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Balloon tibioplasty vs ORIF for the treatment of Schatzker II-IV Tibial Plateau Fractures : a study protocol of randomised controlled trial

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3 **Title: Balloon tibioplasty vs ORIF for the treatment of Schatzker II-IV Tibial Plateau**
4 **Fractures : a study protocol of randomised controlled trial**
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16
17 **Abstract**

18 **Introduction:** Balloon tibioplasty as an emerging technology, and has shown its
19 advantages on recovering the depression of the articular surface. However, the
20 clinical outcomes of balloon tibioplasty and ORIF are insufficient. This is the first
21 randomised study to compare balloon tibioplasty against traditional ORIF and will
22 provide guidance for treating patients with schatzker II-IV tibial plateau fractures.
23

24 **Methods and analysis:** A blinded randomised controlled trial will be conduct and a
25 total of 100 participants with schatzker II-IV tibial plateau fracture will be randomly
26 divided to either the balloon tibioplasty group or the ORIF group at a ratio of 1:1. The
27 primary clinical outcome measures are the knee functional scores and the
28 percentage of satisfactory recovered joint area. Secondary clinical outcome measures
29 are intraoperative blood loss, operation time, VAS scores after surgery, length of
30 hospital stay after surgery, fracture healing time and complications.
31

32 **Ethics and dissemination:** This study has been reviewed and approved by the
33 Institutional Review Board of the Second Affiliated Hospital of Wenzhou Medical
34 University (batch: 2017-12). The results will be presented in peer-reviewed journals
35 after completion of the study.
36

37 Trial registration number: NCT03327337, Pre-results
38

39 **Introduction**

40 Tibial plateau fractures are complex intra-articular and metaphyseal lesions,
41 accounting for 1-2% of all fractures[1], caused by either a valgus or varus force in
42 combination with axial force[2]. The acknowledged operative indication was
43 depressed fragments greater than 10 mm or instability >10° in a fully extended
44 knee[3]. Many classification systems have been developed for tibial plateau fractures
45 and used for preoperative planning and prognosis[4]. The Schatzker classification
46 system is rather simple and widely used among orthopaedic surgeons in clinical
47 practice. Schatzker II-IV tibial plateau fractures includes lateral or medial depressed
48 articular fragments, the loss of joint congruity in these injuries has been shown to
49 carry a poor prognosis such as posttraumatic arthrosis and valgus deformity despite
50 proper management, so restoration of the joint surface is the goal of surgery[5-7].
51 The traditional ORIF treatment has a series of demerits, for instance, too much
52 damage, the limited exposure of articular cavity, the insufficient diagnosis and
53 treatment for the internal joint injury[8].
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3 In recent years, with the development of technology, the treatment concept of tibial
4 plateau fractures has developed from original mechanical fixation to biomechanical
5 fixation and minimally invasive surgical[9], borrowing from the successful vertebral
6 kyphoplasty technique, scholars put forward arthroscopic assisted balloon
7 tibioplasty[10], a novel minimally invasive technique for the reduction of depressed
8 tibial plateau fractures. Balloon tibioplasty as an emerging technology, which aims to
9 visualize the articular surface and use balloon distension tibial plasty assisted by
10 arthroscope to recover the depression of the articular surface, and then fixed the
11 fracture according to patient's specific fracture type[11]. This technology has shown
12 its advantages on recovering the depression of the articular surface[12], treating
13 additional intraarticular lesions during the operation, and minimizing surgical trauma.
14 Furthermore, under fluoroscopic, optimal centering of the expanding tibioplasty
15 balloon allows a widespread and continuously increasing reduction force to the
16 fracture area[13]. However, there are some factors influencing the clinical promotion
17 of this surgical technique, for example, the application time of this surgical technique is
18 short, the large number of case data and long-term follow-up is lacking, and the cost
19 of operation is higher than traditional ORIF[14].

20
21 Esmat Elabjer et al[15] examined the outcomes of arthroscopically-assisted reduction
22 and internal fixation (ARIF) vs ORIF for the treatment of Schatzker I–III tibial plateau
23 fractures, they showed that ARIF has a statistically significant less duration of hospital
24 stay, both ARIF and ORIF can provide good results, in addition ARIF offer a more
25 precise evaluation and treatment of associated intraarticular lesions. Ollivier et al[16]
26 showed that the use of balloon guided inflation tibioplasty with injection of a
27 resorbable bone substitute is safe, and results in a high rate of anatomic reduction
28 and good clinical outcomes in patients with depressed tibial plateau fractures.

29
30 As we all know, no randomised controlled study of the clinical outcomes of balloon
31 tibioplasty vs ORIF has been performed and high-quality RCTs are often deemed to
32 be the gold standard for clinical research. In this study, we will perform an RCT to
33 compare balloon tibioplasty and traditional ORIF.

34 **Methods and design**

35
36 This study is approved by the Institutional Ethics Review Board of the Second
37 Affiliated Hospital of Wenzhou Medical University and conforms to the Declaration of
38 Helsinki. All the patients provided informed consent to participate in this study. This
39 trial has been registered at the US National Institutes of Health Clinical Trials Registry:
40 NCT03327337. The protocol conforms to the Standard Protocol Items
41 Recommendations for Interventional Trials. Figure 1 provides the chart of the trial
42 design.

43 **Participants**

44
45 This study is a parallel group RCT conducted at the department of orthopaedics, the
46 Second Affiliated Hospital of Wenzhou Medical University. The diagnosis of tibial
47 plateau fracture was made on AP and lateral X-rays, CT scan was used to classify it.

48 **Inclusion criteria**

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50 (1) fresh closed fracture, X-ray and CT scan showing Schatzker type II-IV tibial plateau
51 fracture
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3 (2) no history of knee-joint dislocation or other knee trauma

4 (3) no previous surgery on the knee

5 (4) the informed consent form signed

6 (5) age from 18 to 80 years

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8 **Exclusion criteria**

9 (1) other types (Schatzker type I, V, and VI) of tibial plateau fracture

10 (2) open fractures, pathological fractures, immunodeficiency, hematological diseases
11 and severe hepatorenal disorders

12 (3) the informed consent form unsigned

13
14 **Randomisation and blinding**

15 Pre-randomisation eligibility checks will be carried out to ensure that participants are
16 eligible for study inclusion. A computerised randomisation was performed and the
17 participants were divided into two groups by a sealed envelope: one group was
18 treated with balloon tibioplasty and the other with ORIF. The patient and trial
19 statistician were blinded until the last questionnaires have been completed.

20
21 **Interventions**

22 Balloon tibioplasty group:

23 Preoperative preparation: After the success continuous epidural anesthesia, the
24 patients were placed in supine position with elevation of the affected knee slightly
25 flexed at 45 degrees. The conventional arthroscopic approach was used to check
26 the patient's joint cavity carefully and hemorrhage was removed, and combined
27 ligament injury was explored. If combined with anterior or posterior cruciate
28 ligament injury, we would reconstruct the ligament firstly.

29
30 Step 1: If there is a splitting tibial plateau fracture, an incision would be made in
31 proximal tibia according to the fracture type. A small locking T-plate would be placed
32 using minimally invasive techniques, then a temporary cortical bone screw would be
33 pre-placed for prevention of cortical rupture when the balloon was enlarged. The
34 temporary fixation of cortical bone screw permitted further adjustment on the
35 position of the plate. If there is no splitting tibial plateau fracture, proceed to step 2
36 directly.

37
38 Step 2: 3 kirschner wires were placed under fluoroscopy on a surface locating below
39 the depressed fragments. The suitable position for placing the balloon was
40 predetermined under fluoroscopy. Then the surgeon gradually inflated the balloon
41 with contrast solution and elevated the fragment till it was visually anatomically
42 reduced on a true AP fluoroscopic view. Then the arthroscope was used to make
43 sure the anatomical reduction. If not, the balloon would be deflated, repositioned,
44 and re-inflated to reduce the persistent depression. After balloon removal, we carefully
45 injected calcium phosphate cement to the balloon-created cavity under fluoroscopic,
46 making sure no excessive cement overflowed into the tibial medullary cavity. We
47 took out the 3 kirschner wires, inserted the rest screws, and finally sutured the
48 incision.

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53 **ORIF group:**

54 Preoperative preparation: After the success continuous epidural anesthesia, the
55 patients were placed in supine position with elevation of the affected knee slightly

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3 flexed at 45 degrees. The patients were treated with traditional Open Reduction and
4 Internal Fixation(ORIF) and bone graft.

5 The patients were allowed to bear no weight within 4 weeks. 6-8 weeks after the
6 operation, the patients were allowed to walk with sticks until the fracture was
7 completely healed.
8

9 **Outcome measurements**

10 **Primary Outcome Measure:**

11 1.The knee functional scores after surgery will be assessed by the Rasmussen scores
12 of knee function. The Rasmussen scores will be recorded at 1、 2、 3、 6、 12 and 24
13 mouths postoperatively.

14
15 2.The percentage of satisfactory recovered joint area after operation will be assessed
16 by the CT scan at 1、 2、 3、 6、 12 and 24 mouths postoperatively.
17

18 **Secondary Outcome Measures:**

19 1.The Intraoperative blood loss will be recorded in the anesthesia records, which
20 included the blood in suction bottles (after subtracting the lavage fluid used during
21 the surgery) and in weighed sponges that were used during the operation.
22

23 2.Operation time.

24 3.The pain degree of lower limb after surgery will be assessed by the VAS scores. The
25 scores of VAS of leg pain will be recorded from operation day to leave hospital day(up
26 to 2 weeks).

27 4. length of hospital stay after surgery.

28 5.Fracture healing time.

