RESEARCH ARTICLE

Plate Breakage Following Internal Fixation of Long Bone Diaphyseal Fractures: A 150-Case Analysis

Yan-zi Liu, MMed; Wei Zhu, MMed; Xue-dong Tian, MMed

Research performed at Zibo Hospital of Traditional Chinese Medicine, Zibo, Shandong, China

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Abstract

Objectives: This study analyzed cases of plate breakage following internal fixation of long bone diaphyseal fractures to identify contributing factors and inform clinical practice.

Methods: A retrospective analysis of 150 plate breakage cases after diaphyseal fracture fixation was conducted using data from the "DXY" forum in November 2023. Patient demographics, fracture characteristics, plate specifications, surgical techniques, and outcomes were evaluated.

Results: Plate breakages occurred most frequently in the femur (67.3%), predominantly in wedge or multifragmentary fractures (60.7%). Locking plates were used in 64.7% of cases. Despite high rates of anatomical reduction (87.9% in complex fractures), plate failures occurred at an average of 11.3 months post-operation. High screw density (0.83-0.89 screws used/total holes) was observed across fracture types. In femoral fractures, the fracture zone length to working plate length ratio was notably high (0.91), indicating a relatively short working length.

Conclusion: Findings suggest that prioritizing anatomical reduction and rigid fixation may contribute to plate breakage, potentially due to impaired biological healing. Adherence to contemporary AO principles, emphasizing relative stability and biological fixation techniques, may be crucial in preventing these complications. The study highlights the need for a balanced approach between mechanical stability and biological considerations in fracture management.

Level of evidence: IV

Keywords: Biological fixation, Biomechanics, Fracture healing, Implant failure, Surgical technique

Introduction

Since the 1950s, internal fixation has progressively become a pivotal modality in fracture management, bolstered by the advocacy of organizations like the Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation (AO/ASIF).[1] Internal fixation plates provide temporary support to promote bone healing, with the goal of becoming unnecessary as the bone regains strength and allows for early functional rehabilitation[1]. Internal fixation materials, whether metals or alloys, are distinct from the vital bone tissue they support. When subjected to repeated stresses and strains, these non-living materials gradually accumulate localized damage, ultimately leading to partial or complete failure known as metal fatigue.[2] when metal fatigue occurs before fracture union, there is a high likelihood of internal fixation failure.[3]

Metal fixation plates, composed of materials like stainless steel, titanium alloys, and pure titanium, are essential for internal fracture fixation.[4] Plate breakage following internal fixation, while relatively uncommon, presents a significant clinical challenge. The probability of plate breakage in the fixation of diaphyseal fractures of the extremities is a significant concern in orthopedic surgery, particularly due to the potential for complications that can affect patient outcomes. Research indicates that the incidence of implant breakage during internal fixation surgery ranges from

Corresponding Author: Xue-dong Tian, Department of Orthopedic Surgery , Zibo Hospital of Traditional Chinese Medicine, Zibo, Shandong, China

Email: txdxt@qq.com

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approximately 3.5% to 13.3% depending on various factors, including patient demographics and surgical techniques employed.[5,6] These adverse events not only impact patient outcomes but also contribute to increased healthcare costs due to extended hospital stays, rehabilitation needs, and the complexity of revision procedures. Despite the clinical and economic burden associated with plate breakage, there is a dearth of large-scale studies investigating its risk factors, particularly within the context of contemporary surgical techniques and implant designs.

The scarcity of large-scale studies within single medical institutions makes it challenging to prevent plate fractures and identify plate types susceptible to failure. This study presents an analysis of 150 cases of fixation plate fractures in long bone diaphyseal fractures. This analysis describes relevant case data and identifies preventative measures to inform clinical practice and future research.

Materials and Methods

General Information

The primary data for this investigation were obtained from case discussions within the orthopedics section of DXY (bbs.dxy.cn), a prominent Chinese medical forum for orthopedic surgeons. This forum hosts a large number of reliable case discussions. In November 2023, a search was conducted on this forum using keywords such as "internal fixation," "fracture," and "plate breakage." The inclusion and exclusion criteria were delineated as follows:

Inclusion Criteria:

Cases were selected involving long bone diaphyseal fractures, including those of the femur, tibia/fibula, humerus, and ulna/radius. These correspond to AO classifications of 12, 2R2/2U2, 32, and 42/4F2, respectively. This search identified 150 cases.

Exclusion Criteria:

- Cases with incomplete clinical data.
- Non-diaphyseal fractures (e.g., articular, spinal, hand, foot, clavicle).
- Periprosthetic fractures following joint arthroplasty.
- Pathological fractures.

