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REVIEW: Primary Bone Grafting in Comminuted Intertrochanteric Fractures Treated with Cephalomedullary Nails: Biological Rationale, Current Evidence, and Clinical Decision-Making

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ABSTRACT

Comminuted intertrochanteric fractures remain among the most challenging proximal femoral injuries despite the widespread use of cephalomedullary nails. In these fractures, loss of cortical continuity, metaphyseal voids, and severe posteromedial comminution may compromise both mechanical stability and biological continuity. Primary bone grafting has therefore been proposed as an adjunct to enhance fracture healing, yet its role during index fixation remains uncertain.
To provide a narrative review of the biological rationale, current evidence, and clinical decision-making considerations surrounding primary bone grafting in comminuted intertrochanteric fractures treated with cephalomedullary nails.
A focused narrative review was performed using PubMed/MEDLINE, Scopus, and Google Scholar. Relevant English-language studies and reviews addressing intertrochanteric fracture fixation, fracture healing biology, bone grafting, nonunion, augmentation strategies, and cephalomedullary nail complications were reviewed and synthesized.
The available literature strongly supports the importance of mechanical optimization, including acceptable reduction, restoration of medial support, appropriate implant placement, and construct stability. In contrast, direct comparative evidence evaluating cephalomedullary nail fixation with and without primary bone grafting in acute comminuted intertrochanteric fractures is scarce. Evidence supporting graft use is therefore largely indirect and derives from fracture healing biology, nonunion treatment, revision surgery, and the management of bone defects. These data suggest that while grafts may enhance osteogenesis, osteoinduction, and osteoconduction, routine grafting for all unstable fractures is not currently supported.
Primary bone grafting should not be considered a routine component of fixation for all comminuted intertrochanteric fractures. Mechanical stability remains the principal determinant of union. Primary grafting may be considered selectively in the presence of major residual defects, persistent biological disadvantage, or situations in which fracture biology appears compromised despite adequate fixation. The current evidence supports a selective, individualized approach rather than universal graft augmentation.

Introduction

Intertrochanteric femoral fractures account for a substantial proportion of hip fractures and continue to impose a major clinical and socioeconomic burden worldwide, especially in older adults with osteoporosis (1-4). The goals of treatment are rapid mobilization, restoration of function, and prevention of complications related to prolonged recumbency. Contemporary management has shifted toward intramedullary fixation for unstable patterns, and cephalomedullary nails are widely accepted because they function as load-sharing devices with a shorter lever arm and favorable biomechanical characteristics (5-9). Despite advances in implant design and surgical technique, comminuted intertrochanteric fractures remain difficult to treat. Severe comminution, disruption of the medial buttress, loss of the posteromedial fragment, poor bone quality, and residual metaphyseal voids may compromise fixation and healing (10-15). Failure after fixation is typically multifactorial and may include varus collapse, excessive sliding, cut-out, cut-through, delayed union, nonunion, and implant breakage (12,14-17).

The central controversy addressed in this review is whether biological augmentation in the form of primary bone grafting should be added during index fixation of these fractures. The attractiveness of grafting is understandable. Bone grafts may provide osteogenic cells, osteoinductive mediators, and osteoconductive scaffolds, potentially improving the local environment for healing (18-21). Nevertheless, an appealing biological rationale does not necessarily justify routine clinical use, particularly in acute fractures of a region with generally favorable vascularity and cancellous bone content.

A critical distinction must be made between mechanical insufficiency and biological deficiency. Many failures in intertrochanteric fracture fixation arise because of suboptimal reduction, poor restoration of support, inappropriate implant positioning, or inadequate stability rather than the absence of biologic stimulus (10-16,22). Bone grafting cannot compensate for poor mechanics. Conversely, once a stable construct has been achieved, biological augmentation may be relevant in selected circumstances, such as large residual metaphyseal defects or severely compromised bone stock.

The purpose of the present narrative review is therefore not to advocate routine grafting, but to clarify the biological rationale, appraise the strength and limits of the available evidence, and propose a practical framework for selective decision-making. Our guiding thesis is that mechanical stability is mandatory, whereas biological augmentation should be selective.

Scope and Literature Search Approach

This article was prepared as a narrative review. A focused literature search was carried out using PubMed/MEDLINE, Scopus, and Google Scholar. Search combinations included the terms “intertrochanteric fracture,” “pertrochanteric fracture,” “cephalomedullary nail,” “intramedullary nail,” “bone graft,” “bone augmentation,” “fracture healing,” “nonunion,” “revision fixation,” and “bone substitute.”