29 6.complications.
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31 **Follow-up**

32 Follow-up will be conducted at 1,2,3,6,12 and 24 months postoperatively.
33

34 **Monitoring**

35 All investigators who have completed training could independently collect the data
36 and assess the clinical outcomes. Safety and data monitoring will be performed
37 periodically during the study. All paper and electronic data will be stored for 10 years
38 in the secure research archives at the Second Affiliated Hospital of Wenzhou Medical
39 University with restricted access.
40

41 **Sample size**

42 In order to pilot this study, the investigators have decided to recruit 50 patients into
43 each arm of the trial and allow for a dropout rate of 20% for an effective sample size
44 of 40 patients in each arm. The sample size is considered adequate to verify the
45 research hypothesis.
46

47 **Statistical analysis**

48 The trial data will be calculated by the SPSS V.19.0 software. Differences in the
49 operative time and intraoperative blood loss, the percentage of joint area recovered
50 satisfactory, and complications between 2 groups will be analysed by two
51 independent-samples t-tests. VAS scores and Rasmussen scores will be analysed by a
52 repeated-measures analysis of variance. Changes in the data between different
53 follow-up time points and the baseline will also be calculated, and the changes in
54 data between 2 groups will be assessed by two independent-samples t-tests.
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Discussion

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Ideal treatment of schatzker II-IV tibial plateau fracture not only has to achieve anatomical restoration of joint surface to prevent cartilage damage and post-traumatic arthritis, but also rigid fixation to allow early post-operative rehabilitation[17]. Balloon tibioplasty is reported as a minimally invasive technique, which creating a symmetric, contained defect to hold a bone filler for subchondral support, and the balloon allows access to the posterior compressions while eliminating the neurological and vascular risks of a conventional approach[14]. This technique has already been used for kyphoplasty and maxillofacial surgery, and recently used for tibial plateau fractures[18]. This paper describes the protocol for conducting an RCT in China that will investigate the efficacy of balloon tibioplasty in treating schatzker II-IV tibial plateau fractures. In this trial, we designed a ORIF group as a controlled group to identify the clinical outcomes of schatzker II-IV tibial plateau fractures with balloon tibioplasty fixation. It is hypothesised that balloon tibioplasty, compared with ORIF, is superior in reducing disability and thus has a better clinical outcome. This study is the first RCT to compare schatzker II-IV tibial plateau fractures with balloon tibioplasty against traditional ORIF in china. In the case that our hypothesis is confirmed, our consequences will have an important value in the schedule and development of treatment options in schatzker II-IV tibial plateau fractures surgery. We anticipate that the results will provide more reliable evidence and clarify the value of balloon tibioplasty as a treatment for patients with schatzker II-IV tibial plateau fractures.

Contributors

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Ji-Qi Wang helped to design the trial and wrote the manuscript. Bing-Jie Jiang helped to design the trial. Wei-Jun Guo helped to conceive the trial and revised the manuscript. Wei-Jiang Zhang recruit the patients and conduct the trial. A-Bing Li will planned the statistical analysis. You-Ming Zhao helped to design the study and critically revised the manuscript. All authors read and approved the final manuscript.

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The funders had no role in the design, execution or writing of the study.

Competing interests

None declared.

Patient consent

Obtained.

Ethics approval

The study had been reviewed and approved by the ethics committee of the Second Affiliated Hospital of the Wenzhou Medical University, Wenzhou, China (batch: 2017-12).

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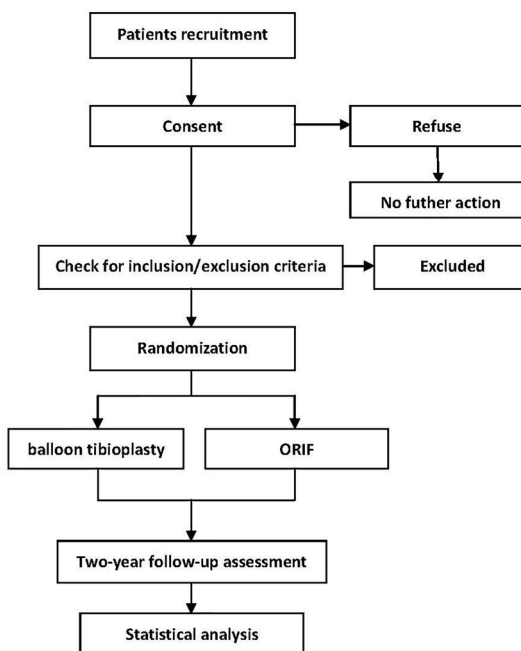
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24 Figure 1. Flow chart showing the steps in participant recruitment, treatment and
25 analysis. balloon tibioplasty, arthroscopic assisted balloon tibioplasty group; ORIF,
26 open reduction and internal fixation group.
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Flow chart showing the steps in participant recruitment, treatment and analysis. balloon tibioplasty, arthroscopic assisted balloon tibioplasty group; ORIF, open reduction and internal fixation group.

189x170mm (300 x 300 DPI)

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Arthroscopic-assisted balloon tibioplasty versus open reduction internal fixation (ORIF) for treatment of Schatzker II–IV tibial plateau fractures: Study protocol of a randomized controlled trial

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Primary Subject Heading:	Surgery
Secondary Subject Heading:	Sports and exercise medicine, Surgery
Keywords:	ORTHOPAEDIC & TRAUMA SURGERY, Knee < ORTHOPAEDIC & TRAUMA SURGERY, Adult orthopaedics < ORTHOPAEDIC & TRAUMA SURGERY

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3 **1 Arthroscopic-assisted balloon tibioplasty versus open reduction internal fixation (ORIF) for**
4 **2 treatment of Schatzker II–IV tibial plateau fractures: Study protocol of a randomized**
5 **3 controlled trial**
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8 5 Ji-Qi Wang¹, Bing-Jie Jiang¹, Wei-Jun Guo¹, Wei-Jiang Zhang¹, A-Bing Li¹, You-Ming Zhao¹
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22 12 Keywords: Tibial plateau fracture; Arthroscopic-assisted surgery; Balloon tibioplasty; Open
23 13 Reduction Internal Fixation; Protocol
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26 15 Word count: 2467
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29 17 Abstract

30 18 Introduction: Arthroscopic-assisted balloon tibioplasty is an emerging technology that has shown
31 19 advantages in recovering depression of the articular surface. However, arthroscopic-assisted
32 20 balloon tibioplasty does not produce sufficiently beneficial clinical outcomes. This is the first
33 21 randomized study to compare arthroscopic-assisted balloon tibioplasty with traditional open
34 22 reduction internal fixation (ORIF), and will provide guidance for treating patients with Schatzker
35 23 II–IV tibial plateau fractures.

36 24 Methods and analysis: A blinded randomized controlled trial will be conducted and a total of 80
37 25 participants with Schatzker II–IV tibial plateau fracture will be randomly divided into either the
38 26 arthroscopic-assisted balloon tibioplasty group or the ORIF group, at a ratio of 1:1. The primary
39 27 clinical outcome measures are the knee functional scores, Rasmunssen radiological evaluation
40 28 scores, and the quality of reduction based on postoperative computed tomography scan. Secondary
41 29 clinical outcome measures are intraoperative blood loss, surgical duration, visual analog scale
42 30 score after surgery, hospital duration after surgery, complications, and SF-36 score.

43 31 Ethics and dissemination: This study has been reviewed and approved by the Institutional Review
44 32 Board of the Second Affiliated Hospital of Wenzhou Medical University (batch: 2017-12). The
45 33 results will be presented in peer-reviewed journals after completion of the study.

46 34 Trial registration number: NCT03327337, Pre-results

47 35 Strengths and limitations of this study: This trial is designed to have a feasible, comparative
48 36 effectiveness trial design that has similarities to common clinical situations. This study is the first
49 37 RCT to compare the outcomes of Schatzker II–IV tibial plateau fractures between
50 38 arthroscopic-assisted balloon tibioplasty and traditional ORIF in China. The size of the study
51 39 sample limits the power of the observations.
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1 Introduction

2 Tibial plateau fractures are complex intraarticular and metaphyseal lesions, accounting for 1–2%
3 of all fractures [1] caused by either a valgus or varus force in combination with an axial force [2].
4 The acknowledged surgical indication for a tibial plateau fracture is tilt or valgus malalignment
5 exceeding 5°, articular step-off exceeding 3 mm, or condylar widening exceeding 5 mm (lateral
6 tibial plateau fracture), or tilt or any displacement (medial tibial plateau fracture) [3]. Many
7 classification systems have been developed for tibial plateau fractures and are used for
8 preoperative planning and prognostic purposes [4-6]. The Schatzker classification system is
9 simple and widely used among orthopedic surgeons in clinical practice. Schatzker II–IV tibial
10 plateau fractures include lateral or medial depressed articular fragments, and loss of joint
11 congruity in these injuries is associated with a poor prognosis, such as posttraumatic arthrosis and
12 valgus deformity despite proper management. Therefore, restoration of the joint surface is the goal
13 of surgery [7-9].

14 Open reduction internal fixation (ORIF) for treatment of this type of fracture has yielded
15 promising results. Gavaskar *et al.* [10] reported that ORIF could achieve satisfactory radiological
16 and functional results in split depression lateral tibial plateau fractures. After ORIF for 15 cases of
17 medial tibial plateau fractures, Morin *et al.* [11] reported that 93% of patients were satisfied or
18 very satisfied with their functional recovery and there were no cases of pseudarthrosis or
19 secondary varus displacement. However, traditional ORIF treatment has a number of
20 disadvantages, e.g., excessive damage, limited exposure of the articular cavity, and insufficient
21 ability to diagnose and address internal joint injury [12].

22 With recent technological advances, the treatment concept of tibial plateau fractures has
23 progressed from mechanical fixation to minimally invasive surgical interventions for
24 biomechanical stability [13,14]. Based on the success of vertebral kyphoplasty, arthroscopic
25 assisted balloon tibioplasty [15] has been developed as a novel minimally invasive technique for
26 reducing depressed tibial plateau fractures. Arthroscopic-assisted balloon tibioplasty is an
27 emerging technology that aims to visualize the articular surface, and uses balloon distension tibial
28 plasty assisted by arthroscopy to recover depression of the articular surface and fix the fracture
29 according to its specific type [16]. This technology has shown advantages in recovering
30 depression of the articular surface [17], treating additional intraarticular lesions during the
31 operation, and minimizing surgical trauma. Furthermore, under fluoroscopy, optimal centering of
32 the expanding tibioplasty balloon allows a widespread and continuously increasing reduction force
33 to be applied to the fracture area [18]. Primary data from Ollivier *et al.* [19] showed that depressed
34 tibial plateau fractures treated with arthroscopic-assisted balloon tibioplasty had a high rate of
35 anatomic reduction and good clinical outcomes. Similar results were also reported by Pizanis *et al.*
36 [15] using arthroscopic-assisted balloon tibioplasty without classic fenestration of the tibia, which
37 would minimize surgical trauma. However, a number of factors influence the clinical adoption of
38 this surgical technique: the application time of is short, there is a paucity of case data and
39 information regarding long-term follow-up, and the cost of operation is higher than traditional
40 ORIF [20].

