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Evaluating the Efficacy of Proximal Femoral Nail Antirotation with Augmentation in Managing Osteoporotic Intertrochanteric Fractures: A Comprehensive Review

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ABSTRACT

Addressing intertrochanteric fractures in those with impaired bone quality using orthopedic surgery is a huge challenge. This review assesses the effectiveness of Proximal Femoral Nail Antirotation (PFNA) with augmentation, cement being the best augmentation compared to others, in healing these fractures. Comparative analyses show that PFNA is significantly better than PFN, with reduced operative times, blood loss and complications, especially in high-risk elderly patients. This review compiles data from 15 articles which aims to provide an overall picture of the present evidence on the use of PFNA technique supplemented by the application of osteoporotic intertrochanteric fractures. Augmentation methods, such as cement augmentation, have come to the forefront as important adjuncts to increase stability and effectiveness in PFNA procedures. Research has demonstrated that adapting the cement augmentation technique helps to restore load-bearing capacity, lower implant failure rate and to better the clinical results in total joint arthroplasty. PFNA with cement augmentation effectively treats intertrochanteric fractures in osteoporosis hips, providing satisfactory results and potential for further clinical development. This review brings to the forefront the necessity of stabilizing the osteodensification and the proper cement augmentation, all of which aid in enhancing stability, occasioning less complications and leading to better postoperative outcomes. The future development in PFNA techniques and the trending advancement of augmentation strategies would allow the field of surgery to benefit from an even more optimized way of dealing with these fractures in the clinical setting which is both promising and favorable.

INTRODUCTION

Osteoporosis is a prevalent disease caused by the low density of bone mass, poor bone microarchitecture and fragility fractures. Osteoporosis has been a major concern worldwide, affecting 200 million people (Noh *et al.*, 2020). The high rate of global morbidity osteoporosis is emphasized by its incidence in the population size of the majority of regions, estimating 18.3% of the entire world population, with a gender disparity showing a higher incidence rate in females with 23.1%, as opposed to men with 11.7% (Salari *et al.*, 2021). Such figures favor the importance of developing health systems that take into consideration gender-specific factors, more especially the hormonal changes during and after menopause in women.

Witnessing a similar situation in China where adults aged 40 and above reveal a considerably high incidence of osteoporosis in men at 5.0% and women at 20.6% as well as a rather high occurrence of vertebral fractures in males at 10.5% and females at 9.7%, the pattern also follows at the global level (Wang *et al.*, 2021). The figures from China not only reflect the extensive gender discrepancy in osteoporosis prevalence, but also remind of the worldwide challenge of osteoporosis management. Surprisingly, though, only a small fraction of patients with osteoporosis or patients who have suffered from a fracture are being properly treated in China, implying to the existence of wide gap of treatment.

Proximal Femoral Nail Antirotation (PFNA)

PFNA is a cutting-edge orthopedic implant designed for managing proximal femoral fractures, which are commonly seen in the geriatric population with osteoporosis as fractures predominantly occur at the intertrochanteric site (Sachin, 2019). The intramedullary fixation gadget has changed shock management progressions by creating extreme stability and rotational control that is of core significance in the management of fracture cases (Bizzoca *et al.*, 2023). Notably, this PFN has a threaded titanium alloy at its proximal end. The design of the medical screw, the helical blade, is decisive in enhancing the primary stability of the damaged area by engaging tightly to the cancellous bone from the neck to the head of the femur (Wang *et al.*, 2020). This links with the bone amalgamation within the bone readily reduces the chances of implant migration as a result of complications that if not addressed would be a setback in the treatment especially in the event of osteoporotic bone where screw fixation may not be adequate.

Furthermore, the PFNA comes at the cutting edge of technology as its features allows for customization of the implant in line with patient anatomy and various fracture patterns. Doctors can design the implant in a way that exactly fits each case by accurately controlling the implant configuration according to the need of each case, to enhance stability and provoke better healing (Ledet *et al.*, 2018; Meng *et al.*, 2023). The architecture of

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the PFNA is designed and developed very smoothly to take on the pressing forces that are experienced by the body during weight-bearing (Augat & von Rüdén, 2020). Its novel generation eliminates the stress concentration close to the fractured part of the femoral shaft and by the consequence, protects the implant's integrity and prevents its possible failure. As many of its effects are due to structural integrity, the PFNA enables early stages of mobilization and rehabilitation that could be invaluable for functional recovery and independence induction in patients. Through its function of rendering the bone firm in position and by promoting wound endogenous healing, the PFNA aids in completing the recovery process faster and improves the patient's general situation (Yu *et al.*, 2020).

