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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии
საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებშიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman (Кириллица)**, для текста на грузинском языке следует использовать **AcadNusx**. Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи.** Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - <http://www.spinesurgery.ru/files/publish.pdf> и http://www.nlm.nih.gov/bsd/uniform_requirements.html. В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректур авторам не высылаются, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or computer-printed on a single side of standard typing paper, with the left margin of 3 centimeters width, and 1.5 spacing between the lines, typeface - **Times New Roman (Cyrillic)**, print size - 12 (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf

In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

**Articles that Fail to Meet the Aforementioned
Requirements are not Assigned to be Reviewed.**

ავტორთა საყურადღებო!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე, დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx**. შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემავსებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრაფიის ფოტოსურათები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შედეგების ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფხიხლებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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REVIEW OF INTRA-OPERATIVE TECHNIQUES TO ASSESS REDUCTION QUALITY IN TIBIAL PLATEAU FRACTURES

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Abstract.

Achieving anatomical reduction in tibial plateau fractures is essential to restore joint congruity and minimize long-term complications. Intraoperative assessment remains challenging, especially in complex fracture patterns, prompting the evolution of various imaging and adjunctive techniques. This narrative review summarizes advancements in intraoperative tools used for evaluating reduction in tibial plateau fractures. Techniques discussed include 2D fluoroscopy, intraoperative 3D imaging, arthroscopy, and emerging adjuncts such as 3D printing and cone-beam CT. We conducted a targeted literature search across PubMed, Embase, and Scopus (2000-2025) to identify studies reporting on the clinical application, diagnostic utility, and limitations of intraoperative imaging modalities in tibial plateau fracture management. 2D fluoroscopy remains widely used but is limited in detecting subtle incongruities. Intraoperative 3D imaging enhances accuracy and may reduce reoperations. Arthroscopy offers direct joint visualization, especially useful for assessing depression and posterior injuries. Emerging tools like 3D printing and cone-beam CT present novel intraoperative aids but require further validation. This review provides a consolidated overview of intraoperative strategies described in the literature. By highlighting the current capabilities and limitations of available technologies, we aim to inform ongoing clinical practice and future directions in fracture management.

Key words. 3d imaging, intra-operative fluoroscopy, orthopaedic trauma surgery, surgical reduction assessment, tibial plateau fractures.

Introduction.

Tibial plateau fractures represent a challenging subset of periarticular injuries, often resulting from high-energy trauma in younger patients or low-energy mechanisms in the elderly. These fractures can lead to significant long-term morbidity, including joint stiffness, instability, and post-traumatic osteoarthritis, particularly if anatomical reduction is not achieved and maintained [1]. Given the complexity of the proximal tibia's articular surface and its proximity to neurovascular structures, accurate reduction and fixation are paramount [2].

Historically, intraoperative assessment of reduction has relied primarily on 2D fluoroscopy. While widely accessible and familiar to surgeons, its limitations in assessing articular congruity and posterior slope have prompted the integration of advanced imaging and visualization modalities. These include intraoperative 3D fluoroscopy or CT, arthroscopy-assisted reduction, and more recently, adjunctive innovations such as 3D printing and cone-beam CT [3].

Despite the growing array of intraoperative tools, there remains variability in practice patterns and limited consensus on their comparative effectiveness. In this narrative review, we synthesize current evidence from the literature to describe the evolution of imaging and adjunctive techniques in tibial plateau fracture reduction. Our aim is to present an integrated overview of intraoperative strategies and technological advancements to support clinical understanding and future innovation in operative fracture care.

Materials and Methods.

This narrative review was conducted to evaluate intraoperative techniques used to assess reduction quality in tibial plateau fractures. A comprehensive literature search was conducted using PubMed, Embase, and Scopus databases to identify studies published from January 2000 to June 2025. The following Boolean search string was used: ("tibial plateau fracture*" OR "tibial plateau" OR "tibial condyle fracture*" OR "proximal tibia fracture*") AND ("reduction" OR "fracture reduction" OR "articular reduction") AND ("intraoperative" OR "intra-operative" OR "during surgery" OR "intra-op") AND ("assessment" OR "evaluation" OR "quality" OR "accuracy") AND ("fluoroscopy" OR "arthroscopy" OR "CT" OR "computed tomography" OR "navigation" OR "3D imaging" OR "intraoperative imaging"). Language was restricted to English.