41 To our knowledge, there have been no randomized controlled trials (RCTs) of the clinical
42 outcomes of arthroscopic-assisted balloon tibioplasty versus ORIF, where high-quality RCTs are
43 generally deemed to be the gold standard in clinical research. In this study, we will perform an
44 RCT to compare arthroscopic-assisted balloon tibioplasty and traditional ORIF.

1 Methods and design

2 This study has been approved by the Ethics Committee of the Second Affiliated Hospital of
3 Wenzhou Medical University, and conforms to the Declaration of Helsinki. All patients will
4 provide informed consent prior to participation in this study. This trial has been registered at the
5 US National Institutes of Health Clinical Trials Registry (NCT03327337). The protocol conforms
6 to the Standard Protocol Items Recommendations for Interventional Trials. Figure 1 shows a chart
7 of the trial design.

8 Participants

9 This study is a parallel group RCT conducted at the Department of Orthopaedics, the Second
10 Affiliated Hospital of Wenzhou Medical University. Fractures will be evaluated on anteroposterior
11 (AP) and laterolateral (LL) radiographs and by computed tomography (CT), which can analyze the
12 fracture pattern more precisely.

13 Inclusion criteria

14 (1) Acute closed fractures less than 10 days old, and X-ray and CT scan showing Schatzker type II,
15 III or IV with depression of the medial tibial plateau only. (supplementary information, S1)

16 (2) No history of knee joint dislocation or other knee trauma.

17 (3) Signed informed consent.

18 (4) Age of 18–80 years.

19 Exclusion criteria

20 (1) Other types of tibial plateau fracture (Schatzker type I, IV with split or comminute fracture, V,
21 and VI).

22 (2) Concomitant injuries that will interfere with functional recovery, such as combined fracture of
23 the lower limb.

24 (3) Open fractures, pathological fractures, immunodeficiency, hematological diseases, or severe
25 hepatorenal disorders.

26 Patient involvement

27 The design of this study was not directly involved in the patients, and the intervention in this study
28 is not considered to change the patient's direct perception of the preoperative and intraoperative
29 processes or the postoperative rehabilitation therapy. As the enrolment in study may influence the
30 patient's view of the clinical work or even feel like a burden, the patients will be interviewed
31 randomly to identify adverse effects. The results will be informed by mail to all the patients
32 involved.

33 Randomization and blinding

34 Pre-randomization eligibility checks will be carried out to ensure that participants are eligible for
35 inclusion in the study. Patients will be randomly assigned to one of two groups (experimental or
36 control) using a computer-generated random assignment in a 1:1 ratio, and allocation will be
37 concealed until the point of randomization. Patients, researchers performing the follow-up
38 measurements, and the trial statistician will be blinded to the group allocations until the last
39 questionnaires have been completed.

40 Interventions

41 Arthroscopic-assisted balloon tibioplasty group:

42 Step 1: In cases with a splitting tibial plateau fracture (Schatzker type II), an incision will be made
43 in the proximal tibia according to the fracture type, for placement of a small locking T-plate
44 (Synthes, Freiburg, Germany) using minimally invasive techniques. Then, a temporary cortical

1
2
3 1 bone screw will be inserted to prevent cortical rupture when the balloon is enlarged. Temporary
4 2 fixation of the cortical bone screw will permit further adjustment of the position of the plate. In
5 3 cases with no splitting tibial plateau fracture (Schatzker type III or IV with depression of the
6 4 medial tibial plateau only), we will proceed to step 2 directly.

7
8 5 Step 2: Three Kirschner wires (2 mm) will be placed below the depressed fragment under
9 6 fluoroscopy. Using live fluoroscopy, the balloon will be placed in the optimal position and slowly
10 7 inflated with contrast solution (Ultravist®; Schering, Berlin, Germany). The arthroscope will then
11 8 be used to confirm anatomical reduction of the depressed fragment. The balloon will be deflated,
12 9 repositioned, and reinflated to reduce the persistent depression. After removal of the balloon, we
13 10 will use a Kirschner wire (2 mm) to temporarily lift the depressed fragment and carefully inject
14 11 calcium phosphate cement (Osteopal® V; Heraeus Medical GmbH, Wehrheim, Germany) into the
15 12 cavity produced by the balloon under fluoroscopic guidance, ensuring there is no excessive
16 13 cement overflow into the tibial medullary cavity. (supplementary information, S2)

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18
19 14 ORIF group:

20 15 For this technique, a lateral or medial surgical approach will be used according to the type of
21 16 fracture. The depressed fragment will be elevated by a metal tamp through a small cortical
22 17 window in the proximal tibia, and bone substitute will be used. Finally, internal fixation will be
23 18 performed when an acceptable reduction has been achieved.

24
25 19 If satisfactory reduction cannot be achieved using arthroscopic-assisted balloon tibioplasty,
26 20 patients will undergo ORIF and be excluded from the study. All patients will receive rehabilitation
27 21 therapy regardless of the group to which they are allocated, and progressive partial weight-bearing
28 22 will be permitted with the aid of two crutches. Postoperative CT scans will be performed
29 23 immediately, and at 2 weeks and 1, 3, 6, 12, and 24 months, and Rasmussen radiological
30 24 evaluation will be performed [21]. To evaluate functional recovery of the knee joint and
31 25 health-related quality of life, all patients will complete Rasmussen functional score and
32 26 Short-Form Health Survey (SF-36) questionnaires during the follow-up period. Scoring will
33 27 be performed by two researchers who not involved in the initial treatment.

34
35
36 28 Outcome measurements

37 29 Primary outcome measure:

38 30 1. Knee functional recovery will be assessed by the Rasmussen functional score, which will be
39 31 recorded at 3, 6, 12, and 24 months postoperatively.

40 32 2. Rasmussen radiological evaluation will be recorded immediately, and at 2 weeks and 1, 3, 6,
41 33 12, and 24 months postoperatively.

42 34 3. The quality of reduction will be determined based on postoperative CT scans, which can
43 35 directly measure the amount of residual depression, at 2 weeks and 1, 3, 6, 12, and 24 months
44 36 postoperatively.

45
46
47 37 Secondary outcome measures:

48 38 1. Intraoperative blood loss will be recorded in the anesthesia records, and will include the blood
49 39 in suction bottles (after subtracting the lavage fluid used during the surgery), and that in the
50 40 weighed sponges used during the operation.

51 41 2. Surgical duration.

52 42 3. The severity of lower limb pain after surgery will be assessed using a visual analog scale (VAS)
53 43 pain score. The VAS scores of leg pain will be recorded from the day of the operation to the day of
54 44 discharge from hospital (up to 2 weeks).

1
2
3 1 4. Hospitalization period after surgery.
4 2 5. Complications including wound infection (defined as minor, major, early, or late according to
5 3 the criteria described by the Surgical Infection Study Group [22]), reoperations, and posttraumatic
6 4 arthritis (PTA) will be recorded.

7
8 5 PTA may not be seen in patients within the 24-month follow-up period, and we will perform
9 6 follow-up for at least 10 years in all patients.

10 7 6. Health-related quality of life will be measured using the Short-Form Health Survey (SF-36)
11 8 questionnaire during follow-up.

12 9 The SF-36 is a health-related quality of life questionnaire used to assess both the mental and
13 10 physical health of the patient.

11 11 Baseline demographics

12 12 Sex, age, body mass index (BMI), mechanism of injury, smoking status, alcohol use, and
13 13 comorbidities (i.e., hypertension, diabetes, cardiopathy)

14 14 Follow-up

15 15 Follow-up will be conducted at 2 weeks and 1, 3, 6, 12, and 24 months postoperatively.

16 16 Monitoring

17 17 All investigators who have completed training are capable of independently collecting the data
18 18 and assessing the clinical outcomes, and all electronic data will be recorded by an electronic data
19 19 capture system (DAP Software Company, Beijing, China). Safety and data monitoring will be
20 20 performed periodically during the study. All paper and electronic data will be stored for 10 years
21 21 in the secure research archives at the Second Affiliated Hospital of Wenzhou Medical University,
22 22 with restricted access.

23 23 Sample size calculation

24 24 There have been no previous studies on which to base the sample size calculation. In a related
25 25 study [21], the excellent Rasmussen radiological evaluation proportion of the control group was
26 26 60%, and the proportion of the intervention group was 70%. We carried out power analysis to
27 27 determine the sample size required to show safety with a type I error probability of 5% and an
28 28 80% probability of avoiding a type II error. Using these assumptions, the required sample size is
29 29 35 per group. With the assumption of a 12.5% loss to follow-up, we will include 40 participants
30 30 per group.

31 31 Statistical analysis

32 32 The trial data will be analyzed using SPSS for Windows software (ver. 19.0; SPSS Inc., Chicago,
33 33 IL). For continuous variables, the Shapiro–Wilk test will be applied to determine if they follow a
34 34 normal distribution. For normally distributed variables, the means will be calculated and compared
35 35 using the independent samples *t* test (Student's *t* test); otherwise, the Mann–Whitney U test will be
36 36 used for group comparisons. The chi-square test will be used to analyze qualitative variables. In
37 37 all analyses, $P < 0.05$ will be taken to indicate statistical significance.

38 38 Discussion

39 39 There have been a number of reports describing treatment for tibial plateau fractures. In a
40 40 systematic review of the treatment of tibial plateau fractures, Metcalfe *et al.* [23] suggested that
41 41 ORIF and external fixation are both acceptable strategies for managing bicondylar tibial plateau
42 42 fractures, with no statistically significant differences found in the rates of complications between
43 43 the two methods. In addition, after a systematic review of all studies reporting return to sport
44 44 following tibial plateau fracture, Robertson *et al.* [24] reported that the rate of return to sport for

1 the total cohort was 70%, versus 60% for those with fractures managed with ORIF and 83% for
2 fractures treated with arthroscopic-assisted reduction internal fixation (OR 3.22, 95% CI:
3 2.09–4.97, $P < 0.001$).