Osteoporotic Intertrochanteric Fractures & PFNA

Osteoporotic fractures are linked to decreased quality of life, greater morbidity and in some cases of pelvic, spine and hip fractures, higher chances of death (Gold *et al.*, 2019). The fracture mostly affects the regions of the hip, spine, and distal radius, with hip fractures, especially intertrochanteric fractures, being the most serious due to their higher rates of morbidity, disability, and mortality (Bishnoi *et al.*, 2018). However, the management of osteoporotic intertrochanteric fractures which causes bone demineralization in the elderly requires new advancement in orthopedic surgical methods to produce efficient treatment results. Intertrochanteric fractures near the proximal end of the femur, one of the most common types of osteoporotic fractures, interfere with many daily tasks such as walking and performing other weight-bearing exercises. This can greatly reduce a patient's quality of life (Maffulli & Aicale, 2022). However, the issues that occur while treating these fractures are caused by compromised bone quality of osteoporosis that usually result in problems with the achievement and maintenance of a fixation which is stable (Chen *et al.*, 2022). The usual fixation techniques are very helpful in dealing with general bone damage, but when a problem arises in the context of osteoporotic bone the approach is limited due to the lack of bone mass and the specific changes in biomechanical properties.

The PFNA system transformed orthopedic surgery through the development of an advanced method for stabilizing and managing fractures in the proximal femur, increasing stability and aiding the natural bone healing process (Yu *et al.*, 2020). This particular implant, was designed unmistakably to face to the problems caused by osteoporotic bone disease (Patil, 2019). Among its attributes that heighten the rigidity of the implant fixation the PFNA stands out. The operation of the PFNA system in antirotation is another remarkable feature that targets the high rate of the rotation of the femoral head and neck cost as an enormous failure of the conventional fixation systems (Chen *et al.*, 2020). The PFNA system specifically addresses these drawbacks as it offers an internal alignment device that promotes the

mechanical stability of the fracture site, thereby enabling the patient to start rehabilitation earlier and decreasing the risk of potential problems (Zheng *et al.*, 2021). Through the use of augmentation, the optimal observance of the moderation principle is reached. As bone cement and a strong ligation structure strengthen the damaged area, they become an invaluable tool in the modern treatment of intertrochanteric fractures in osteoporosis (Ni *et al.*, 2022). This context demonstrates the urgent need for pioneering and innovative surgical solutions like PFNA system to be developed in order to prevent the onset of osteoporotic fractures in an aging global population.

Moreover, the PFNA system provides an essential addition to the therapy of these types of bone fractures as they proceed towards the next level. Implants (pin, screws, plates, bone cements) are used to increase weight-bearing capacity, to reinforce the fixation, and to provide additional support to the osteoporotic bone (Hollensteiner *et al.*, 2019). PFNA with hyperextension is developed with biomechanical principles of fracture fixation in mind. Thus, the PFNA unit helps in bringing about a steady healing environment within the bone which enhances the chance of bone healing. The PFNA design targets to reduce the strain on the bone, distribute uneven loads, and minimize the risk of the head of the femur twisting and collapsing, which are known complications in the healed intertrochanteric fracture in osteoporotic condition (Ingishetty, 2019; Lakhmania, 2020).

The clinical data showed that the PFNA system was highly effective in managing fractures in the intertrochanteric region of the bone associated with osteoporosis (Su *et al.*, 2022). Studies have proven better results regarding shorter operating times, less bleeding and quick healing of operated areas (Xu *et al.*, 2018). What is more, the amplified treatment has been demonstrated to considerably lower the risk of implant failure and secondary procedures, solutions which bring in more risks in the treatment of osteoporotic fracture. The general surgeon, patient screening, and technical part of PFNA implantation involve some certain things to be considered so as to *get all* the benefits from the PFNA system. On top of the healing benefits of any other surgical intervention, the specific PFNA system has its own risks and complications, which stresses the need for all clinicians to know the indications, contraindications, and surgical principles for an optimal procedure.

Augmentation

Augmentation in orthopedic surgery is supplementary to bone-implant interfaces, parallelly improving stability and better treatment outcomes. It is very appropriate where the bone scenarios are challenging i.e. osteoporotic fractures. This approach bases its actions on several strategies directed at enhancing the fixation knowing and reducing the chance of implant loss. Once the bone cement is injected, it comes around the implant, usually polymethyl methacrylate (PMMA), that it has been part of the fractured site (Soleymani Eil Bakhtiari *et al.*, 2021). Its

role here is to seal the gaps within the porous bone as well as deliver stronger and better connection or an anchor for the implant. The ability of cement augmentation to enhance the contact area of the bone-implant and transfer the loads as well as provide biomechanical stability, which is vital for fracture healing success, is emphasized by a way of hauling up the bone-implant contact area (Weiser *et al.*, 2018).

