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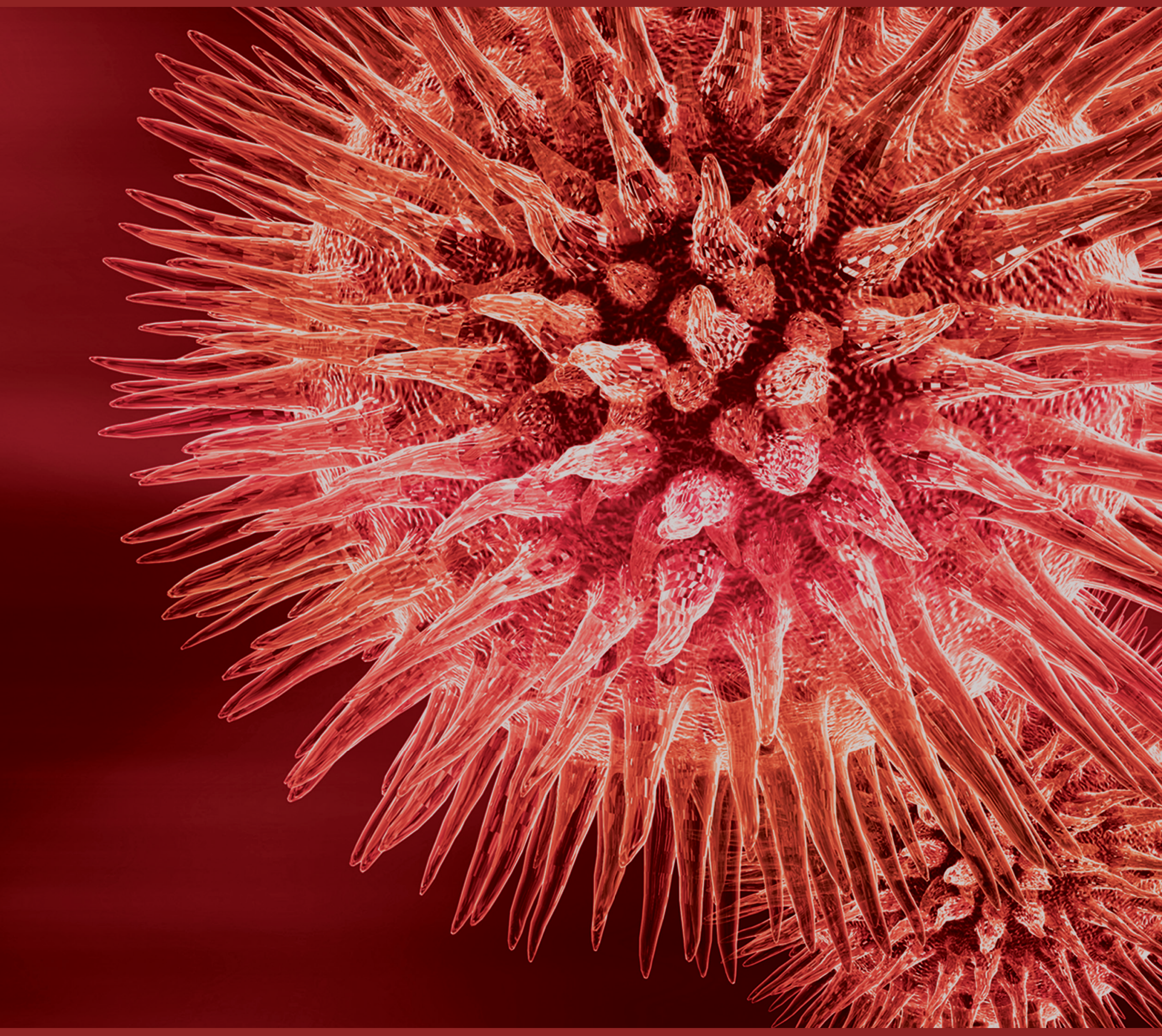
Guest Editors: Zhiyong Hou, Cyril Mauffrey, Wade R. Smith, and Marius M. Scarlat



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Editorial

Fragility Fractures in Orthopaedics: An Update

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Osteoporosis is the most common metabolic bone disorder, and its incidence increases with age. It is predicted that in 2050 there will be a large explosion in the elderly population in China, with up to 400 million aged 65+ (26.9% of the total population) and 150 million aged 80+ [1]. Due to the osteoporotic change of bone, a significant number of osteoporotic patients experience fragility fractures. There were reports that fragility fractures account for close to 2 million fractures annually in United States and could increase to more than 3 million by 2025 [2]. Owing to the high morbidity and mortality, fragile fractures significantly decrease the survival quality of the elderly [3]. Additionally, the fragile bone tissue increases the difficulty of operative fixation. Thus, fragility fractures present challenges for orthopaedic surgeons in the modern era. Up till now, there has been a continuous effort in improving the prevention and treatment for fragile fractures. Therefore, we create this special issue to provide better understanding of fragility fractures.

This special issue covers a variety of articles focused on the appealing topics of fragility fractures. These original researches from different countries include risk factor analysis, epidemiologic research, imaging diagnosis, and clinical study.

Fragility fractures may occur with relatively small energy of trauma, and fall related fractures are very important health issue in this more aging society. In one research article, H.-Y. Pi et al. tried to identify the risk factors of those fractures and effective preventive measures and found that dementia that emerged is the most important risk factor for the in-hospital complications of fall-related fractures, while most of the preventive measurements could not reduce the incidence of the in-hospital complications. Fragility fractures associated with osteoporosis may also be caused by thyroid disease. In this issue, G. Maccagnano et al. defined the prevalence of fragility fractures in relation to thyroid disease in a region of southern Italy and confirmed the role of thyroid disease as a risk factor in the onset of fragility fractures. Since patients receiving glucocorticoid are at a higher risk of developing secondary osteoporosis, assessment of bone microarchitecture may be used to evaluate risk of fragility fractures of osteoporosis. Within this issue, a pre-post study of M.-H. Chuang et al. declared that trabecular bone score (TBS) and fracture risk assessment tool (FRAX) adjusted with TBS (T-FRAX) showed an amplified predictive ability in the evaluation of risk of fragility fractures in patients receiving glucocorticoid therapy.

As the ageing trend is predicted to continue [4], new treatment strategies have been popularised for managing fractures associated with osteoporosis, including the use of new devices and surgical skills. A. Ortega-Briones et al. reported that column fixation and simultaneous total hip arthroplasty is a viable option for complex geriatric acetabular fractures and as well showed excellent mid-term results. Vertebral compression fractures are one of the most common fragility fractures in osteoporotic patients [5]. B.-S. Chang et al. suggested that anterior spinal column reconstruction using femoral shaft allografts improved kyphosis and resulted in minimal subsidence and therefore recommended it as an effective treatment option for dealing with osteoporotic vertebral collapse and kyphotic deformity. Surgical treatment of proximal humeral fractures in osteoporotic bone of elderly patients is challenging. Through the analysis of the clinical and radiological outcome, R. Bogner et al. recommended the use of Humerusblock device for the treatment of two- and three-part proximal humeral fractures. Locking plate has made a great progress in treating displaced proximal humeral fractures, which makes the joint-preserving surgery method more successful in elderly osteoporotic patients [6]. Given the characteristics of osteoporosis, L. Jin et al. introduced a probing method with depth gauge to determine the proximal screw length, which can make the screw-tip adjoin the subchondral bone and keep the articular surface of humeral head intact and at the same time effectively avoid frequent X-ray fluoroscopy and adjusting the screws.

In summary, fragile fractures are always challenging the orthopaedic surgeons. We have selected some valuable articles in this special issue. In the future, continuous efforts will be made to seek optimal prevention and treatment strategies in this field.

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Zhiyong Hou
Cyril Mauffrey
Wade R. Smith
Marius M. Scarlat

References

[1] E. F. Fang, M. Scheibye-Knudsen, H. J. Jahn et al., "A research agenda for aging in China in the 21st century," *Ageing Research Reviews*, vol. 24, pp. 197–205, 2015.

[2] R. Burge, B. Dawson-Hughes, D. H. Solomon, J. B. Wong, A. King, and A. Tosteson, "Incidence and economic burden of osteoporosis-related fractures in the United States, 2005—2025," *Journal of Bone and Mineral Research*, vol. 22, no. 3, pp. 465–475, 2007.

[3] A. Svedbom, E. Hernlund, M. Ivergård et al., "Osteoporosis in the European Union: a compendium of country-specific reports," *Archives of Osteoporosis*, vol. 8, article 137, 2013.

[4] P. Gerland, A. E. Raftery, H. Ševčíková et al., "World population stabilization unlikely this century," *Science*, vol. 346, no. 6206, pp. 234–237, 2014.

[5] Y.-S. Park and H.-S. Kim, "Prevention and treatment of multiple osteoporotic compression fracture," *Asian Spine Journal*, vol. 8, no. 3, pp. 382–390, 2014.

[6] R. A. Meier, P. Messmer, P. Regazzoni, W. Rothfischer, and T. Gross, "Unexpected high complication rate following internal fixation of unstable proximal humerus fractures with an angled blade plate," *Journal of Orthopaedic Trauma*, vol. 20, no. 4, pp. 253–260, 2006.

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Research Article

Acetabular Fractures in the Elderly: Midterm Outcomes of Column Stabilisation and Primary Arthroplasty

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Background. Interest in arthroplasty techniques for periarticular or intra-articular fractures in the elderly/osteoporotic patient continues to rise, including for geriatric acetabular fractures. In line with this, many acetabular fracture surgeons are now undertaking acute total hip arthroplasty in elderly/osteoporotic patients. Little is known however of the outcomes of this procedure, beyond the first year after surgery. *Questions/Purposes*. We determined the clinical outcomes of a series of elderly osteoporotic patients (mean age at surgery 77.4 years) treated for acetabular fractures with column fixation and simultaneous total hip arthroplasty, at a mean of 49 months after surgery. *Methods*. 24 patients (25 hips) were reviewed at a mean of 49 months after surgery. The surgical technique employed has previously been described. Radiographs were obtained, and clinical outcomes were assessed using Harris Hip Scores and the Merle d'Aubigné score. *Results*. 14 hips were available for assessment (9 deceased, 2 lost to follow-up). No patient suffered any complications beyond the perioperative period, no acetabular components were loose clinically or on latest radiographs, and the mean Harris Hip Score was 92. All but one patient scored good or excellent on the Merle d'Aubigné score. *Conclusions*. Column fixation and simultaneous total hip arthroplasty are a viable option for complex geriatric acetabular fractures, with encouraging midterm results. We conclude that THR is a viable long-term solution in this situation provided that the acetabular columns are stabilised prior to implantation, but more research is needed to aid in overall management decision making.

1. Introduction

As the population of developed countries ages, new challenges are facing orthopaedic surgeons, and this ageing trend is predicted to continue [1]. As a result new techniques have been popularised for managing osteoporotic fractures, including the use of new devices such as locking plate technology, as well as augmenting fixation with substances such as bone cement [2–4] or impaction bone grafting [5]. Periarticular fractures in the elderly are becoming more common also, and with advances in arthroplasty techniques the role of acute joint replacement for periarticular fractures is expanding—particularly around the shoulder, elbow, hip, and knee. The ideal extent of this role however has yet to be defined for most joints. Patients with osteoporotic acetabular fractures represent a significant and increasingly common challenge to the orthopaedic surgeon [6]; management options are several, with no agreed algorithm defined so far to guide the treating surgeon reliably to the best option [7]. We have previously reported on the use of column fixation with simultaneous total hip replacement (THR) to allow immediate full weight bearing, but reported only early outcomes and 1-year mortality rates [8]. We now present the later clinical outcomes of the same group of patients, with follow-up to a mean of 49 months (range 33 to 69).

2. Patients and Methods

The senior author's preference (MR) for management of elderly/osteoporotic acetabular fractures is simultaneous internal fixation and primary total hip arthroplasty. The technique has previously been described in detail, along

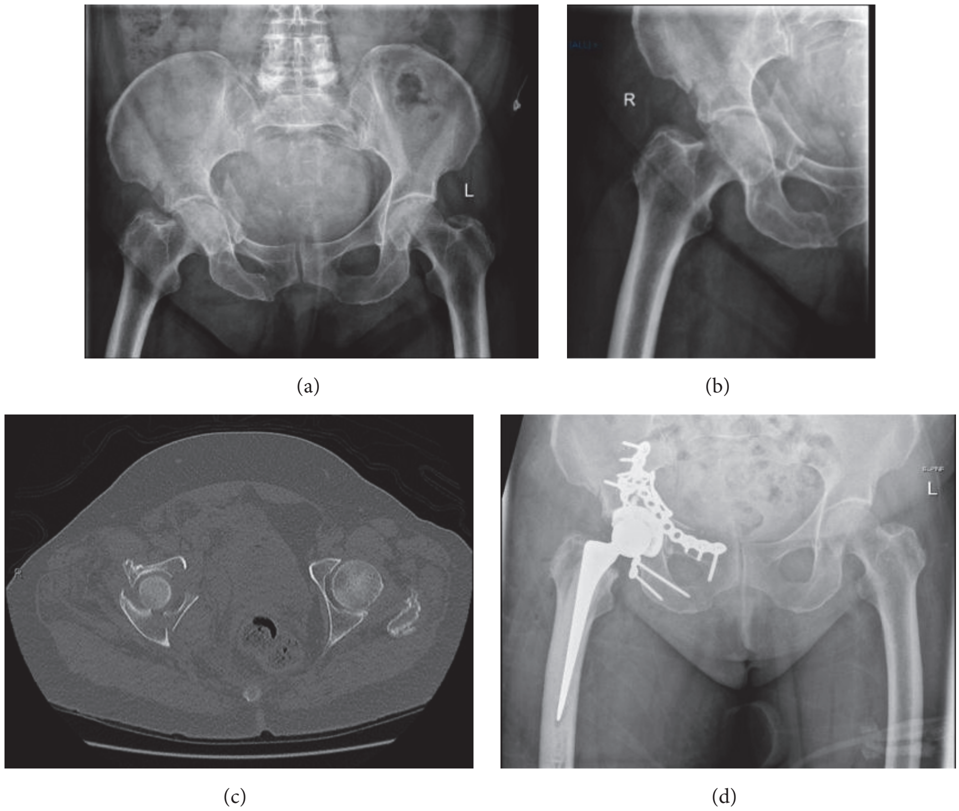


Figure 1: Pre- and post-op images of a typical case involving fractures of both columns. (a, b) Initial AP pelvis and film of right hip. (c) Axial CT scan of the fracture showing displacement of both columns. (d) Postoperative X-ray. Both columns have been reduced and plated, and a hip replacement was performed.

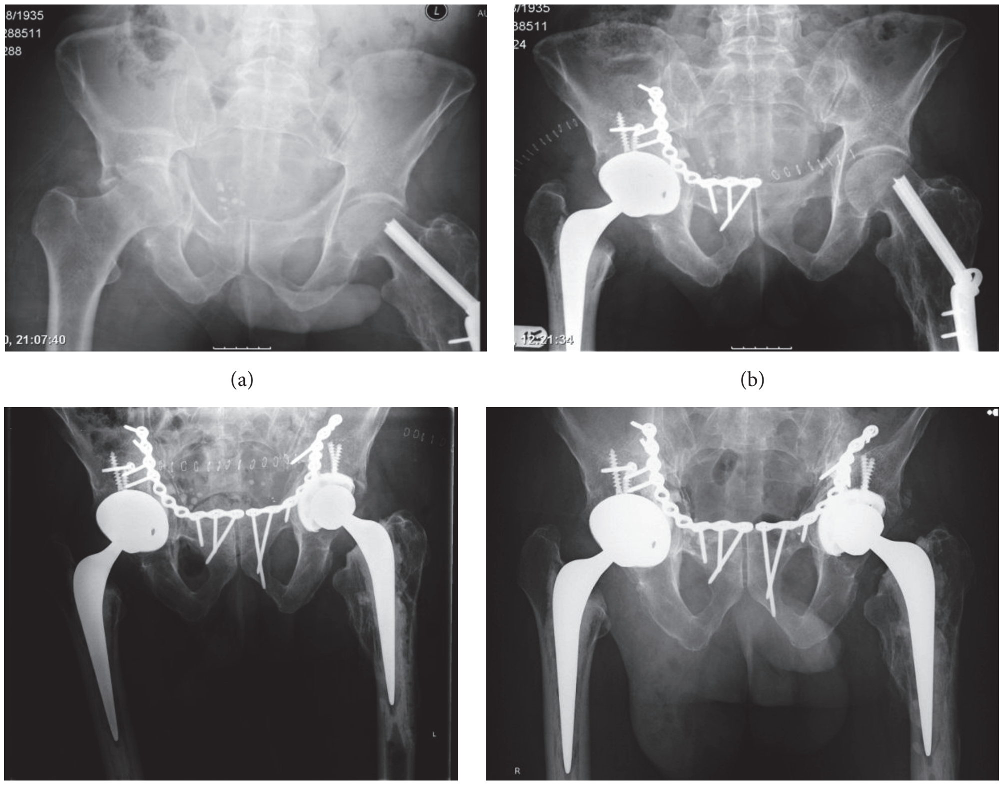
with decision making processes [9]. In the absence of a past history of confirmed osteoporosis, patients were assumed to have an osteoporotic fracture based on patient age, low energy of injury and fracture pattern, and the presence of specific markers such as femoral impaction fractures or marked acetabular marginal impaction. In summary, all hip replacements were done through a Kocher-Langenbeck approach, with simultaneous fixation of the posterior column if necessary; prior to this, if there was an anterior column fracture then this was approached separately (most commonly through a modified Stoppa approach) and also secured with a plate and screws (Figure 1). This results in a stable construct, allowing a standard total hip arthroplasty to be performed using primary implants, with enough stability to allow immediate full weight bearing. All of this is done under a single anaesthetic. 25 hips in 24 patients are included in this report—the early results of which have previously been described [8]. In addition to the previously published series, one of the original 24 patients has since sustained a similar injury on the opposite side, and this new injury is also included in this paper (Figure 2).