4 An ideal treatment method for Schatzker II–IV tibial plateau fracture not only has to achieve
5 anatomical restoration of the knee joint, but also rigid fixation to allow early postoperative
6 rehabilitation [25]. Traditional ORIF requires extensive soft tissue dissection, which may lead to
7 numerous negative outcomes such as slow wound healing, infection, and PTA [26]. Due to limited
8 exposure, intraarticular lesions, such as meniscus or anterior cruciate ligament (ACL) injuries,
9 cannot be diagnosed and treated properly [27]. Ruffolo *et al.* [28] reported that nonunion and deep
10 infections occur commonly after ORIF, and long surgical durations are associated with higher
11 rates of infection. With the development of arthroscopic techniques, arthroscopy-assisted
12 reduction and internal fixation (ARIF) has been widely adopted in the treatment of tibial plateau
13 fractures [29], and has shown good functional recovery and radiological results [30–32]. After
14 comparing the Rasmussen and Hospital for Special Surgery knee-rating (HSS) scores between
15 ARIF and ORIF, Dall'oca *et al.* [12] reported that the ARIF technique improved the clinical
16 outcome in Schatzker type II–IV fractures. Balloon tibioplasty is an arthroscopic-assisted
17 minimally invasive technique that creates a symmetrical, contained defect to hold bone filler for
18 subchondral support; the balloon also allows eliminate the neurological and vascular risks of the
19 conventional approach[20]. This technique has already been used for kyphoplasty and
20 maxillofacial surgery, and has recently been applied for tibial plateau fractures [15,19,33].
21 Mauffrey *et al.* [20] reported early positive results with arthroscopy-assisted balloon tibioplasty
22 used as an alternative reduction method, and the method is gaining in acceptance. This paper
23 describes the protocol for conducting an RCT in China that will investigate the efficacy of
24 arthroscopic-assisted balloon tibioplasty in treating Schatzker II–IV tibial plateau fractures. The
25 design of this trial included an ORIF group as a control group, to compare the clinical outcomes of
26 Schatzker II–IV tibial plateau fractures with those of arthroscopic-assisted balloon tibioplasty
27 fixation. Arthroscopic-assisted balloon tibioplasty is hypothesized to be superior in reducing
28 surgical trauma, and to have better clinical outcomes in comparison with ORIF. This study is the
29 first RCT to compare the outcomes of Schatzker II–IV tibial plateau fractures between
30 arthroscopic-assisted balloon tibioplasty and traditional ORIF in China. If our hypothesis is
31 confirmed, our results will be important for informing the scheduling and development of
32 treatment options for Schatzker II–IV tibial plateau fracture surgery. We anticipate that the results
33 will provide reliable evidence and clarify the value of arthroscopic-assisted balloon tibioplasty as
34 a treatment for patients with Schatzker II–IV tibial plateau fractures.

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37 rehabilitation therapy for all patients involved in this study.

38 Contributors

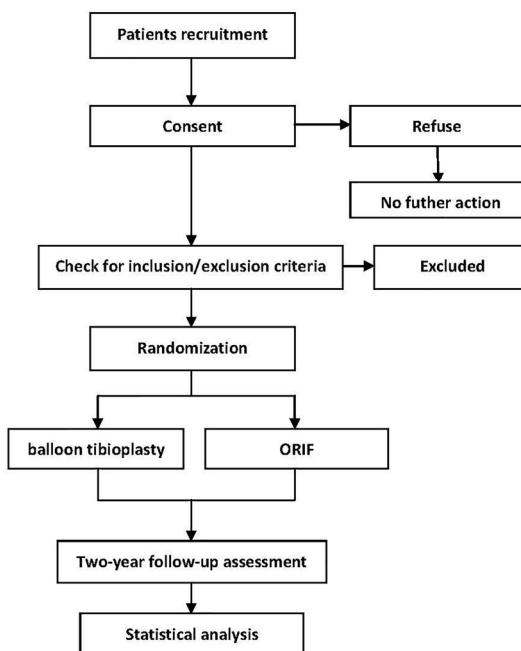
39 Ji-Qi Wang helped to design the trial and wrote the manuscript. Bing-Jie Jiang helped to design
40 the trial. Wei-Jun Guo helped to conceive the trial and revised the manuscript. Wei-Jiang Zhang
41 recruit the patients and conduct the trial. A-Bing Li will planned the statistical analysis. You-Ming
42 Zhao helped to design the study and critically revised the manuscript. All authors read and
43 approved the final manuscript.

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2
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5 3 The funders had no role in the design, execution or writing of the study.
6 4 Competing interests
7 5 None declared.
8 6 Patient consent
9 7 Obtained.
10 8 Ethics approval
11 9 The study had been reviewed and approved by the ethics committee of the Second Affiliated
12 10 Hospital of the Wenzhou Medical University, Wenzhou, China (batch: 2017-12).
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28 technique in the management of tibial plateau fracture: A multicentric experience review. *Journal*
29 *of orthopaedics* 14 (1):176-181. doi:10.1016/j.jor.2016.12.002
- 30
- 31 Figure 1. Flow chart showing the steps in participant recruitment, treatment and analysis. balloon
32 tibioplasty, arthroscopic assisted balloon tibioplasty group; ORIF, open reduction and internal
33 fixation group.



Flow chart showing the steps in participant recruitment, treatment and analysis. balloon tibioplasty, arthroscopic assisted balloon tibioplasty group; ORIF, open reduction and internal fixation group.

189x170mm (300 x 300 DPI)

supplementary information

title: Arthroscopic-assisted balloon tibioplasty versus open reduction internal fixation (ORIF) for treatment of Schatzker II–IV tibial plateau fractures: Study protocol of a randomized controlled trial

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supplementary information, S1

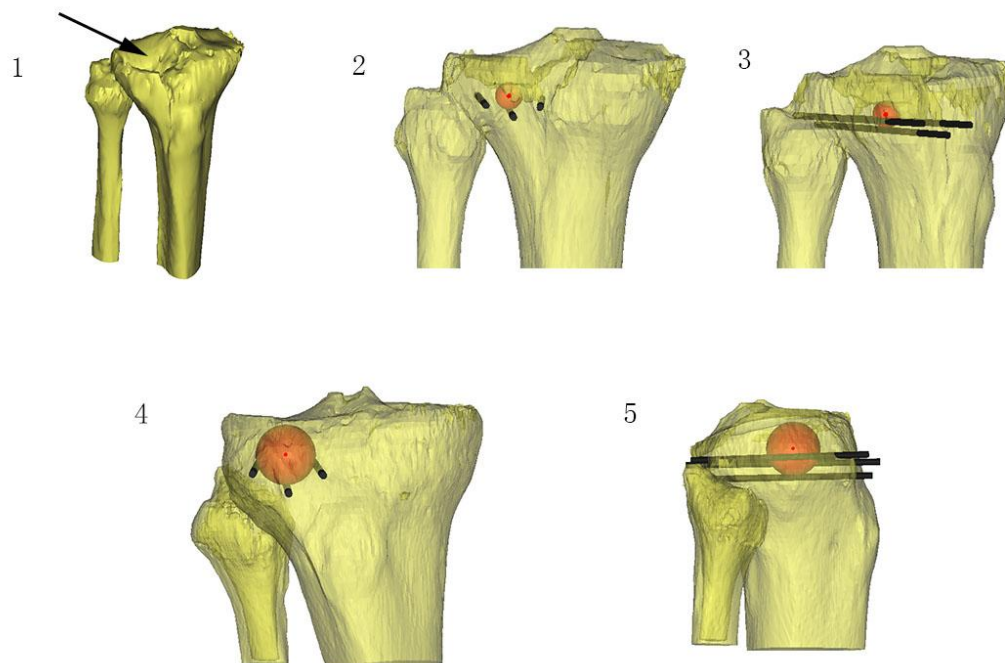
CT scan of Schatzker II to IV tibial plateau fractures, which conform to our inclusion criteria.



1, CT scan of Schatzker II tibial plateau fracture, which include the lateral platform split and depression (left limb); 2, CT scan of Schatzker III tibial plateau fracture, which only include the lateral tibial plateau depression (left limb); 3, CT scan of Schatzker IV tibial plateau fracture, which only include the medial tibial plateau depression (left limb).

supplementary information, S2

Simulated the operation process of Schatzker III tibial plateau fracture with Mimics software



1, The black arrowhead in the figure points to the depression of the lateral tibial plateau; 2, Three Kirschner wires and the balloon are placed below the depressed fragment under fluoroscopy (anteroposterior); 3, Three Kirschner wires and balloon are placed below the depressed fragment under fluoroscopy (laterolateral); 4, The balloon slowly inflated with contrast solution, and the depression of the lateral tibial plateau will be anatomical reduction (anteroposterior); 5, The balloon slowly inflated with contrast solution, and the depression of the lateral tibial plateau will be anatomical reduction (laterolateral). After removal of the balloon, calcium phosphate cement will be injected into the cavity produced by the balloon under fluoroscopic guidance, ensuring there is no excessive cement overflow into the tibial medullary cavity.