Further the concept of augmentation extends beyond just the use of extra grafts and pins, where additional fixation elements like cerclage wires or cables are also employed to strengthen the construct and minimize the stress concentrations (Thakur, 2022). These adjunctive stabilization techniques supplement the implant and even out the stress it faces. This may help to reduce the risk of implant migration failure. The use of these enrichment techniques in orthopedic surgery is extensive to enhance the outcome in various procedures, such as the fixation of fracture, joint arthroplasty, and spinal fusion (Schuetze *et al.*, 2019). One of the major functions of augmentation is to reinforce implant stability and to merge bone-implant integration that in turn will raise the chances of early mobilization and rehabilitation leading to the quick recovery of the patients with an improved outcome (Tolstunov *et al.*, 2019). Specifically, augmentation is a proven auxiliary treatment in orthopedic surgery providing biomechanical reinforcement, improving the general condition of fractures and thus offering complex clinical care.

This review intends to report on the impact of

employing the Proximal Femoral Nail Antirotation (PFNA) alongside the augmentation therapies in the care of osteoporotic intertrochanteric fractures. This review aims to analyze the current literature representing a combination of clinical studies and articles that will determine effectiveness and safety of PFNA augmentation compared to standard fixation techniques. Primarily, the review will focus on the outcomes such as rate of healing of the fractures, stability of the implants, complications after surgery and patient's satisfaction with the recovery progress. Moreover, the examination reveals the possible pros and cons of merging the augmentation procedure with the PFNA technique employed in the treatment of osteoporotic intertrochanteric fractures, taking into account bone quality, the implant positioning, and surgical method. This review aims to summarize the positive impact of PFNA in bone augmentation, aiming to improve treatment results and patient lives for femoral neck fractures.

METHODOLOGY

Search Strategy

The table 1 below shows the methods used in search strategies to identify corresponding studies of the searched literature to the research topic. The strategy includes a set of keywords and terms relevant to PFNA, osteoporotic fractures, augmentation techniques, and surgical fixation methods, as they are intended to provide the broadest coverage of the journals containing the research on this topic.

Table 1: Search Strategy

S. no	Search Strategies
1.	("Proximal Femoral Nail Antirotation") AND ("PFNA") AND ("Osteoporotic Fractures") AND ("Osteoporotic Intertrochanteric Fractures") AND ("Treatment Approaches to Osteoporosis")
2.	("Osteoporosis Management Strategies") AND ("Augmentation Techniques") AND ("Bone Cement Augmentation") AND ("Surgical Fixation Methods") AND ("Cement Augmentation Femur Fractures") AND ("Biomechanical Studies on Augmentation")

Inclusion and Exclusion Criteria

The table 2 provides the details of inclusion and exclusion criteria that are used to filter out the relevant studies with a focus on the role of Proximal Femoral Nail Antirotation (PFNA) and augmentation in the

management of osteoporotic intertrochanteric fractures. Studies that met the desired criteria, dealt with the topic within the specified timeframe, and utilized the defined keywords as themes were included for analysis.

Table 2: Inclusion and Exclusion criteria

Inclusion Criteria	Exclusion Criteria
Studies that focuses on the use of Proximal Femoral Nail Antirotation (PFNA) and Augmentation in the management of osteoporotic intertrochanteric fractures.	Studies that do not focuses on the use of Proximal Femoral Nail Antirotation (PFNA) and Augmentation in the management of osteoporotic intertrochanteric fractures.
Studies published within the last six years (2018-2023) have been included.	Studies older than six years have been excluded.
Studies that are in relation with the keywords from the title were included.	Studies that are not in relation with the keywords from the title were excluded.

Article Selection

The table 3 below specifies criteria for article inclusion in the review and elucidates studies that assess the effectiveness of Proximal Femoral Nail Antirotation (PFNA) and augmentation techniques in treating

osteoporotic intertrochanteric fractures. The research covers several works published in different journals and various years. It analyzes both surgical strategies and their consequences, focusing on PFNA and general augmentation.