Fractures were classified into Types A (simple), B (wedge), and C (multifragmentary) according to the AO classification system.

Standards for fracture reduction (quality of reduction) are stratified into three grades:

Grade I: Anatomical reduction, in which all displacement is corrected, restoring normal anatomy with excellent apposition and alignment. Grade II: Functional reduction, in which functional anatomy is restored despite not achieving anatomical precision. This includes restoring length, alignment, rotational axis, and, particularly in the lower limb, the load-bearing axis.

Grade III: Poor reduction, indicating that the criteria for either anatomical or functional restoration have not been met.

Two senior physicians jointly assessed the quality of fracture reduction to ensure a consensus-based and experienced evaluation.

Statistical Analysis

Given the retrospective nature of this study on surgical failures, descriptive statistics, including odds and percentages, were used for analysis. Microsoft Excel 2019 was used for data collection and analysis. This study analyzes the general characteristics of patients who experienced postoperative plate breakages, including demographics (age, gender), fracture characteristics, plate specifications, anatomical location of the fracture (humerus, ulna/radius, femur, tibia/fibula), and time to plate breakage. Preoperative and postoperative radiographs were analyzed to evaluate the quality of reduction, time to plate breakage, and plate-related factors (fracture length, working length, total length, locking mechanism) in both simple and wedge/multifragmentary fractures. Descriptive statistics of these parameters were used to analyze plate breakages.

Results

Patient Demographics

This study included 150 patients with diaphyseal fractures and subsequent plate breakage: 122 males (81.3%) and 28 females (18.7%). The mean age at the time of plate breakage was 47.9 years, occurring at a mean of 11.3 months postoperatively. The most common fracture site was the femoral shaft (n=101, 67.3%), followed by the ulna/radius (n=20, 13.3%), tibia/fibula (n=17, 11.3%), and humerus (n=12, 8.0%). Wedge and multifragmentary fractures were most common (n=91, 60.7%), and locking plates were frequently used (n=97, 64.7%) [Table 1].

Table 1. General Information

Location	N	Postoperative time to plate breakage (months)	Age (years)	Gender		Fracture Classification		Plate type	
				Male	*Female*	*A*	*B/C*	*non locking plate*	*Locking plates*
Humerus	12	9.5±4.1 (4~16)	53.2±9.8 (40~66)	10	2	5	7	3	9
Radius/Ulna	20	5.8±3.3 (2~12)	44.4±11.1 (30~61)	16	4	7	13	14	6
Femur	101	13.3±4.0 (2~16)	49.2±18.6 (11~89)	81	20	36	65	31	70
Tibia/Fibula	17	7.2±3.9 (2~12)	41.0±14.6 (21~58)	15	2	11	6	5	12
Total	150	11.3±4.2 (2~16)	47.9±17.3 (11-89)	122	28	59	91	53	97

Plate Breakage in Simple Fractures

In Type A fractures, plate breakage occurred most frequently in the femoral shaft (n=39, 66.1%). At these sites, 79.7% (n=33) achieved anatomical reduction, indicating high reduction quality. In simple fractures, plate breakage was most commonly associated with locking plates (n=41, 69.5%). The working length to total length ratio of the fractured plates ranged from 0.20 to 0.27 across different fracture sites. The screw-to-screw hole ratio ranged from 0.83 to 0.89 [Table 2].

Table 2. Plate breakage in Simple Fractures

Location	N	Postoperative time to plate breakage (months)	quality of reduction		working length /total length	Screws / screw holes	Types of plate	
			I	*II*			*Non- locking plate*	*Locking plate*
Hrmerus	2	7.7±3.9 (4~10)	2	0	0.26	0.88	1	1
Radius/Ulna	14	6.6±3.1 (5~10)	10	4	0.27	0.83	11	3
Femur	39	9.4±4.8 (4~16)	33	6	0.20	0.89	5	34
Tibia/Fibula	4	8.1±2.5 (2~10)	2	2	0.25	0.88	1	3

Plate Breakages in Wedge and Multifragmentary Fractures

In Type B and C fractures, the femoral shaft remained the most common site of plate breakage (68.1%). Anatomical reduction was achieved in 87.9% of these cases. Plate breakage was predominantly associated with locking plates (82.4%).

The fracture zone length to working plate length ratio ranged from 0.40 to 0.91, with the highest value (0.91) observed in femoral shaft fractures, indicating a relatively shorter working length in these cases.

The working length to total length ratio of the fractured plates ranged from 0.28 to 0.33 across different fracture sites. The screw-to-screw hole ratio ranged from 0.83 to 0.89 [Table 3].