SPIRIT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents*

Section/item	Item No	Description
Administrative information		
Title (P1)	1	Descriptive title identifying the study design, population, interventions, and, if applicable, trial acronym
Trial registration (P1)	2a	Trial identifier and registry name. If not yet registered, name of intended registry
	2b	All items from the World Health Organization Trial Registration Data Set
Protocol version (Not mentioned)	3	Date and version identifier
Funding (P7)	4	Sources and types of financial, material, and other support
Roles and responsibilities (P6)	5a	Names, affiliations, and roles of protocol contributors
	5b	Name and contact information for the trial sponsor
	5c	Role of study sponsor and funders, if any, in study design; collection, management, analysis, and interpretation of data; writing of the report; and the decision to submit the report for publication, including whether they will have ultimate authority over any of these activities
	5d	Composition, roles, and responsibilities of the coordinating centre, steering committee, endpoint adjudication committee, data management team, and other individuals or groups overseeing the trial, if applicable (see Item 21a for data monitoring committee)
Introduction		
Background and rationale (P2)	6a	Description of research question and justification for undertaking the trial, including summary of relevant studies (published and unpublished) examining benefits and harms for each intervention
	6b	Explanation for choice of comparators
Objectives (P6)	7	Specific objectives or hypotheses

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Trial design (P2) 8 Description of trial design including type of trial (eg, parallel group, crossover, factorial, single group), allocation ratio, and framework (eg, superiority, equivalence, noninferiority, exploratory)

Methods: Participants, interventions, and outcomes

Study setting (P2) 9 Description of study settings (eg, community clinic, academic hospital) and list of countries where data will be collected. Reference to where list of study sites can be obtained

Eligibility criteria (P3) 10 Inclusion and exclusion criteria for participants. If applicable, eligibility criteria for study centres and individuals who will perform the interventions (eg, surgeons, psychotherapists)

Interventions (P3-P4) 11a Interventions for each group with sufficient detail to allow replication, including how and when they will be administered

11b Criteria for discontinuing or modifying allocated interventions for a given trial participant (eg, drug dose change in response to harms, participant request, or improving/worsening disease)

11c Strategies to improve adherence to intervention protocols, and any procedures for monitoring adherence (eg, drug tablet return, laboratory tests)

11d Relevant concomitant care and interventions that are permitted or prohibited during the trial

Outcomes (P4-P5) 12 Primary, secondary, and other outcomes, including the specific measurement variable (eg, systolic blood pressure), analysis metric (eg, change from baseline, final value, time to event), method of aggregation (eg, median, proportion), and time point for each outcome. Explanation of the clinical relevance of chosen efficacy and harm outcomes is strongly recommended

Participant timeline (P3) 13 Time schedule of enrolment, interventions (including any run-ins and washouts), assessments, and visits for participants. A schematic diagram is highly recommended (see Figure)

Sample size (P5) 14 Estimated number of participants needed to achieve study objectives and how it was determined, including clinical and statistical assumptions supporting any sample size calculations

Recruitment (P5) 15 Strategies for achieving adequate participant enrolment to reach target sample size

Methods: Assignment of interventions (for controlled trials)

Allocation:

1			
2	Sequence	16a	Method of generating the allocation sequence (eg, computer-
3	generation (P3)		generated random numbers), and list of any factors for stratification.
4			To reduce predictability of a random sequence, details of any planned
5			restriction (eg, blocking) should be provided in a separate document
6			that is unavailable to those who enrol participants or assign
7			interventions
8			
9	Allocation	16b	Mechanism of implementing the allocation sequence (eg, central
10	concealment		telephone; sequentially numbered, opaque, sealed envelopes),
11	mechanism		describing any steps to conceal the sequence until interventions are
12	(P3)		assigned
13			
14	Implementation	16c	Who will generate the allocation sequence, who will enrol participants,
15	(P3)		and who will assign participants to interventions
16			
17	Blinding	17a	Who will be blinded after assignment to interventions (eg, trial
18	(masking) (P3)		participants, care providers, outcome assessors, data analysts), and
19			how
20			
21		17b	If blinded, circumstances under which unblinding is permissible, and
22			procedure for revealing a participant's allocated intervention during
23			the trial
24			
25			

Methods: Data collection, management, and analysis

26			
27			
28	Data collection	18a	Plans for assessment and collection of outcome, baseline, and other
29	methods (P4)		trial data, including any related processes to promote data quality (eg,
30			duplicate measurements, training of assessors) and a description of
31			study instruments (eg, questionnaires, laboratory tests) along with
32			their reliability and validity, if known. Reference to where data
33			collection forms can be found, if not in the protocol
34			
35		18b	Plans to promote participant retention and complete follow-up,
36			including list of any outcome data to be collected for participants who
37			discontinue or deviate from intervention protocols
38			
39	Data	19	Plans for data entry, coding, security, and storage, including any
40	management (P5)		related processes to promote data quality (eg, double data entry;
41			range checks for data values). Reference to where details of data
42			management procedures can be found, if not in the protocol
43			
44			
45	Statistical	20a	Statistical methods for analysing primary and secondary outcomes.
46	methods (P5)		Reference to where other details of the statistical analysis plan can be
47			found, if not in the protocol
48			
49		20b	Methods for any additional analyses (eg, subgroup and adjusted
50			analyses)
51			
52		20c	Definition of analysis population relating to protocol non-adherence
53			(eg, as randomised analysis), and any statistical methods to handle
54			missing data (eg, multiple imputation)
55			
56			
57			
58			
59			
60			

Methods: Monitoring

Data monitoring (P5)	21a	Composition of data monitoring committee (DMC); summary of its role and reporting structure; statement of whether it is independent from the sponsor and competing interests; and reference to where further details about its charter can be found, if not in the protocol. Alternatively, an explanation of why a DMC is not needed
	21b	Description of any interim analyses and stopping guidelines, including who will have access to these interim results and make the final decision to terminate the trial
Harms (P5)	22	Plans for collecting, assessing, reporting, and managing solicited and spontaneously reported adverse events and other unintended effects of trial interventions or trial conduct
Auditing (P5)	23	Frequency and procedures for auditing trial conduct, if any, and whether the process will be independent from investigators and the sponsor

Ethics and dissemination

Research ethics approval (P6)	24	Plans for seeking research ethics committee/institutional review board (REC/IRB) approval
Protocol amendments (Not mentioned)	25	Plans for communicating important protocol modifications (eg, changes to eligibility criteria, outcomes, analyses) to relevant parties (eg, investigators, REC/IRBs, trial participants, trial registries, journals, regulators)
Consent or assent (P7)	26a	Who will obtain informed consent or assent from potential trial participants or authorised surrogates, and how (see Item 32)
	26b	Additional consent provisions for collection and use of participant data and biological specimens in ancillary studies, if applicable
Confidentiality (P5)	27	How personal information about potential and enrolled participants will be collected, shared, and maintained in order to protect confidentiality before, during, and after the trial
Declaration of interests (P7)	28	Financial and other competing interests for principal investigators for the overall trial and each study site
Access to data (P5)	29	Statement of who will have access to the final trial dataset, and disclosure of contractual agreements that limit such access for investigators
Ancillary and post-trial care (Not mentioned)	30	Provisions, if any, for ancillary and post-trial care, and for compensation to those who suffer harm from trial participation

1 2 3 4 5 6 7 8 9 10 11 12	Dissemination policy (P5)	31a	Plans for investigators and sponsor to communicate trial results to participants, healthcare professionals, the public, and other relevant groups (eg, via publication, reporting in results databases, or other data sharing arrangements), including any publication restrictions
13 14 15 16 17 18		31b	Authorship eligibility guidelines and any intended use of professional writers
19 20 21 22		31c	Plans, if any, for granting public access to the full protocol, participant-level dataset, and statistical code

Appendices

23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60	Informed consent materials (Not mentioned)	32	Model consent form and other related documentation given to participants and authorised surrogates
	Biological specimens (Not applicable)	33	Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in the current trial and for future use in ancillary studies, if applicable

*It is strongly recommended that this checklist be read in conjunction with the SPIRIT 2013 Explanation & Elaboration for important clarification on the items. Amendments to the protocol should be tracked and dated. The SPIRIT checklist is copyrighted by the SPIRIT Group under the Creative Commons "[Attribution-NonCommercial-NoDerivs 3.0 Unported](https://creativecommons.org/licenses/by-nc-nd/3.0/)" license.

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Arthroscopic-assisted balloon tibioplasty versus open reduction internal fixation (ORIF) for treatment of Schatzker II–IV tibial plateau fractures: Study protocol of a randomized controlled trial

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3 **1 Arthroscopic-assisted balloon tibioplasty versus open reduction internal fixation (ORIF) for**
4 **2 treatment of Schatzker II–IV tibial plateau fractures: Study protocol of a randomized**
5 **3 controlled trial**
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7 4

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15 11

16 12 **Keywords:** Tibial plateau fracture; Arthroscopic-assisted surgery; Balloon tibioplasty; Open
17 13 Reduction Internal Fixation; Protocol
18 14

19 15 **Word count:** 2467
20 16

21 17 **Abstract**

22 18 **Introduction:** Arthroscopic-assisted balloon tibioplasty is an emerging technology that has shown
23 19 advantages in recovering depression of the articular surface. However, studies evaluating clinical
24 20 outcomes between arthroscopic-assisted balloon tibioplasty and traditional open reduction internal
25 21 fixation (ORIF) are sparse. This is the first randomized study to compare arthroscopic-assisted
26 22 balloon tibioplasty with ORIF, and will provide guidance for treating patients with Schatzker type
27 23 II, III and IV with depression of the medial tibial plateau only.

28 24 **Methods and analysis:** A blinded randomized controlled trial will be conducted and a total of 80
29 25 participants will be randomly divided into either the arthroscopic-assisted balloon tibioplasty
30 26 group or the ORIF group, at a ratio of 1:1. The primary clinical outcome measures are the knee
31 27 functional scores, Rasmunssen radiological evaluation scores, and the quality of reduction based
32 28 on postoperative computed tomography scan. Secondary clinical outcome measures are
33 29 intraoperative blood loss, surgical duration, visual analog scale score after surgery, hospital
34 30 duration after surgery, complications, and SF-36 score.

35 31 **Ethics and dissemination:** This study has been reviewed and approved by the Institutional
36 32 Review Board of the Second Affiliated Hospital of Wenzhou Medical University (batch: 2017-12).
37 33 The results will be presented in peer-reviewed journals after completion of the study.