Table 3: Article Selection

S.no	Author	Journal	Year	Findings
1.	Schuetze, Konrad MD; Eickhoff, Alexander MD; Röderer, Goetz MD; Gebhard, Florian MD; Richter, Peter H. MD	Journal of Orthopaedic Trauma	2019	The article offers insights into the efficacy of augmentation techniques in orthopedic surgery for managing osteoporotic fractures, addressing challenges related to mechanical failure and exploring diverse augmentation materials and strategies.
2.	Dr. Vinod Nair, Dr. Shubhanshu Gupta, Dr. Anant Krishna, Dr. Amol Patil and Dr. Avinash Kumar	International Journal of Orthopaedics Sciences	2019	The study compared the effectiveness of Proximal Femoral Nail (PFN) and Proximal Femoral Nail Antirotation (PFNA) in stabilizing unstable intertrochanteric fractures, finding PFNA significantly reduced operative duration, blood loss, and hospital stays.
3.	Mittal, Ankit; Gill, Simrat P.S.; Kumar, Dinesh; Singh, Jasveer; Kumar, Harish; Rajput, Ajay	MAMC Journal of Medical Sciences	2021	This study compared the effectiveness of PFNA and PFN in treating intertrochanteric fractures. Despite similar functional outcomes upon fracture union, PFNA exhibited fewer complications and shorter operative times, indicating potential benefits for osteoporotic, elderly patients.
4.	Avate Shivaji, Gaonkar Kiran L., Vatsa Madhuranjan, Kumari Lipi, Patil Sudhir	Research Journal of Pharmacy and Technology	2023	The study evaluated the functional outcomes of PFN A-II implants for intertrochanteric and sub trochanteric femur fractures, revealing their stability, biomechanical acceptability, and minimal complications.
5.	Noratep Kulachote, Paphon Sangasoongsong, Norachart Sirisreetreerux, Kulapat Chulsomlee, Sorawut Thamyongkit, Siwadol Wongsak,	Geriatric Orthopaedic Surgery & Rehabilitation	2020	The study assessed outcomes of elderly intertrochanteric fracture patients treated with PFNA, with and without cement augmentation, finding higher return rates to prefracture ambulatory level with cement augmentation, suggesting its efficacy in improving functional outcomes in high-risk geriatric patients.
6.	Hu S, Du S, Xiong W, Chen S, Song H, Chang S	Chinese Journal of Reparative and Reconstructive Surgery	2021	The study evaluated the effectiveness of proximal femoral nail anti-rotation (PFNA) in treating high plane intertrochanteric femur fractures, finding satisfactory outcomes, good fracture reduction quality, and prevention of internal fixation failure.
7.	Alexander M. Keppler, Daniel Pfeufer, Fabian Kau, Christoph Linhart, Christian Zeckey, Carl Neuerburg, Wolfgang Böcker, Christian Kammerlander	Injury	2021	The study evaluated the impact of cement augmentation of the Proximal Femoral Nail antirotation (PFNA) on postoperative load capacity in older adult proximal femur fracture patients, revealing a significant increase in early mobilization, especially in frail patients with poor bone quality.
8.	Liqin Zheng, Xinmin Chen, Yongze Zheng, Xingpeng He, Jingxiong Wu & Ziling Lin	BMC Musculoskeletal Disorders	2021	A study using finite element analysis compared cement augmented PFNA in stable and unstable intertrochanteric fractures, finding that cement augmentation improves cutout resistance, especially in unstable fractures, suggesting potential clinical benefits.

9.	Konrad Schuetze, S. Ehinger, A. Eickhoff, C. Dehner, F. Gebhard & P. H. Richter	Archives of Orthopaedic and Trauma Surgery	2021	The study demonstrates the safety and efficacy of cement augmentation of the PFNA blade, effectively preventing mechanical failure without increasing complications or mortality. Careful decision-making and preparation are emphasized to manage potential blood pressure changes during the procedure.
10.	Navin Kumar Singh, Vijay Sharma, Vivek Trikha, Shiva Gamanagatti, Amit Roy, Avtar Singh Balawat, Aravindh Palaniswamy, Amrut Raje Diwakar	Journal of Clinical Orthopaedics and Trauma	2019	In a prospective study comparing PFNA-II and DHS in stable intertrochanteric fractures in elderly patients, comparable functional and radiological outcomes were found, indicating that PFNA-II may offer advantages in high-risk elderly patients, including shorter surgical time and reduced blood loss.
11.	Ong-art Phruetthiphath, Teerapat Tutaworn, Yanin Plumarom, Thipachart Punyaratabandhu, Chaisiri Chaichankul, and Warat Tassanawipas	Journal of Clinical Case Studies	2019	In a preliminary study on elderly patients with unstable intertrochanteric fractures, cement-augmented PFNA demonstrated no mechanical failures, suggesting its potential as a safe alternative for managing these fractures.
12.	Eleonora Piccirilli, Ida Cariati, Matteo Primavera, Rebecca Triolo, Elena Gasbarra & Umberto Tarantino	BMC Musculoskeletal Disorders	2022	A literature review on augmentation techniques for osteoporotic fragility fractures found promising outcomes in stability and strength compared to non-augmented fractures. The review recommends considering augmentation techniques for elderly patients with comminuted fractures and poor bone quality.
13.	Stefano Marcia, Mario Muto, Joshua A. Hirsch, Ronil V. Chandra, Nicole Carter, Paola Crivelli, Emanuele Piras & Luca Saba	Neuroradiology	2018	A narrative review on vertebral augmentation for osteoporotic vertebral compression fractures (VCFs) highlights its safety and effectiveness in reducing pain and disability, despite ongoing debate. The review indicates favorable outcomes with low rates of serious complications and no increased risk of subsequent fractures.
14.	Leonardo Stramazzo, Salvatore Ratano, Francesco Monachino, Davide Pavan, Giuseppe Rovere, Lawrence Camarda	Journal of Clinical Orthopaedics and Trauma	2021	A systematic review emphasizes the safety and effectiveness of cement augmentation in stabilizing trochanteric hip fractures, leading to satisfactory mobility outcomes and minimizing complications. Cement augmentation is identified as a valuable method for enhancing fixation in osteoporotic hip fractures.
15.	An Sermon, Ivan Zderic, Roberto Khatchadourian, Simon Scherrer, Matthias Knoke, Karl Stoffel, Boyko Gueorguiev	Journal of Biomechanics	2021	The study found that bone cement augmentation significantly improves the cut-out resistance of PFNA and TFNA head elements in cadaveric femoral heads with poor bone quality, suggesting its potential as a valuable treatment option in these cases.