The search emphasized studies published from 1990 through 2026, together with several older landmark publications relevant to fracture healing biology and the biomechanical principles of fixation. Preference was given to clinical studies, systematic reviews, narrative reviews of established relevance, and foundational experimental or conceptual articles that informed current thinking. Because direct comparative trials of acute intertrochanteric fracture fixation with and without primary bone grafting are limited, evidence from nonunion treatment, bone defect management, and augmentation studies was also considered when clinically informative.

This review was not designed as a formal systematic review or meta-analysis. Consequently, the synthesis that follows is interpretive and clinically oriented. The objective was to integrate current knowledge into a practical perspective rather than to quantitatively pool results.

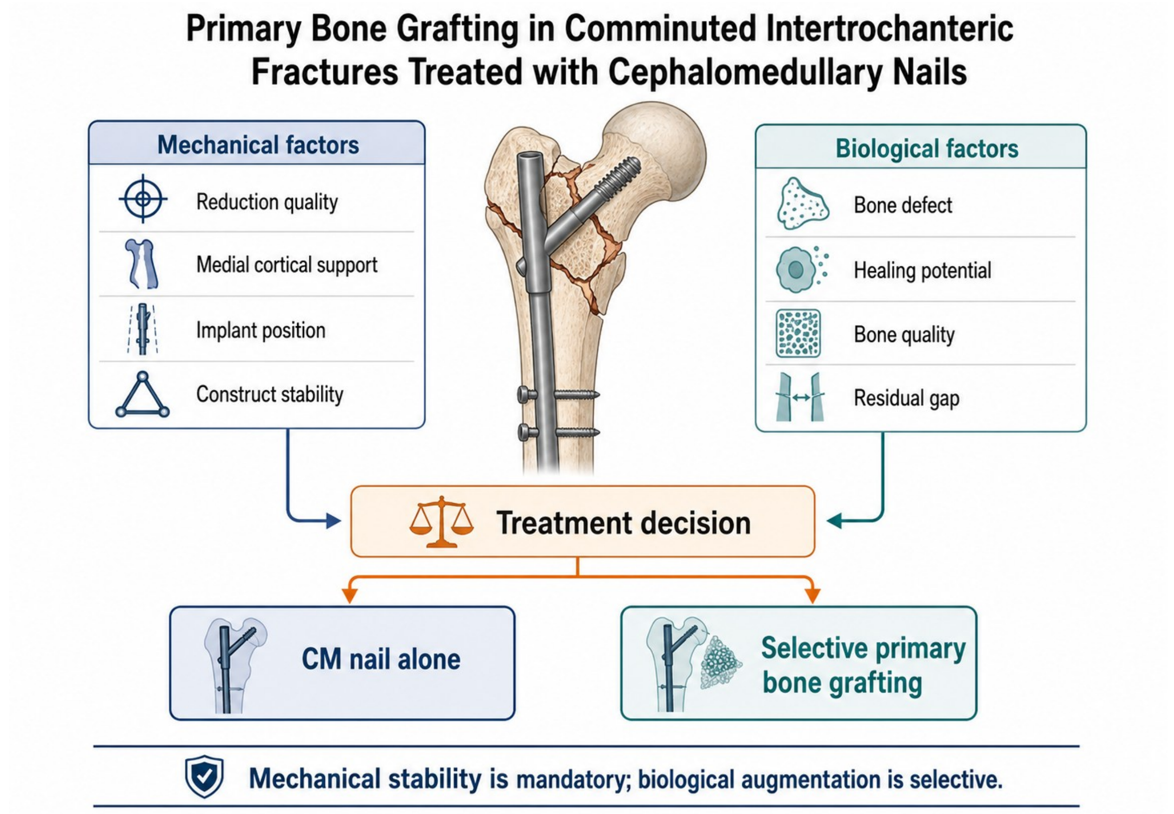

Figure 1. Graphical abstract summarizing the balance between mechanical factors, biological factors, and the selective role of primary bone grafting.

Why Comminuted Intertrochanteric Fractures Are Different

Cephalomedullary nails have become the preferred fixation devices for unstable intertrochanteric fractures because they offer a load-sharing construct and a shorter bending moment than extramedullary implants (5-9). However, even with modern implants, comminuted fractures remain especially challenging. The most problematic features are posteromedial comminution, lesser trochanter fragmentation, medial calcar deficiency, poor lateral wall integrity, and osteoporosis (10-15).

