS

Search Results

Of the 146 articles obtained through literature research, 127 did not meet the eligibility criteria and were excluded; 18 articles underwent full-text review and only five studies[6,12,19-21] were included in the systematic review.

Study and Patient Characteristics

The characteristics of the studies included in this review are summarized in Table 1. Four studies[6,12,19,21] were comparative retrospective studies and only one[20] was a prospective study. The number of patients included in the studies ranged from 40 to 317, with a total number of 557 participants, 349 male and 228 female. According to the Schatzker tibial plateau classification[22], there were 35 cases of type I, 97 of type II, 59 of type III, and 4 of type IV treated with ARIF procedure; instead, 76 Schatzker type I, 193 type II, 89 type III and 4 type IV were treated with ORIF technique. The typology of bone grafts used to fill the bone defect varied among studies. The method of fixation used during the ARIF procedure was cannulated screws in four studies[6,12,19,20] and a plate in only one study[21]; in all ORIF procedures, a plate was used for fracture fixation.

Clinical Evaluation

The clinical outcomes of the studies are summarized in Table 2. Rasmussen scores, Knee Society Score (KSS), International Knee Documentation Committee (IKDC), and Hospital for Special Surgery (HSS) scores were each reported in 2[12,21] out of 5 studies, while the Lysholm score was reported in only one study[6]. In three studies[12,20,21], there was no statistically significant difference in average clinical scores between the two groups. However, Verona et al[19] and Le Baron et al[6] demonstrated that ARIF led to better results than ORIF. Verona et al[19] showed a correlation between lower clinical scores and Schatzker type of fracture or associated intra-articular lesions, while Le Baron et al[6] asserted that there was no significant association between fracture type and clinical results. The restoration of articular congruity and the reduction of fractures during the ARIF procedure are maintained with cannulated screws or, when needed, with a plate applied without arthrotomy[7].

Radiological Assessment

Only three[6,12,19] out of five studies compared radiographic data between the two groups. Verona et al[19] and Le Baron et al[6] did not find any significant difference between the ARIF and ORIF procedures, while in Wang et al[12] study, the ARIF group performed better than the ORIF group. According to this study, the arthroscopic technique allows for better visualization of the joint surface and possibly more accurate fracture reduction.

In many studies[19-21], there is no significant correlation between the surgical technique and the progression of secondary post-operative osteoarthritis.

Table 1. Study characteristics.

Author	Study design	Sample size	Age (y)	M/F	Mean follow-up	Schatzker classification	Treatment
Verona et al[19] (2019)	Comparative retrospective study	ARIF: 19 ORIF: 21	A: 45.5 (±17.12) O: 50.2 (±14.26)	A: 9/10 O: 12/9	44.4±28.85 months	A: I: 4 (21.1%); II: 8 (42.1%); III: 7 (36.8%) O: I: 1 (4.76%); II: 8 (38.1%); III: 12 (57.14%)	A: Cannulated screws 100% O: Cannulated screws 3 (14.3%); Plate 18 (85.7%)
Le Baron et al[6] (2019)	Comparative retrospective study	ARIF: 77 ORIF: 240	A: 52±14 (20-82) O: 53±13 (20-82)	A: 45/32 O: 143/97	A: 38±23 months O: 37±23 months	A: I: 18; II: 40; III: 19 O: I: 60; II: 135; III: 45	A: Cannulated screws 100% O: Cannulated screws 66 (27.6%); Plate 174 (72.4%)
Elabjer et al[20] (2017)	Prospective study	ARIF: 40 ORIF: 35	Mean age 47 y (20-54)	75: 48 M/27 F	Mean FU 13.3 m (12-15)	A: I: 9; II: 18; III: 13 O: I: 10; II: 15; III: 10	A: Cannulated screws 100% O: Plate 100%
Wang et al[12] (2017)	Comparative retrospective study	ARIF: 26 ORIF: 31	Mean age 46 y (24-65)	57: 36 M/21 F	Mean FU 44.4±11.8 m (24-64)	A: I: 4; II: 13; III: 5; IV: 4; O: I: 5; II: 15; III: 7; IV: 4	A: Cannulated screws 6; plate 12; screw and plate 8 O: Cannulated screws 6; plate 12; screw and plate 13
Huang et al[21] (2023)	Comparative retrospective study	ARIF: 33 ORIF: 35	A: 48.73±7.99 (25-71) O: 50.69±8.81 (21-72)	A: 23/10 O: 23/12	Mean FU 36 m (26-40)	A: II: 18; III: 15; O: II: 20; III: 15	A: Plate 100% O: Plate 100%

ARIF (Arthroscopy-assisted reduction internal fixation); ORIF (Open reduction internal fixation); FU (follow-up); A (arthroscopic); O (open).

Table 2. Summary of clinical outcomes for studies included in this systematic review.

