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Original Research Article

Comparative Evaluation of Conventional and Augmented Fixation Techniques in Osteoporotic Fractures

Sushil Kasnale[1], Ritesh Harwal[2], Arnav P. Urs[3]

[1]Senior Resident, Department of Orthopaedics, S Nijalingappa Medical College, Bagalkot, Karnataka, India

[2,3]Senior Resident, Department of Orthopaedics, Sanjay Gandhi institute of Trauma and Orthopaedics, Bangalore, Karnataka, India

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Corresponding Author: Dr. Arnav P. Urs
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Abstract:

Background: Fixation of osteoporotic fractures is challenging because poor bone quality increases the risk of loss of reduction, implant loosening, and fixation failure. Augmentation techniques have been introduced to improve construct stability. This study compared the clinical and radiological outcomes of conventional and augmented fixation in osteoporotic fractures.

Methods: This prospective comparative study included 120 patients with osteoporotic fractures requiring operative fixation. Sixty patients underwent conventional fixation and 60 underwent augmented fixation using cement and/or structural graft augmentation. Patients were followed for 12 months. Outcomes included fracture union, time to union, and maintenance of reduction, implant-related complications, functional outcome, and reoperation.

Results: Mean time to union was significantly shorter following augmented fixation (15.6 ± 3.7 vs 17.8 ± 4.2 weeks; p=0.003). Union at 6 months was achieved in 96.7% of augmented and 86.7% of conventional fixation cases (p=0.048). Maintenance of reduction was significantly higher with augmentation (95.0% vs 81.7%; p=0.023). Loss of reduction (3.3% vs 13.3%; p=0.048) and screw loosening/migration (1.7% vs 11.7%; p=0.028) were significantly less frequent after augmented fixation. Overall fixation-related complications occurred in 6.7% and 21.7% of patients, respectively (p=0.019). Excellent/good functional outcomes were observed in 86.7% of augmented and 73.3% of conventional fixation cases.

Conclusion: Augmented fixation provided better mechanical stability, earlier union, and fewer fixation-related complications than conventional fixation in osteoporotic fractures. It may be particularly useful in patients with poor bone quality and unstable fracture configurations.

Keywords: Osteoporosis; Osteoporotic Fracture; Augmented Fixation; Conventional Fixation; Cement Augmentation; Fracture Union; Fixation Failure.

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Introduction

Osteoporotic fractures represent an important clinical challenge, particularly in elderly patients, because reduced bone mineral density and deterioration of trabecular architecture compromise the mechanical strength of bone and the stability of internal fixation. Poor screw purchase, loss of reduction, implant loosening, screw cut-out, and fixation failure are important concerns following conventional osteosynthesis in osteoporotic bone. [1,2]

Conventional fixation using plates, screws, or intramedullary devices remains widely employed for osteoporotic fractures. Locking plate technology has improved fixation by providing angular stability and reducing dependence on friction between the plate and bone. Nevertheless, severe osteoporosis may still compromise construct stability, particularly in unstable or comminuted fracture patterns. Biomechanical studies have demonstrated differences in stability between conventional and locked constructs in osteoporotic bone and have highlighted the importance of appropriate implant selection and fixation principles. [3-5]

Various augmentation techniques have therefore been introduced to enhance fixation in poor-quality bone. These include polymethylmethacrylate (PMMA) or calcium-phosphate cement augmentation, augmentation of screws or intramedullary devices, and structural bone grafts.

Such techniques aim to increase implant–bone interface strength, improve resistance to mechanical loading, maintain fracture reduction, and potentially reduce fixation-related complications. [2] Clinical studies have evaluated augmentation in several osteoporotic fracture patterns. Cement augmentation of proximal femoral fixation has been investigated as a method of increasing implant stability and reducing mechanical failure.[6] Similarly, cement augmentation of locking plate fixation in proximal humeral fractures has been evaluated in elderly patients with compromised bone quality.[7] Structural augmentation using fibular grafts has also demonstrated favorable outcomes by providing additional medial support and improving construct stability in osteoporotic proximal humeral fractures. [8]

Despite these potential advantages, augmentation may increase operative complexity, procedure duration, cost, and the risk of augmentation-specific complications. The clinical benefit of routinely using augmentation over appropriately performed conventional fixation therefore remains an important consideration.

The present study was undertaken to compare conventional and augmented fixation techniques in osteoporotic fractures, with particular emphasis on fracture union, maintenance of reduction, functional recovery, fixation failure, implant-related complications, and requirement for reoperation.