In line with the senior authors' standard practice, none of the patients in this series were actively discharged from follow-up but were seen yearly for clinical and radiographic review—this facilitated recent reviews of most patients. Those who had not attended clinic routinely were contacted and reviewed again, although 2 patients could not be found and were lost to follow-up. In line with standard protocols, patients underwent clinical review and plain radiographs, scores were calculated for the Harris Hip Score [10] and d'Aubigné and Postel [11] score, and complications/reoperations were noted as well as current functional levels.

3. Results

The study group contained 25 hips in 24 patients. Nine patients had died since surgery and 2 were lost to follow-up, leaving a cohort of 14 hips in 13 patients. The mean time to follow-up of the surviving patients was 49 months, range 33 to 69. The patient details and outcomes are shown in Table 1.

The mean overall age at surgery for the group was 77.4 years (range 62 to 92). The age at surgery of patients now deceased was 78.8 (range 63 to 90) compared to 76.9 (range 64 to 92) for those still surviving. Similarly there was no detectable difference in ASA grade, comorbidities, or mechanism of injury between those patients living and deceased. No patients underwent revision surgery prior to death (or reported any problems with the operated hip), and the single reoperation which was performed for a superficial infection was described in the previous paper.



(a) (b) (c) (d)

Figure 2: Images of patients 4 and 25, who sustained bilateral fractures at different time points. (a) Initial fracture in January 2010. (b) Postoperative view in January 2010. (c) Postoperative X-ray after second surgery in January 2012. (d) Most recent X-ray in June 2015.

Table 1: Details of surviving patients.

Patient	Age	Sex	Walking aids	Harris Hip Score	Merle D'A Score	Months to present follow-up
3	79	M	None	96	Excellent	57
4	75	M	1 stick	90	Good	65
5	65	M	None	100	Excellent	49
6	71	M	None	100	Excellent	50
11	70	M	None	65	Fair	51
12	73	M	None	100	Excellent	69
14	86	M	1 stick	90	Good	47
15	87	M	1 stick	84	Good	45
16	77	F	None	96	Excellent	45
17	64	M	None	100	Good	40
18	75	F	None	84	Good	50
19	72	M	None	96	Excellent	38
21	84	F	Lost	Lost	Lost	Lost to follow-up
22	92	F	Wheelchair	n/a	n/a	33
23	84	M	Lost	Lost	Lost	Lost to follow-up
25	77	M	1 stick	96	Good	41

The mean Harris Hip Score was 92 (range 65 to 100), and 13 of 14 hips rated as excellent or good on the Merle d'Aubigné rating system. One patient has become wheelchair-bound secondary to general poor health and severe dementia, and thus no score was recorded for this patient. Radiologically, all fractures were healed with well-fixed acetabular components, and no cup migration was seen in any case. Radiologically no cup appeared to be at risk of loosening or revision surgery for any reason. No new complications had occurred since the perioperative period in any patient.

4. Discussion

This paper shows encouraging outcomes at a mean of 49 months after surgery, both in terms of implant survival and clinical results. No new complications have been seen since the perioperative period, and we therefore conclude that the use of acetabular column stabilisation and simultaneous total hip replacement with subsequent immediate full weight bearing can give excellent results, even in the longer term.

There are limitations to this paper. Firstly, the cohort is small, with only 14 surviving patients at the time of writing. Secondly, although the authors have not seen any cup migration in this series, this has only been judged on plain radiographs which may not be as accurate as using RSA technology [12]; however, we believe that no visible migration at 4 years after implantation is a positive sign, especially when combined with good functional scores. In addition, as described in our initial paper, all of the patients received trabecular metal acetabular shells. The initial stability of trabecular metal appears to be excellent, and in revision hip surgery it has been shown to osseointegrate exceedingly well [13]. However, the authors have little experience of using traditional uncemented acetabular components in this setting and cannot offer any evidence to support the use of trabecular metal over other devices; rather we have simply continued to do what appears to have been successful for us so far.

Our results are based on outcomes from 14 hips, with 9 patients having died within the study period. Using standardised mortality rates for the UK, it would be expected that approximately 5 patients would have died within this time; there is clearly an impact on mortality as a result of this injury. The presumed logic behind performing such large procedures on elderly patients comes at least in part from evidence around neck of femur fracture patients. It is now widely accepted that in that elderly population long periods of forced immobility lead to high rates of morbidity and mortality. Surgical strategies for management of neck of femur fractures in the elderly therefore almost always aim for early surgery that allows immediate full weight bearing. Evidence that the same factors affect the elderly acetabular fracture population in the same way does not exist, however tempting it may be to assume that the same applies. In addition, very few patients from the neck of femur population are deemed unfit for surgery, whereas for elderly patients with acetabular fractures it is much more likely that they will be labelled "unfit" and thus managed nonoperatively. This results in a selection bias, with published series of surgically managed elderly acetabular fractures being inherently healthier than those of neck of femur fractures. Gary et al. attempted to look at mortality with a retrospective review of cases from 3 level 1 trauma centres, cases being stratified into nonoperative, percutaneous fixation, open reduction and internal fixation, or acute total hip replacement [14]. Although they found no significant improvement of surgical over nonoperative management (and thus concluded that decisions regarding surgical management of these cases should not be based on concern over the mortality of nonoperative management) their final adjusted mortality by treatment graph shows a clinically important if not statistically significant advantage to immediate hip arthroplasty over all other forms of management. Of note, this is the only treatment modality in their groupings that would allow immediate full weight bearing.

The real difficulty remains however in deciding when to choose acute arthroplasty over the other options available for this difficult group of fractures. Risk factors for failure of more conventional methods are poorly defined within the literature but almost certainly include marginal impaction [7, 15], femoral head damage [16, 17], significant fracture comminution [12, 16], and the presence of a "gull sign" [7, 17, 18]; evidence on the use of nonoperative strategies is almost nonexistent for modern medicine, with most commonly quoted papers now being historic [19–21]. The use of acute total hip replacement for the elderly osteoporotic acetabular fracture has attractive features—it should allow immediate weight bearing and mobility, and provided that it is successful it should provide a definitive solution for the patient from a single surgical procedure. This is in contrast to internal fixation in this age group, which is almost universally followed by a period of protected weight bearing (and in this age group often immobility) and commonly leading to joint replacement surgery at a later date [7]. There have been numerous reports of the use of acute arthroplasty for acetabular fractures in the past, although posterior fracture patterns predominate, and most did not allow early weight bearing. One relevant paper by Solomon reported the early outcomes of a very similar patient group, but using a different method of oversized acetabular components; whilst also achieving some success, their RSA studies showed that 3 of their 10 cases migrated a significant amount [12]. Many commonly quoted papers are no longer truly relevant, using cemented cups, small femoral heads, and older stem designs [22, 23]. In addition, a number of papers previously published on outcomes of "elderly" patients with acetabular fractures define elderly as over 55 or 60 [7, 18, 24, 25]. Perhaps the reader can decide if this is a true definition of the word, but in orthopaedic terms the difficult population is typically patients aged over 70. All but 2 of our patients were over 70, but little attention is paid to this specific group within the literature. Not only are today's patients older, but the fractures seen in the current orthopaedic climate are often different to those seen 50 years ago, when the current classification system of Letournel was devised. Underlying bone quality is different, and activities have changed in the elderly, resulting in the generation of a different set of fracture patterns with a predominance of anterior column damage combined with often incomplete posterior fractures [26]. As such, it is not unreasonable to assume that we may need different solutions to the problem in addition to those that were popularised in the past. Duarka et al. [7] published a systematic review of the literature in 2014 on the outcome of patients over the age of 55 with acetabular fractures. Their conclusions were that there is little or no clear evidence that any one treatment strategy is better than any other and that there was little published either on the nonoperative management of this group or to delineate the outcomes between early and delayed arthroplasty.

Patients considered for surgery in this age group will fall into one of 3 broad groups: those who would not survive the perioperative period, those who will die within a year, and those who will live for a substantial period of time. In an ideal world, accurate prediction of this grouping would allow the surgeon to manage patients accordingly, and in all probabilities the first group is best managed nonoperatively and the second with internal fixation. The third group however ideally requires a single long-lasting surgical procedure—the inherent problem being the high revision rate of internal fixation in this group, especially beyond 1 year.

5. Conclusion

This is the first report that the authors are aware of showing midterm outcomes for elderly patients undergoing acute total hip replacement for acetabular fractures, using trabecular metal and allowing immediate full weight bearing. No cups were loose at a mean of 49 months and late complications have not been seen. We conclude that THR is a viable long-term solution in this situation provided that the acetabular columns are stabilised prior to implantation, but more research is needed to aid overall management decision making.

Competing Interests

The authors declare that they have no competing interests.

References

[1] P. Gerland, A. E. Raftery, H. Ševčíková et al., "World population stabilization unlikely this century," *Science*, vol. 346, no. 6206, pp. 234–237, 2014.

[2] F. Fensky, J. V. Nüchtern, J. P. Kolb et al., "Cement augmentation of the proximal femoral nail antirotation for the treatment of osteoporotic pertrochanteric fractures—a biomechanical cadaver study," *Injury*, vol. 44, no. 6, pp. 802–807, 2013.

[3] S. Larsson, V. A. Stadelmann, J. Arnoldi et al., "Injectable calcium phosphate cement for augmentation around cancellous bone screws. In vivo biomechanical studies," *Journal of Biomechanics*, vol. 45, no. 7, pp. 1156–1160, 2012.

[4] D. Wähnert, M. J. Raschke, and T. Fuchs, "Cement augmentation of the navigated iliosacral screw in the treatment of insufficiency fractures of the sacrum: a new method using modified implants," *International Orthopaedics*, vol. 37, no. 6, pp. 1147–1150, 2013.

[5] G. J. van de Pol, L. D. Iselin, S. A. Callary et al., "Impaction bone grafting has potential as an adjunct to the surgical stabilisation of osteoporotic tibial plateau fractures: early results of a case series," *Injury*, vol. 46, no. 6, pp. 1089–1096, 2015.

[6] T. A. Ferguson, R. Patel, M. Bhandari, and J. M. Matta, "Fractures of the acetabulum in patients aged 60 years and older: an epidemiological and radiological study," *The Journal of Bone and Joint Surgery—Series B*, vol. 92, no. 2, pp. 250–257, 2010.

[7] J. S. Daurka, P. S. Pastides, A. Lewis, M. Rickman, and M. D. Bircher, "Acetabular fractures in patients aged > 55 years: a systematic review of the literature," *The Bone & Joint Journal*, vol. 96, no. 2, pp. 157–163, 2014.

[8] M. Rickman, J. Young, A. Trompeter, R. Pearce, and M. Hamilton, "Managing acetabular fractures in the elderly with fixation and primary arthroplasty: aiming for early weightbearing," *Clinical Orthopaedics and Related Research*, vol. 472, no. 11, pp. 3375–3382, 2014.

[9] M. Rickman, J. Young, M. Bircher, R. Pearce, and M. Hamilton, "The management of complex acetabular fractures in the elderly with fracture fixation and primary total hip replacement," *European Journal of Trauma and Emergency Surgery*, vol. 38, no. 5, pp. 511–516, 2012.

[10] W. H. Harris, "Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation," *The Journal of Bone & Joint Surgery—American Volume*, vol. 51, no. 4, pp. 737–755, 1969.

[11] R. M. d'Aubigné and M. Postel, "The classic: functional results of hip arthroplasty with acrylic prosthesis. 1954," *Clinical Orthopaedics and Related Research*, vol. 467, no. 1, pp. 7–27, 2009.

[12] L. B. Solomon, P. Studer, J. M. Abrahams et al., "Does cup-cage reconstruction with oversized cups provide initial stability in THA for osteoporotic acetabular fractures?" *Clinical Orthopaedics and Related Research*, vol. 473, no. 12, pp. 3811–3819, 2015.

[13] X. Flecher, S. Sporer, and W. Paprosky, "Management of severe bone loss in acetabular revision using a trabecular metal shell," *The Journal of Arthroplasty*, vol. 23, no. 7, pp. 949–955, 2008.

[14] J. L. Gary, E. Paryavi, S. D. Gibbons et al., "Effect of surgical treatment on mortality after acetabular fracture in the elderly: a multicenter study of 454 patients," *Journal of Orthopaedic Trauma*, vol. 29, no. 4, pp. 202–208, 2015.

[15] H. J. Kreder, N. Rozen, C. M. Borkhoff et al., "Determinants of functional outcome after simple and complex acetabular fractures involving the posterior wall," *The Journal of Bone & Joint Surgery—British Volume*, vol. 88, no. 6, pp. 776–782, 2006.

[16] J. L. Gary, K. A. Lefaivre, F. Gerold, M. T. Hay, C. M. Reinert, and A. J. Starr, "Survivorship of the native hip joint after percutaneous repair of acetabular fractures in the elderly," *Injury*, vol. 42, no. 10, pp. 1144–1151, 2011.

[17] Y.-L. Li and Y.-Y. Tang, "Displaced acetabular fractures in the elderly: results after open reduction and internal fixation," *Injury*, vol. 45, no. 12, pp. 1908–1913, 2014.

[18] J. O. Anglen, T. A. Burd, K. J. Hendricks, and P. Harrison, "The 'Gull Sign'. A Harbinger of failure for internal fixation of geriatric acetabular fractures," *Journal of Orthopaedic Trauma*, vol. 17, no. 9, pp. 625–634, 2003.

[19] M. Heeg, H. J. M. Oostvogel, and H. J. Klasen, "Conservative treatment of acetabular fractures: the role of the weight-bearing dome and anatomic reduction in the ultimate results," *The Journal of Trauma*, vol. 27, no. 5, pp. 555–559, 1987.

[20] R. F. Spencer, "Acetabular fractures in older patients," *The Journal of Bone & Joint Surgery—British Volume*, vol. 71, no. 5, pp. 774–776, 1989.

[21] W. W. Tipton, R. D. D'Ambrosia, and G. P. Ryle, "Non-operative management of central fracture-dislocations of the hip," *The Journal of Bone & Joint Surgery—American Volume*, vol. 57, no. 7, pp. 888–893, 1975.

[22] K. P. Boardman and J. Charnley, "Low-friction arthroplasty after fracture-dislocations of the hip," *The Journal of Bone and Joint Surgery—Series B*, vol. 60, no. 4, pp. 495–497, 1978.

[23] D. W. Romness and D. G. Lewallen, "Total hip arthroplasty after fracture of the acetabulum. Long-term results," *The Journal of Bone & Joint Surgery—British Volume*, vol. 72, no. 5, pp. 761–764, 1990.

[24] J. M. Matta, "Fractures of the acetabulum: accuracy of reduction and clinical results in patients managed operatively within three weeks after the injury," *The Journal of Bone & Joint Surgery—American Volume*, vol. 78, no. 11, pp. 1632–1645, 1996.

[25] D. L. Helfet, J. Borrelli Jr., T. DiPasquale, and R. Sanders, "Stabilization of acetabular fractures in elderly patients," *The Journal of Bone & Joint Surgery—American Volume*, vol. 74, no. 5, pp. 753–765, 1992.

[26] J. R. B. Hutt, A. Ortega-Briones, J. S. Daurka, M. D. Bircher, and M. S. Rickman, "The ongoing relevance of acetabular fracture classification," *The Bone & Joint Journal*, vol. 97, no. 8, pp. 1139–1143, 2015.

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Research Article

Trabecular Bone Score Reflects Trabecular Microarchitecture Deterioration and Fragility Fracture in Female Adult Patients Receiving Glucocorticoid Therapy: A Pre-Post Controlled Study

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A recently developed diagnostic tool, trabecular bone score (TBS), can provide quality of trabecular microarchitecture based on images obtained from dual-energy X-ray absorptiometry (DXA). Since patients receiving glucocorticoid are at a higher risk of developing secondary osteoporosis, assessment of bone microarchitecture may be used to evaluate risk of fragility fractures of osteoporosis. In this pre-post study of female patients, TBS and fracture risk assessment tool (FRAX) adjusted with TBS (T-FRAX) were evaluated along with bone mineral density (BMD) and FRAX. Medical records of patients with ($n = 30$) and without ($n = 16$) glucocorticoid treatment were retrospectively reviewed. All patients had undergone DXA twice within a 12- to 24-month interval. Analysis of covariance was conducted to compare the outcomes between the two groups of patients, adjusting for age and baseline values. Results showed that a significant lower adjusted mean of TBS ($p = 0.035$) and a significant higher adjusted mean of T-FRAX for major osteoporotic fracture ($p = 0.006$) were observed in the glucocorticoid group. Conversely, no significant differences were observed in the adjusted means for BMD and FRAX. These findings suggested that TBS and T-FRAX could be used as an adjunct in the evaluation of risk of fragility fractures in patients receiving glucocorticoid therapy.

1. Introduction

Osteoporosis is a well-defined systemic disorder characterized by low bone mass accompanied by a microarchitecture weakening of the bone tissue, with a subsequent increase in bone breakability [1–5]. The diminished bone density associated with this disease is a major risk factor for fractures, especially fractures of the hip, spine, and wrist. Osteoporosis is primarily a consequence of physiological bone loss, but it can be secondary to certain medical treatment (e.g., glucocorticoid (GC), anticonvulsants, cytotoxic drugs, excessive thyroxine, heparin, aluminum-contained antacids, lithium, and tamoxifen) or diseases, such as rheumatoid arthritis, diabetes, chronic kidneys, and primary hyperparathyroidism [6–8].

Long-term use of GC is frequent among patients with various systematic diseases, such as rheumatoid arthritis, systemic lupus erythematosus, inflammatory bowel diseases, and chronic obstructive lung diseases [7, 9]. However, GC use can affect mineral metabolism in bone cells, damage coupling activities of bone formation and resorption, promote osteoblasts apoptosis, inhibit osteoblasts propagation, and synthesize type I collagen and osteocalcin [10–12]. In addition, GC can reduce intestinal absorption of calcium, while increasing calcium excretion from the kidneys, causing an increase in parathyroid hormone secretion. All of these together can lead to significant damage to the bone tissue of vertebral and nonvertebral bones [13, 14], leading to the development of GC-induced osteoporosis (GIO). Previous studies have shown that fractures occur in 30%–50% of patients receiving long-term GC therapy [15]. Moreover, patients receiving GC therapy have an increased risk of fracture at a higher level of bone mineral density (BMD) value compared to patients who were not receiving GC therapy [16, 17].