Author	Clinical outcomes	Clinical score	ROM of the knee after surgery
Verona et al[19] (2019)	Knee Society Score (KSS)	A: 92.37 (±6.3) O: 86.29 (±11.54)	A: 127.89 (±6.3) O: 124.76 (±9.55)
Le Baron et al[6] (2019)	International Knee Documentation Committee (IKDC) Hospital for Special Surgery (HSS) Lysholm	*HHS* A: 85±14 O: 73±32.8 *IKDC score* A: 74±29.3 O: 70±31.9 *Lysholm score* A: 85±15.7 O: 85±14.7	A: 130±19 (range, 80-160); O: 130±16 (range, 60-140)
Elabjer et al[20] (2017)	Rasmussen clinical score	A: 29.20 (±0.72) O: 29.30 (±1.19)	NA
Wang et al[12] (2017)	Rasmussen clinical score KSS (Knee Society Score)	*Rasmussen* A: 25.8 (±2.9) (18-30) O: 25.5 (±3.0) (18-30) *KKS* A: 81.3 (±8.3) (60-96) O: 78.8 (±8.2) (56-94)	NA
Huang et al[21] (2023)	International Knee Documentation Committee (IKDC) score Hospital for Special Surgery (HSS) score	*IKDC* A: 89.09 (±5.54) O: 88.69 (±5.23) *HHS* A: 86.21 (±8.83) O: 85.69 (±8.30)	A: 124.18±4.43 O: 119.83±11.82

In this review, only one study[21] showed the degree of preoperative osteoarthritis, and only two studies[12,20] indicated the degree of osteoarthritis at the final follow-up, without any statistical difference between the ORIF and ARIF groups.

Complications, Failures, and Concomitant Intra-articular Injuries

Complications, failures, and intra-articular injuries correlated to the procedure are reported in all studies of this review and are summarized in Table 3.

The most common complications include infection, knee stiffness, deep vein thrombosis, and intolerance to plates and screws. According to a recent meta-analysis[23], overall complication rates ranged from 0 to 26%[19]. The authors reported higher rates of perioperative complications in the ORIF group compared to the ARIF group, seemingly more related to the fixation hardware than to the surgical technique itself. The selected studies described a total of 9 complications in the ARIF group and 28 in the ORIF group, but this review does not demonstrate a statistical difference in complications between the two procedures.

Treatment failures were described in two studies[6,12] and are mostly caused by infections and mechanical complications.

Table 3. Summary of complications, failures and intra-articular injuries of studies included in this systematic review.

Author	Complications	Failures	Cause of failure	Intra-articular injuries
Verona et al[19] (2019)	Overall complication 10% (not a statistically significant difference) A: none O: 1 deep infection; 3 intolerance to plates	NA	NA	A: Meniscal tear 8 (80%); Anterior tibial spine avulsion 2 (20%); ACL rupture 0 O: Meniscal tear 9 (81.8%); Anterior tibial spine avulsion 1 (9.1%); ACL rupture 1 (9.1%)
Le Baron et al[6] (2019)	A: 7 (9%) O: 18 (8%)	A: 4 O: 9	A: 2 infections and 2 mechanical complications O: 4 infections and 5 mechanical complications	NA
Elabjer et al[20] (2017)	The overall complication rate in the two groups of patients was found to be rather high (12%). However, there was no statistically significant difference	NA	NA	A: Meniscal tear 12 (60%) Condral lesion 6 (30%); ACL rupture 2 (10%) O: Meniscal tear 4 (57.1%); Condral lesion 2 (28.6%); ACL rupture 1 (14.3%)
Wang et al[12] (2017)	A: 1 deep infection O: 1 knee stiffness	None	None	A: Meniscal tear 12 (57.2%); ACL rupture 5 (23.8%); MCL rupture 4 (19%); LCL rupture 0 O: Meniscal tear 0; ACL rupture 0; MCL rupture 4 (80%); LCL rupture 1 (20%)
Huang et al21 (2023)	The complication rate for all patients was 11% A (2): 1 superficial infection; 1 deep vein thrombosis O (5): 3 superficial infections; 1 valgus deformity; 1 knee stiffness	NA	NA	A (21): Meniscal tear 13 (62%); ACL rupture 3 (14%); PCL rupture 1 (5%); Cartilage contusion 4 (19%) O (8): Meniscal tear 5 (63%); ACL rupture 2 (25%); Cartilage contusion 1 (12%)

A (arthroscopic); O (open); ACL (anterior cruciate ligament); MCL (medial collateral ligament); PCL (posterior cruciate ligament).

Hospital Length of Stay and Functional Recovery

Three studies[19,20,21] reported the length of hospital stay, and all authors agree that there is a statistical difference between the ARIF and ORIF procedures. The difference in the mean duration of hospital stay has been attributed to more significant post-operative edema and soft tissue swelling due to ORIF procedures[19].

Risk of Bias

Risk of bias is reported for each study in Table 4 and Table 5.

Table 4. Risk of bias according to Newcastle-Ottava Scale (NOS) guidelines for comparative studies.

Author	Study design	Selection points	Comparability points	Outcome/ Exposure points	Total of points	Quality of study
Verona et al[19] (2019)	Comparative retrospective study	4	2	3	9	Good
Le Baron et al[6] (2019)	Comparative retrospective study	4	1	2	7	Good
Wang et al[12] (2017)	Comparative retrospective study	4	2	3	9	Good
Huang et al[21] (2023)	Comparative retrospective study	4	2	2	8	Good

Table 5. Risk of bias according to Cochrane Collaboration's tool in a randomized trial.