RESULTS AND DISCUSSION

Efficacy and Management of PFNA with Augmentation

The efficacy of PFNA with augmentation in managing osteoporotic intertrochanteric fractures has been the focus of relatively more interest and research within the orthopedic surgery as of late. With the help of an extensive literature review, it becomes apparent that

the techniques of augmentation, particularly the use of cement augmentation, are an essential part of enhancing the efficiency of PFNA and patients' outcomes. Osteoporotic intertrochanteric fracture is a special challenge because of its compromised bone quality and hence a high risk of instrumentation failure (Rozell *et al.*, 2019). PFNA is generally preferred intramedullary fixation device it does this through its central anchoring

in the proximal femoral canal (Patil, 2019). In the case of osteoporotic bone, on the other hand, the conventional fixation techniques may not be sufficient enough to guarantee enough stability throughout the healing period. This is the place where the augmentation techniques play an important role, which is to reinforce the construction and impede any mechanical failure (Schuetze *et al.*, 2019). Several studies have examined the efficacy of PFNA in augmentation, with a stronger interest on cement augmentation than in other bone graft augmentations (Piccirilli *et al.*, 2022). The studies in this area clearly show these strategies to add stability and reduce shortcomings such as instrumentation cutout or implant failure. Achieving this goal is possible as PFNA in combination with cement bonding allows for improved implant fixation and better load distribution, thus reducing the risk of implant failure (Guo *et al.*, 2022). The PFNA and augmentation is quite prominent in this context as they are capable of improving the outcome in the postoperative situation. Lower operative time, less amount of bleeding and days of hospital stay are documented in patients having cement augmentation rather enforced with the conventional PFNA fixation (Kulachote *et al.*, 2020). This simply means less time spent in hospital, fewer resources used, and more positive feedback after discharge. Such outcomes not only help the hospital to cut costs, but also improve patient outcomes, which in turn contributes to their faster recovery.

Furthermore, along with PFNA, augmentation helps to promote early ambulation of the elderly patients with osteoporotic fractures; thereby, this is very important (Piccirilli *et al.*, 2022). Cement augmentation, as one of the augmentation techniques, was successful in restoring postoperative load capacity, allowing patients to bear weight and engage in rehab early. Early ambulation not only shortens the rehabilitation cycle but also minimizes the rate of post-surgery problems like deep vein thrombosis and pressure ulcers caused due to long isolation (Wang *et al.*, 2023). The evidence undoubtedly confirms that for the treatment of osteoporotic fractures of the femur that involves the intertrochanteric region, a PFNA osteosynthesis combined with augmentation technique is the best option. Techniques of augmentation, including bone cement augmentation, ensure a good stability of fracture but reduce the risk of postoperative morbidity and accelerate the patient recovery, result in positive clinical outcomes (Chiapasco & Casentini, 2018). Nevertheless, it should be noted that despite improvements in the augmentation strategies, one should also mind the need for more research to suitably optimize them and make sure that their long-term outcomes are good enough, especially concerning implant survival and healing fractures. In spite of this, the augmented PFNA remains a very effective method of managing the osteoporotic intertrochanteric fractures which should be employed not only in postoperative but in long-term patient's care.

The research confirmed that bone cement reinforcement

could increase the shear strength of the PFNA and TFNA heads in human femoral heads with poor bone quality. This finding showed the possible use of bone cement cementation in these situations. The comprehension of literature also reveals that those patients did better in terms of stability and strength after fracture repair which they previously did not have by being augmented compared to non-augmented patients. The review suggested the use of supplemental techniques for elderly patients with comminuted fractures and bad bone stock (Sermon *et al.*, 2021). Moreover, the examination provides evidence concerning the safety and efficiency of strengthening the PFNA delivery system by augmenting the blade with cement, however, risks and complications are not increased and mortality remains as it was (Schuetze *et al.*, 2021). Typically, attention is paid towards the careful decision-making and early planning to allow proper management of potential effects on blood pressure during the procedure. The evidence presented indicates that the use of addition techniques, especially cement augmentation, plays a leading role in influencing the effectiveness of the PFNA procedure. Interestingly, the outcome of the procedure can be greatly improved in conditions where poor bone quality is detected.