The BMD value, acquired with a dual-energy X-ray absorptiometry (DXA) scanner, is an estimation of the quantity of the bone. A low BMD value is inversely proportional to an increase in fracture risk [5, 18]. Only quantitative information can be produced from the two-dimensional DXA images (i.e., areal BMD) and no qualitative three-dimensional information relating to bone structure can be obtained from BMD alone. However, microarchitectural and qualitative properties must also be considered when assessing the ability of bone to resist fracture. Therefore, BMD values may not be able to adequately reflect the increased fracture risk related to alterations in bone microstructure among patients receiving long-term GC therapy [19, 20]. Similarly, while fracture risk assessment tool (FRAX) can be used to predict the 10-year probability of a major osteoporotic fracture, such as spine, hip, forearm, or humorous fractures [21], many fragility fractures occur in osteopenic individuals (T-score between −1.0 and −2.5) rather than just in those with osteoporosis (T-score < -2.5) [22]. Consequently, factors such as bone geometry and bone microarchitecture are important in determining risk of fractures in addition to BMD.

A recently developed diagnostic tool, trabecular bone score (TBS), can provide quantified information on trabecular microarchitecture [23–28] using gray-level texture measurements of lumbar spine DXA images. Since TBS can be extracted from DXA images of the lumbar spine, it can readily be retrospectively applied to existing DXA images obtained from the majority of standard DXA devices. Therefore, TBS can provide additional skeletal information that is not available in standard BMD measurement. An elevated TBS value indicates a stronger skeletal texture, which is a reflection of better microarchitecture. Existing literature indicated that the use of TBS is valuable in predicting the associations between fragility fractures in healthy women [29, 30] and in patients with various clinical disorders, such as rheumatoid arthritis, diabetes, chronic kidneys, and primary hyperparathyroidism [31–33]. Moreover, an improvement in fracture prediction capacity has been documented when TBS was used to adjust FRAX (T-FRAX) [34]. To this end, the aim of this study was to evaluate the performance of TBS and T-FRAX in comparison to BMD and FRAX for predicting fracture risk in adult female patients receiving GC treatment.

2. Materials and Methods

2.1. Study Population. Medical records, during the period from 2011 to 2014, from a regional hospital in southern Taiwan were retrospectively reviewed. Adult female patients (40 to 89 years old) who underwent BMD measurements by DXA were identified. Only patients who had received two DXA scans of the lumbar spine and bilateral hip areas within an interval of 12 to 24 months were included in the study. For the exclusion criteria, patients who had undergone a surgical procedure to the spinal vertebrae or hips, such as internal fixation or total hip replacement, and diseases related to secondary osteoporosis, including type-2 diabetes, hyperparathyroidism, and hypercortisolism, were excluded from the study. In addition, patients who had received the following concomitant medications were excluded: tamoxifen > 5 years prior to baseline; lithium > 2 years prior to baseline; carbamazepine, phenobarbital, or proton pump inhibitors > 1 year prior to baseline, phenytoin, or heparin > 3 months prior to baseline; and cyclophosphamide or high-dose (≥500 mg/m^2) methotrexate > 1 month prior to baseline.

A total of 46 women were included in this study and they were divided into two groups based on their GC use. The GC group ($n = 30$) comprised of patients receiving glucocorticoid therapy, while the non-GC group ($n = 16$) was comprised of patients without receiving GC therapy. The latter group consisted of patients who had undergone routine health examinations at the study hospital.

2.2. DXA, BMD, and TBS Assessments. Areal BMD of the lumbar spine (vertebrae L1–L4) was measured with DXA (Discovery Wi, Hologic Inc., Boston, MA, USA). TBS values of the same lumbar vertebrae were determined based on DXA images using dedicated analysis software (TBS iNsight, version 2.1.2.0, Medimaps, Mérignac, France).

2.3. FRAX Measurements and Fracture Risk Assessments. The FRAX [35], developed by the World Health Organization Collaborating Centre for Metabolic Bone Diseases, provides estimates for a 10-year probability of major and hip osteoporotic fracture [36]. A higher risk value indicates the necessity for treatment, whereas a low risk value suggests that only a follow-up is required. Fracture risk was assessed for all patients using the online FRAX tool provided by the Centre for Metabolic Bone Diseases at Sheffield University (http://www.shef.ac.uk/FRAX/tool.jsp). Furthermore, T-FRAX was also obtained using an online tool (http://www.shef.ac.uk/TBS/CalculationTool.aspx).

2.4. Statistical Analysis. All results are expressed as mean ± standard deviation except indicated otherwise. Comparisons between the basic characteristics of the patients with and without GC therapy at baseline were analyzed by t-test and Fisher's exact test for continuous variables and categorical variables, respectively. Comparisons of BMD, TBS, FRAX, and T-FRAX between baseline and follow-up (within group) were based on the percentage changes of baseline value ($\Delta = 100 \times$ [follow-up value − baseline value]/baseline value). One-sample t-test was used to evaluate whether Δ was significantly different from 0. In addition, analysis of covariance (ANCOVA) was used to compare BMD, TBS, FRAX, and T-FRAX between the GC group and the non-GC group, adjusting for age and baseline values. Results of ANCOVA are presented as least-squares adjusted means with 95% confidence intervals. All statistical analyses were conducted using SPSS software, version 24.0 (IBM Corp., Armonk, NY, USA). A p value < 0.05 was considered statistically significant.

Table 1: Basic characteristics of female patients with and without glucocorticoid therapy ($N = 46$).

Variable	GC group ($n = 30$)	Non-GC group ($n = 16$)	p
Age (years)	62.9 ± 13.0	71.1 ± 12.9	0.047
Height (cm)	152.5 ± 5.5	151.4 ± 7.6	0.555
Weight (kg)	55.6 ± 8.3	51.6 ± 9.4	0.146
Body mass index (kg/m^2)	23.9 ± 3.4	22.4 ± 2.7	0.129
Follow-up period (months)	14.6 ± 6.5	18.6 ± 9.2	0.141
Rheumatoid disease, n (%)	4 (13.3)	0 (0)	0.282
Fractures, n (%)	5 (16.7)	13 (81.3)	<0.001

p values were obtained from Fisher's exact test for categorical variables and t-test for continuous variables. Data are expressed as mean ± standard deviation unless otherwise indicated.

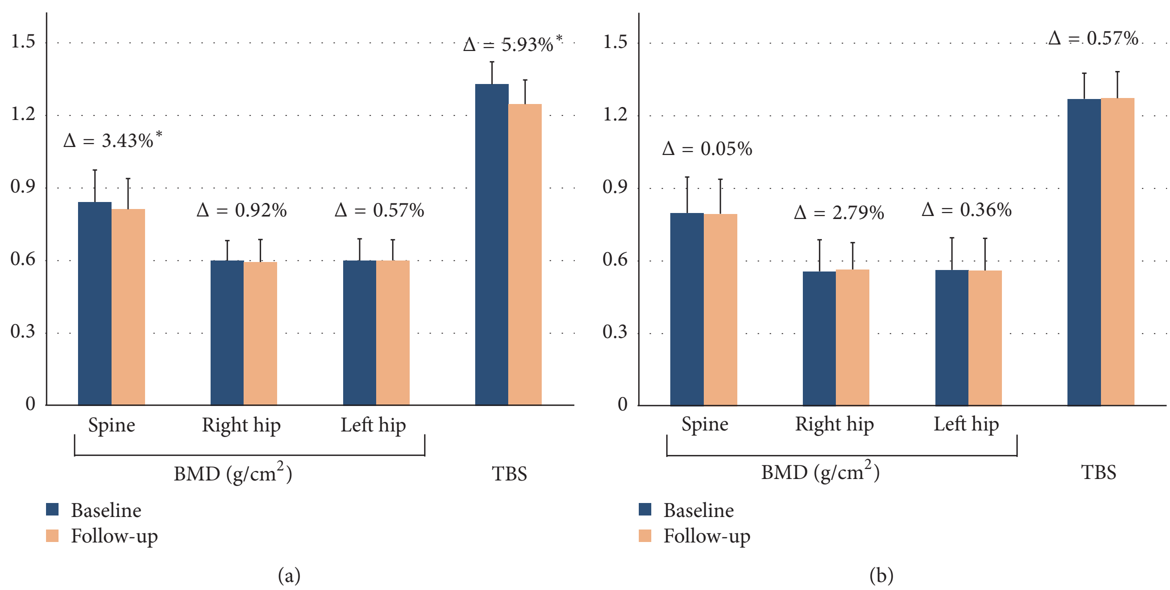

Figure 1: Bone mineral density (BMD) and trabecular bone score (TBS) values of the detected areas at baseline (blue) and follow-up period (orange) in the GC (a) and non-GC (b) groups. Values shown above the data bars are Δ, calculated as 100 × (follow-up value − baseline value)/baseline value. $^{*}p < 0.05$.

3. Results

3.1. Basic Characteristics of the Study Patients. The baseline characteristics of the patients are shown in Table 1. Age was significantly younger in the GC group ($p = 0.047$). The proportion of patients with fractures was significantly lower in the GC group ($p < 0.001$). There were no significant differences in height, weight, body mass index, follow-up period, and the proportion with rheumatoid disease between the two groups.

3.2. Changes in Bone Mineral Density between Baseline and Follow-Up. Table 2 shows the percentage changes of BMD over time analyzed separately for the GC and non-GC group. In the GC group, there was a significant decline in the average lumbar spine BMD from baseline to follow-up ($p = 0.004$), with a Δ of −3.43. The change in TBS (Δ = −5.93, $p < 0.001$) over time was also significant with a larger magnitude of Δ than that of BMD. No significant differences in the percentage change over time in the right and left hip BMD were observed. In the non-GC group, neither BMD nor TBS showed significant differences in their percentage changes over time (Figure 1).

3.3. Assessment of Fracture Risk. For the assessment of fracture risk in the GC group, T-FRAX exhibited a significant increase in both the risk for major osteoporotic fracture (Δ = 14.60, $p < 0.001$) and hip fracture (Δ = 26.46, $p = 0.001$). On the other hand, no significant differences were observed in the percentage change of FRAX over time. For the assessment of fracture risk in the non-GC group, neither the percentage change in FRAX nor T-FRAX was significantly different between baseline and follow-up (Figure 2).

3.4. Comparison of Age- and Baseline-Adjusted Means at Follow-Up between the GC and Non-GC Group. Results from ANCOVA (Table 3) indicated that the age and baseline value adjusted mean of TBS was significantly lower in the GC

Table 2: Comparison of bone mineral density, trabecular bone score, and fracture risk assessment tool score between baseline and follow-up for patients with and without glucocorticoid therapy ($N = 46$).

Variable	Glucocorticoid group ($n = 30$) Baseline	Follow-up	Δ (%)	p for Δ	Nonglucocorticoid group ($n = 16$) Baseline	Follow-up	Δ (%)	p for Δ
BMD (g/cm^2)								
Lumbar spine	0.8423 ± 0.1324	0.8120 ± 0.1272	−3.43 ± 6.03	0.004	0.7986 ± 0.1486	0.7951 ± 0.1427	−0.05 ± 7.02	0.977
Right hip	0.5996 ± 0.0831	0.5940 ± 0.0932	−0.92 ± 7.76	0.519	0.5575 ± 0.1303	0.5654 ± 0.1106	2.79 ± 8.6	0.214
Left hip	0.6004 ± 0.0900	0.6011 ± 0.0851	0.57 ± 7.76	0.691	0.5632 ± 0.1327	0.5608 ± 0.1330	−0.36 ± 9.12	0.876
TBS	1.3285 ± 0.0928	1.2467 ± 0.0996	−5.93 ± 7.54	<0.001	1.2703 ± 0.1057	1.2723 ± 0.1101	0.57 ± 10.04	0.822
FRAX (%)								
Right, major fracture	19.11 ± 11.51	20.77 ± 12.87	12.71 ± 41.38	0.103	18.17 ± 9.34	16.78 ± 7.55	−1.18 ± 19.86	0.815
Right, hip fracture	8.12 ± 7.46	9.05 ± 8.53	18.52 ± 55.89	0.080	7.86 ± 6.17	6.58 ± 4.42	6.54 ± 69.34	0.711
Left, major fracture	19.73 ± 10.83	20.67 ± 11.56	8.53 ± 29.48	0.124	18.08 ± 8.94	17.51 ± 8.79	0.48 ± 17.86	0.916
Left, hip fracture	8.54 ± 6.94	8.86 ± 8.13	12.54 ± 43.37	0.124	7.75 ± 5.52	7.14 ± 5.28	7.96 ± 44.81	0.488
T-FRAX (%)								
Major fracture	17.56 ± 10.70	19.79 ± 12.65	14.60 ± 16.48	<0.001	18.04 ± 8.82	17.25 ± 8.08	−0.05 ± 18.40	0.991
Hip fracture	7.37 ± 7.06	8.29 ± 8.31	26.46 ± 37.68	0.001	7.89 ± 5.90	7.31 ± 5.07	10.76 ± 43.87	0.342

BMD: bone mineral density; FRAX: fracture risk assessment tool; TBS: trabecular bone score; T-FRAX: TBS-adjusted FRAX;
Δ: 100 × (follow-up value − baseline value)/baseline value.
p values were obtained from one-sample t-test of Δ.
Data are expressed as mean ± standard deviation.

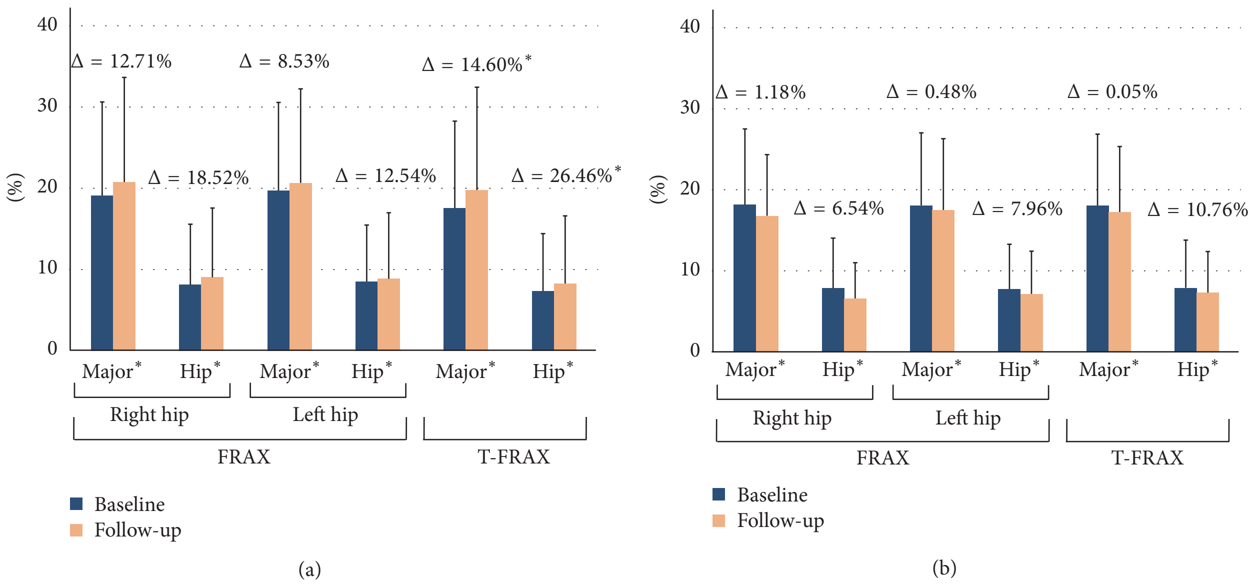

FIGURE 2: Fracture risk at baseline (blue) and follow-up period (orange) in the GC (a) and non-GC (b) groups. Fracture risks for major osteoporotic (labeled as "major*") and hip fractures (labeled as "hip*") were measured using the FRAX tool and with FRAX adjusted for TBS (T-FRAX). Values shown above the data bars are Δ, calculated as 100 × (follow-up value − baseline value)/baseline value. $^{*}p < 0.05$.

TABLE 3: Comparison of age-adjusted bone mineral density, trabecular bone score, and fracture risk assessment tool score of female patients with and without glucocorticoid therapy at follow-up ($N = 46$).

Variable	Age- and baseline-adjusted mean (95% confidence interval)		p
	GC group ($n = 30$)	Non-GC group ($n = 16$)	
BMD (g/cm^2)			
Lumbar spine	0.797 (0.778–0.817)	0.822 (0.796–0.849)	0.138
Right hip	0.580 (0.564–0.596)	0.591 (0.569–0.613)	0.445
Left hip	0.588 (0.574–0.603)	0.585 (0.564–0.605)	0.785
TBS	1.233 (1.199–1.267)	1.298 (1.250–1.346)	0.035
FRAX (%)			
Right, major fracture	20.23 (17.93–22.52)	17.79 (14.50–21.09)	0.257
Right, hip fracture	8.90 (7.43–10.38)	6.86 (4.78–8.93)	0.127
Left, major fracture	20.41 (18.27–22.54)	18.00 (14.93–21.07)	0.231
Left, hip fracture	8.60 (7.27–9.92)	7.63 (5.76–9.50)	0.419
T-FRAX (%)			
Major fracture	20.01 (18.78–21.24)	16.83 (15.10–18.57)	0.006
Hip fracture	8.52 (7.58–9.45)	6.89 (5.58–8.20)	0.056

BMD: bone mineral density; FRAX: fracture risk assessment tool; TBS: trabecular bone score; T-FRAX: TBS-adjusted FRAX.
p values comparing the two groups were obtained from analysis of covariance, adjusted for age and baseline values.

group ($p = 0.035$). In addition, the age and baseline value adjusted mean T-FRAX for major osteoporotic fracture was significantly higher in the GC group ($p = 0.006$). The age and baseline value adjusted mean T-FRAX for hip fracture was marginally higher in the GC group ($p = 0.056$). Conversely, no significant differences were observed in the age and baseline value adjusted mean for BMD and FRAX between the two groups.