Table 3. Plate breakages in Wedge and Multifragmentary Fractures

Location	N	Postoperative time to plate breakage (months)	quality of reduction		fracture zone length/ working length	working length / total length	Screws/ screw holes	Types of plate	
			I	*II*				*Non- locking plate*	*Locking plate*
Hrmerus	10	10.3±5.5 (6~16)	8	2	0.81	0.32	0.79	2	8
Radius/Ulna	6	5.9±2.3 (2~12)	5	1	0.40	0.33	0.89	1	5
Femur	62	14.6±3.7 (2~12)	55	7	0.91	0.28	0.89	11	51
Tibia/Fibula	13	6.2±4.2 (4~12)	12	1	0.77	0.31	0.84	2	11

Discussion

While the fundamental AO principles of anatomy, fixation, biology, and biomechanics remain unchanged, their application and interpretation have evolved over the past four decades, reflecting advances in research and clinical practice.[7] While rigid internal fixation was once considered standard for all fracture types, the current consensus recommends it primarily for periarticular fractures, emphasizing the importance of preserving blood supply and soft tissue integrity.

This study found that most plate breakages occurred in cases with Grade I reduction, many achieving anatomical realignment. This finding suggests that some surgeons still prioritize anatomical reduction and a "perfect" postoperative radiograph, even in cases where this approach might not be optimal and could lead to complications. Diaphyseal fracture management should prioritize restoring length, alignment, and rotational axis. If plate fixation is clinically necessary, meticulous planning and minimally invasive techniques should be used to minimize disruption to fracture fragment blood supply and surrounding soft tissues.

Precise reduction of diaphyseal fractures is generally unnecessary, with a focus instead on restoring length, rotation, and mechanical axes. Simple diaphyseal fractures (Type A) respond differently to intramedullary nails than to plate fixation. While absolute stability is crucial for plate fixation in these cases, multifragmentary fractures (Types B and C) can often be effectively managed with splinting techniques. Due to their unique long bone morphology and static joint functions, forearm diaphyseal fractures warrant special consideration.[8]

While osteoporosis and refractures were once attributed to stress shielding or stress protection, compromised blood supply is now recognized as a more significant contributing factor. Excessive manipulation of fracture ends can severely disrupt regional blood supply, delaying fracture healing. If patients begin rehabilitation based on standard timelines despite impaired healing, the risk of plate breakage increases.[9]

When treating a fracture, it is crucial to consider the patient's overall health status, as factors like smoking and diabetes can contribute to early implant failure.[10] while primary bone healing is possible, secondary healing, characterized by callus formation, is the more common pathway to fracture union. The concept of biological fixation emphasizes preserving the biological microenvironment of fracture healing. This approach favors indirect reduction techniques and limited open approaches, minimizing direct exposure and manipulation of the fracture ends. The plate is often positioned extraperiosteally to avoid periosteal stripping. Excessive disruption of blood supply can delay union or even lead to nonunion, increasing the likelihood of plate failure. Delayed unions resulting from vascular compromise are more challenging to manage than those caused solely by fixation instability. This study found that most multifragmentary fractures achieved Grade I or II reduction, suggesting potentially extensive periosteal stripping during surgery. This finding contrasts with the principles of biological fixation and might contribute to delayed healing and plate breakage.

As a living tissue, bone follows biomechanical principles, with morphology and composition influenced by an individual's activity level. Bone morphology optimizes both mechanical load bearing and efficient metabolic transport. Wolff's Law states that bone adapts to mechanical stimuli, altering its structure in response. The "use it or lose it" principle highlights that diaphyseal fractures require only functional alignment, as the bone will remodel under stress to accommodate function. Reduced bone stress due to the presence of a metal plate can lead to decreased bone density, potentially resulting in osteoporosis or osteonecrosis.[11]

Reduction techniques are crucial in fracture management. Excessive displacement of fracture ends can impair angiogenesis, promote fibroconnective tissue proliferation, and ultimately hinder callus formation by disrupting intramembranous and endochondral ossification. Tissue tolerance to deformation varies widely: granulation tissue (up to 100%), cartilage (up to 10%), and bone tissue (only 2%). While interfragmentary movement with a 30% strain promotes callus formation in gaps less than 2mm, this micromotion hinders callus formation in larger gaps. Selecting the appropriate degree of stability (relative or absolute) based on fracture type is crucial for achieving bone healing (direct or indirect) and preventing complications like nonunion, osteolysis, or plate failure.[7]

Thorough preoperative planning, including a comprehensive analysis of the fracture's characteristics, is essential for selecting an appropriate fixation strategy. Intraoperatively, adherence to biomechanical principles is crucial, recognizing the intended function of the fixation plate—compression, protection, bridging, tensioning, support, or internal scaffolding. This approach helps achieve the desired biomechanical effects, optimizing the mechanical environment for callus formation, growth, and ultimately, a favorable therapeutic outcome.[12]