Several studies have shown that restoration of support—particularly the medial and lateral buttresses—is critical for avoiding fixation failure (10,11,13). When these stabilizing structures are absent, the fixation construct is subjected to greater stress, which may translate into cut-out, cut-through, excessive collapse, or implant fatigue (14-17). The surgeon must therefore aim for an acceptable reduction, appropriate neck-shaft alignment, and optimal cephalic implant placement.

A second challenge is that comminution may create a residual metaphyseal defect. These gaps can be small and clinically inconsequential if stability is satisfactory, but large defects may reduce bridging potential and magnify concerns regarding both biology and mechanics. This is precisely the scenario in which some surgeons begin to consider primary grafting during index fixation.

It is essential, however, not to equate fracture complexity with biological insufficiency. A highly comminuted fracture may heal uneventfully when stability is restored, while a less dramatic fracture may fail because of poor mechanics. The complexity of morphology should therefore trigger careful assessment, not automatic grafting.

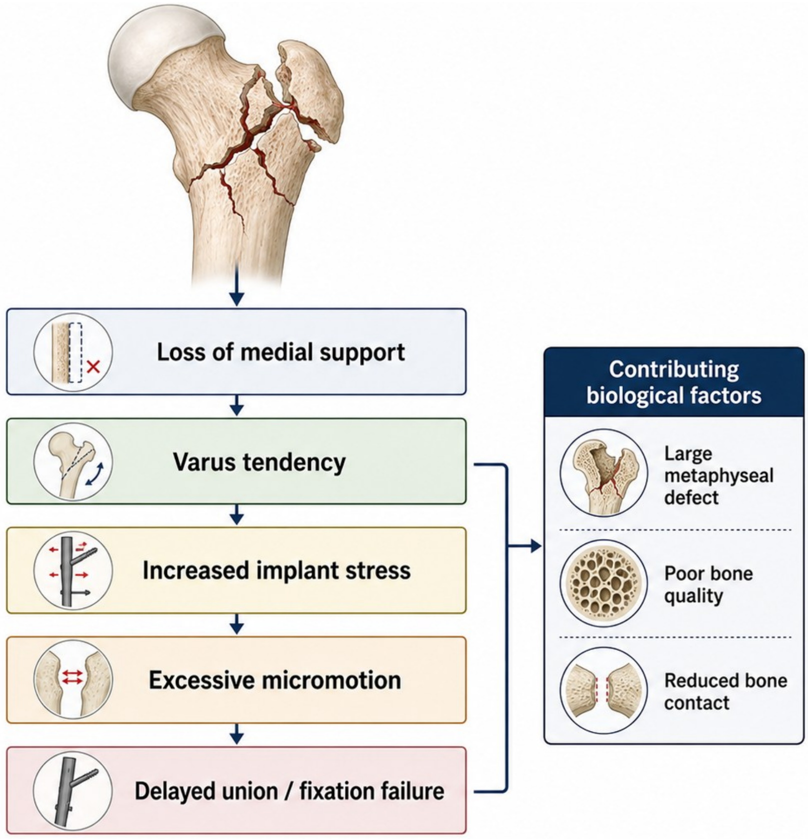

Figure 2. Schematic representation of why comminuted intertrochanteric fractures may fail, emphasizing progressive mechanical compromise and contributing biological factors.

Mechanical Determinants of Healing and Fixation Failure

Successful fracture healing depends on a coordinated interaction between mechanics and biology. The "diamond concept" proposed by Giannoudis and colleagues emphasizes the importance of osteogenic cells, osteoinductive factors, osteoconductive scaffolds, and mechanical stability (18,19). Although this concept emerged primarily from long-bone nonunion research, it is directly relevant to the problem of whether bone grafting might improve healing in comminuted intertrochanteric fractures.

Mechanical stability is indispensable. Perren's strain theory and subsequent biomechanical work highlight that the local mechanical environment determines the pathway and quality of repair (23,24). Excessive motion leads to failure of bridging and persistent instability, whereas controlled motion within an acceptable range facilitates callus formation. In intertrochanteric fractures, the proximal femur is exposed to substantial axial and rotational forces. Loss of medial cortical continuity shifts force transmission to the implant and may result in progressive varus collapse and increased implant stress (10-12,25).

The intertrochanteric region possesses abundant cancellous bone and a generally favorable vascular supply. These features partly explain why healing usually occurs when fixation is adequate. However, severe comminution may create areas of reduced bone contact, metaphyseal voids, and cortical insufficiency. Such defects raise the question of whether the biological healing environment remains sufficiently robust after fixation alone.