Materials and Methods

Study Design and Participants: This prospective comparative study included 120 patients with osteoporotic fractures requiring operative fixation. Patients were divided into two groups according to the fixation technique employed:

Group C (Conventional Fixation): 60 patients treated using standard internal fixation without additional augmentation.

Group A (Augmented Fixation): 60 patients treated using internal fixation supplemented with an appropriate augmentation technique.

Patients fulfilling the eligibility criteria were enrolled consecutively during the study period and followed until fracture union or completion of the predetermined follow-up period.

Inclusion Criteria: Patients aged 50 years or older with radiologically confirmed osteoporotic or fragility fractures requiring operative fixation were included. Osteoporosis was identified on the basis of available bone mineral density assessment and/or established clinical and radiological criteria. Patients with fracture patterns suitable for either conventional or augmented internal fixation or who were able to comply with postoperative follow-up were eligible.

Exclusion Criteria: Patients with pathological fractures secondary to malignancy, open fractures with severe soft-tissue injury, active infection, periprosthetic fractures, and fractures requiring primary arthroplasty, severe neurovascular injury, revision fixation procedures, or medical conditions precluding operative treatment were excluded.

Preoperative Assessment: A detailed history was obtained regarding age, sex, mechanism of injury, comorbidities, previous fragility fractures, osteoporosis treatment, and functional status. Clinical examination included assessment of the affected limb, soft-tissue condition, deformity, neurovascular status, and associated injuries.

Standard anteroposterior and lateral radiographs were obtained for fracture characterization. Computed tomography was performed where required for detailed evaluation of complex fracture morphology. Bone mineral density was assessed using dual-energy X-ray absorptiometry (DEXA) when available. Fractures were classified using the appropriate established classification system according to anatomical location.

Conventional Fixation: Patients in Group C underwent standard fracture reduction and internal fixation using an implant appropriate for the fracture location and configuration. Fixation included locking/non-locking plates, screws, or intramedullary devices as clinically indicated. Reduction and implant positioning were confirmed intraoperatively using fluoroscopy.

Augmented Fixation: Patients in Group A underwent fracture fixation using an appropriate standard implant combined with an augmentation technique selected according to fracture morphology and bone quality. Augmentation consisted of cement augmentation of screws or fixation devices and/or structural bone graft augmentation, as appropriate.

When cement augmentation was employed, augmentation material was introduced in a controlled manner around the fixation site or through appropriately designed implants to improve implant purchase. When structural graft augmentation was used, the graft was positioned to provide additional support to the fracture construct. Fluoroscopic guidance was used to confirm satisfactory reduction, implant position, and augmentation placement.

Postoperative Management: Postoperative analgesia, wound care, thromboprophylaxis, and physiotherapy were provided according to standard institutional protocols. Early joint mobilization was encouraged where fracture stability permitted. Progression from protected to partial and full weight-bearing was determined according to fracture location, fixation stability, and radiological evidence of healing.

Patients with osteoporosis were advised appropriate medical management, including calcium and vitamin D supplementation and anti-osteoporotic therapy where indicated.

Follow-up and Outcome Assessment: Patients were evaluated at 6 weeks, 3 months, 6 months, and 12 months following surgery. Clinical and radiological assessments were performed at each relevant follow-up.

The primary outcome was successful fracture union. Union was defined clinically by absence of significant pain or tenderness at the fracture site and radiologically by evidence of bridging callus or progressive trabecular continuity across the fracture.

Secondary outcomes included:

- Time to radiological union
- Maintenance of fracture reduction
- Implant loosening or screw cut-out
- Loss of alignment
- Fixation failure
- Time to full weight-bearing
- Functional outcome
- Postoperative complications
- Requirement for reoperation

Functional outcomes were assessed using an appropriate validated anatomical-region-specific scoring system, such as the Harris Hip Score, Constant–Murley Score, or DASH score, depending on the fracture location.

Radiological Assessment: Serial radiographs were evaluated for fracture healing, maintenance of alignment, implant position, loss of reduction, screw migration or cut-out, implant loosening, and mechanical failure. Any change in fracture alignment or implant position compared with immediate postoperative radiographs was documented.

Statistical Analysis: Data were analyzed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Continuous variables between the two groups were compared using the independent Student's t-test, while categorical variables were analyzed using the Chi-square test or Fisher's exact test. Within-group changes in continuous outcomes were assessed using the paired t-test where appropriate. A p-value <0.05 was considered statistically significant.

Results

A total of 120 patients with osteoporotic fractures requiring operative fixation were included in the study. Sixty patients underwent conventional fixation (Group C), while 60 underwent augmented fixation (Group A). The two groups were comparable with respect to baseline demographic and fracture characteristics. Patients were followed for 12 months.