Comparative Analysis of PFNA with Other Instruments

Comparative study between Proximal Femoral Nail Antirotation (PFNA) and Proximal Femoral Nail (PFN) are essential for the selection of suitable treatment techniques for intertrochanteric fractures, particularly the osteoporotic and elderly individuals (Nair *et al.*, 2019). The analysis of influential studies in connection with PFNA indicates that PFNA has unique benefits of better stability, outcomes, and complication risk compared to the PFN. In trials wherein PFNA and PFN were compared, PFNA more often turned out to be the option most preferred for managing intertrochanteric fractures, particularly among patients with osteoporotic bone quality (Mittal *et al.*, 2021). While both PFNA and PFN provide similar functional results after fracture union, the additional advantages of superior biomechanical support and fixation failure prevention contribute to choosing PFNA over PFN in addressing the patients.

Not only does PFNA reduce the operative duration as well as its incumbent morbidity, but it also has a shorter period of convalescence in comparison to PFN (Duramaz & İltter, 2019). Several comparative studies revealed that the operative time for PFNA was shorter, which was attributed to the design features of PFNA as it is known to be easy to insert and has many advanced features. Besides reduced bleeding inside the operating room anesthesia time will be minimized and patients will have improved outcomes not being into such exposure for a long time (Patil, 2019). Apart from this, PFNA is associated with a lower rate of complications than in the case of PFN and therefore, the superiority of PFNA is obvious in the management of intertrochanteric fractures

(Mittal *et al.*, 2021). There are potential complications related to the implant's migration, cutout, and secondary fractures, but the frequency of these events is lower with PFNA that exhibits better biomechanical properties and stability of its fixation. This is notably the case for elderly patients whose osteoporosis puts them at heightened risk of the fixation breakdown and the subsequent revision surgery.

The results of the prospective study that compared the outcomes between Proximal Femoral Nail Antirootation (PFNA-II) and Dynamic Hip Screw (DHS) for stable intertrochanteric fractures among elderly patients were similar with respect to functions and radiology images. The results imply PFNA-II is quite effective procedure, especially for elderly patients in high-risk group with less surgical time and blood loss volume (Singh *et al.*, 2019). These outcomes bring emphasis to PFNA-II as a prime preference in such group of patients with benefit of simple yet direct implants that cope with skeletal complications and sophisticated patient's outcomes. The research carried out a particular PFNA-II implants, used for intertrochanteric and sub-trochanteric femoral fractures, for the ability of stability, biomechanical acceptability, and low complications. This outcome shows that such PFNA-II implants with augmentation equally enable the reduction of lateral fracture union in high-risk elderly individuals, which usually leads to the recovery of acceptable functional outcomes (Avate *et al.*, 2023).

Functional Results of Augmentation in Conjunction with PFNA-II Implants

The PFNA-II implants evaluation for intertrochanteric fractures indicates not only their intrinsic stability and biomechanical compatibility but also stresses the significance of utilized augmentations for optimum recovery. Augmentation, mainly with cement, gives more strength to the PFNA-II fixations by improving fixation and resistance to a variety of complications (Ni *et al.*, 2022). Cement augmentation plays a vital role together with PFNA-II implant, the added lateral stability and biomechanical support for the osteoporotic bone help prevent prosthesis migration. This increase in the concrete content side by side with the cement augments the surgeons' ability to achieve a stronger implant stronger anchorage with femoral heads utilizing the load distribution for the prevention of implant migration, cutout, and secondary fractures. This is particularly meaningful in elderly patients with impaired bone quality in a high-risk geriatric category, where conventional fixation methods may lead to fractures that are incapable to endure physiological stresses (Singaram & Naidoo, 2019).

Some studies show that cementing as well as augmentation can produce satisfactory functional outcomes and adequate fracture reduction when used concurrently with PFNA-II implants (Yang *et al.*, 2020). The addition of cement to the implant is not only beneficial to the biomechanical characteristics of the implant but also

assists the motion process of the patient and accelerates the whole healing process, thus, lead to the better patient satisfaction and faster recovery. On the one side the absence of complications involving PFNA-II implant may also have been facilitated by use of cement augmentation which implies even greater reliability of this option for fracture fixation in high-risk geriatric patients. The additional stability provided by cement augmentation mitigates complications like implant migration, breakout and secondary fractures resulting in improved clinical outcomes and reduced number of revision surgeries.

Advantages and Disadvantages of Cement Augmentation

Cement augmentation is one of the main techniques used in the management of intertrochanteric fractures associated with osteoporosis, an especially common choice in cases where the poor bone quality hampers the obtainment of a stable fixation. Cement augmentation helps to increase the fixation through the stimulation of bone interface, which limits the movement and subsequently boosts the clinical outcomes (Weiser *et al.*, 2018). Among the many advantages that cement augmentation presents are the fast mechanical support it brings. Adding bone cement to fill the gaps between the implant and surrounding bone eliminates the effect of dynamic forces, increasing the stability and durability of the implant, and as a result, it will be less susceptible to loosening or displacement. This is very much evident in osteoporosis bone tissue, during which the bone healing is very much dependent on the after fixation of the bone (Winkler *et al.*, 2018).