38 34 **Trial registration number:** NCT03327337, Pre-results

39 35 **Article summary:**

40 36 **Strengths and limitations of this study:**

41 37 **This trial is designed to have a feasible, comparative effectiveness trial design that has**
42 38 **similarities to common clinical situations.**

43 39 **This study is the first RCT to compare the outcomes of Schatzker II–IV tibial plateau fractures**
44 40 **between arthroscopic-assisted balloon tibioplasty and traditional ORIF in China.**

1
2
3 1 **Our results may be limited by heterogeneity due to differences in age, gender, region and race.**

4 2 **The size of the study sample limits the power of the observations.**

5 3 **Risk of bias due to death, loss of follow -up or uncompliant patients unable to complete tests or**
6 4 **questionnaires.**

7
8
9 6 **Introduction**

10 7 Tibial plateau fractures are complex intraarticular and metaphyseal lesions, accounting for 1–2%
11 8 of all fractures [1] caused by either a valgus or varus force in combination with an axial force [2].
12 9 The acknowledged surgical indication for a tibial plateau fracture is tilt or valgus malalignment
13 10 exceeding 5°, articular step-off exceeding 3 mm, or condylar widening exceeding 5 mm (lateral
14 11 tibial plateau fracture), or tilt or any displacement (medial tibial plateau fracture) [3]. Many
15 12 classification systems have been developed for tibial plateau fractures and are used for
16 13 preoperative planning and prognostic purposes [4-6]. The Schatzker classification system is
17 14 simple and widely used among orthopedic surgeons in clinical practice. Schatzker II–IV tibial
18 15 plateau fractures include lateral or medial depressed articular fragments, and loss of joint
19 16 congruity in these injuries is associated with a poor prognosis, such as posttraumatic arthrosis and
20 17 valgus deformity despite proper management. Therefore, restoration of the joint surface is the goal
21 18 of surgery [7-9].

22 19 Open reduction internal fixation (ORIF) for treatment of this type of fracture has yielded
23 20 promising results. Gavaskar *et al.* [10] reported that ORIF could achieve satisfactory radiological
24 21 and functional results in split depression lateral tibial plateau fractures. After ORIF for 15 cases of
25 22 medial tibial plateau fractures, Morin *et al.* [11] reported that 93% of patients were satisfied or
26 23 very satisfied with their functional recovery and there were no cases of pseudarthrosis or
27 24 secondary varus displacement. However, traditional ORIF treatment has a number of
28 25 disadvantages, e.g., excessive damage, limited exposure of the articular cavity, and insufficient
29 26 ability to diagnose and address internal joint injury [12].

30 27 With recent technological advances, the treatment concept of tibial plateau fractures has
31 28 progressed from mechanical fixation to minimally invasive surgical interventions for
32 29 biomechanical stability [13,14]. Based on the success of vertebral kyphoplasty, arthroscopic
33 30 assisted balloon tibioplasty [15] has been developed as a novel minimally invasive technique for
34 31 reducing depressed tibial plateau fractures. Arthroscopic-assisted balloon tibioplasty is an
35 32 emerging technology that aims to visualize the articular surface, and uses balloon distension tibial
36 33 plasty assisted by arthroscopy to recover depression of the articular surface and fix the fracture
37 34 according to its specific type [16]. This technology has shown advantages in recovering
38 35 depression of the articular surface [17], treating additional intraarticular lesions during the
39 36 operation, and minimizing surgical trauma. Furthermore, under fluoroscopy, optimal centering of
40 37 the expanding tibioplasty balloon allows a widespread and continuously increasing reduction force
41 38 to be applied to the fracture area [18]. Primary data from Ollivier *et al.* [19] showed that depressed
42 39 tibial plateau fractures treated with arthroscopic-assisted balloon tibioplasty had a high rate of
43 40 anatomic reduction and good clinical outcomes. Similar results were also reported by Pizanis *et al.*
44 41 [15] using arthroscopic-assisted balloon tibioplasty without classic fenestration of the tibia, which
45 42 would minimize surgical trauma. However, a number of factors influence the clinical adoption of
46 43 this surgical technique: the application time of is short, there is a paucity of case data and
47 44 information regarding long-term follow-up, and the cost of operation is higher than traditional

1
2
3 1 ORIF [20].

4 2 To our knowledge, there have been no randomized controlled trials (RCTs) of the clinical
5 3 outcomes of arthroscopic-assisted balloon tibioplasty versus ORIF, where high-quality RCTs are
6 4 generally deemed to be the gold standard in clinical research. In this study, we will perform an
7 5 RCT to compare arthroscopic-assisted balloon tibioplasty and traditional ORIF.

6 **Methods and design**

7 This study has been approved by the Ethics Committee of the Second Affiliated Hospital of
8 Wenzhou Medical University, and conforms to the Declaration of Helsinki. All patients will
9 provide informed consent prior to participation in this study. This trial has been registered at the
10 US National Institutes of Health Clinical Trials Registry (NCT03327337). The protocol conforms
11 to the Standard Protocol Items Recommendations for Interventional Trials. Figure 1 shows a chart
12 of the trial design.

13 **Participants**

14 This study is a parallel group RCT conducted at the Department of Orthopaedics, the Second
15 Affiliated Hospital of Wenzhou Medical University. Fractures will be evaluated on anteroposterior
16 (AP) and laterolateral (LL) radiographs and by computed tomography (CT), which can analyze the
17 fracture pattern more precisely.

18 **Inclusion criteria**

19 (1) Acute closed fractures less than 10 days old, and X-ray and CT scan showing Schatzker type II,
20 III or IV with depression of the medial tibial plateau only. (supplementary information, S1)

21 (2) No history of knee joint dislocation or other knee trauma.

22 (3) Signed informed consent.

23 (4) Age of 18–80 years.

24 **Exclusion criteria**

25 (1) Other types of tibial plateau fracture (Schatzker type I, IV with split or comminute fracture, V,
26 and VI).

27 (2) Concomitant injuries that will interfere with functional recovery, such as combined fracture of
28 the lower limb.

29 (3) Open fractures, pathological fractures, immunodeficiency, hematological diseases, or severe
30 hepatorenal disorders.

31 **Patient involvement**

32 The design of this study was not directly involved in the patients, and the intervention in this study
33 is not considered to change the patient's direct perception of the preoperative and intraoperative
34 processes or the postoperative rehabilitation therapy. As the enrolment in study may influence the
35 patient's view of the clinical work or even feel like a burden, the patients will be interviewed
36 randomly to identify adverse effects. The results will be informed by mail to all the patients
37 involved.

38 **Randomization and blinding**

39 Pre-randomization eligibility checks will be carried out to ensure that participants are eligible for
40 inclusion in the study. Patients will be randomly assigned to one of two groups (experimental or
41 control) using a computer-generated random assignment in a 1:1 ratio, and allocation will be
42 concealed until the point of randomization. Patients, researchers performing the follow-up
43 measurements, and the trial statistician will be blinded to the group allocations until the last
44 questionnaires have been completed.

1 **Interventions**

2 Arthroscopic-assisted balloon tibioplasty group:

3 Step 1: In cases with a splitting tibial plateau fracture (Schatzker type II), an incision will be made
4 in the proximal tibia according to the fracture type, for placement of a small locking T-plate
5 (Synthes, Freiburg, Germany) using minimally invasive techniques. Then, a temporary cortical
6 bone screw will be inserted to prevent cortical rupture when the balloon is enlarged. Temporary
7 fixation of the cortical bone screw will permit further adjustment of the position of the plate. In
8 cases with no splitting tibial plateau fracture (Schatzker type III or IV with depression of the
9 medial tibial plateau only), we will proceed to step 2 directly.

10 Step 2: Three Kirschner wires (2 mm) will be placed below the depressed fragment under
11 fluoroscopy. Using live fluoroscopy, the balloon will be placed in the optimal position and slowly
12 inflated with contrast solution (Ultravist®; Schering, Berlin, Germany). The arthroscope will then
13 be used to confirm anatomical reduction of the depressed fragment. The balloon will be deflated,
14 repositioned, and reinflated to reduce the persistent depression. After removal of the balloon, we
15 will use a Kirschner wire (2 mm) to temporarily lift the depressed fragment and carefully inject
16 calcium phosphate cement (Osteopal® V; Heraeus Medical GmbH, Wehrheim, Germany) into the
17 cavity produced by the balloon under fluoroscopic guidance, ensuring there is no excessive
18 cement overflow into the tibial medullary cavity. (supplementary information, S2)

19 ORIF group:

20 For this technique, a lateral or medial surgical approach will be used according to the type of
21 fracture. The depressed fragment will be elevated by a metal tamp through a small cortical
22 window in the proximal tibia, and bone substitute will be used. Finally, internal fixation will be
23 performed when an acceptable reduction has been achieved.

24 If satisfactory reduction cannot be achieved using arthroscopic-assisted balloon tibioplasty,
25 patients will undergo ORIF and be excluded from the study. All patients will receive rehabilitation
26 therapy regardless of the group to which they are allocated, and progressive partial weight-bearing
27 will be permitted with the aid of two crutches. Postoperative CT scans will be performed
28 immediately, and at 2 weeks and 1, 3, 6, 12, and 24 months, and Rasmussen radiological
29 evaluation will be performed [21]. To evaluate functional recovery of the knee joint and
30 health-related quality of life, all patients will complete Rasmussen functional score and
31 Short-Form Health Survey (SF-36) questionnaires during the follow-up period. Scoring will
32 be performed by two researchers who not involved in the initial treatment.

33 **Outcome measurements**

34 Primary outcome measure:

- 35 1. Knee functional recovery will be assessed by the Rasmussen functional score, which will be
36 recorded at 3, 6, 12, and 24 months postoperatively.
- 37 2. Rasmussen radiological evaluation will be recorded immediately, and at 2 weeks and 1, 3, 6,
38 12, and 24 months postoperatively.
- 39 3. The quality of reduction will be determined based on postoperative CT scans, which can
40 directly measure the amount of residual depression, at 2 weeks and 1, 3, 6, 12, and 24 months
41 postoperatively.

42 Secondary outcome measures:

- 43 1. Intraoperative blood loss will be recorded in the anesthesia records, and will include the blood
44 in suction bottles (after subtracting the lavage fluid used during the surgery), and that in the

1 weighed sponges used during the operation.
2
3 2. Surgical duration.
4
5 3. The severity of lower limb pain after surgery will be assessed using a visual analog scale (VAS)
6 pain score. The VAS scores of leg pain will be recorded from the day of the operation to the day of
7 discharge from hospital (up to 2 weeks).
8
9 4. Hospitalization period after surgery.
10
11 5. Complications including wound infection (defined as minor, major, early, or late according to
12 the criteria described by the Surgical Infection Study Group [22]), reoperations, and posttraumatic
13 arthritis (PTA) will be recorded.
14 PTA may not be seen in patients within the 24-month follow-up period, and we will perform
15 follow-up for at least 10 years in all patients.