Table 1: Baseline Demographic and Fracture Characteristics

Variable	Conventional Fixation (n=60)	Augmented Fixation (n=60)	p-value
Age (years), mean ± SD	68.4 ± 7.6	69.1 ± 7.2	0.605
Male, n (%)	22 (36.7%)	20 (33.3%)	0.702
Female, n (%)	38 (63.3%)	40 (66.7%)	
BMI (kg/m²), mean ± SD	25.8 ± 3.4	26.1 ± 3.6	0.639
Mean BMD T-score	−2.91 ± 0.38	−2.96 ± 0.41	0.491
Low-energy fall, n (%)	49 (81.7%)	51 (85.0%)	0.624
Previous fragility fracture	11 (18.3%)	13 (21.7%)	0.644
Diabetes mellitus	14 (23.3%)	16 (26.7%)	0.671
Hypertension	27 (45.0%)	29 (48.3%)	0.715
Proximal femur fracture	24 (40.0%)	24 (40.0%)	
Proximal humerus fracture	18 (30.0%)	18 (30.0%)	1.000
Distal radius/other fragility fracture	18 (30.0%)	18 (30.0%)	

The mean age was 68.4 ± 7.6 years in the conventional fixation group and 69.1 ± 7.2 years in the augmented fixation group. Females constituted the majority in both groups. There were no statistically significant differences in demographic characteristics, bone mineral density, comorbidities, mechanism of injury, or distribution of fracture sites between the groups ($p>0.05$).

Table 2: Fracture Union and Rehabilitation Outcomes

Outcome	Conventional Fixation (n=60)	Augmented Fixation (n=60)	p-value
Union at 3 months	35 (58.3%)	44 (73.3%)	0.083
Union at 6 months	52 (86.7%)	58 (96.7%)	0.048
Final fracture union	55 (91.7%)	59 (98.3%)	0.094
Mean time to union (weeks)	17.8 ± 4.2	15.6 ± 3.7	0.003
Delayed union	7 (11.7%)	2 (3.3%)	0.083
Nonunion	5 (8.3%)	1 (1.7%)	0.094
Time to full weight-bearing/mobilization* (weeks)	12.4 ± 3.1	10.7 ± 2.8	0.002

***Assessed according to fracture location and permitted rehabilitation protocol.**

Patients treated with augmented fixation demonstrated earlier fracture healing. Mean time to union was significantly shorter in the augmented group (15.6 ± 3.7 weeks) than in the conventional group (17.8 ± 4.2 weeks; p=0.003). By 6 months, union was achieved in 96.7% of patients following augmented fixation compared with 86.7% following conventional fixation (p=0.048).

Patients in the augmented group also achieved full weight-bearing or unrestricted functional mobilization significantly earlier.

Table 3: Radiological and Mechanical Fixation Outcomes

Outcome	Conventional Fixation (n=60)	Augmented Fixation (n=60)	p-value
Maintained satisfactory reduction	49 (81.7%)	57 (95.0%)	0.023
Loss of reduction	8 (13.3%)	2 (3.3%)	0.048
Screw loosening/migration	7 (11.7%)	1 (1.7%)	0.028
Screw cut-out/penetration	5 (8.3%)	1 (1.7%)	0.094
Implant-related mechanical failure	6 (10.0%)	1 (1.7%)	0.052
Varus/valgus collapse	6 (10.0%)	1 (1.7%)	0.052
Overall fixation-related complication†	13 (21.7%)	4 (6.7%)	0.019

†Patients were counted once for the overall fixation-related complication rate even when more than one mechanical complication was present.

Maintenance of fracture reduction was significantly better following augmented fixation (95.0% vs 81.7%; p=0.023).

Loss of reduction occurred in 13.3% of patients treated with conventional fixation compared with 3.3% following augmented fixation (p=0.048). Screw loosening or migration was also significantly less frequent in the augmented group (1.7% vs 11.7%; p=0.028).

Overall fixation-related complications occurred in 21.7% of conventional fixation cases and 6.7% of augmented fixation cases (p=0.019).

Table 4. Clinical Outcome, Complications, and Reoperation

Outcome	Conventional Fixation (n=60)	Augmented Fixation (n=60)	p-value
Excellent functional outcome	17 (28.3%)	23 (38.3%)	
Good functional outcome	27 (45.0%)	29 (48.3%)	
Fair functional outcome	10 (16.7%)	6 (10.0%)	
Poor functional outcome	6 (10.0%)	2 (3.3%)	
Excellent/good outcome	44 (73.3%)	52 (86.7%)	0.067
Superficial infection	3 (5.0%)	2 (3.3%)	1.000
Deep infection	1 (1.7%)	1 (1.7%)	1.000
Wound complication	2 (3.3%)	2 (3.3%)	1.000
Augmentation-related complication	NA	1 (1.7%)	—
Reoperation	7 (11.7%)	2 (3.3%)	0.083
Overall postoperative complication‡	11 (18.3%)	6 (10.0%)	0.189

‡Mechanical complications already reported in Table 3 were excluded from this overall postoperative complication variable to avoid duplicate counting.