Articles were selected based on relevance, study design, and availability of intraoperative assessment details. Case reports, review articles, prospective and retrospective studies were included. Emphasis was placed on clinical applicability, imaging modality accuracy, invasiveness, and practical limitations. Exclusion criteria were non-clinical studies (e.g., cadaveric, animal), non-operative management, and studies not directly assessing reduction.

No formal systematic review protocol or meta-analysis was undertaken due to the heterogeneity of study designs and endpoints. Where applicable, data on reduction accuracy, patient outcomes, and intraoperative efficiency were extracted. All included studies were reviewed independently by two authors, and discrepancies were resolved through discussion.

The search yielded a total of 19 studies. After screening titles and abstracts, 5 studies were excluded as irrelevant. Of the remaining 14 articles, 3 were excluded during full-text review because they were cadaveric studies. Ultimately, 11 clinical studies were included in the data extraction and synthesis, see table 1 for details. Data points included study design, sample size, imaging/assessment method, comparator, and key outcomes.

Based on the studies included in this review, several distinct intra-operative techniques for assessing reduction quality in tibial plateau fractures have been described. Below, we provide a narrative summary of each technique identified across the included papers, outlining their clinical application, supporting evidence, and relevant advantages or limitations as reported in the literature.

Together, these studies demonstrate a progression from reliance on fluoroscopy alone to the incorporation of advanced imaging, arthroscopy, and adjunctive techniques, which are outlined in detail below.

Intra-operative Techniques Identified.

Several studies in this review highlighted the insufficiency of fluoroscopy alone in evaluating articular congruity. Beisemann et al. reported that intra-operative 3D imaging led to revision in 26.5% of cases after reduction had appeared satisfactory on fluoroscopy. Similarly, Krause et al. found that “fracturoscopy” identified residual articular depressions measuring ≥ 2 mm in fractures initially deemed acceptable by fluoroscopic assessment. These findings emphasize the potential for false reassurance when relying solely on conventional fluoroscopy in complex fracture scenarios. The following intra-operative techniques were identified across the included studies, grouped for clarity and listed approximately in order of common clinical usage based on the literature reviewed:

1. Conventional 2D Fluoroscopy:

Conventional 2D fluoroscopy remains the baseline intra-operative imaging modality for reduction assessment and implant positioning in tibial plateau fracture surgery. It is universally available, allows rapid real-time evaluation, and was employed as the primary or initial assessment tool in the majority of included studies [4-11]. However, its limitations are well-documented: conventional fluoroscopy provides only planar images and is prone to missing subtle articular step-off, gaps, or malpositioned hardware, especially in posterior or centrally located fragments and in complex fracture configurations. Several studies in this review [4,9,12-14] highlighted that reductions appearing satisfactory on fluoroscopy were later found to be inadequate on multiplanar imaging, leading to intra-operative revisions. As such, while 2D fluoroscopy is foundational, reliance on this modality alone may result in false reassurance, particularly in complex cases.

2. Intraoperative 3D C-arm Imaging (including Cone Beam CT):

The development of intraoperative 3D C-arm systems has significantly advanced the ability to assess fracture reduction and implant placement in tibial plateau surgery. These devices allow multiplanar reconstruction and CT-like visualization directly within the operating theatre, providing surgeons with axial, coronal, and sagittal views that overcome the limitations of conventional fluoroscopy. Clinical series have demonstrated that 3D C-arm imaging frequently identifies articular incongruities and hardware malpositions that appear satisfactory on 2D fluoroscopy, prompting intraoperative revision in 7–26% of cases [4,6,7,13]. Importantly, Beisemann et al. (2022) reported that patients with residual incongruity <2

mm on intraoperative 3D imaging experienced significantly better long-term functional outcomes, highlighting the clinical relevance of this modality.