Cement augmentation of a fracture site creates more equal distribution of the load, disappearing the potential stress concentration at bone-implant interface and thus promoting better healing outcomes. Given that, bone regeneration is the means by which this is achieved and results in better implant fixation and reduced rates of implant failure. It provides for earlier mobilization and weight-bearing which was proven to be beneficial for patients recovering and rehabilitation. Conversely, reinforcement of surrounding cement is not without possible risks either. In individuals with osteoporosis, cement augmentation of internal fixation in hip fractures improves stability and lowers the chance of implant failure. Its safety and effectiveness in stabilizing trochanteric fractures are demonstrated by this systematic review, providing this susceptible group with a viable therapy alternative (Stramazzo *et al.*, 2021). One of the possible damaging effects is cement leakage that arises when cement extravasation into the surrounding tissues and causes problems ranging from embolism to nerve injury and pulmonary complications (Yousuf *et al.*, 2021). Precise technique and the full employment of recommended procedures can give certain guarantees to operate without any leakage of cement and any of the associated problems. The association of use of cement augmentation to the Proximal Femoral Nailing

Anti-rotational (PFNA) device is a latest development in treatment options of osteoporotic intertrochanteric fractures, especially in elderly people with non-optimal bone quality. Literature has regularly shown this induction of the load capacity to postoperative state which has the influence of the fixation within the femoral head, increasing the resistance to physiological loads and lesser probability of failure in fixation.

In addition, cement augmentation aids in preventing the fragility endpoints, most frequently seen with osteoporotic intertrochanteric fractures. Through putting cement into the femoral head voids, surgeons increase implant stability and hence the probability of failure or implant migration lowering. Through the use of this, not only the treatment of fractures is improved but also revision surgical needs are reduced, therefore decreasing health costs as well as the patients' suffering. The utilization of cement augmentation does not imply any major increase in the complication rates or mortality, clearly indicating the safety and efficiency of such method as a surgical support in the course of the osteoporotic intertrochanteric fracture management. The figures establish that cement augmentation has performed well while the rate of complications like infection, cement leakage, and pulmonary embolism has minimal positive effects. The above mentioned points emphasize the use of cement augmentation to exclude it out of the surgical intervention of the osteoporotic intertrochanteric fractures which might be very harmful to geriatric patients (Roth *et al.*, 2021; Ulusoy *et al.*, 2018; Yu *et al.*, 2023).

Making sure that thorough preoperative planning and good technique are performed as much as possible is essential to minimize risk of these complications. Since cement augmentation will most likely eliminate reliance on adjusting construction for future revision if fixation fails or nonunion, it could affect the patient's success rate (Schlundt *et al.*, 2018). These risks still exist; however, then them, the advantages of a cement-augmented nail compensate them, above all for those geriatric patients who are prone to fractures and who have poor bone quality.

Future Strategies & Advancements in PFNA Technology

PFNA in the future together with further advancements will be instrumental in shifting management of osteoporotic intertrochanteric fractures to a whole new level, offering new pathways for better outcomes. The biomechanical development has been at the edge of the latest technology of the implant design refinement, researchers will always strive to work better under the unique challenges posed by osteoporotic bone (Chandra & Pandey, 2021). In so doing, the above-mentioned process would include improving implant topography, material constitution, and surface properties so as to ensure better bone integration and more satisfactory bone repair. Moreover, the trend is to develop new strategies of PFNA augmentation incomparable with

the fixation. Scientists are testing new tissue substitutes like bioresorbable polymers as well as biologics, which enhances implant incorporation and final outcomes thereby improve long-term results (Sharma *et al.*, 2021). These advancements demonstrate the ability for the creation of even more stable types of fixation as well as reducing the risk of fixation failure in the generally high-risk of the geriatric patients who also suffer from compromised bone quality.

With MI (Minimally Invasive) technique being a promising fundamental element of PFNA technology, this is another remarkable area that needs to be explored (Villena Gonzales *et al.*, 2019). Technology advances in percutaneous insertion techniques as well as guided navigation systems are intended to decrease surgical trauma, reduce soft tissue damage and facilitate speedy recovery while maintaining the highest possible quality of reduction and fixation of the fracture (Karkenny *et al.*, 2019). This means that these innovations could transform the surgical practice with better patient experiences, reduced recovery time, and greater operational end result. Moreover, the smart implant technology integration carries with it the advantages of not only monitoring in real-time implant performance, but also patient recovery status (Gaobotse *et al.*, 2022). The data generated through the use of sensors and wireless communication systems could provide critical information concerning the cyclic load and fracture healing trajectories that would be used to tailor personalized care for the individual patient and to optimize the treatment plan.