At final follow-up, excellent or good functional outcomes were achieved in 86.7% of patients treated with augmented fixation compared with 73.3% following conventional fixation. Although this difference favored augmented fixation, it did not reach statistical significance (p=0.067). Reoperation was required in 11.7% of conventional fixation patients compared with 3.3% of augmented fixation patients. Infection and wound-related complication rates were comparable between the groups.

Discussion

The present study compared conventional and augmented fixation techniques in 120 patients with osteoporotic fractures. Both techniques achieved satisfactory fracture healing; however, augmented fixation was associated with earlier union, better maintenance of reduction, and fewer fixation-related mechanical complications. These findings suggest that additional structural or cement augmentation may improve fixation stability in compromised osteoporotic bone.

The mean time to union was significantly shorter with augmented fixation (15.6 ± 3.7 weeks) compared with conventional fixation (17.8 ± 4.2 weeks). At 6 months, fracture union was achieved in 96.7% of patients following augmented fixation compared with 86.7% following conventional fixation. Bae et al. [9] demonstrated improved biomechanical performance when locking plate fixation was supplemented with intramedullary fibular strut augmentation in unstable proximal humeral fractures. Such additional structural support may improve load distribution and reduce micromotion at the fracture site, thereby creating a more favorable mechanical environment for healing.

Maintenance of fracture reduction was significantly better in the augmented group (95.0% vs 81.7%). Furthermore, loss of reduction and screw loosening or migration were significantly less frequent following augmentation. Varga et al. [10] demonstrated that cement augmentation, particularly of strategically positioned screws, could reduce the predicted risk of screw cut-out in proximal humeral fixation. These findings support the mechanical rationale for augmentation in patients with poor bone quality.

In the present study, overall fixation-related complications occurred in 6.7% of augmented fixation cases compared with 21.7% of conventional fixation cases. Evidence from Dasari et al. [11] has similarly suggested improved outcomes when locking plate fixation of proximal humeral fractures is supplemented with fibular allograft augmentation. More recent systematic evidence has also indicated that cement augmentation can improve construct stability in osteoporotic proximal humeral fractures, although the magnitude of clinical benefit may vary among studies. [12,13] The potential advantages of augmentation are not restricted to proximal humeral fractures. Augmentation techniques have been investigated for distal radius fractures to provide additional support where metaphyseal bone quality is poor. [14,15] Cement-augmented fixation has also been extensively investigated in osteoporotic spinal instrumentation, where inadequate screw purchase represents a major mechanical challenge. Singh et al. [16] reported that cement augmentation of pedicle screws can improve fixation in osteoporotic vertebrae, further supporting the general principle of strengthening the implant–bone interface in poor-quality bone.

Excellent or good functional outcomes were observed in 86.7% of patients following augmented fixation compared with 73.3% following conventional fixation, although the difference was not statistically significant. Similarly, reoperation was less frequent following augmentation (3.3% vs 11.7%), but this difference did not reach statistical significance. The potential reduction in fixation failure and subsequent procedures may also have economic implications. Joeris et al. [17] evaluated the cost-effectiveness of cement augmentation in unstable trochanteric fractures, highlighting the importance of considering both clinical outcomes and resource utilization.

Despite its advantages, augmentation should be used selectively. Cement leakage, thermal effects, difficulty during revision, additional operative steps, and increased implant or material costs are potential concerns. Structural graft augmentation may also increase operative complexity. Thus, fracture pattern, severity of osteoporosis, anatomical location, expected mechanical loading, and patient characteristics should guide the decision to augment fixation. Overall, the present findings indicate that augmented fixation may provide greater mechanical stability and reduce fixation-related complications in osteoporotic fractures. However, larger fracture-specific studies with longer follow-up are required to establish whether these advantages result in superior long-term functional outcomes.

Conclusion

Both conventional and augmented fixation techniques were effective in the management of osteoporotic fractures. Augmented fixation was associated with earlier fracture union, better maintenance of reduction, less screw loosening, and fewer fixation-related mechanical complications. Functional outcomes also favored augmentation, although the difference was not statistically significant. Augmentation may therefore be particularly beneficial in patients with severe osteoporosis or unstable fracture patterns where conventional implant purchase is inadequate.

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