16 6. Health-related quality of life will be measured using the Short-Form Health Survey (SF-36)
17 questionnaire during follow-up.

18 The SF-36 is a health-related quality of life questionnaire used to assess both the mental and
19 physical health of the patient.

20 **Baseline demographics**

21 Sex, age, body mass index (BMI), mechanism of injury, smoking status, alcohol use, and
22 comorbidities (i.e., hypertension, diabetes, cardiopathy)

23 **Follow-up**

24 Follow-up will be conducted at 2 weeks and 1, 3, 6, 12, and 24 months postoperatively.

25 **Monitoring**

26 All investigators who have completed training are capable of independently collecting the data
27 and assessing the clinical outcomes, and all electronic data will be recorded by an electronic data
28 capture system (DAP Software Company, Beijing, China). Safety and data monitoring will be
29 performed periodically during the study. All paper and electronic data will be stored for 10 years
30 in the secure research archives at the Second Affiliated Hospital of Wenzhou Medical University,
31 with restricted access.

32 **Sample size calculation**

33 There have been no previous studies on which to base the sample size calculation. In a related
34 study [21], the excellent Rasmussen radiological evaluation proportion of the control group was
35 60%, and the proportion of the intervention group was 70%. We carried out power analysis to
36 determine the sample size required to show safety with a type I error probability of 5% and an
37 80% probability of avoiding a type II error. Using these assumptions, the required sample size is
38 35 per group. With the assumption of a 12.5% loss to follow-up, we will include 40 participants
39 per group.

40 **Statistical analysis**

41 The trial data will be analyzed using SPSS for Windows software (ver. 19.0; SPSS Inc., Chicago,
42 IL). For continuous variables, the Shapiro–Wilk test will be applied to determine if they follow a
43 normal distribution. For normally distributed variables, the means will be calculated and compared
44 using the independent samples *t* test (Student's *t* test); otherwise, the Mann–Whitney U test will be
45 used for group comparisons. The chi-square test will be used to analyze qualitative variables. In
46 all analyses, $P < 0.05$ will be taken to indicate statistical significance.

47 **Discussion**

48 There have been a number of reports describing treatment for tibial plateau fractures. In a

1
2
3 1 systematic review of the treatment of tibial plateau fractures, Metcalfe *et al.* [23] suggested that
4 2 ORIF and external fixation are both acceptable strategies for managing bicondylar tibial plateau
5 3 fractures, with no statistically significant differences found in the rates of complications between
6 4 the two methods. In addition, after a systematic review of all studies reporting return to sport
7 5 following tibial plateau fracture, Robertson *et al.* [24] reported that the rate of return to sport for
8 6 the total cohort was 70%, versus 60% for those with fractures managed with ORIF and 83% for
9 7 fractures treated with arthroscopic-assisted reduction internal fixation (OR 3.22, 95% CI:
10 8 2.09–4.97, $P < 0.001$).

11 9 An ideal treatment method for Schatzker II–IV tibial plateau fracture not only has to achieve
12 10 anatomical restoration of the knee joint, but also rigid fixation to allow early postoperative
13 11 rehabilitation [25]. Traditional ORIF requires extensive soft tissue dissection, which may lead to
14 12 numerous negative outcomes such as slow wound healing, infection, and PTA [26]. Due to limited
15 13 exposure, intraarticular lesions, such as meniscus or anterior cruciate ligament (ACL) injuries,
16 14 cannot be diagnosed and treated properly [27]. Ruffolo *et al.* [28] reported that nonunion and deep
17 15 infections occur commonly after ORIF, and long surgical durations are associated with higher
18 16 rates of infection. With the development of arthroscopic techniques, arthroscopy-assisted
19 17 reduction and internal fixation (ARIF) has been widely adopted in the treatment of tibial plateau
20 18 fractures [29], and has shown good functional recovery and radiological results [30–32]. After
21 19 comparing the Rasmussen and Hospital for Special Surgery knee-rating (HSS) scores between
22 20 ARIF and ORIF, Dall'oca *et al.* [12] reported that the ARIF technique improved the clinical
23 21 outcome in Schatzker type II–IV fractures. Balloon tibioplasty is an arthroscopic-assisted
24 22 minimally invasive technique that creates a symmetrical, contained defect to hold bone filler for
25 23 subchondral support; the balloon also allows eliminate the neurological and vascular risks of the
26 24 conventional approach[20]. This technique has already been used for kyphoplasty and
27 25 maxillofacial surgery, and has recently been applied for tibial plateau fractures [15,19,33].
28 26 Mauffrey *et al.* [20] reported early positive results with arthroscopy-assisted balloon tibioplasty
29 27 used as an alternative reduction method, and the method is gaining in acceptance. This paper
30 28 describes the protocol for conducting an RCT in China that will investigate the efficacy of
31 29 arthroscopic-assisted balloon tibioplasty in treating Schatzker II–IV tibial plateau fractures. The
32 30 design of this trial included an ORIF group as a control group, to compare the clinical outcomes of
33 31 Schatzker II–IV tibial plateau fractures with those of arthroscopic-assisted balloon tibioplasty
34 32 fixation. Arthroscopic-assisted balloon tibioplasty is hypothesized to be superior in reducing
35 33 surgical trauma, and to have better clinical outcomes in comparison with ORIF. This study is the
36 34 first RCT to compare the outcomes of Schatzker II–IV tibial plateau fractures between
37 35 arthroscopic-assisted balloon tibioplasty and traditional ORIF in China. If our hypothesis is
38 36 confirmed, our results will be important for informing the scheduling and development of
39 37 treatment options for Schatzker II–IV tibial plateau fracture surgery. We anticipate that the results
40 38 will provide reliable evidence and clarify the value of arthroscopic-assisted balloon tibioplasty as
41 39 a treatment for patients with Schatzker II–IV tibial plateau fractures.

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42 42 rehabilitation therapy for all patients involved in this study.

43 **Contributors**

44 Ji-Qi Wang helped to design the trial and wrote the manuscript. Bing-Jie Jiang helped to design

1 the trial. Wei-Jun Guo helped to conceive the trial and revised the manuscript. Wei-Jiang Zhang
2 recruit the patients and conduct the trial. A-Bing Li will planned the statistical analysis. You-Ming
3 Zhao helped to design the study and critically revised the manuscript. All authors read and
4 approved the final manuscript.

5 **Funding**

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7 the Wenzhou Medical University (SAHoWMU-CR2017-08-105).

8 The funders had no role in the design, execution or writing of the study.

9 **Competing interests**

10 None declared.

11 **Patient consent**

12 Obtained.

13 **Ethics approval**

14 The study had been reviewed and approved by the ethics committee of the Second Affiliated
15 Hospital of the Wenzhou Medical University, Wenzhou, China (batch: 2017-12).

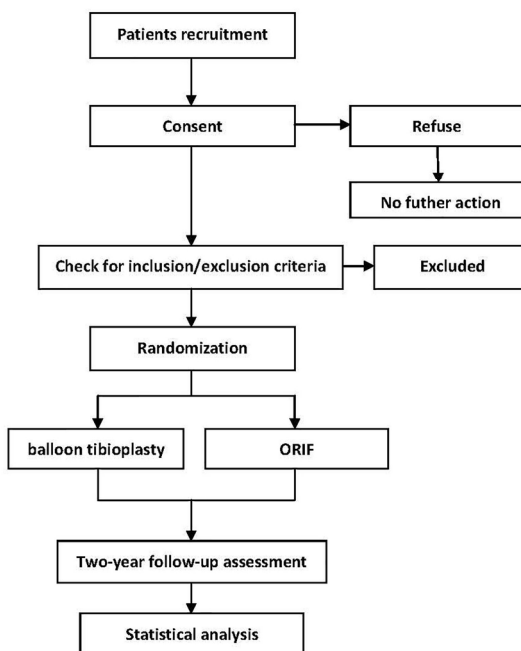
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37 Figure 1. Flow chart showing the steps in participant recruitment, treatment and analysis. balloon
38 tibioplasty, arthroscopic assisted balloon tibioplasty group; ORIF, open reduction and internal
39 fixation group.



Flow chart showing the steps in participant recruitment, treatment and analysis. balloon tibioplasty, arthroscopic assisted balloon tibioplasty group; ORIF, open reduction and internal fixation group.

189x170mm (300 x 300 DPI)

supplementary information

title: Arthroscopic-assisted balloon tibioplasty versus open reduction internal fixation (ORIF) for treatment of Schatzker II–IV tibial plateau fractures: Study protocol of a randomized controlled trial

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supplementary information, S1

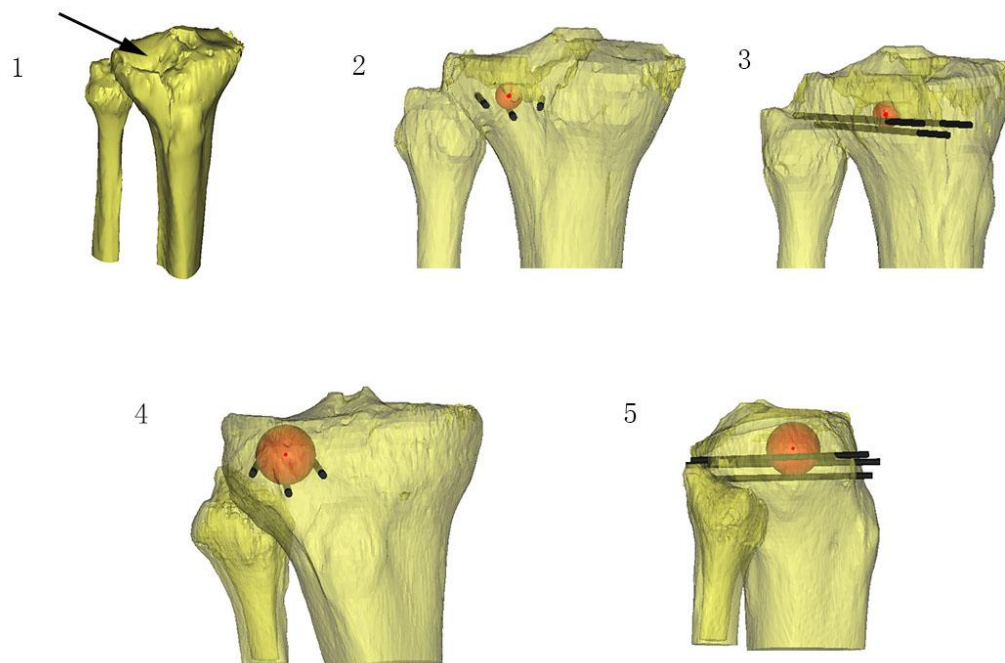
CT scan of Schatzker II to IV tibial plateau fractures, which conform to our inclusion criteria.