The practical implication is clear: bone grafting should only be considered after the mechanical foundation has been addressed. If reduction is poor or the construct is unstable, the principal problem remains mechanical. In that setting, biologic augmentation is unlikely to rescue a failing fixation construct.

Table 1. Mechanical and biological factors affecting union after cephalomedullary fixation

Domain	Factor	Clinical implication
Mechanical	Poor reduction	Increased implant stress and malalignment
Mechanical	Loss of medial cortical support	Varus collapse and shortening
Mechanical	Suboptimal implant position	Cut-out, cut-through, or failure
Mechanical	Inadequate stability	Delayed union or nonunion
Biological	Large metaphyseal defect	Reduced bridging potential
Biological	Poor bone quality	Compromised fixation and healing
Biological	Reduced bone contact	Weaker biological continuity

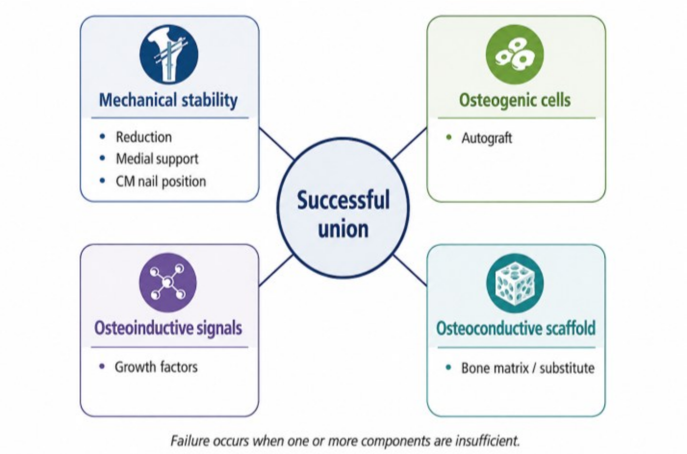

Figure 3. Diamond concept applied to intertrochanteric fracture healing, highlighting the interaction between mechanical stability and biological components.

Biological Rationale for Primary Bone Grafting

Bone grafts are traditionally valued for three major biological properties: osteogenesis, osteoinduction, and osteoconduction (20,21,26,27). Autologous cancellous graft is the most biologically active option because it contains viable osteogenic cells and growth factors within a natural scaffold. These attributes explain its enduring role in nonunion surgery and bone defect reconstruction.

In acute intertrochanteric fractures, osteogenesis may theoretically be beneficial when direct bone contact is limited and the local defect is substantial. Osteoinduction may promote recruitment and differentiation of mesenchymal progenitors, while osteoconduction may provide a scaffold across voids. These properties appear particularly attractive in fractures with severe metaphyseal comminution or compromised bone stock.

The biologic rationale for grafting is therefore strongest when the remaining problem after fixation is a genuine biological disadvantage, such as a major residual defect, severely compromised bone contact, or a patient profile suggesting impaired healing. Outside those circumstances, the theoretical benefits may not justify the additional intervention.

Table 2. Comparison of bone graft materials relevant to intertrochanteric fracture augmentation

Material	Biological profile	Advantages	Limitations
Autologous cancellous graft	Osteogenic, osteoinductive, osteoconductive	Highest biological activity; no immune reaction	Donor-site morbidity; longer surgery
Allograft	Primarily osteoconductive	No harvesting required; useful for defect filling	Lower cellular activity; slower incorporation
Synthetic substitutes	Scaffold function; variable bioactivity	Available; customizable; no donor morbidity	Variable performance; limited clinical evidence