This study found that the ratio of screws used to total screw holes ranged between 0.8 and 0.9 in cases of plate breakage, regardless of fracture type (simple or wedge/multifragmentary). This high screw density can lead to stress concentration on the plate, increasing its susceptibility to fracture under repetitive loading. Sommer et al. recommend maintaining a 2-3 hole gap at the fracture site when using bridging plates and enhancing support for osteoporotic fractures with additional screws and bicortical fixation.[13] Fracture healing should be assessed clinically and radiographically. Nonunion or delayed healing can increase the risk of plate breakage due to metal fatigue induced by weight-bearing. Internal fixation materials are primarily metals like titanium alloys, stainless steel, and pure titanium, designed to accommodate the anatomy and biomechanical demands of long bones. Stainless steel is favored for its strength and ductility, while titanium alloys offer superior biocompatibility and corrosion resistance. Repetitive stress from orthopedic use inevitably subjects metal plates to fatigue. Patient factors such as weight, activity level, and adherence to rehabilitation protocols influence the forces acting on the plate. A metal plate aids in bone healing but cannot replace normal bone structure. Furthermore, plate design is inherently limited by bone and soft tissue anatomy, impacting plate volume and strength.

This study did not analyze the specific materials or designs of the fractured plates, precluding conclusions about the relationship between these factors and plate breakage. Preoperative review of the selected internal fixation device's certification and instructions is essential, although not always routinely practiced. As the adage goes, "The expertise of ten material scientists cannot compensate for one poor fixation." Lv et al. identified plate screw placement near the fracture line as an independent risk factor for implant fracture (HR=2.165). This finding has led to the development of novel plates with screw-free sections near the fracture line to mitigate this risk.[5] These screw-free sections, located adjacent to the fracture line, mitigate the risk of fracture. Using finite element analysis, Wang et al. determined that the working length, the presence of holes within the working length, and the overall length of the plate significantly affect the mechanical environment at the fracture site.[14] Compared to non-perforated plates, traditional perforated plates lead to greater interfragmentary motion and stress concentration, potentially hindering fracture healing. These findings have significant implications for internal fixation device development and clinical practice.

Non-surgical treatment is preferred for simple diaphyseal humeral fractures, with limited evidence supporting surgical intervention. Surgical indications generally include open fractures, vascular or nerve injuries, bilateral humeral diaphyseal fractures, segmental fractures, and failed non-surgical treatment. Evidence suggests that plate fixation, compared to intramedullary nailing, can effectively reduce reoperation rates and the incidence of shoulder injuries.[15] Evidence-based research on the treatment of diaphyseal fractures of both the ulna and radius in the forearm is limited. A recent meta-analysis suggests that elastic intramedullary nailing, compared to plate fixation, may improve overall treatment efficacy, shorten time to radiographic union and hospital stay, and reduce complications like refractures and implant fractures.[16]

This study highlights a continued preference for plate fixation in lower limb diaphyseal fractures. Due to a high risk of complications, non-surgical treatment for femoral shaft fractures is no longer recommended, with intramedullary nailing now considered the treatment of choice. Reamed intramedullary nailing, using either an antegrade or retrograde approach, is appropriate for adult femoral shaft fractures.[17] Current evidence supports the use of static, locked, reamed intramedullary nailing for both closed, unstable adult tibial fractures and open tibial fractures in adults after appropriate soft tissue management.[15]

The lack of a control or comparison group is a limitation of this study, as it prevents conclusions about causality or differences between treatment groups. Further research with larger sample sizes and control groups is needed to confirm and build upon these findings.

Conclusion

Excessive emphasis on anatomical reduction, coupled with insufficient attention to biological principles, may contribute to delayed unions and subsequent plate failures under repetitive stress. Analysis of screw density, working length, and overall plate dimensions suggests that localized stress concentrations may contribute to material fatigue. Management of long bone diaphyseal fractures should adhere to relevant evidence-based medical guidelines, with careful consideration given to the choice of treatment modality. When surgical intervention is chosen, treatment should consider the biological and biomechanical characteristics of the fracture, guided by contemporary AO principles.

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Yan-zi Liu MMED [1]
Wei Zhu MMED [2]
Xue-dong Tian MMED [1]

1 Department of Orthopedic Surgery, Zibo Hospital of Traditional Chinese Medicine (Zibo Orthopedic Hospital), Zibo, Shandong, China

2 Department of Ophthalmology Surgery, Zibo Central Hospital, Zibo, Shandong, China

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