4. Discussion

In this pre-post controlled study comparing patients with and without GC therapy, our results revealed that the lumbar vertebrae showed a statistically significant decline over time in the GC group (Table 2). In contrast, both BMD for the hip areas and FRAX did not show significant percentage changes between baseline and follow-up. This finding is consistent with the notion that the use of oral GC is generally associated with an impairment of the microarchitectural texture at the central skeleton but not BMD at other sites [37]. On the other hand, we found a significant decrease in the percentage change in TBS for lumbar spine and an increased risk (T-FRAX) for major fracture and hip fracture. This observation is also consistent with findings from previous studies that TBS could differentiate between GC-treated and non-GC-treated female patients [20]. In addition, in the GC group, the magnitude of percentage change in TBS was approximately twice as large as that in the BMD value (−5.93% *versus* −3.43%). This pattern was not apparent in the non-GC group, neither in TBS nor in T-FRAX, in comparison to that of BMD or FRAX. This suggests that TBS and T-FRAX appeared to provide an augmented risk evaluation for fragility fractures in long-term GC-treated female patients.

Another important finding in this study is that significant differences at follow-up were observed in TBS and T-FRAX (major osteoporotic fracture) in the GC group compared with the non-GC group. On the other hand, no significant differences between the two groups were observed in BMD or FRAX at the follow-up (Table 3). The effects of different age and baseline values were adjusted in these comparisons using ANCOVA. This finding further demonstrated the potential value of TBS and T-FRAX over BMD alone for assessing the risk of fragility fractures.

Our study has several limitations that deserve mention. First, TBS is not a direct physical measurement of the bone microarchitecture. Factors affecting the digital radiography image quality can influence the accuracy of TBS measurements. Image acquisition noise, such as X-ray quantum noise, detector defects, quantization noise, or scatter radiation, can lead to DXA image resolution degradation and therefore affecting TBS estimation. Second, our TBS results may not be comparable with other studies using different DXA machines. Third, our data were based on records from a single hospital, which may limit the generalizability of our results. Fourth, our study design is observational and therefore the possibility of confounding by unmeasured variables cannot be completely ruled out.

Despite the aforementioned limitations, there are also important strengths in this study. To our knowledge, this is the first study that used a longitudinal design to assess the changes in BMD and TBS over time in female patients receiving GC. Our findings demonstrated that TBS and T-FRAX were able to detect changes over time in bone quality that was not apparent from BMD measurement alone. An enlarged effect of percentage changes over time in TBS over BMD in predicting the bone mineral differences was also observed, which provide support for the use of TBS as an adjunct measurement for assessing the risk of fragility fractures.

5. Conclusion

Bone quality, in addition to quantity, plays an important role in the risk of fragility fractures. Patients receiving GC therapy usually experience significantly diminished BMD values and increased fracture risk, as measured by FRAX. Findings from our study revealed that TBS and T-FRAX showed an amplified predictive ability for osteoporotic fracture risk assessment in patients receiving GC therapy. Therefore, from a clinician's point of view, TBS and T-FRAX, which can readily be obtained from DXA images, should be considered as an adjunct tool for the risk evaluation of fragility fractures in patients receiving GC therapy.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] E. Chrischilles, T. Shireman, and R. Wallace, "Costs and health effects of osteoporotic fractures," *Bone*, vol. 15, no. 4, pp. 377–386, 1994.

[2] R. N. Clayton, "Mortality in Cushing's disease," *Neuroendocrinology*, vol. 92, supplement 1, pp. 71–76, 2010.

[3] R. S. Braithwaite, N. F. Col, and J. B. Wong, "Estimating hip fracture morbidity, mortality and costs," *Journal of the American Geriatrics Society*, vol. 51, no. 3, pp. 364–370, 2003.

[4] D. W. Dempster, "Osteoporosis and the burden of osteoporosis-related fractures," *The American journal of managed care*, vol. 17, no. 6, pp. S164–S169, 2011.

[5] J. A. Kanis, E. V. McCloskey, H. Johansson, C. Cooper, R. Rizzoli, and J.-Y. Reginster, "European guidance for the diagnosis and management of osteoporosis in postmenopausal women," *Osteoporosis International*, vol. 24, no. 1, pp. 23–57, 2013.

[6] V. S. Kalaiselvi, K. Prabhu, M. Ramesh, and V. Venkatesan, "The association of serum osteocalcin with the bone mineral density in post menopausal women," *Journal of Clinical and Diagnostic Research*, vol. 7, no. 5, pp. 814–816, 2013.

[7] J. M. Albaum, S. Youn, L. E. Levesque, A. S. Gershon, and S. M. Cadarette, "Osteoporosis management among chronic glucocorticoid users: a systematic review," *Journal of Population Therapeutics and Clinical Pharmacology*, vol. 21, no. 3, pp. e486–e504, 2014.

[8] K. Walker-Bone, "Recognizing and treating secondary osteoporosis," *Nature Reviews Rheumatology*, vol. 8, no. 8, pp. 480–492, 2012.

[9] T. Petranova, I. Sheytanov, S. Monov, R. Nestorova, and R. Rashkov, "Denosumab improves bone mineral density and microarchitecture and reduces bone pain in women with osteoporosis with and without glucocorticoid treatment," *Biotechnology and Biotechnological Equipment*, vol. 28, no. 6, pp. 1127–1137, 2014.

[10] H.-J. Kim, H. Zhao, H. Kitaura et al., "Glucocorticoids and the osteoclast," *Annals of the New York Academy of Sciences*, vol. 1116, pp. 335–339, 2007.

[11] S. Ito, N. Suzuki, S. Kato, T. Takahashi, and M. Takagi, "Glucocorticoids induce the differentiation of a mesenchymal progenitor cell line, ROB-C26 into adipocytes and osteoblasts, but fail to induce terminal osteoblast differentiation," *Bone*, vol. 40, no. 1, pp. 84–92, 2007.

[12] R. S. Weinstein, "Glucocorticoid-induced bone disease," *New England Journal of Medicine*, vol. 365, no. 1, pp. 62–70, 2011.

[13] T. P. Van Staa, "The pathogenesis, epidemiology and management of glucocorticoid-induced osteoporosis," *Calcified Tissue International*, vol. 79, no. 3, pp. 129–137, 2006.

[14] T. P. Van Staa, H. G. M. Leufkens, and C. Cooper, "The epidemiology of corticosteroid-induced osteoporosis: a meta-analysis," *Osteoporosis International*, vol. 13, no. 10, pp. 777–787, 2002.

[15] E. Canalis, G. Mazziotti, A. Giustina, and J. P. Bilezikian, "Glucocorticoid-induced osteoporosis: pathophysiology and therapy," *Osteoporosis International*, vol. 18, no. 10, pp. 1319–1328, 2007.

[16] K. G. Saag, D. Agnusdei, D. Hans et al., "Trabecular bone score in patients with chronic glucocorticoid therapy-induced osteoporosis treated with alendronate or teriparatide," *Arthritis and Rheumatology*, vol. 68, no. 9, pp. 2122–2128, 2016.

[17] T. P. Van Staa, R. F. Laan, I. P. Barton, S. Cohen, D. M. Reid, and C. Cooper, "Bone Density Threshold and Other Predictors of Vertebral Fracture in Patients Receiving Oral Glucocorticoid Therapy," *Arthritis and Rheumatism*, vol. 48, no. 11, pp. 3224–3229, 2003.

[18] L. P. Piodi, A. Poloni, and F. M. Ulivieri, "Managing osteoporosis in ulcerative colitis: something new?" *World Journal of Gastroenterology*, vol. 20, no. 39, pp. 14087–14098, 2014.

[19] J. A. Kanis, H. Johansson, A. Oden et al., "A meta-analysis of prior corticosteroid use and fracture risk," *Journal of Bone and Mineral Research*, vol. 19, no. 6, pp. 893–899, 2004.

[20] M. A. Paggiosi, N. F. A. Peel, and R. Eastell, "The impact of glucocorticoid therapy on trabecular bone score in older women," *Osteoporosis International*, vol. 26, no. 6, pp. 1773–1780, 2015.

[21] J. A. Kanis, O. Johnell, A. Oden, H. Johansson, and E. McCloskey, "FRAX™ and the assessment of fracture probability in men and women from the UK," *Osteoporosis International*, vol. 19, no. 4, pp. 385–397, 2008.

[22] L. D. Hordon, M. Raisi, J. E. Aaron, S. K. Paxton, M. Beneton, and J. A. Kanis, "Trabecular architecture in women and men of similar bone mass with and without vertebral fracture: I. Two-dimensional histology," *Bone*, vol. 27, no. 2, pp. 271–276, 2000.

[23] K. Briot, "DXA parameters: beyond bone mineral density," *Joint Bone Spine*, vol. 80, no. 3, pp. 265–269, 2013.

[24] B. C. Silva, W. D. Leslie, H. Resch et al., "Trabecular bone score: a noninvasive analytical method based upon the DXA image," *Journal of Bone and Mineral Research*, vol. 29, no. 3, pp. 518–530, 2014.

[25] C. Muschitz, R. Kocijan, J. Haschka et al., "TBS reflects trabecular microarchitecture in premenopausal women and men with idiopathic osteoporosis and low-traumatic fractures," *Bone*, vol. 79, pp. 259–266, 2015.

[26] V. Bousson, C. Bergot, B. Sutter, P. Levitz, and B. Cortet, "Trabecular bone score (TBS): available knowledge, clinical relevance, and future prospects," *Osteoporosis International*, vol. 23, no. 5, pp. 1489–1501, 2012.

[27] D. Hans, N. Barthe, S. Boutroy, L. Pothuaud, R. Winzenrieth, and M.-A. Krieg, "Correlations between trabecular bone score, measured using anteroposterior dual-energy X-ray absorptiometry acquisition, and 3-dimensional parameters of bone microarchitecture: an experimental study on human cadaver vertebrae," *Journal of Clinical Densitometry*, vol. 14, no. 3, pp. 302–312, 2011.

[28] J. P. Roux, J. Wegrzyn, S. Boutroy, M. L. Bouxsein, D. Hans, and R. Chapurlat, "The predictive value of trabecular bone score (TBS) on whole lumbar vertebrae mechanics: an ex vivo study," *Osteoporosis International*, vol. 24, no. 9, pp. 2455–2460, 2013.

[29] B. Rabier, A. Héraud, C. Grand-Lenoir, R. Winzenrieth, and D. Hans, "A multicentre, retrospective case-control study assessing the role of trabecular bone score (TBS) in menopausal Caucasian women with low areal bone mineral density (BMDa): analysing the odds of vertebral fracture," *Bone*, vol. 46, no. 1, pp. 176–181, 2010.

[30] E. Leib, R. Winzenrieth, O. Lamy, and D. Hans, "Comparing bone microarchitecture by trabecular bone score (TBS) in Caucasian American women with and without osteoporotic fractures," *Calcified Tissue International*, vol. 95, no. 3, pp. 201–208, 2014.

[31] F. M. Ulivieri, B. C. Silva, F. Sardanelli, D. Hans, J. P. Bilezikian, and R. Caudarella, "Utility of the trabecular bone score (TBS) in secondary osteoporosis," *Endocrine*, vol. 47, no. 2, pp. 435–448, 2014.

[32] T. Neumann, S. Lodes, B. Kästner et al., "Trabecular bone score in type 1 diabetes—a cross-sectional study," *Osteoporosis International*, vol. 27, no. 1, pp. 127–133, 2016.

[33] E. Koumakis, J. Avouac, R. Winzenrieth et al., "Trabecular bone score in female patients with systemic sclerosis: comparison with rheumatoid arthritis and influence of glucocorticoid exposure," *Journal of Rheumatology*, vol. 42, no. 2, pp. 228–235, 2015.

[34] E. V. McCloskey, A. Odén, N. C. Harvey et al., "A meta-analysis of trabecular bone score in fracture risk prediction and its relationship to FRAX," *Journal of Bone and Mineral Research*, vol. 31, no. 5, pp. 940–948, 2016.

[35] T.-L. Chiang, "Taiwan's 1995 health care reform," *Health Policy*, vol. 39, no. 3, pp. 225–239, 1997.

[36] J. A. Kanis, A. Oden, O. Johnell et al., "The use of clinical risk factors enhances the performance of BMD in the prediction of hip and osteoporotic fractures in men and women," *Osteoporosis International*, vol. 18, no. 8, pp. 1033–1046, 2007.

[37] E. S. Leib and R. Winzenrieth, "Bone status in glucocorticoid-treated men and women," *Osteoporosis International*, vol. 27, no. 1, pp. 39–48, 2016.

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Research Article

Risk Factors for In-Hospital Complications of Fall-Related Fractures among Older Chinese: A Retrospective Study

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Purpose. The aim of this study was to investigate the risk factors and the efficacy of the preventive measurements for the in-hospital complications of fall-related fractures. *Methods*. The data on older Chinese patients with fall-related fractures were collected, including information on the patients, diseases, and preventive measurements. The potential risk factors for the in-hospital complications included health status on admission, comorbidity, fractures, preventive measures of the complications, and drugs use for the comorbidity. After univariate analyses, multivariate logistic regression analyses were applied to investigate the impact of the potential risk factors on the number of the complications and each individual complication, respectively, and the efficacy of the preventive measurements. *Results*. A total of 525 male and 1367 female were included in this study. After univariate analyses, multiple logistic regression showed that dementia, pneumonia, antidepressant, postural hypotension, and cerebral infarction could increase the incidence and number of comorbidities. Meanwhile, dementia has shown the strongest association with each individual complication. *Conclusions*. Different combinations of comorbidity, medication use, and preventive measurements were related to the in-hospital complications of fall-related fractures. Dementia emerged as the most important risk factor for these complications, while most of the preventive measurements could not reduce their incidences.

1. Introduction

Falls are an important public health issue among older adults as they are one of the leading causes of fall-related injury and death in the populations [1–4]. Fall-related fracture is one of the most disabling problem of older patients and often trigger a downward spiral in their health which has a close association with the restriction of activity. That may eventually result in many long-term bedfast complications, including pressure ulcer, hospital-acquired pneumonia (HAP), urinary tract infection (UTI), and lower extremity venous thromboembolism (VTE), and even disability or deaths, especially in patients with comorbidity [3, 4].

Several studies have identified the characteristics and potential risk factors for fall-related fractures [1, 3–15]. For example, Sibley et al. [4] studied the relationship between falls and the number of chronic diseases and reported that 62% of fallers had multimorbidity, such as arthritis, visual impairment, hypertension, chronic obstructive pulmonary disease, diabetes, or heart disease, while 23.8% had a single chronic disease. Other studies also showed that comorbidity is an important factor for falls [6, 16]. Some acute diseases and medication use, such as cardiovascular or psychotropic drugs, also have been considered the primary precipitating risk factors for falls [6, 17].

However, there are limited studies on risk factors and preventive measurements for in-hospital complications of fall-related fractures. This study is an attempt to identify the risk factors for in-hospital complications of fall-related fractures among older Chinese patients and if the preventive measurements used in the clinical activities could decrease the incidence of these in-hospital complications. We collected health and clinical characteristics on patients, including their comorbidity conditions, medication use, and other health statuses of the populations, and tried to explore the interactive relationships between these viable and preventive measurements and their impact on the incidences of in-hospital complications.

2. Materials and Methods

2.1. Design and Patients. This retrospective study was conducted at Chinese PLA General Hospital and approved by the hospital's Ethics and Institutional Review Committees (Code: S2014-055-07). The waiver of patients' informed consent was granted due to the retrospective nature and anonymous patients data of the study. Data were obtained on old Chinese patients with fall-related fractures who were admitted to the Department of Orthopedics and Trauma at the Chinese PLA General Hospital between April 2004 and July 2014. Eligible patients were those aged 60 years or older who had fall-related fractures on admission.

Patients who were admitted with high energy fractures caused by traffic accident or high falling were excluded from the study. Patients who were transferred from other hospitals were also excluded.

2.2. Information on the Patients and Diseases. Information on the patients and injuries was obtained from the electrical medical records. Six types of in-hospital complications were noted, including pressure ulcer, HAP, UTI, lower extremity VTE, constipation, foot drop, and incision complications. The potential risk factors for the in-hospital complications of fall-related fractures were classified as the following five categories: physical status on admission, comorbidities, fracture sites, preventive measures of the in-hospital complications, and drugs use for the comorbidities. Two individual doctors collected half of all the data in an independent manner and checked it with each other after entire collection.

The physical status on admission includes nutritional status, conscious status, and sensory impairment. The nutritional status is assessed by using the short-form Mini-Nutritional Assessment and classified as three grades (malnourished, moderate/at risk of malnutrition, and normal) according to the protocol [18]. The conscious status is classified as five grades, including normal, confusion, delirium, somnolence, and coma, in order of decreased level. Sensory impairment is defined as hearing or vision impairment. The comorbidities include cardiovascular diseases (hypertension, coronary heart disease, postural hypotension, atrial fibrillation, ventricular tachycardia, supraventricular tachycardia, atrial flutter, atrioventricular block, sick sinus syndrome, ventricular premature beat, acute myocardial infarction, rheumatic heart disease, sinus bradycardia, hyperlipemia, etc.), central nervous system (CNS) diseases (cerebral infarction, dementia, cerebral hemorrhage, transient ischemic attack, Parkinson's disease, myasthenia gravis, epilepsy, etc.), bone and joint diseases (osteoarthritis, osteoporosis, protrusion of intervertebral disc, pathological fracture, bone hyperplasia, cervical spondylosis, etc.), respiratory system diseases (pneumonia, chronic obstructive pulmonary disease, etc.), diabetes, cataract, and anemia. In addition, skin problems were also noted, including broken skin, skin yellowing, hematocyanosis, rash, hyperpigmentation, ochrodermia, edema, dehydration, furuncle, petechia, bruise or blood spot, scar, and pale skin.

The fracture site includes radial fracture, femoral neck fracture, femoral intertrochanteric fracture, femoral shaft fracture, spinal fracture, and minor fracture, and the characteristics of fracture are classified as upper extremity, lower extremity, and spinal or multiple fractures.

2.3. Preventive Measures of In-Hospital Complications. In our clinical activities, several preventive measures of complications were used as a routine nursing work and performed on the included patients. The number and combination of the preventive measures performed were dependent on different attending doctors' decision based on the condition of each patient.