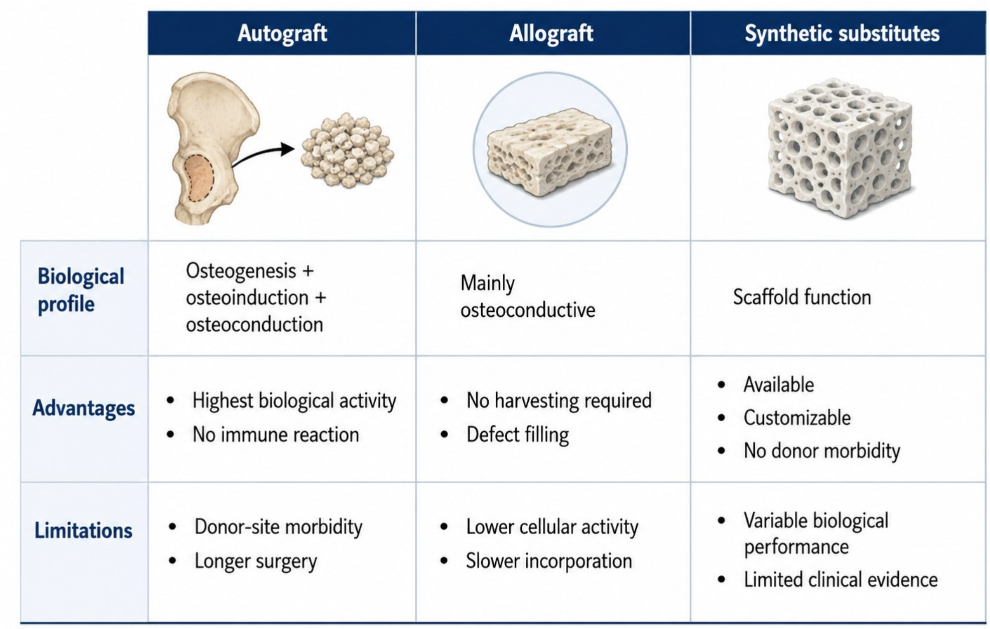

Figure 4. Comparison of bone graft materials relevant to primary augmentation.

What Does the Current Evidence Actually Show?

The greatest limitation in this field is the lack of robust direct evidence. Few if any high-quality comparative studies specifically evaluate acute comminuted intertrochanteric fractures treated with cephalomedullary nails with versus without primary bone grafting. As a result, the clinical argument for or against routine grafting cannot rest on direct comparative outcome data alone.

Most of the supportive evidence for grafting comes indirectly from three sources. First, fracture healing biology strongly suggests that grafts may improve a deficient local environment (18-21). Second, intertrochanteric nonunion and revision literature shows that combined mechanical correction and biological augmentation can be highly effective in compromised healing scenarios (31-34). Third, studies of fixation failure in unstable fractures repeatedly emphasize the central role of mechanical factors, thereby clarifying that biologic augmentation should not be expected to rescue poor reduction or unstable fixation (10-17,35,36).

Published reports on intertrochanteric nonunion are particularly instructive. Although nonunion in this region is uncommon, when it occurs it is often associated with malreduction, inadequate stability, implant failure, osteoporosis, or comminution (31-34). Revision procedures that combine restoration of alignment and stability with bone grafting frequently achieve union, supporting the idea that grafting is useful when biology is compromised, but also showing that it is most effective when mechanical problems are simultaneously corrected.

The absence of direct acute-fracture evidence does not invalidate selective grafting. Instead, it argues against routine use. Current knowledge supports a nuanced conclusion: for most comminuted intertrochanteric fractures, satisfactory fixation alone is appropriate; for a subset with major residual defects or obvious biological disadvantage despite adequate fixation, grafting may be reasonable.

From a practical standpoint, the question is not “Can grafting help?”, it probably can in some settings, but rather “Which patients are likely to benefit enough to justify the added procedure?” That question remains incompletely answered and should be a focus of future comparative studies.

Table 3. Evidence summary relevant to primary bone grafting

Evidence source	Main observation	Clinical implication
Fracture healing biology	Grafts enhance osteogenesis, osteoinduction, and osteoconduction	Supports biological rationale
Intertrochanteric nonunion/revision literature	Union often improves when mechanics are corrected and graft is added	Supports selective use in compromised healing
CMN outcome literature	Mechanical factors dominate many failures	Fixation quality remains the priority
Direct acute fracture comparisons	Very limited evidence	Routine grafting cannot be recommended