Author	Study design	Selection (sequence generation)	Selection (allocation concealment)	Performance	Attrition	Detection	Reporting	Other
Elabjer et al[20] (2017)	Prospective study	Low	Low	Low	Low	Unclear	Low	Unclear

DISCUSSION

Tibial plateau fractures are injuries that can impact the long-term functional outcome of the knee in both young and older patients[24]. The studies included in this review evidenced that displacement of the fracture and the pattern of articular cartilage involvement may influence the severity of the lesion and the treatment strategy[19,20,21]. Furthermore, anatomical reduction, stable fixation, repair of soft tissue injuries, and an unrestricted passive and active range of motion are mandatory to achieve satisfactory clinical results[20,25,26]. Inadequate or incomplete treatment of these fractures may result in pain, joint instability, and a restricted range of motion.

Currently, arthroscopy plays a key role in managing tibial plateau fractures because it allows for an evaluation of fracture reduction without extensive arthrotomy and enables optimal treatment of concomitant intra-articular lesions. The clinical benefits of arthroscopic-assisted surgery are most pronounced when stable percutaneous fixation is performed. Fixation with plates results in significant trauma to the soft tissues, compromising the blood supply to the bone. The tibial plateau receives its blood supply from both an intramedullary network and a periosteal network. Fractures of the proximal tibia compromise the blood supply from the intramedullary network without injuring the periosteal net-

work[27,28]. Percutaneous fixation preserves the periosteal network, while open reduction and internal fixation damage the proximal tibial vessels, increasing the risk of severe complications such as necrosis and non-union. Cift et al[29], in an experimental model, demonstrated that percutaneous screw fixation was less stable than plate-screw fixation. Nevertheless, no clinical studies have established the necessity of the plate screw in patients who will not bear weight on the affected limb for two months after surgery. Therefore, invasive plate fixation diminishes the clinical benefits of arthroscopic treatment, making percutaneous fixation a reasonable choice in tibial plateau fractures. Additionally, a ligament reconstruction tibial guide allows articular depression to be reduced with optimal positioning of the cannulated screws under the articular surface[6].

ARIF combines a minimally invasive surgical procedure with the integrity of the knee capsule. This procedure avoids an arthrotomy, which is necessary for joint surface visualization and may lead to stiffness, proprioceptive disorders, severe pain, and scar-related complications. Furthermore, ARIF aids in treating intra-articular injuries during the operation. If there is a meniscal tear, the orthopedic surgeon can perform a meniscal repair; if chondral damage exists, intra-articular cartilage fragments can be removed, and if a cruciate ligament rupture is present, a second-stage operation can be scheduled to avoid time-buying procedures and reduce the risk of further complications due to increased soft-tissue damage of the knee[19,22]. The preoperative diagnosis of intra-articular lesions mainly depends on MRI, but the presence of hematoma inside the knee may lead to false positive or false negative results[30]. Arthroscopic procedures may encounter technical issues, especially during fracture bleeding; this difficulty can be minimized by using a pump but with the risk of compartment syndrome. The risk of compartment syndrome, not present in any of the studies in this review, is a more frequent complication in medial plateau or bicondylar fractures due to continuous infusion of irrigation fluid into the knee cavity, the greater the infusion pressure, and the longer the operative time[19,21].

In this review, the most common fracture types were Schatzker type I, II, and III. The studies showed that ARIF procedures with minimally invasive techniques result in faster recovery and shorter hospital stays, better management of intra-articular lesions, and comparable complication rates with ORIF treatment. ARIF procedures seem to offer better clinical results than ORIF, but further studies with larger patient samples are necessary.

Limitations

The present study has several limitations and potential biases. Firstly, one limitation may be that the selection criteria are strict. Furthermore, meta-analysis was not performed, and no PICO framework was used in search.

Secondly, the small sample size of patients included in the review does not allow for the drawing of well-grounded conclusions and reflects the low incidence of this type of fracture. Thirdly, the duration of follow-up in the studies varies, with a mean range oscillating from 13.3 to 44.4 months, which does not permit the observation of the development and progression of post-operative osteoarthritis. Finally, the different clinical functional scores used in these studies may lead to an incorrect and incomplete comparison of the results.

CONCLUSIONS

Both ARIF and ORIF procedures can provide good clinical and radiological outcomes in the treatment of tibial plateau fractures. However, ARIF procedures may show better results in selected tibial plateau fractures and reduce the duration of hospital stay. Further studies with a prospective design, a larger sample size, and long-term follow-up are necessary to confirm the effectiveness of ARIF in tibial plateau fractures.

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Not applicable.

Authors' Contributions:
Francesco Roberto Evola, Riccardo Compagnoni and Pietro Simone Randelli have given substantial contributions to the design of the manuscript. Arianna Pieroni, Francesco Roberto Evola and Paolo Ferrua to acquisition, analysis, and interpretation of the data. All authors have participated in drafting the manuscript. All authors read and approved the final version of the manuscript.

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