The preventive measures of pressure ulcer include (1) replacing the clothes and sheets regularly and keeping the bed clean and dry; (2) keeping the crissum and entire skin clean and dry; (3) turning patients over regularly; (4) providing patients dietary guidance; (5) other preventive measures.

The preventive measures of HAP include (1) guiding patients to deep breathing and coughing exercises; (2) assisting patients to regularly change the posture; (3) turning patients over and knocking back regularly; (4) atomization inhalation treatment; (5) other preventive measures.

The preventive measures of UTI include (1) drinking plenty of water; (2) disinfecting the urinary catheter regularly; (3) clipping the urinary catheter intermittently and instructing patients to strengthen the urinary sphincter with bladder training exercises; (4) replacing the urine bag and catheter regularly; (5) bladder irrigation regularly; (6) other preventive measures.

The preventive measures of lower extremity VTE include (1) guiding patients with lower limb functional exercise regularly; (2) wearing antithrombotic pressure belt with double lower limbs; (3) anticoagulant drugs use; (4) other preventive measures.

The preventive measures of constipation include (1) eating high-fiber foods; (2) taking abdominal massage regularly; (3) using glycerine enema or other laxatives; (4) other preventive measures.

2.4. Statistical Analysis. After proving normal distribution of the data, the mean differences of the continuous data between groups were compared by independent samples

Table 1: The patients' general information.

	Male (N = 525, mean ± SD)	Female (N = 1367, mean ± SD)	p	Total (N = 1892, mean ± SD)	Range
Age (years)	77.31 ± 8.16	75.74 ± 8.7	<0.001	76.18 ± 8.58	60–101
Hospital LOS (days)	14.75 ± 17.40	11.68 ± 24.39	0.008	12.53 ± 22.71	0–615
Grade 1 nursing (days)	11.94 ± 13.2	9.19 ± 21.26	0.006	9.95 ± 19.4	0–527

N: number; SD: standard deviation; LOS: length of stay.

t-test. Pearson's Chi square test and Fisher's exact test were used for detecting the interaction of two categorical variables. Kruskal-Wallis test was used for intergroup comparisons of three or multiple categorical variables. Correlations between categorical variables were determined using Spearman's correlation analysis. After univariate analyses, ordinal or multivariate analyses were applied to investigate the potential risk factors for the number of complications and each individual complication, respectively. The validity of the model was tested by Hosmer-Lemeshow statistic for goodness of fit. The hazard ratio of the potential risk factor was expressed as odds ratio (OR) values or regression coefficients (β). A p value less than 0.05 was considered statistically significant. All statistical procedures were accomplished with SPSS 20 software (SPSS Inc., Chicago, IL, USA).

3. Results

The population included are of a mean age of 76.18 years with 525 male and 1367 female. Both hospital length of stay (LOS) and length of grade 1 nursing are significantly longer in the male than female group. The general information is summarized in Table 1.

3.1. Comparison of the Health and Clinical Characteristics. Table 2 presents the comparison of the physical status and clinical characteristics between genders. It can be shown that the incidences of normal or malnourished nutritional status, femoral shaft fractures, thoracic vertebra fractures, and other minor fractures were significantly higher in female than male group with all p values < 0.05. The incidences of one or two CNS diseases, intertrochanteric fractures, and upper or lower extremity fractures were significantly higher in male than female group with all p values < 0.05. Spearman's correlation analysis shows that age has a significantly positive correlation with lower extremity fractures (r = 0.367, p < 0.001) and negative correlations with upper extremity fractures (r = −0.361, p < 0.001) and spinal fractures (r = −0.128, p < 0.001). However, the negative association of age to spinal fractures only exists in female group (r = −0.141, p < 0.001).

There are also significantly positive correlations of the number of comorbidities to hospital length of stay (r = 0.141, p < 0.001) and length of grade 1 nursing (r = 0.13, p < 0.001). Meanwhile, 48.57% of male and 46.65% of female patients have two comorbidities and over, although there is no significant difference of the number of comorbidities between genders.

The differences of the numbers of the preventive measures of the complications are also not consistent between genders (Table 2). However, there are no significant differences of the number of the complications or the incidences of each individual complication between different genders groups (Table 3).

3.2. Univariate and Multivariate Analysis for the Factors of the Conscious Status. Pearson's Chi square test shows that intertrochanteric fracture, cerebral hemorrhage, cerebral infarction, dementia, other CNS diseases, diabetes, antidiabetic drug, antidepressant, pale skin, other skin diseases, constipation, sensory impairment, and nutritional status are risk factors for the conscious status (Table 4). Kruskal-Wallis one-way ANOVA shows that the age is significantly higher in the "confusion" group than in the "normal" group (p < 0.001) and higher in the "somnolence" group than in the "confusion" group (p = 0.024).

With the factors abovementioned as independent variables ordinal logistic regression also shows that age, nutritional status, dementia, and pale skin are independent risk factors for conscious status (Table 5).

Spearman's correlation analysis also shows that there are weak but significant positive correlations between conscious status and age (r = 0.112, p < 0.001), nutritional status (r = 0.131, p < 0.001), sensory impairment (r = 0.108, p < 0.001), dementia (r = 0.154, p < 0.001), and pale skin (r = 0.104, p < 0.001).

3.3. Univariate and Multivariate Analysis for the Factors of Each Individual Complication. Pearson's Chi square test shows that femoral shaft fracture, broken skin, cerebral hemorrhage, dementia, turning over regularly, skin yellowing, rash, other skin problems, hypertension, and anemia are all risk factors for pressure ulcer. However, multivariate analysis shows that only femoral shaft fracture (OR = 23.64, p = 0.023), broken skin (OR = 14.324, p = 0.07), cerebral hemorrhage (OR = 555.49, p = 0.002), dementia (OR = 145.3, p = 0.002), and turning over regularly (OR = 0.039, p = 0.017) are independent risk factors for pressure ulcer (Table 6).

Pearson's Chi square test shows that atrial fibrillation, cerebral infarction, dementia, changing posture regularly, and antihypertensive drugs are all risk factors for HAP. However, multivariate analysis excludes the risk of antihypertensive drugs (Table 7).

Univariate analysis of the risk of urinary tract infection shows that cerebral infarction, dementia, anemia, drinking more water, bladder irrigation, broken skin, skin yellowing, rash, and cerebral hemorrhage are all risk factors for UTI. However, multivariate logistic regression shows that only

TABLE 2: Comparison of the physical status and characteristics of injuries between genders.

Factors	Grade/N	Male/N (%)	Female/N (%)	p	Total/N (%)
Nutritional status				0.036	
	Normal	340 (64.76)	953 (69.71)	0.038	1293 (68.34)
	Moderate	175 (33.33)	377 (27.58)	0.203	552 (29.17)
	Malnourished	10 (1.9)	37 (2.71)	0.013	47 (2.48)
Mental status				0.433	
	Normal	506 (96.38)	1320 (96.56)	0.726	1826 (96.51)
	Confusion	18 (3.43)	44 (3.22)	0.818	62 (3.27)
	Delirium	1 (0.19)	0	0.277	1 (0.05)
	Somnolence	0	2 (0.15)	0.522	2 (0.11)
	Coma	0	1 (0.07)	0.723	1
Sensory impairment	No	451 (85.9)	1216 (88.95)	0.067	1667 (88.11)
	Yes	74 (14.1)	151 (11.05)	0.067	225 (11.89)
Dermal problems				0.335	
	0	126 (24)	347 (25.38)	0.534	473 (25)
	1	388 (73.9)	1000 (73.15)	0.74	1388 (73.36)
	2	10 (1.9)	20 (1.46)	0.307	30 (1.59)
	3	1 (0.19)	0	0.277	1 (0.05)
Cardiovascular diseases				0.596	
	0	260 (49.52)	630 (46.09)	0.18	890 (47.04)
	1	199 (37.7)	534 (39.06)	0.589	733 (38.74)
	2	61 (11.62)	186 (13.61)	0.251	247 (13.05)
	3	5 (0.95)	16 (1.17)	0.685	21 (1.11)
	4	0	1 (0.07)	0.723	1 (0.05)
CNS diseases				<0.001	
	0	367 (69.9)	1094 (80.03)	<0.001	1461 (77.22)
	1	137 (26.1)	246 (18)	<0.001	383 (20.24)
	2	19 (3.62)	23 (1.68)	0.011	42 (2.22)
	3	2 (0.38)	4 (0.29)	0.53	6 (0.32)
Bone and joint diseases				0.187	
	0	461 (87.81)	1185 (86.69)	0.515	1646 (87)
	1	59 (11.24)	177 (12.95)	0.313	236 (12.47)
	2	5 (0.95)	4 (0.29)	0.073	9 (0.48)
	3	0	1 (0.07)	0.723	1 (0.05)
Respiratory system diseases	0	504 (96)	1317 (96.34)	0.408	1821 (96.25)
	1	21 (4)	50 (3.66)	0.408	71 (3.75)
Fracture site				0.018[a]	
	Radius	61 (11.6)	154 (11.3)	0.828	215 (11.36)
	Femoral shaft	23 (4.4)	91 (6.7)	0.037	114 (6.3)
	Femoral neck	199 (37.9)	487 (35.6)	0.356	686 (36.26)
	Intertrochanteric	196 (37.3)	409 (29.9)	0.001	605 (31.98)
	Lumbar vertebra	35 (6.7)	104 (7.6)	0.276	139 (7.35)
	Thoracic vertebra	0	16 (1.2)	0.005	16 (0.85)
	Minor fracture	26 (5)	131 (9.6)	<0.001	157 (8.3)
Fracture characteristics				0.076	
	Upper extremity	56 (10.67)	186 (13.61)	0.049	242 (12.79)
	Lower extremity	409 (77.9)	1000 (73.15)	0.019	1409 (74.47)
	Spine	42 (8)	144 (10.53)	0.056	186 (9.83)
	Multiple	18 (3.43)	37 (2.71)	0.243	55 (2.91)

Table 2: Continued.

Factors	Grade/N	Male/N (%)	Female/N (%)	p	Total/N (%)
Preventive measures of pressure ulcer				0.001	
	0	3 (0.57)	5 (0.37)	0.074	8 (0.42)
	1	5 (0.95)	12 (0.88)	0.029	17 (0.9)
	2	128 (24.38)	327 (23.92)	<0.001	455 (24.05)
	3	59 (11.24)	272 (19.9)	0.013	331 (17.49)
	4	226 (43.05)	520 (38.04)	<0.001	746 (39.43)
	5	104 (19.81)	231 (16.9)	0.002	335 (17.71)
Preventive measures of HAP				0.009	
	0	0	3 (0.22)	0.377	3 (0.16)
	1	11 (2.1)	28 (2.05)	0.007	39 (2.06)
	2	9 (1.71)	26 (1.9)	0.479	35 (1.85)
	3	286 (54.48)	863 (63.13)	0.005	1149 (60.73)
	4	191 (36.38)	399 (29.19)	0.004	590 (31.18)
	5	28 (5.33)	48 (3.51)	0.016	76 (4.02)
Preventive measures of UTI				0.028	
	0	3 (0.57)	11 (0.8)	0.01	14 (0.74)
	1	106 (20.19)	365 (26.7)	<0.001	471 (24.89)
	2	18 (3.43)	62 (4.54)	0.364	80 (4.23)
	3	100 (19.05)	251 (18.36)	<0.001	351 (18.55)
	4	269 (51.24)	592 (43.31)	0.402	861 (45.51)
	5	28 (5.33)	85 (6.22)	0.482	113 (5.97)
	6	1 (0.19)	1 (0.07)	0.522	2 (0.11)
Preventive measures of lower extremity VTE				0.058	
	0	7 (1.33)	8 (0.59)	0.007	15 (0.79)
	1	238 (45.33)	669 (48.94)	<0.001	907 (47.94)
	2	231 (44)	526 (38.48)	<0.001	757 (40.01)
	3	48 (9.14)	159 (11.63)	<0.001	207 (10.94)
	4	1 (0.19)	5 (0.37)	0.53	6 (0.32)
Preventive measures of constipation				0.628	
	0	12 (2.29)	23 (1.68)	<0.001	35 (1.85)
	1	373 (71.05)	961 (70.3)	0.001	1334 (70.51)
	2	137 (26.1)	378 (27.65)	<0.001	515 (27.22)
	3	3 (0.57)	4 (0.29)	0.621	7 (0.37)
	4	0	1 (0.07)	0.723	1 (0.05)

[a]Wilcoxon test; N: number; UTI: urinary tract infection; VTE: venous thromboembolism; HAP: hospital-acquired pneumonia; PU: pressure ulcer; CNS: central nervous system.

cerebral infarction, dementia, anemia, drinking more water, and bladder irrigation are independent risk factors for UTI. Meanwhile, the risk of UTI development can be significantly reduced by drinking more water (OR = 0.013, $p = 0.021$) but increased by bladder irrigation (OR = 14.954, $p = 0.009$) (Table 8).

Both univariate and multivariate analyses for the influencing factors of foot drop show that broken skin, cerebral infarction, dementia, and postural hypotension are independent risk factors for foot drop (Table 9).

3.4. Univariate and Multivariate Analysis for the Factors of the Complications Number. Pearson's Chi square test shows that the numbers of CNS diseases, respiratory system diseases, and dermal problems are significantly different between different groups of the complications number (Table 10). Spearman's correlation analysis shows that there are weak but significantly positive correlations between the complications number and the number of CNS diseases ($r = 0.09$, $p < 0.001$) and respiratory system diseases ($r = 0.072$, $p < 0.001$), respectively. Kruskal-Wallis one-way ANOVA shows that the complications numbers are shown significantly greater in one or two CNS diseases groups than in no CNS disease group with p values of 0.008 and 0.014, respectively, and not significantly different between other groups.

With the number of CNS diseases, respiratory system diseases, and dermal problems as independent variables, ordinal logistic regression also shows that the number of CNS

Table 3: Comparison of the complications rates between genders.

Factors	N	Male/N (%)	Female/N (%)	p	Total/N (%)
Total complications				0.592	
	0	520 (99.04)	1356 (99.19)	0.47	1876 (99.15)
	1	3 (0.57)	4 (0.29)	0.302	7 (0.37)
	2	2 (0.38)	2 (0.15)	0.309	4 (0.21)
	3	0	1 (0.07)	0.723	1 (0.05)
	4	0	1 (0.07)	0.723	1 (0.05)
	5	0	3 (0.22)	0.377	3 (0.16)
Pressure ulcer		0	6 (0.44)	0.142	6 (0.31)
HAP		2 (0.38)	7 (0.51)	0.524	9 (0.48)
UTI		0	5 (0.37)	0.196	5 (0.26)
VTE		0	1 (0.07)	0.723	1 (0.05)
Constipation		0	3 (0.22)	0.377	3 (0.16)
Foot drop		3 (0.57)	7 (0.51)	0.555	10 (0.53)
Incision problem		2 (0.38)	1 (0.07)	0.188	3 (0.16)

N: number; UTI: urinary tract infection; VTE: venous thromboembolism; HAP: hospital-acquired pneumonia.

diseases and respiratory system diseases are independent risk factors for the complications number (Table 10).

When all individual potential risk factors are analysed by Pearson's Chi square test, it can be shown that broken skin, skin yellowing and rash, hematocyanosis, hyperpigmentation, cerebral infarction and hemorrhage, dementia, pneumonia, postural hypotension, antidepressant, femoral shaft fracture, osteoarthritis, and anemia are risk factors for the number of the complications (Table 11). However, multivariate analysis shows that only dementia, pneumonia, antidepressant, postural hypotension, and cerebral infarction are independent risk factors for the number of the complications (Table 12).

4. Discussion

To our knowledge, this is the first study to explore and describe the relationships between the conditions of comorbidity, medication use, health characteristics, preventive measurements, and the incidences of in-hospital complications. Except lower extremity VTE, constipation, and incision complications, the risk factors for other four complications could be determined using multiple logistic regression model. Vu et al. reported that men hospitalized due to a fall had a higher comorbidity rate than women [12]. However, our findings were discordant with their results.

4.1. Conscious Status. In Freter et al.'s study, age was not a risk factor for preoperative delirium, and the strongest association with preoperative delirium was cognitive impairment, substance use, sensory impairment, and wait time for surgery in fall-related hip fracture patients [19]. Our study cannot reveal any independent risk factors for delirium. However, it is shown that antidepressant use is a risk factor for decreased level of conscious status in univariate analysis (OR = 29.532, $p = 0.001$) (Table 4), and multiple logistic regression model has age, nutritional status, dementia, and sensory impairment as independent risk factors for decreased level of conscious status after adjustment for other potential risk factors (Table 5).

4.2. Pressure Ulcer. Kwong et al. showed that bedfast or chairfast patients with stroke were at higher risk for pressure ulcer development [20]. Van Marum et al. also found cerebrovascular accident was a risk factor for decubitus ulcers [21].

In our findings, the cerebral hemorrhage is also an independent risk factor for pressure ulcer development; however, to turn patients over regularly can significantly decrease the risk of pressure ulcer.

Meanwhile, pressure ulcer in univariate analysis was significantly associated with poorer Glasgow coma scale in traumatic brain injury patients [22]. Sayar et al. also found that pressure ulcer development had significant correlation with decreased level of consciousness [23].

However, we cannot find this relationship in the fall-related fracture patients. The possible reason might be that the fracture patients included in our study all accepted the operative treatment which could reduce LOS in the bed and permit the patients early rehabilitation exercise, mobilization, and comprehensive nursing postoperatively even for the patients with severe consciousness impairment.

4.3. HAP. HAP is one of the most common nosocomial infections. In the present study, two male (0.38%) and seven female (0.51%) patients developed HAP, and there is no significant difference of HAP incidence between genders.

Sopena et al. reported that patients with malnutrition, anemia, depression of consciousness, and comorbidity had higher incidence of HAP [24]. Zhu et al. proposed that atrial fibrillation was an independent risk factor for HAP [25]. In Guzmán-Herrador et al.'s study, decreased level of consciousness on admission was a risk factor for HAP [26].

In the present study, in addition to atrial fibrillation and decreased level of conscious state we find that cerebral infarction and dementia significantly increase the incidence of HAP.