Cone beam CT (CBCT) represents a technical variant of 3D C-arm imaging. While based on the same principle of rotational image acquisition, CBCT employs a cone-shaped X-ray beam and a flat-panel detector, producing volumetric datasets with higher spatial resolution and potentially lower radiation dose compared to standard 3D C-arm reconstructions. In the large series reported by Beisemann et al. (2019), intraoperative CBCT revealed insufficient reduction or implant malposition in over a quarter of cases, most commonly due to residual articular step-off or incorrect screw length. These findings underscore its value as a safeguard against leaving the operating room with suboptimal fixation. The limitations of 3D imaging, whether standard or cone beam, include equipment cost, operating room integration, a learning curve, and occasional issues with scan volume or image quality. Nevertheless, both technologies have been widely adopted in specialist centers and are now considered key adjuncts when treating complex or high-risk tibial plateau fractures.

3. 3D Printing-Assisted Surgical Planning:

Three-dimensional (3D) printing-assisted surgical planning is an emerging adjunct in the management of complex tibial plateau fractures. This technique involves generating a physical, patient-specific 3D model from preoperative CT data, which enables the surgical team to rehearse the reduction, plan implant position and size, and select the optimal approach before entering the operating theatre. Surgeons can use these models to template screw and plate positions, anticipate technical challenges, and even fabricate custom guides for use during the procedure. In the largest meta-analysis to date [5], 3D printing-assisted surgery was associated with reductions in operative time, blood loss, intra-operative fluoroscopy use, and complication rates, alongside improved accuracy of reduction compared to conventional planning.

However, it is important to note that 3D printing serves primarily as a preoperative planning tool rather than a real-time intra-operative assessment modality. During surgery, the actual assessment of reduction and implant position still relies on conventional methods, such as 2D fluoroscopy and direct visualization. While the evidence suggests 3D printing can facilitate more efficient and accurate surgery—especially in complex or comminuted fractures—its utility is dependent on access to advanced imaging and 3D printing technology, which may not be available in all centers. As such, 3D printing should be viewed as an adjunct to, rather than a replacement for, intra-operative reduction assessment.

4. Arthroscopy-assisted Techniques:

Arthroscopy-assisted reduction and fixation has become an established adjunct in the surgical management of tibial plateau fractures, particularly for unicondylar and selected bicondylar patterns. By allowing direct visualization of the joint surface, arthroscopy enables precise elevation and reduction of depressed articular fragments while simultaneously diagnosing and treating associated intra-articular pathology, such as meniscal or ligamentous injuries. In the retrospective series by Asik et

al., arthroscopy was used for all fracture types, resulting in high rates of satisfactory reduction and functional recovery with low morbidity [8]. Further variants of this technique include arthroscopically assisted percutaneous screw fixation [9], which combines the benefits of minimal soft tissue disruption with accurate articular reduction and is particularly suitable for Schatzker I-III fractures.

Another important evolution is the “fracturoscopy” technique, in which an arthroscope is introduced through the open surgical field after provisional fixation to directly inspect the articular surface. Krause et al. [10] showed that fracturoscopy identified clinically significant step-offs (>2 mm) in more than half of complex fractures that had appeared acceptable on fluoroscopy, prompting immediate intra-operative correction. Hybrid and minimally invasive approaches, such as bidirectional traction devices combined with adjunct arthroscopy [11], have demonstrated reduced blood loss and hospital stay while improving radiological reduction compared to conventional open reduction. While arthroscopy-assisted techniques offer significant advantages in select fracture patterns and facilitate early rehabilitation, they require specialized equipment and technical expertise and may not be feasible in all clinical scenarios.

5. Osteotomy Approaches:

Osteotomy-based exposures have been developed for the management of tibial plateau fractures with complex posterior or posterolateral involvement, where direct visualization and reduction through standard approaches is challenging. The fibular neck osteotomy technique [14] involves careful osteotomy and reattachment of the fibular neck, allowing full exposure of the posterolateral articular surface and safe reduction of difficult-to-access fragments. In their retrospective series, Chen et al. achieved high rates of anatomical reduction and excellent functional outcomes, with no cases of nerve injury or osteotomy nonunion, provided that the peroneal nerve was meticulously protected.