Additionally, research on biological enhancement options, like growth factors, stem cells or bone substitutes, are likely to explore other strategies are effectively to improve the healing of fractures and implants integration (Perez *et al.*, 2018). Preclinical trials and clinical trials should be conducted to understand the safety and efficacy of the combination of novel treatment modalities with the PFNA fixation. At the end of the day, these innovations greatly affect the quality of care and ultimate results of patient outcomes. Much good can come from individualized treatment plans designed to accommodate given patient peculiarities and features of their particular fracture (Moore, 2019). Such an approach can help to control complications and optimize treatment outcomes. The new advanced operating techniques and minimally invasive approaches are the major aspects that guarantee enhanced patient experience characterized by the shortening of postoperative pains, early recovery and mobilization of a patient. With the innovations that are yet to be fully implemented, a new future awaits the treatment of osteoporotic intertrochanteric fractures. It will heavily rely on more efficient and precise approaches that will cater for the individual's needs.

RESULTS

The trend to examine the effectiveness of proximal femoral nail antirotation (PFNA) with augmentation as a method for treatment of osteoporotic intertrochanteric

fractures can be seen as an especially strong trend in recent orthopedic surgery (Jin *et al.*, 2021; Zheng *et al.*, 2021). However, during extensive literature review, it soon comes apparent that allocation techniques, particularly cement augmentation, has been largely adopted as in to boosting the effectiveness of PFNA and to better the patients' prospects. The problem of intertrochanteric fracture in osteoporosis is particularly complicated because of loss of bone quality, an effect that raises the risk of instrumentation failure. Among others, PFNA is a preferred intramedullary fixation as its central anchoring of the proximal femoral canal makes it possible to overcome the problem of giving the fixation the desired amount of stability in the cases of osteoporotic bone (Patil, 2019). Precautionary augmentations, thus, rationalizes stress reinforcement and also reduces risks of failure.

Although PFNA and augmentation approaches have shown indisputable positive results, the research and development still require continued development of these modalities to guarantee long-term success. Though the procedure has proved its effectiveness in regard to stability and its inherent complication reduction, future research should thus be directed to improving cement filling and the development of more advanced cement substitutes that could minimize the risk of leakage (Yee *et al.*, 2020). Besides, we also need study designs comparing different types of augmentations and implant styles in order to choose the most effective strategy for the treatments of osteoporotic intertrochanteric fractures. In addition, evaluating the effectiveness of biological augmentation approaches, such as growth factors or stem cells, in promoting the integration of both the healing of fractures and implants, are worth studying before trials during which preclinical and clinical trials will be implemented. Clinicians can utilize research results to optimize therapeutic measures and improve patient outcomes in proximal femoral fracture fractures.

Introduction of PFNA with augmentation in the site of osteoporotic intertrochanteric fractures will have a profound effect on the health care system and better outcomes for the patients. The augmentation techniques, generally the cement augmentation, provide stability better, faster surgeries, and shorter hospitalization time instead of traditional fixation methods. While such innovative technologies contribute to better cost management of the healthcare facilities, they also yield the improved patient experience and faster recovery outcomes. In addition, the employment of these augmentation techniques makes it possible for ambulation earlier and for partial weight-bearing, which is necessary for reducing the complications of postoperative and ensuring the fracture heals properly (Chirayath *et al.*, 2024). By using PFNA together with enhancement in clinical practice, surgeons can have an osteoporotic intertrochanteric fractures adequate treatment and a good patient outcome.

There is the effectiveness of PFNA in conjunction with augmentation discovered in managing the trochanteric

fractures. So, this progress contributes some stability and additional support of bones injured by osteoporosis in orthopedic surgery. The employment of constructing procedures especially using cement augmentation techniques at their core has proven to be the crucial aspects greatly targeted at achieving stability and achieving reduced risk of complication common with initial fixation methods. Nonetheless, for augmentation to be old and trusted, more scientific exploration has to be done such as on the most effective strategies as well as for the long-term success. Exploration of these areas of inquiry helps clinicians develop better treatment methods and enhance patient outcomes by providing more effective things in the management of osteoporotic intertrochanteric fractures which, in turn, will improve quality of life and be beneficial to patients in care.

CONCLUSION

This review underscores the credibility of Proximal Femoral Nail Antirotation (PFNA) with augmentation, which significantly boost the chances of this approach being favored for the management of osteoporotic intertrochanteric fractures. The comparative research justifies the use of PFNA instead of the known proximal femoral nail (PFN) especially in the high risk elderly patients. Cement incorporation will be the undeniable support throughout the postoperative period, as research shows the high load capacity and implant stability. In short, cement augmentation along with PFNA technique based on the results of 15 concerns included in this review provides a reliable way to treat fractures produced due to osteoporosis in the intertrochanteric area of the femur.

RECOMMENDATION

Future study should examine the long-term effects of PFNA with cement augmentation in osteoporotic intertrochanteric fractures, as well as comparing its efficacy and safety to alternative stabilizing procedures in randomized controlled trials, in order to optimize treatment protocols for this high-risk population.

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