4.4. UTI. Redder et al. reported that patients with hospital-acquired UTI used indwelling urinary catheters more frequently and had more genitourinary or nervous system diseases than the control group [27]. In the present study, CNS diseases, especially cerebral infarction and dementia, can increase the incidence of hospital-acquired UTI.

In Hagerty et al.'s study, anemia was a variable significantly associated with hospital-acquired UTI in patients with subarachnoid hemorrhage [28]. In our multiple regression

Table 4: Pearson's Chi square test for the risk factors of conscious status.

Factors	Yes/no	Conscious status 1	2	3	4	5	χ^2/p
Intertrochanteric fracture	No	1253	33	0	0	1	13.392/0.01
	Yes	573	29	1	2	0	
Cerebral hemorrhage	No	1801	62	1	0	1	139.118/<0.001
	Yes	25	0	0	2	0	
Cerebral infarction	No	1663	55	0	2	1	10.773/0.029
	Yes	163	7	1	0	0	
Dementia	No	1808	55	1	2	1	48.886/<0.001
	Yes	18	7	0	0	0	
Other CNS diseases	No	1708	59	1	2	0	14.982/0.005
	Yes	118	3	0	0	1	
Diabetes	No	1502	55	1	0	0	15.945/0.003
	Yes	324	7	0	2	1	
Antidiabetic drug	No	1508	57	1	0	0	18.315/0.001
	Yes	318	5	0	2	1	
Antidepressant	No	1826	61	1	2	1	29.532/0.001
	Yes	0	1	0	0	0	
Pale skin	No	1813	58	1	2	1	22.221/<0.001
	Yes	13	4	0	0	0	
Other skin problems	No	1059	47	0	0	0	13.473/0.009
	Yes	767	15	1	2	1	
Constipation	No	1825	61	1	2	1	13.791/0.008
	Yes	1	1	0	0	0	
Sensory impairment	No	1621	42	1	2	1	25.854/<0.001
	Yes	205	20	0	0	0	
Nutritional status	Normal	1267	22	1	2	1	68/<0.001
	Moderate	522	30	0	0	0	
	Malnourished	37	10	0	0	0	

CNS: central nervous system.

Table 5: Ordinal logistic regression for conscious status[1].

Factors	Grade	β	p	95% CI for β
Age		0.043	0.023	0.006–0.079
Nutritional status	Normal	−1.935	<0.001	−2.82–−1.049
	Moderate	−1.337	0.002	−2.188–−0.486
	Malnourished	0		
Dementia	No	−2.145	<0.001	−3.124–−1.165
	Yes	0		
Sensory impairment	No	−0.708	0.02	−1.305–−0.111
	Yes	0		

[1]Hosmer-Lemeshow test, $p < 0.001$; β: regression coefficient; CI: confidential interval.

model, anemia is also an independent risk factor for hospital-acquired UTI in fall-related fractures patients (OR = 39.985, $p = 0.034$). In addition, the preventive measure of bladder irrigation also can increase the incidence of UTI (OR = 14.954, $p = 0.009$), while drinking more water is a protective factor for this complication (OR = 0.013, $p = 0.021$).

4.5. Foot Drop. The complication of foot drop has been shown to be an association with knee dislocation and ligaments' injures and knee arthroplasty surgery [29, 30].

In the present study, 10 patients (0.53%) developed foot drop during hospitalization. Multiple logistic regression model shows that patients with postural hypotension (OR = 68.657, $p = 0.002$), dementia (OR = 19.223, $p = 0.002$), broken skin (OR = 10.826, $p = 0.001$), and cerebral infarction (OR = 7.165, $p = 0.011$) are at a higher risk for foot drop development. The possible reason might be the longer time in bed for these patients. However, we cannot find the differences of hospital length of stay or grade 1 nursing between the patients with these comorbidities and without them.

4.6. Complications Number. Harvey et al. reported that patients with dementia were disproportionately represented in injury-related hospitalizations, experienced longer hospital LOS, and had poorer outcomes [31]. Other studies

Table 6: Univariate and multivariate analysis for risk factors of pressure ulcer.

Factors	Univariate analysis			Multivariate logistic regression[1]		
	OR	p	95% CI	OR	p	95% CI
Femoral shaft fracture	7.92	0.005	1.435–43.704	23.640	0.023	1.541–362.673
Broken skin	12.597	<0.001	2.27–69.904	14.324	0.07	0.806–254.494
Cerebral hemorrhage	14.308	0.002	1.615–126.778	555.49	0.002	10.017–30805.37
Dementia	40.5	<0.001	7.063–232.241	145.3	0.003	5.711–3697.031
Turning over regularly	0.036	<0.001	0.006–0.201	0.039	0.017	0.003–0.562
Skin yellowing	34.091	<0.001	3.676–316.197			
Skin rash	20.756	<0.001	2.308–186.691			
Other skin problems	0.995	0.039	0.99–0.999			
Hypertension	0.994	0.034	0.99–0.999			
Anemia	14.308	0.002	1.615–126.778			

[1]Hosmer-Lemeshow test, $p = 0.217$; OR: odds ratio; CI: confidential interval.

Table 7: Univariate and multivariate analysis for risk factors of hospital-acquired pneumonia.

Factors	Univariate analysis			Multivariate logistic regression[1]		
	OR	p	95% CI	OR	p	95% CI
Atrial fibrillation	95.789	0.004	4.184–2192.782	95.789	0.007	6.42–1890.43
Cerebral infarction	5.104	0.011	1.265–20.594	25.791	0.001	3.728–178.45
Dementia	23.106	<0.001	4.553–117.267	8.545	0.007	1.795–40.678
Conscious state	1.138	0.031	1.017–2.139	1.850	0.007	0.511–3.189
Antihypertensive drugs	0.992	0.011	0.987–0.997			

[1]Hosmer-Lemeshow test, $p = 0.629$; OR: odds ratio; CI: confidential interval.

Table 8: Univariate and multivariate analysis of risk factors for urinary tract infection.

Factors	Univariate analysis			Multivariate logistic regression[1]		
	OR	p	95% CI	OR	p	95% CI
Cerebral infarction	6.777	0.016	1.125–40.842	88.807	0.026	1.688–4671.192
Dementia	54.029	<0.001	8.617–338.782	1017.668	0.002	12.626–82027.991
Anemia	17.894	<0.001	1.933–165.622	39.985	0.034	1.317–1213.702
Drinking more water	0.043	<0.001	0.005–0.401	0.013	0.021	0.000–0.515
Bladder irrigation	25.716	<0.001	4.251–155.588	14.954	0.009	1.983–112.788
Skin yellowing	42.636	<0.001	4.405–412.712			
Skin rash	25.958	<0.001	2.764–243.819			
Broken skin	16.806	<0.001	2.765–102.139			
Cerebral hemorrhage	17.894	<0.001	1.933–165.622			

[1]Hosmer-Lemeshow test, $p = 0.652$; OR: odds ratio; CI: confidential interval.

Table 9: Univariate and multivariate analysis for risk factors of foot drop.

Factors	Univariate analysis			Multivariate logistic regression[1]		
	OR	p	95% CI	OR	p	95% CI
Broken skin	17.257	<0.001	4.762–62.534	10.826	0.001	2.640–44.388
Cerebral infarction	4.372	0.02	1.12–17.066	7.165	0.011	1.567–32.77
Dementia	20.207	<0.001	4.067–100.396	19.223	0.002	2.915–126.765
Postural hypotension	52.167	<0.001	5.298–513.636	68.657	0.002	4.801–981.923

[1]Hosmer-Lemeshow test, $p = 0.398$; OR: odds ratio; CI: confidential interval.

Table 10: Univariate and multivariate analysis for risk factors of the number of complications.

Comorbidities	N	Univariate analysis: Complications 0	1	2	3	4	5	χ^2/p	Ordinal logistic regression[1]: β	p	95% CI for β
CNS diseases	0	1455	3	3	0	0	0	34.236/0.003	14.785	<0.001	13.157–16.412
	1	375	3	1	1	1	2		16.432	<0.001	14.853–18.011
	2	40	1	0	0	0	1		17.255		17.255–17.255
	3	6	0	0	0	0	0		0		
Respiratory system diseases	0	1808	4	4	1	1	3	30.072/<0.001	−1.788	0.007	−3.079–−0.498
	1	68	3	0	0	0	0		0		
Dermal problems	0	468	1	2	1	1	0	27.808/0.023			
	1	1378	6	2	0	0	2				
	2	29	0	0	0	0	1				
	3	1	0	0	0	0	0				

[1]Hosmer-Lemeshow test for CNS diseases and respiratory system diseases, $p = 0.005$ and 0.022, respectively; β: regression coefficient; CNS: central nervous system.

Table 11: Univariate analysis for risk factors of the number of complications.

Factors	Univariate analysis: χ^2	p
Cerebral infarction	22.378	<0.001
Dementia	98.549	<0.001
Pneumonia	32.099	<0.001
Postural hypotension	52.423	<0.001
Antidepressant	88.58	<0.001
Broken skin	38.418	<0.001
Femoral shaft fracture	17.387	0.004
Skin yellowing	51.049	<0.001
Hematocyanosis	28.338	<0.001
Skin rash	31.709	<0.001
Hyperpigmentation	18.587	0.002
Cerebral hemorrhage	21.921	0.001
Osteoarthritis	14.201	0.014
Anemia	21.921	0.001

also showed that delirium was associated with several complications, including longer hospital LOS, more function and cognition impairment, increased risk of nursing home placement, and even death, in elderly orthopedic patients [32–35].

In our findings, dementia is also shown to be the strongest association with all the types of complications. However, we cannot find that hospital LOS is longer in dementia patients than patients without it. Besides dementia, cerebral infarction and broken skin are also independent risk factors for four and three types of complications, respectively. However, multiple logistic regression model only has pneumonia, postural hypotension, and antidepressant as independent risk factors for the complications number rather than broken skin.

4.7. Limitations. This study has several limitations. First, we cannot determine the risk factors for lower extremity VTE, constipation, and incision complications based on the present database. The possible reason might be that the incidences of the lower extremity VTE, constipation, and incision complications were too low with 0.05%, 0.16%, and 0.16%, respectively. Second, most of the preventive measures of the complications analysed in this study cannot increase or reduce the incidences of in-hospital complications analysed, except the self-contradictory impact of bladder irrigation and drinking more water on UTI. Third, no control group but only fall-related fracture patients are included and analysed. Thus, the risk factors for fall-related fractures cannot be explored and analysed in this study. Fourth, no long-term follow-up results, such as internal fixation failure or death, and the corresponding incidences and risks factors are collected and determined.

5. Conclusion

Different combinations of comorbidity, medication use, and preventive measurements were related to the number and pattern of in-hospital complications of patients with fall-related fractures. Dementia emerged as the most important risk factor for these complications, while most of the preventive measurements could not reduce the incidence of the in-hospital complications. Continued studies are still warranted to verify these associations and determine how to incorporate consideration of comorbidity into preventive assessments of in-hospital complications of fall-related fractures.

Disclosure

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests

The authors declare that they have no conflict of interests.

Table 12: Ordinal logistic regression for risk factors of the number of complications.

Factors	Yes/no	Ordinal logistic regression[1]		
		β	p	95% CI for β
Cerebral infarction	No	−1.610	0.028	−3.045–−0.175
	Yes	0		
Dementia	No	−3.232	<0.001	−4.936–−1.527
	Yes	0		
Pneumonia	No	−2.162	0.007	−3.741–−0.582
	Yes	0		
Postural hypotension	No	−3.495	0.024	−6.530–−0.460
	Yes	0		
Antidepressant	No	−4.251	0.007	−7.358–−1.144
	Yes	0		

[1]Hosmer-Lemeshow test, $p < 0.001$; β: regression coefficient; CI: confidential interval.

Authors' Contributions

Jing Wang and Yuan Gao collected the data and drafted the manuscript. Hong-Ying Pi and Meng-Meng Hu revised the manuscript. Hong-Ying Pi and Yuan Gao conceived the study and participated in its design and coordination. Statistical analysis was done by Pei-Pei Peng and Dan Nie. All authors read and approved the final manuscript.

References

[1] L. Z. Rubenstein and K. R. Josephson, "Falls and their prevention in elderly people: what does the evidence show?" *Medical Clinics of North America*, vol. 90, no. 5, pp. 807–824, 2006.

[2] P. Kannus, H. Sievänen, M. Palvanen, T. Järvinen, and J. Parkkari, "Prevention of falls and consequent injuries in elderly people," *The Lancet*, vol. 366, no. 9500, pp. 1885–1893, 2005.

[3] R. M. Ravindran and V. R. Kutty, "Risk factors for fall-related injuries leading to hospitalization among community-dwelling older persons: a hospital-based case-control study in Thiruvananthapuram, Kerala, India," *Asia-Pacific Journal of Public Health*, vol. 28, no. 1, pp. 70S–76S, 2016.

[4] K. M. Sibley, J. Voth, S. E. Munce, S. E. Straus, and S. B. Jaglal, "Chronic disease and falls in community-dwelling Canadians over 65 years old: a population-based study exploring associations with number and pattern of chronic conditions," *BMC Geriatrics*, vol. 14, article no. 22, 2014.

[5] W. Muangpaisan, S. Suwanpatoomlerd, V. Srinonprasert, W. Sutipornpalangkul, A. Wongprikron, and P. Assantchai, "Causes and course of falls resulting in hip fracture among elderly Thai patients," *Journal of the Medical Association of Thailand*, vol. 98, no. 3, pp. 298–305, 2015.

[6] B. Leavy, L. Byberg, K. Michaëlsson, H. Melhus, and A. C. Åberg, "The fall descriptions and health characteristics of older adults with hip fracture: a mixed methods study," *BMC Geriatrics*, vol. 15, no. 1, article 40, 2015.

[7] T. S. H. Jørgensen, A. H. Hansen, M. Sahlberg et al., "Nationwide time trends and risk factors for in-hospital falls-related major injuries," *International Journal of Clinical Practice*, vol. 69, no. 6, pp. 703–709, 2015.

[8] S.-I. Toyabe, "Development of a risk assessment tool to predict fall-related severe injuries occurring in a hospital," *Global Journal of Health Science*, vol. 6, no. 5, pp. 70–80, 2014.

[9] K.-Y. Cheng, W.-C. Lin, W.-N. Chang et al., "Factors associated with fall-related fractures in Parkinson's disease," *Parkinsonism and Related Disorders*, vol. 20, no. 1, pp. 88–92, 2014.

[10] F. Nilson, S. Moniruzzaman, and R. Andersson, "Fall-related fracture trends among elderly in Sweden—exoring transitions among hospitalized cases," *Journal of Safety Research*, vol. 45, pp. 141–145, 2013.

[11] W. L. Watson and R. Mitchell, "Conflicting trends in fall-related injury hospitalisations among older people: variations by injury type," *Osteoporosis International*, vol. 22, no. 10, pp. 2623–2631, 2011.

[12] T. Vu, C. F. Finch, and L. Day, "Patterns of comorbidity in community-dwelling older people hospitalised for fall-related injury: a cluster analysis," *BMC Geriatrics*, vol. 11, article no. 45, 2011.

[13] H. Shimada, M. Suzukawa, T. Ishizaki, K. Kobayashi, H. Kim, and T. Suzuki, "Relationship between subjective fall risk assessment and falls and fall-related fractures in frail elderly people," *BMC Geriatrics*, vol. 11, article 40, 2011.

[14] Medical Advisory Secretariat, "Prevention of falls and fall-related injuries in community-dwelling seniors: an evidence-based analysis," *Ontario Health Technology Assessment Series*, vol. 8, no. 2, pp. 1–78, 2008.

[15] C. Wallace, G. E. Reiber, J. LeMaster et al., "Incidence of falls, risk factors for falls, and fall-related fractures in individuals with diabetes and a prior foot ulcer," *Diabetes Care*, vol. 25, no. 11, pp. 1983–1986, 2002.

[16] M. E. Tinetti and C. Kumar, "The patient who falls: 'it's always a trade-off'," *The Journal of the American Medical Association*, vol. 303, no. 3, pp. 258–266, 2010.

[17] K. Kallin, J. Jensen, L. L. Olsson, L. Nyberg, and Y. Gustafson, "Why the elderly fall in residential care facilities, and suggested remedies," *Journal of Family Practice*, vol. 53, no. 1, pp. 41–52, 2004.

[18] M. C. Murphy, C. N. Brooks, S. A. New, and M. L. Lumbers, "The use of the Mini-Nutritional Assessment (MNA) tool in elderly orthopaedic patients," *European Journal of Clinical Nutrition*, vol. 54, no. 7, pp. 555–562, 2000.

[19] S. Freter, M. Dunbar, K. Koller, C. MacKnight, and K. Rockwood, "Risk of pre-and post-operative delirium and the delirium elderly at risk (DEAR) tool in hip fracture patients," *Canadian Geriatrics Journal*, vol. 18, no. 4, pp. 212–216, 2015.

[20] E. W.-Y. Kwong, S. M.-C. Pang, G. H. Aboo, and S. S.-M. Law, "Pressure ulcer development in older residents in nursing homes: influencing factors," *Journal of Advanced Nursing*, vol. 65, no. 12, pp. 2608–2620, 2009.

[21] R. J. Van Marum, J. H. Meijer, M. E. Ooms, P. J. Kostense, J. T. Van Eijk, and M. W. Ribbe, "Relationship between internal risk factors for development of decubitus ulcers and the blood flow response following pressure load," *Angiology*, vol. 52, no. 6, pp. 409–416, 2001.

[22] M. Dhandapani, S. Dhandapani, M. Agarwal, and A. K. Mahapatra, "Pressure ulcer in patients with severe traumatic brain injury: significant factors and association with neurological outcome," *Journal of Clinical Nursing*, vol. 23, no. 7-8, pp. 1114–1119, 2014.

[23] S. Sayar, S. Turgut, H. Doğan et al., "Incidence of pressure ulcers in intensive care unit patients at risk according to the Waterlow scale and factors influencing the development of pressure ulcers," *Journal of Clinical Nursing*, vol. 18, no. 5, pp. 765–774, 2009.