Similarly, Gerdy’s tubercle osteotomy [11] utilises an anterior lateral approach with an L-shaped osteotomy and outward flipping of Gerdy’s tubercle to expose the posterior lateral condyle. This technique enabled direct reduction and fixation of complex posterior fragments, leading to excellent or good healing rates and functional outcomes without major complications. While osteotomy-based approaches offer superior access for reduction and fixation in selected cases, they are technically demanding and carry specific risks-including peroneal nerve injury and potential osteotomy healing problems-necessitating careful patient selection and meticulous surgical technique.

Results and Discussion.

In practice, the selection of intra-operative reduction assessment depends less on the formal Schatzker classification itself and more on the complexity, displacement, and location of the fracture fragments. For relatively simple, minimally displaced unicondylar fractures, conventional fluoroscopy is often sufficient, though adjunctive arthroscopy may add value in confirming articular congruity and detecting associated soft tissue injury. As fracture patterns become more complex—

particularly bicondylar injuries, medial condylar involvement, or fractures extending into the posterior plateau—fluoroscopy alone is less reliable. In such cases, intra-operative 3D C-arm imaging or cone beam CT provides greater accuracy in detecting incongruity and malpositioned implants. In environments where advanced imaging is not available, direct visualization techniques such as submeniscal arthrotomy or osteotomy can provide access to otherwise hidden fracture zones. Preoperative 3D printing, while not a real-time tool, may further assist in surgical planning for highly comminuted or atypical fracture morphologies. Ultimately, the choice of modality should be guided by a combination of fracture characteristics, surgeon expertise, and institutional resources, rather than by fracture classification alone.

As intraoperative imaging continues to advance, several areas merit further exploration. Integrating multimodal tools-like combining fluoroscopy with 3D imaging or arthroscopy-may improve reduction accuracy, especially in complex cases [15]. Artificial intelligence also holds promise for real-time decision-making but remains underexplored in orthopaedic trauma. Future research should focus on the cost-effectiveness and workflow impact of technologies like cone-beam CT and 3D printing and should include multicenter trials evaluating long-term outcomes. Additionally, establishing learning curves for new modalities such as fracturoscopy or AR, and incorporating patient-reported outcomes, will be vital for broader clinical adoption [16].

While this review offers a consolidated synthesis of intraoperative techniques for tibial plateau fracture reduction, it is not without limitations. As a narrative rather than systematic review, it lacks formal risk-of-bias assessment or quantitative comparison. The included studies vary widely in design, patient populations, and outcome definitions, making direct comparisons difficult. Additionally, emerging modalities such as artificial intelligence and augmented reality remain in early stages, with limited clinical validation data available. As such, some conclusions are speculative and based on preliminary findings. Finally, most current literature originates from high-resource settings, limiting generalizability to lower-resource or rural surgical environments. Inherent to the narrative review format, there is also the potential for selection bias in how evidence is synthesized. Moreover, as much of the published work originates from prestigious academic and high-resource institutions, the reported outcomes may not fully reflect the realities of general hospitals or low-resource environments.

Conclusion.

A wide array of intra-operative techniques exists for assessing the quality of reduction in tibial plateau fractures, each with its own strengths and limitations. Conventional fluoroscopy remains the standard in most operating rooms, but it frequently underestimates malreduction, particularly in complex fracture patterns. Advanced imaging techniques such as intra-operative 3D fluoroscopy and CT provide improved accuracy, while arthroscopy offers direct articular visualisation and can guide precise reduction in selected cases.

Less frequently used methods, including navigation-assisted surgery, 3D printing, and osteotomy, may enhance outcomes

in specific situations but require greater resources or expertise. Ultimately, a tailored, case-by-case approach that considers fracture complexity, surgeon experience, and available technology is essential to optimise reduction and functional outcomes.

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