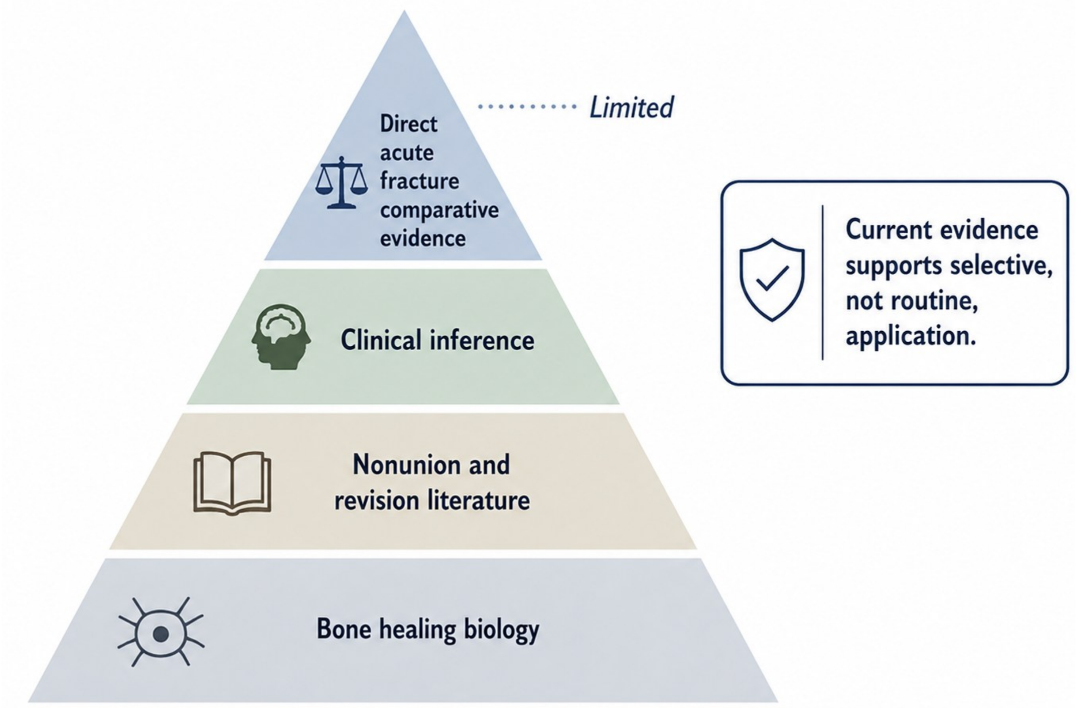

Figure 5. Evidence map showing that direct acute fracture comparative evidence is limited, whereas much of the rationale derives from biology, nonunion, and clinical inference.

Primary Grafting Versus No Grafting: Clinical Decision-Making

A pragmatic decision algorithm should begin with mechanical assessment. The surgeon must first determine whether reduction is acceptable, medial support is restored as much as possible, implant position is appropriate, and overall construct stability is satisfactory. If the answer is no, the priority is to improve fixation rather than add graft.

The overarching principle is simple: fix mechanics first; augment biology selectively. This concept aligns available evidence with common clinical sense and avoids both overuse and underuse of grafting.

Which Patients Might Benefit?

Once mechanics are acceptable, the next step is to assess whether a residual biological deficit remains. This includes consideration of large metaphyseal defects, persistent medial deficiency, severely reduced bone contact, and patient-specific factors that may impair healing. In these scenarios, primary bone grafting may reasonably be considered as a selective adjunct.