[24] N. Sopena, E. Heras, I. Casas et al., "Risk factors for hospital-acquired pneumonia outside the intensive care unit: a case-control study," *American Journal of Infection Control*, vol. 42, no. 1, pp. 38–42, 2014.

[25] J. Zhu, X. Zhang, G. Shi, K. Yi, and X. Tan, "Atrial fibrillation is an independent risk factor for hospital-acquired pneumonia," *PLOS ONE*, vol. 10, no. 7, Article ID e0131782, 2015.

[26] B. Guzmán-Herrador, C. D. Molina, M. F. Allam, and R. F. Navajas, "Independent risk factors associated with hospital-acquired pneumonia in an adult ICU: 4-year prospective cohort study in a university reference hospital," *Journal of Public Health*, vol. 38, no. 2, pp. 378–383, 2016.

[27] J. D. Redder, R. A. Leth, and J. K. Møller, "Analysing risk factors for urinary tract infection based on automated monitoring of hospital-acquired infection," *Journal of Hospital Infection*, vol. 92, no. 4, pp. 397–400, 2016.

[28] T. Hagerty, L. Kertesz, J. M. Schmidt et al., "Risk factors for catheter-associated urinary tract infections in critically Ill patients with subarachnoid hemorrhage," *Journal of Neuroscience Nursing*, vol. 47, no. 1, pp. 51–54, 2015.

[29] G. Cush and K. Irgit, "Drop foot after knee dislocation: evaluation and treatment," *Sports Medicine and Arthroscopy Review*, vol. 19, no. 2, pp. 139–146, 2011.

[30] J. W. Pritchett, "Lumbar decompression to treat foot drop after hip arthroplasty," *Clinical Orthopaedics and Related Research*, no. 303, pp. 173–177, 1994.

[31] L. Harvey, R. Mitchell, H. Brodaty, B. Draper, and J. Close, "The influence of dementia on injury-related hospitalisations and outcomes in older adults," *Injury*, vol. 47, no. 1, pp. 226–234, 2016.

[32] M. Krogseth, T. B. Wyller, K. Engedal, and V. Juliebø, "Delirium is a risk factor for institutionalization and functional decline in older hip fracture patients," *Journal of Psychosomatic Research*, vol. 76, no. 1, pp. 68–74, 2014.

[33] A. Morandi, D. Davis, D. M. Fick et al., "Delirium superimposed on dementia strongly predicts worse outcomes in older rehabilitation inpatients," *Journal of the American Medical Directors Association*, vol. 15, no. 5, pp. 349–354, 2014.

[34] M. G. Kat, J. F. de Jonghe, R. Vreeswijk et al., "Mortality associated with delirium after hip-surgery: A 2-year Follow-up Study," *Age and Ageing*, vol. 40, no. 3, pp. 312–318, 2011.

[35] J. Witlox, L. S. M. Eurelings, J. F. M. de Jonghe, K. J. Kalisvaart, P. Eikelenboom, and W. A. van Gool, "Delirium in elderly patients and the risk of postdischarge mortality, institutionalization, and dementia: a meta-analysis," *The Journal of the American Medical Association*, vol. 304, no. 4, pp. 443–451, 2010.

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Research Article

Structural Femoral Shaft Allografts for Anterior Spinal Column Reconstruction in Osteoporotic Spines

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This study was to investigate the clinical and radiographical outcomes of anterior spinal column reconstruction using structural femoral shaft allografts in osteoporotic patients. Retrospective analyses of medical records, radiographic parameters, and postoperative complications were performed in twenty-one patients who underwent anterior spinal column reconstruction surgery for osteoporotic vertebral collapse or nonunion. Surgical invasiveness, clinical outcomes, postoperative complications, and radiographic outcomes were evaluated. Ambulatory status and back pain significantly improved. The Cobb's angle of segmental kyphosis significantly improved immediately after surgery with slight progression at the final follow-up. There were two cases of failed reconstruction with marked progression of kyphosis; both were related to loosening of screws rather than subsidence of the graft. Anterior spinal column reconstruction using femoral shaft allografts improved kyphosis and resulted in minimal subsidence and therefore is recommended as an effective treatment option for dealing with osteoporotic vertebral collapse and kyphotic deformity.

1. Introduction

Osteoporosis is the most common metabolic bone disorder affecting more than 10 million individuals in the United States alone [1]. Due to loss of bone mass and compromised bone strength, a significant number of osteoporotic patients experience fragility fractures. Vertebral compression fractures are one of the most common fragility fractures in osteoporotic patients [2], and the incidence of vertebral fracture is steadily increasing with the growing population of older adults.

For osteoporotic patients with a vertebral body fracture, conservative management with bed rest, bracing, and pain management with analgesics remains the mainstay of treatment [3]. When initial conservative management fails, percutaneous vertebral body augmentation procedures such as vertebroplasty or kyphoplasty are commonly undertaken to help relieve pain and disability [4, 5]. However, some patients suffer progressive collapse or nonunion of the vertebral body that results in focal kyphotic deformity and neurologic compromise from retropulsion of bony fragments into the spinal canal [6, 7]. For these patients, percutaneous vertebral body augmentation procedures are contraindicated with concerns relating to aggravation of fragment retropulsion and spinal cord compression. To address these concerns, surgical reconstruction of the anterior spinal column should be considered to restore spinal alignment following anterior decompression. Although rare, complications following percutaneous vertebral augmentation procedures using polymethylmethacrylate (PMMA) cement such as infection, recollapse, and cement dislodgement necessitate surgical treatment for resection of the lesion and reconstruction of the anterior spinal column [8]. However, due to mechanical and biological vulnerability of osteoporotic bone, reconstruction of osteoporotic spinal columns frequently results in subsidence and failure of fixation [9].

Structural femoral shaft allografts are commonly used to reconstruct segmental defects following revision arthroplasty or resection of tumorous or infected bone. Furthermore, femoral shaft allografts are occasionally used for interbody spine fusion or vertebral replacement for patients with tumours, acute fractures, and spinal deformities [10, 11]. Therefore, we hypothesize that femoral shaft allografts could be a viable option for replacement of a collapsed vertebral body in osteoporotic spinal columns. Due to the advantages that femoral shaft allografts have over metal implants in terms of their morphometric and biomechanical properties, they are less likely to experience penetration into and subsidence of the weak vertebral body endplates in osteoporotic spines. The purpose of this study was to investigate the clinical and radiographical outcomes of anterior spinal column reconstruction using femoral shaft allografts for osteoporotic patients with vertebral collapse.

2. Materials and Methods

This study was performed according to the guidelines of and with approval from the Institutional Review Board of our institution. From January 2004 to June 2014, 21 consecutive patients who were diagnosed with complicated osteoporotic compression fracture (i.e., with progressive pain, disability, severe kyphosis causing sagittal imbalance, neurologic compromise, or treatment failure after initial conservative treatment or vertebroplasty) and had undergone anterior vertebral corpectomy and replacement of vertebra(e) by structural femoral shaft allografting with anterior or posterior instrumentation were included in the study. The exclusion criteria were (i) pathologic fracture, (ii) traumatic compression or burst fracture, and (iii) use of a cage for vertebral replacement. All patients were observed clinically and radiographically for a minimum of 1 year. Each patient's medical records and radiographs were reviewed for demographics, diagnosis, ambulatory status, level of lesion, operative findings, and information about clinical and radiographic follow-up (Table 1).

Surgical anterior column reconstruction was performed with freeze-dried, segmental, femoral shaft allografts following corpectomy of the affected vertebra(e) via an anterior transthoracic, retroperitoneal, or combination approach across the diaphragm according to location of the lesion. For both, patients without neurologic compromise and those with neurologic compromise associated with dynamic compression of the spinal cord because of intravertebral instability with nonunion or Kummell's disease, the surgical goal was to achieve rigid reconstruction of the spinal column without direct decompression of the anterior epidural space. For patients with neurologic compromise due to spinal cord compression from retropulsion of bony fragments (usually in cases of a healed burst fracture) or dislodged bone cement, thorough decompression of the anterior epidural space was performed under a microscope prior to grafting and fixation. Anterior instrumentation was performed with Kaneda's technique using staples, screws, and a cross-linked double-rod construct (Figure 1) [12]. Posterior instrumentation was performed with percutaneous or conventional pedicle screws (Figures 2 and 3). Since the femoral shaft only has a solid cortical component surrounding a hollow medullary space without osteoconductive, osteoinductive, or osteogenic potential, autologous bone from resected vertebral body (not in complicated cases with infection of bone cement) or rib was packed with additional fresh frozen allograft bone chips into the middle of the femoral shafts prior to grafting. All patients started ambulation as soon as possible, within 1 week after surgery, and thoracolumbosacral orthosis (TLSO) was applied for 12 weeks postoperatively.

Medical records were reviewed to assess clinical outcomes, perioperative complications, and surgical invasiveness in terms of operation time and estimated blood loss. For assessment of clinical outcomes, ambulatory function was evaluated using a modified Nurick scale: Grade 1, no difficulty in walking; Grade 2, mild effects on gait; Grade 3, difficulty in walking alone or able to walk a few steps with assistance; Grade 4, difficulty standing or able to stand with assistance; Grade 5, chair-bound or bedridden.

Modified Nurick Grade to Assess Ambulatory Function

(0) Signs or symptoms of root involvement but without evidence of spinal cord disease

(1) Signs of spinal cord disease but no difficulty in walking

(2) Slight difficulty in walking which does not prevent full-time employment

(3) Difficulty in walking alone; able to walk a few steps with assistance

(4) Barely able to walk; only stands with someone else's help or with the aid of a frame

(5) Chair-bound or bedridden

Severity of subjective pain was measured using the visual analog scale (VAS) score for back pain and/or radiating leg pain, with 0 indicating no pain and 10 indicating severe pain. For radiographic assessment, Cobb's angle of segmental kyphosis, allograft subsidence, subsequent postoperative fractures, and instrument-related complications including screw loosening and implant breakage were evaluated. Radiographs of the spine were taken in the standing position in anteroposterior and lateral views and multiplanar reconstruction was used to examine computed tomography images. Clinical and radiographic results were assessed preoperatively, postoperatively within the 2 weeks before discharge, and at the time of the last follow-up. Observers independent of the main surgeons evaluated clinical and radiographic assessments.

Statistical analysis was performed using SPSS software (version 21.0, SPSS Inc., Chicago, IL, USA). A Wilcoxon rank-sum test was used to for statistical comparisons between preoperative and postoperative, preoperative and final follow-up, and postoperative and final follow-up endpoints. A p value ≤ 0.05 was considered statistically significant. Data are presented as mean (range) or mean (95% confidence interval, CI) unless otherwise stated.

3. Results

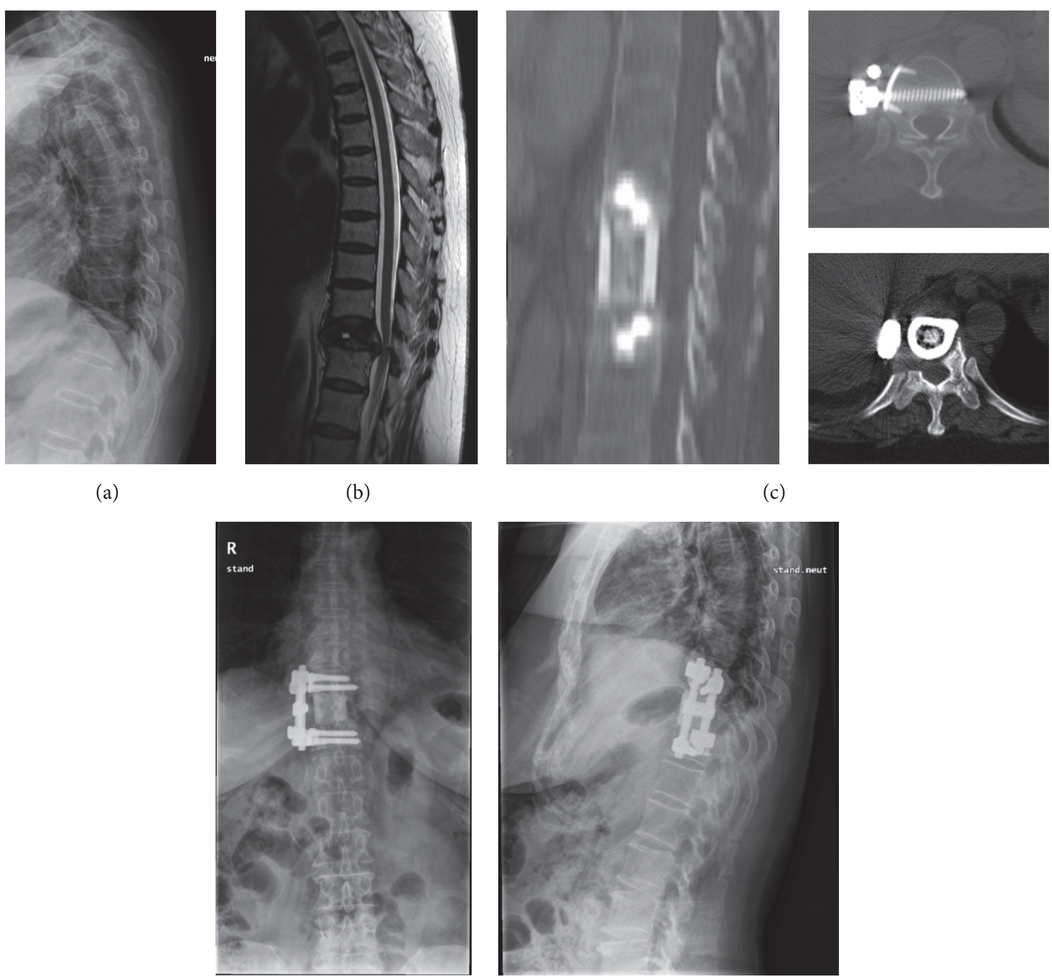
The mean age of the study subjects, 3 men and 18 women, was 74.0 years (range, 57 to 85 years). Thirteen patients underwent

Table 1: Details of 21 study patients.

Case number	Age	Sex	Diagnosis	Ambulatory status	Level of lesion	Instrumentation	Follow-up (months)
1	72	F	Delayed collapse after fracture with spinal cord compression	Assisted standing	T12, L1	Anterior dual rod and screw with staple	113
2	85	F	Delayed collapse after fracture with spinal cord compression	Assisted standing	T12	Anterior dual rod and screw with staple	81
3	68	M	Delayed collapse after fracture with spinal cord compression	Assisted standing	L5	Posterior conventional pedicle screw	14
4	76	F	Recollapse after vertebroplasty with dislodgement of PMMA, with spinal cord compression	Assisted standing	T12, L1	Anterior dual rod and screw with staple	84
5	72	F	Recollapse after vertebroplasty with dislodgement of PMMA, with spinal cord compression	Assisted standing	T12	Anterior dual rod and screw with staple	54
6	79	F	Delayed collapse after fracture with spinal cord compression	Assisted standing	L3	Posterior percutaneous pedicle screw	83
7	61	F	Delayed collapse after fracture with spinal cord compression	Assisted gait	T10	Anterior dual rod and screw with staple	80
8	60	F	Delayed collapse after fracture with spinal cord compression	Assisted gait	T11, L1	Anterior dual rod and screw with staple	64
9	83	F	Infected vertebroplasty with spinal cord compression	Impossible	L1	Anterior dual rod and screw with staple	60
10	70	F	Recollapse after vertebroplasty with spinal cord compression	Assisted standing	L1	Anterior dual rod and screw with staple	52
11	77	F	Delayed collapse after fracture with spinal cord compression	Assisted standing	L4	Posterior percutaneous pedicle screw	36
12	78	F	Delayed collapse after fracture with spinal cord compression	Impossible	L1	Anterior dual rod and screw with staple	18
13	74	F	Delayed collapse after fracture with spinal cord compression	Assisted standing	T12	Anterior dual rod and screw with staple	12
14	84	F	Delayed collapse after fracture with spinal cord compression	Assisted standing	L1	Anterior dual rod and screw with staple	14
15	78	F	Delayed collapse after fracture with spinal cord compression	Impossible	L4	Posterior percutaneous pedicle screw	23
16	79	F	Delayed collapse after fracture with spinal cord compression	Assisted standing	L2	Anterior dual rod and screw with staple	20
17	57	F	Multilevel kyphotic collapse with marked sagittal imbalance	Assisted gait	T11, L1	Posterior conventional pedicle screw	18

Table 1: Continued.