1, CT scan of Schatzker II tibial plateau fracture, which include the lateral platform split and depression (left limb); 2, CT scan of Schatzker III tibial plateau fracture, which only include the lateral tibial plateau depression (left limb); 3, CT scan of Schatzker IV tibial plateau fracture, which only include the medial tibial plateau depression (left limb).

1
2
3 supplementary information, S2

4
5 Simulated the operation process of Schatzker III tibial plateau fracture with Mimics software



34 1, The black arrowhead in the figure points to the depression of the lateral tibial plateau; 2, Three
35 Kirschner wires and the balloon are placed below the depressed fragment under fluoroscopy
36 (anteroposterior); 3, Three Kirschner wires and balloon are placed below the depressed fragment
37 under fluoroscopy (laterolateral); 4, The balloon slowly inflated with contrast solution, and the
38 depression of the lateral tibial plateau will be anatomical reduction (anteroposterior); 5, The balloon
39 slowly inflated with contrast solution, and the depression of the lateral tibial plateau will be
40 anatomical reduction (laterolateral). After removal of the balloon, calcium phosphate cement will
41 injected into the cavity produced by the balloon under fluoroscopic guidance, ensuring there is no
42 excessive cement overflow into the tibial medullary cavity.
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SPIRIT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents*

Section/item	Item No	Description
Administrative information		
Title (P1)	1	Descriptive title identifying the study design, population, interventions, and, if applicable, trial acronym
Trial registration (P1)	2a	Trial identifier and registry name. If not yet registered, name of intended registry
	2b	All items from the World Health Organization Trial Registration Data Set
Protocol version (Not mentioned)	3	Date and version identifier
Funding (P7)	4	Sources and types of financial, material, and other support
Roles and responsibilities (P6)	5a	Names, affiliations, and roles of protocol contributors
	5b	Name and contact information for the trial sponsor
	5c	Role of study sponsor and funders, if any, in study design; collection, management, analysis, and interpretation of data; writing of the report; and the decision to submit the report for publication, including whether they will have ultimate authority over any of these activities
	5d	Composition, roles, and responsibilities of the coordinating centre, steering committee, endpoint adjudication committee, data management team, and other individuals or groups overseeing the trial, if applicable (see Item 21a for data monitoring committee)
Introduction		
Background and rationale (P2)	6a	Description of research question and justification for undertaking the trial, including summary of relevant studies (published and unpublished) examining benefits and harms for each intervention
	6b	Explanation for choice of comparators
Objectives (P6)	7	Specific objectives or hypotheses

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Trial design (P2) 8 Description of trial design including type of trial (eg, parallel group, crossover, factorial, single group), allocation ratio, and framework (eg, superiority, equivalence, noninferiority, exploratory)

Methods: Participants, interventions, and outcomes

Study setting (P2) 9 Description of study settings (eg, community clinic, academic hospital) and list of countries where data will be collected. Reference to where list of study sites can be obtained

Eligibility criteria (P3) 10 Inclusion and exclusion criteria for participants. If applicable, eligibility criteria for study centres and individuals who will perform the interventions (eg, surgeons, psychotherapists)

Interventions (P3-P4) 11a Interventions for each group with sufficient detail to allow replication, including how and when they will be administered

11b Criteria for discontinuing or modifying allocated interventions for a given trial participant (eg, drug dose change in response to harms, participant request, or improving/worsening disease)

11c Strategies to improve adherence to intervention protocols, and any procedures for monitoring adherence (eg, drug tablet return, laboratory tests)

11d Relevant concomitant care and interventions that are permitted or prohibited during the trial

Outcomes (P4-P5) 12 Primary, secondary, and other outcomes, including the specific measurement variable (eg, systolic blood pressure), analysis metric (eg, change from baseline, final value, time to event), method of aggregation (eg, median, proportion), and time point for each outcome. Explanation of the clinical relevance of chosen efficacy and harm outcomes is strongly recommended

Participant timeline (P3) 13 Time schedule of enrolment, interventions (including any run-ins and washouts), assessments, and visits for participants. A schematic diagram is highly recommended (see Figure)

Sample size (P5) 14 Estimated number of participants needed to achieve study objectives and how it was determined, including clinical and statistical assumptions supporting any sample size calculations

Recruitment (P5) 15 Strategies for achieving adequate participant enrolment to reach target sample size

Methods: Assignment of interventions (for controlled trials)

Allocation:

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2	Sequence	16a	Method of generating the allocation sequence (eg, computer-
3	generation (P3)		generated random numbers), and list of any factors for stratification.
4			To reduce predictability of a random sequence, details of any planned
5			restriction (eg, blocking) should be provided in a separate document
6			that is unavailable to those who enrol participants or assign
7			interventions
8			
9	Allocation	16b	Mechanism of implementing the allocation sequence (eg, central
10	concealment		telephone; sequentially numbered, opaque, sealed envelopes),
11	mechanism		describing any steps to conceal the sequence until interventions are
12	(P3)		assigned
13			
14	Implementation	16c	Who will generate the allocation sequence, who will enrol participants,
15	(P3)		and who will assign participants to interventions
16			
17	Blinding	17a	Who will be blinded after assignment to interventions (eg, trial
18	(masking) (P3)		participants, care providers, outcome assessors, data analysts), and
19			how
20			
21		17b	If blinded, circumstances under which unblinding is permissible, and
22			procedure for revealing a participant's allocated intervention during
23			the trial
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Methods: Data collection, management, and analysis

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28	Data collection	18a	Plans for assessment and collection of outcome, baseline, and other
29	methods (P4)		trial data, including any related processes to promote data quality (eg,
30			duplicate measurements, training of assessors) and a description of
31			study instruments (eg, questionnaires, laboratory tests) along with
32			their reliability and validity, if known. Reference to where data
33			collection forms can be found, if not in the protocol
34			
35		18b	Plans to promote participant retention and complete follow-up,
36			including list of any outcome data to be collected for participants who
37			discontinue or deviate from intervention protocols
38			
39	Data	19	Plans for data entry, coding, security, and storage, including any
40	management (P5)		related processes to promote data quality (eg, double data entry;
41			range checks for data values). Reference to where details of data
42			management procedures can be found, if not in the protocol
43			
44			
45	Statistical	20a	Statistical methods for analysing primary and secondary outcomes.
46	methods (P5)		Reference to where other details of the statistical analysis plan can be
47			found, if not in the protocol
48			
49		20b	Methods for any additional analyses (eg, subgroup and adjusted
50			analyses)
51			
52		20c	Definition of analysis population relating to protocol non-adherence
53			(eg, as randomised analysis), and any statistical methods to handle
54			missing data (eg, multiple imputation)
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Methods: Monitoring

Data monitoring (P5)	21a	Composition of data monitoring committee (DMC); summary of its role and reporting structure; statement of whether it is independent from the sponsor and competing interests; and reference to where further details about its charter can be found, if not in the protocol. Alternatively, an explanation of why a DMC is not needed
	21b	Description of any interim analyses and stopping guidelines, including who will have access to these interim results and make the final decision to terminate the trial
Harms (P5)	22	Plans for collecting, assessing, reporting, and managing solicited and spontaneously reported adverse events and other unintended effects of trial interventions or trial conduct
Auditing (P5)	23	Frequency and procedures for auditing trial conduct, if any, and whether the process will be independent from investigators and the sponsor

Ethics and dissemination

Research ethics approval (P6)	24	Plans for seeking research ethics committee/institutional review board (REC/IRB) approval
Protocol amendments (Not mentioned)	25	Plans for communicating important protocol modifications (eg, changes to eligibility criteria, outcomes, analyses) to relevant parties (eg, investigators, REC/IRBs, trial participants, trial registries, journals, regulators)
Consent or assent (P7)	26a	Who will obtain informed consent or assent from potential trial participants or authorised surrogates, and how (see Item 32)
	26b	Additional consent provisions for collection and use of participant data and biological specimens in ancillary studies, if applicable
Confidentiality (P5)	27	How personal information about potential and enrolled participants will be collected, shared, and maintained in order to protect confidentiality before, during, and after the trial
Declaration of interests (P7)	28	Financial and other competing interests for principal investigators for the overall trial and each study site
Access to data (P5)	29	Statement of who will have access to the final trial dataset, and disclosure of contractual agreements that limit such access for investigators
Ancillary and post-trial care (Not mentioned)	30	Provisions, if any, for ancillary and post-trial care, and for compensation to those who suffer harm from trial participation

1 2 3 4 5 6 7 8 9 10 11 12	Dissemination policy (P5)	31a 31b 31c	Plans for investigators and sponsor to communicate trial results to participants, healthcare professionals, the public, and other relevant groups (eg, via publication, reporting in results databases, or other data sharing arrangements), including any publication restrictions Authorship eligibility guidelines and any intended use of professional writers Plans, if any, for granting public access to the full protocol, participant-level dataset, and statistical code
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Appendices

13 14 15 16 17 18 19 20 21 22	Informed consent materials (Not mentioned)	32	Model consent form and other related documentation given to participants and authorised surrogates
23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60	Biological specimens (Not applicable)	33	Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in the current trial and for future use in ancillary studies, if applicable

*It is strongly recommended that this checklist be read in conjunction with the SPIRIT 2013 Explanation & Elaboration for important clarification on the items. Amendments to the protocol should be tracked and dated. The SPIRIT checklist is copyrighted by the SPIRIT Group under the Creative Commons "[Attribution-NonCommercial-NoDerivs 3.0 Unported](https://creativecommons.org/licenses/by-nc-nd/3.0/)" license.