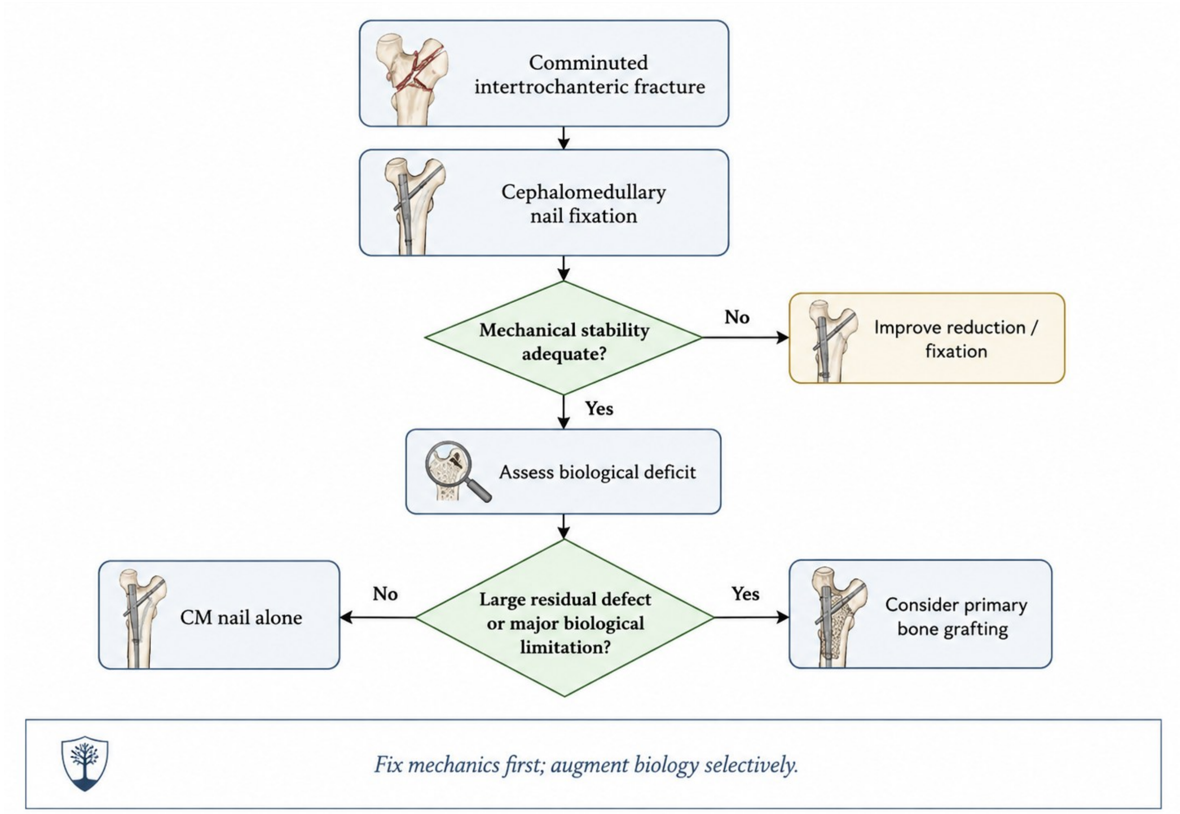

Figure 6. Practical clinical decision algorithm for selective primary bone grafting.

When fixation is stable and residual defects are modest, cephalomedullary nailing alone is generally sufficient. In such cases, routine grafting may add operative burden without clear evidence of improved outcome. Conversely, when a large residual defect remains after adequate reduction, grafting may help fill the void and support bridging. The same logic may apply in select younger patients with high functional demands or in patients with demonstrably poor biologic potential.

The converse is also true: there remain situations in which adequate fixation does not fully resolve the problem. Major residual voids, severely disrupted cancellous architecture, and limited bone contact may represent true biological disadvantages. In such cases, primary grafting may be a rational adjunct. This is not an argument for routine use, but rather for individualized judgment.

Table 4. Practical situations and suggested approach

Clinical situation	Suggested approach
Stable fixation with restored support and modest residual defect	Cephalomedullary nail alone
Large residual metaphyseal defect after adequate fixation	Consider primary bone grafting
Persistent mechanical instability	Improve reduction/fixation first
Established nonunion or revision setting	Mechanical correction plus biological augmentation is often justified

Risks, Limitations, and Unanswered Questions

At the same time, autologous grafting has drawbacks. Harvesting introduces additional surgical trauma, increases operative time, and may cause donor-site pain, hematoma, or infection (20,26). These disadvantages are especially relevant in the elderly population that constitutes the majority of intertrochanteric fracture patients.

Consequently, grafting should not be recommended lightly.

Allograft and synthetic substitutes avoid donor-site morbidity and may help fill larger defects, but they have lower cellular activity than autograft and more variable clinical performance (21,27-30). Synthetic materials are increasingly sophisticated, with improved porosity and bioactivity, yet evidence supporting their routine use in acute intertrochanteric fracture fixation remains limited.

The main strength of this review is that it integrates fracture healing biology, fixation mechanics, and clinically relevant evidence into a practical, surgeon-oriented framework. Instead of presenting a one-sided argument in favor of grafting, it clarifies when and why grafting might be useful, and equally, when it is unlikely to add value.

The principal limitation is the scarcity of direct comparative studies specifically addressing the index use of primary bone grafting in acute comminuted intertrochanteric fractures fixed with cephalomedullary nails. Consequently, several conclusions are necessarily interpretive. Furthermore, as a narrative review, this article does not apply formal systematic review methodology or quantitative pooling of outcomes.

Important unanswered questions include how a clinically meaningful residual defect should be defined, which graft source offers the best benefit-to-risk ratio, and whether selective augmentation improves union, reoperation, function, or cost compared with mechanically sound fixation alone. Until these questions are addressed in prospective comparative studies, recommendations must remain cautious and individualized.

Future Research

The future of this field is likely to move away from empirical routine grafting and toward personalized biological augmentation. Three-dimensional imaging and more refined fracture analysis may improve the ability to quantify residual defects, assess cortical integrity, and identify patterns most likely to benefit from augmentation.

Artificial intelligence and predictive analytics may eventually support individualized decisions by integrating fracture morphology, bone density, implant parameters, and patient characteristics into risk models for delayed union or fixation failure (37-39). Such approaches remain investigational but reflect a broader movement toward personalized orthopaedic care.

Biomaterials research is also evolving rapidly. Synthetic substitutes, bioactive scaffolds, and advanced tissue-engineering platforms may someday provide safer and more effective alternatives to iliac crest autograft (27-30,40). Until high-quality clinical evidence becomes available, however, these technologies should be viewed as promising rather than established.

Future research priorities are clear. Prospective comparative studies should evaluate union rate, time to union, fixation failure, complications, and functional outcomes in acute comminuted intertrochanteric fractures treated with cephalomedullary nails with and without selective grafting. Such studies are essential to move beyond biologic plausibility toward evidence-based indication.

Conclusion

Primary bone grafting in comminuted intertrochanteric fractures treated with cephalomedullary nails is biologically attractive but incompletely validated. Current evidence does not support routine grafting for all cases.

Mechanical optimization, acceptable reduction, restoration of support, proper implant placement, and construct stability, remains the foundation of successful healing. Primary grafting should be considered selectively when a meaningful biological deficit persists after this mechanical foundation has been secured.

In summary, the current treatment philosophy can be stated succinctly: mechanical stability is mandatory; biological augmentation is selective.

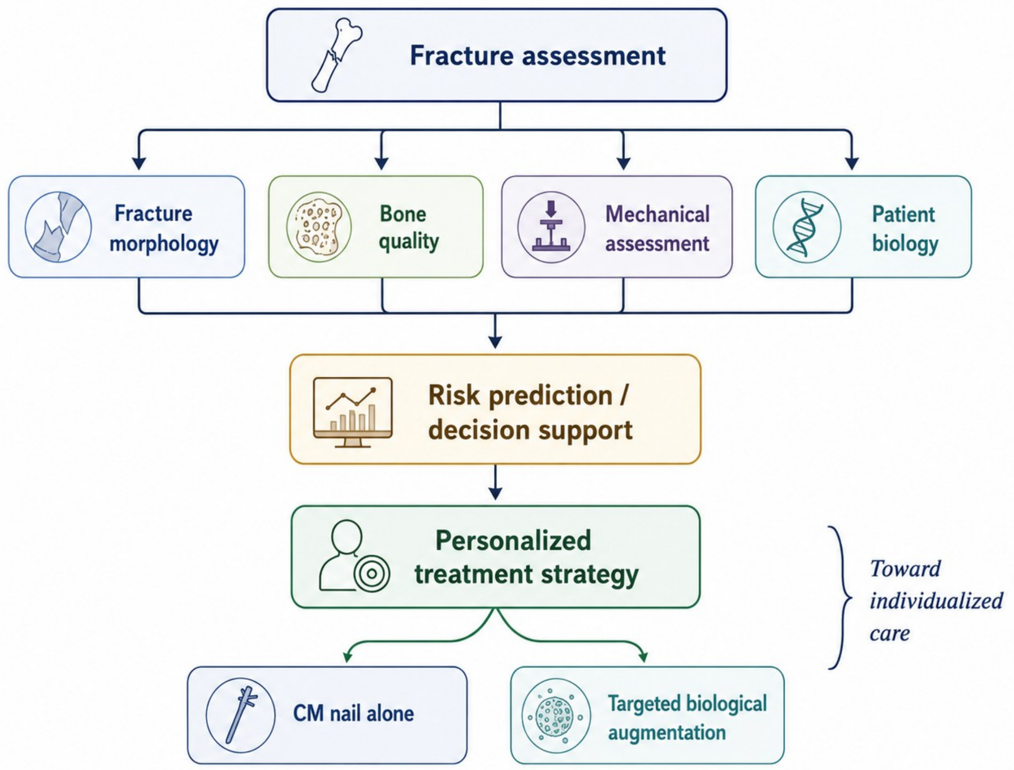

Figure 7. Future personalized augmentation model integrating fracture morphology, bone quality, mechanics, and patient biology.

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Authorship

All authors meet the ICMJE authorship criteria. Seyed Sadegh Shirdel contributed to conceptualization, literature review, drafting of the manuscript, and critical revision. Abolfazl Ghadiry contributed to conceptualization, supervision, critical revision, and final approval of the manuscript.

Conflicts of interest

The authors declared no conflict of interest.

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