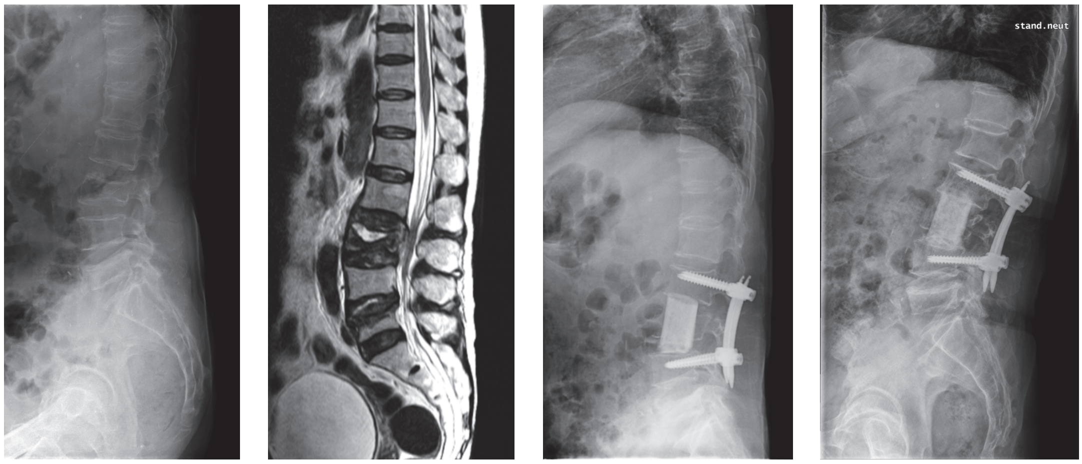
Case number	Age	Sex	Diagnosis	Ambulatory status	Level of lesion	Instrumentation	Follow-up (months)
18	79	M	Infected vertebroplasty with spinal cord compression	Impossible	L1	Posterior conventional pedicle screw	12
19	77	F	Infected vertebroplasty with spinal cord compression	Impossible	L4	Posterior percutaneous pedicle screw	13
20	70	M	Delayed collapse after fracture with spinal cord compression	Impossible	L2	Anterior dual rod and screw with staple	13
21	75	F	Recollapse after vertebroplasty on postoperative flatback	Impossible	L1	Posterior conventional pedicle screw	12



(a) (b) (c)

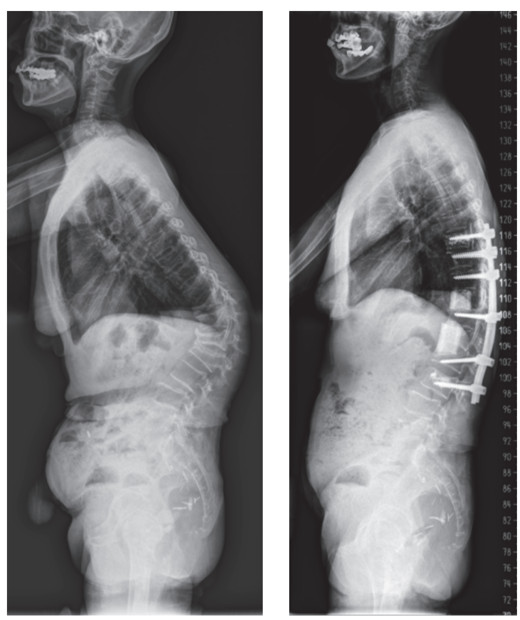
(d) (e)

Figure 1: Illustrative case showing the authors' surgical technique of anterior corpectomy with thorough decompression to anterior epidural space and reconstruction with femoral shaft allograft and dual rod and screw construct with staple. Preoperative simple lateral radiograph (a), T2 weighted sagittal MRI (b), postoperative CT with sagittal and axial image (c), 2-year postoperative simple AP (d), and lateral (e) radiography.



(a) (b) (c) (d)

Figure 2: Illustrative case showing the authors' surgical technique of anterior corpectomy and reconstruction with femoral shaft allograft and posterior percutaneous fixation. Preoperative simple lateral radiograph of AP (a), T2 weighted sagittal MRI (b), postoperative simple lateral radiograph immediately after surgery (c), and 2 years after surgery (d).



(a) (b)

Figure 3: Illustrative case using femoral shaft allograft for correction of global sagittal imbalance that resulted from multilevel osteoporotic compression fractures. Preoperative (a) and 2-year postoperative (b) simple lateral radiograph.

surgery for treatment of delayed collapse of osteoporotic vertebral fractures with spinal cord compression, seven patients for complications following vertebroplasty, and one patient for marked sagittal imbalance related to multilevel kyphotic deformity in the thoracolumbar junction. Levels of affected vertebrae were from T10 to L5. Preoperative mean bone mineral density (BMD) of the lumbar vertebrae (L1 to L4) was 0.614 g/cm^2 (range, 0.475 to 0.713 g/cm^2) as determined by dual-energy X-ray absorptiometry (DEXA). Three patients had been treated with osteoporosis medication preoperatively: one with zoledronate and two with alendronate. The mean body mass index (BMI) of patients included in the study was 23.4 kg/m^2 (range, 15.7 to 29.5 kg/m^2). The mean follow-up period was 47.6 months (range, 12 to 113 months). Instrumentation was performed anteriorly in 13 patients and posteriorly in 8 patients. Thirteen of 14 patients with lower thoracic to proximal lumbar level disease between T10 and L2 underwent anterior instrumentation (10 single level and 3 double level diseases) (Figure 1). Five patients with lower lumbar level disease from L3 to L5 underwent posterior instrumentation (Figure 2). For three patients with sagittal imbalance requiring multilevel instrumentation, long posterior fixation with pedicle screws and rods was performed (Figure 3). All instrumentation was done on the day of corpectomy with the exception of three patients who underwent multistage operations. Two of three patients with infected vertebroplasty underwent multistage posterior instrumentation after antibiotic treatment following anterior corpectomy. Another patient with iatrogenic flat back syndrome due to a previous lumbar fusion from L2 to L5 complicated with the recollapse of a PMMA augmented L1 vertebra underwent multistage posterior long level surgery with pedicle subtraction osteotomy at L3 followed by anterior corpectomy of L1 (Table 1).

Mean operative time was 223.1 minutes (range, 140 to 360 minutes). Mean estimated blood loss was 721.9 mL (range, 350 to 1800 mL). Before surgery, the median Nurick grade of all patients was 4 (range, 4 to 5) and it significantly improved to 3 (range, 2 to 4) at the final follow-up ($p < 0.05$). All patients could walk with or without a cane at the time of discharge. The mean preoperative VAS score of back and/or leg pain was 6.6 (range, 3 to 9) preoperatively and significantly improved to 3.3 (range, 1 to 5) postoperatively, at the time of discharge ($p < 0.05$).

The Cobb's angle of segmental kyphosis in the thoracic and thoracolumbar area was improved from 29.1 degrees (95% CI, 20.4 to 37.8 degree) preoperatively to 10.6 degrees (95% CI, 6.4 to 14.7 degree) postoperatively and slightly worsened to 16.1 degrees (95% CI, 10.5 to 21.7 degree) at the final follow-up. The Cobb's angle of segmental lordosis in the lumbar area was 8.4 degrees (95% CI, – 11.5 to 28.4 degree) preoperatively, 14.7 degrees (95% CI, 9.4 to 20.0 degree) postoperatively, and 11.0 degree (95% CI, 0.8 to 21.3 degree) at the final follow-up. The kyphosis angle and lordosis angle immediately after surgery were both significantly improved ($p < 0.05$), and although both the kyphosis and lordosis angles showed slight progression at final follow-up, the differences were not statistically significant. The radiographically derived average subsidence of femoral shaft allografts at final follow-up was 1.86 mm (95% CI, 0.91 to 2.82 mm). There were 2 cases of marked progression of kyphosis (i.e., an increase >15 degrees), which were concluded to be related to the loosening of screws rather than to subsidence or penetration of the graft into the endplates of adjacent vertebra(e). This conclusion was made because the subsidence in each case was only 1.5 mm and 4.2 mm, respectively (case number 10 and case number 16, Table 1). Eleven patients underwent a transthoracic surgical procedure with the chest tube removed at an average of 4.6 days postoperatively. Three patients experienced mild atelectasis within 2 or 3 days postoperatively and were treated with supportive lung care. Discharge was delayed for 2 patients because of pulmonary complications: one due to pneumonia and 1 due to hydropneumothorax. One patient exhibited delayed infection that occurred as psoas abscess in combination with discitis one level below the index level of surgery. This patient underwent surgical debridement and antibiotic treatment without removal of the graft and associated instrumentation. During follow-up, benign compression fracture of the adjacent vertebral body was found in six cases, that is, 38% of the study population. Three of these patients complained of severe pain

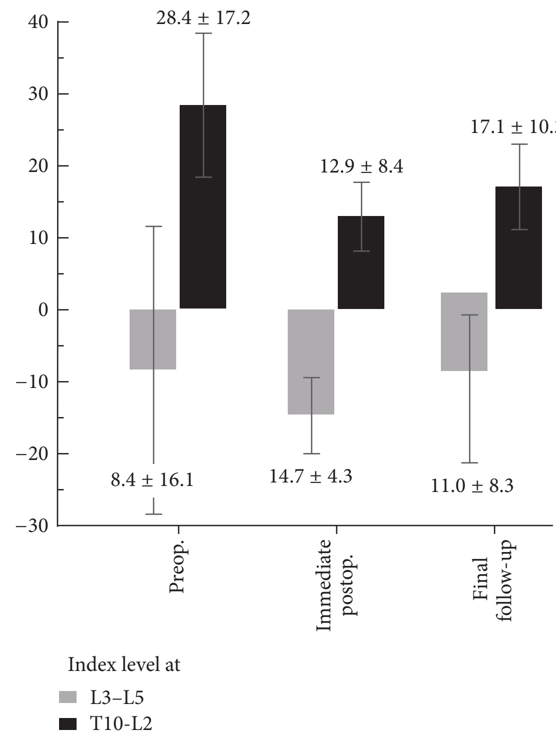
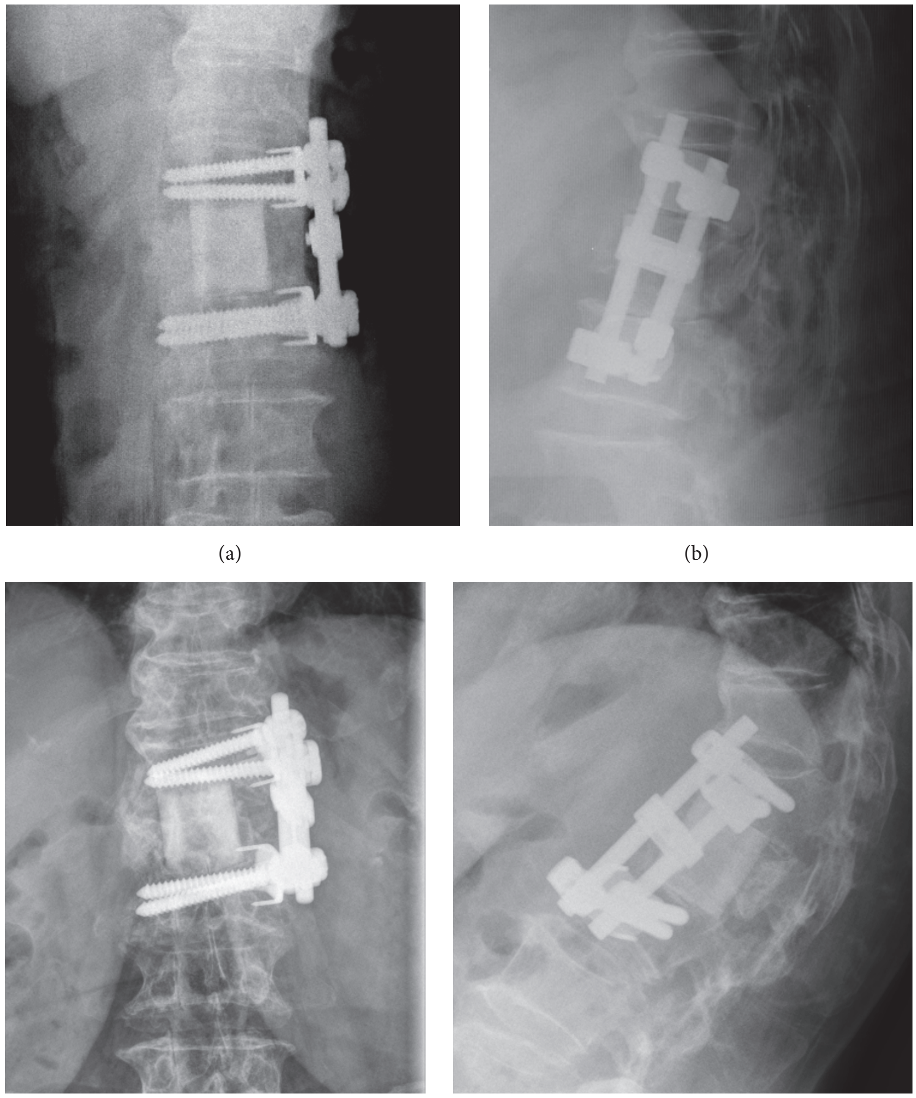


Figure 4: Change of segmental kyphosis or lordosis angle before and after surgery according to the level of the lesion.

and were therefore treated with vertebroplasty. The other three patients were treated with TLSO, and no additional surgical intervention was required. In spite of additional fractures in adjacent levels, the femoral shaft allografts were well maintained in 90.5% of all patients (i.e., 19 of 21 cases), with the two aforementioned cases in which the Cobb's angle of segmental kyphosis increased by more than 15 degrees (Figure 4).

4. Discussion

The results of this study demonstrate that the use of femoral shaft allografts as an anterior column support in between osteoporotic vertebrae results in minimal graft subsidence. The frequent subsidence of grafts or vertebral replacement materials such as mesh cages and the loosening of instruments used for fixation are two of the most common issues that deleteriously affect the efficacy and longevity of constructs used in the reconstruction of osteoporotic spines [13, 14]. Kanayama et al. [15] reported that 20% of patients who underwent anterior spinal reconstruction using ceramic spacers, titanium cages, or iliac bone graft needed additional posterior reinforcement owing to early progression of kyphosis or instrument failure. Anterior column support with a cage of a larger diameter or with multiple cages has been proposed as an approach to avoid high rates of cage subsidence into the adjacent vertebral endplates in osteoporotic patients [16, 17]. However, even in patients with osteoporosis, it is difficult to avoid subsidence with metal implants such as mesh cages. For example, the



(a) (b) (c) (d)

Figure 5: Marked progression of kyphosis of the construct related to loosening of screw fixation and without notable subsidence or penetration of the graft into the adjacent endplate. Preoperative simple radiographs of AP (a) and lateral (b) view and follow-up simple radiograph of AP (c) and lateral view (d) 4 years after surgery.

mean subsidence of titanium mesh cages used for anterior column support in nonosteoporotic patients was reported to be 2.6 mm, with subsidence greater than 5 mm in some cases [18]. The current study using femoral shaft structural allografts for anterior column support showed significant improvement of focal kyphosis after reconstruction surgery. The allograft construct was found to be well maintained until final follow-up with a mean subsidence of 0.8 ± 3.7 mm. Failure of the femoral shaft allograft was observed in only 9.5% of the study population (2 of 21 patients), and it was determined that failure was due to loosening of fixation rather than subsidence of the graft. (Figure 5) Longer posterior instrumentation or combined anterior/posterior fixation is supposed to be considered to prevent that kind of loosening of fixation in addition to PMMA augmented screw-fixation technique [19, 20].

For successful anterior column support, vertebral replacement should provide enough strength to transmit axial compressive forces of the body and/or trunk without penetrating into the adjacent vertebral endplates. Femoral shaft structural allografts exhibit biomechanical properties adequate to support the trunk [21], and, due to their larger contact surface and diameter, interface with the stronger peripheral regions of adjacent endplates thereby decreases the likelihood of subsidence. Another advantage of femoral shaft allografts is that their modulus of elasticity is more similar to autologous bone than to implants made from metal or other artificial materials. As a result, femoral shaft allografts are superior in avoiding stress-shielding effects that reduce bone density and prohibit bone union. Authors suggest that any other type of implant with a larger contact surface and similar mechanical properties allowing load transfer without penetrating into endplate and which also can provide bony integration could be an ideal option for replacement of osteoporotic vertebra(e).

However, the major drawback while using femoral shaft allograft as an anterior spinal column support is the potential for pulmonary complications in elderly patients following anterior thoracotomy. In this study, 45.5% of the patients who underwent anterior thoracotomy (5 of 11) experienced pulmonary complications including 1 case of pneumonia, 1 case of hydropneumothorax, and 3 cases of mild atelectasis. It is for this reason that many recent reports favour posterior approaches using pedicle screws and rod constructs for stabilization and anterior column support in vertebral body augmentation with vertebroplasty or shortening osteotomy [14]. However, some authors still advocate anterior surgery in combination with anterior or posterior instrumentation, emphasizing the importance of rigid anterior column support with bone-to-bone strut grafts and the advantages of a short fusion level [19, 22]. If both posterior and anterior approaches are applicable, authors usually favour the posterior approach with vertebroplasty, especially for patients with collapsed vertebra and neurologic deficit due to intravertebral instability associated with nonunion or pseudarthrosis of osteoporotic vertebral compression fractures. However, there are still patients in whom anterior surgery is favoured in order to provide clearance of the spinal canal and realign the spinal column. For example, anterior surgery is favoured in the case of a fixed fragment compressing the spinal cord or causing severe kyphosis [12, 19, 22]. In these cases, the use of a femoral shaft allograft provides a viable option as an anterior column support if the postoperative pulmonary risk is deemed acceptable. In this vein, modern advances in minimally invasive anterior surgical approaches hold potential to reduce associated pulmonary complications [23].

Although this study was limited in terms of its retrospective design, relatively small number of cases, and lack of controls, we believe that the results presented suggest that femoral shat allografts are a promising alternative approach for anterior column support in osteoporotic spines. Anterior spinal column support using femoral shaft structural allografts in patients with osteoporosis is beneficial in terms of avoiding subsidence and maintaining the mechanical integrity of the construct. However, additional clinical experience and studies including larger patient populations with long-term follow-up are necessary to validate the advantages of femoral shaft allografts.

5. Conclusion

This study demonstrated that the use of femoral shaft allografts as an anterior column support in between osteoporotic vertebrae improved kyphosis and resulted in minimal subsidence. We concluded femoral shaft allografts as an effective treatment option for dealing with osteoporotic vertebral collapse and kyphotic deformity.

Disclosure

This work was carried out at Seoul National University Hospital, Seoul, Korea.

Competing Interests

The authors declare no conflict of interests regarding the publication of this paper.

References

[1] S. V. Bukata, B. F. DiGiovanni, S. M. Friedman et al., "A guide to improving the care of patients with fragility fractures," *Geriatric Orthopaedic Surgery & Rehabilitation*, vol. 2, no. 1, pp. 5–37, 2011.

[2] Y.-S. Park and H.-S. Kim, "Prevention and treatment of multiple osteoporotic compression fracture," *Asian Spine Journal*, vol. 8, no. 3, pp. 382–390, 2014.

[3] A. Rapado, "General management of vertebral fractures," *Bone*, vol. 18, no. 3, pp. 191s–196s, 1996.

[4] C. Druschel, K.-D. Schaser, A. Rohlmann, T. Pirvu, and A. C. Disch, "Prospective quantitative assessment of spinal range of motion before and after minimally invasive surgical treatment of vertebral body fractures," *Archives of Orthopaedic and Trauma Surgery*, vol. 134, no. 8, pp. 1083–1091, 2014.

[5] A. J. Evans, M. E. Jensen, K. E. Kip et al., "Vertebral compression fractures: pain reduction and improvement in functional mobility after percutaneous polymethylmethacrylate vertebroplasty—retrospective report of 245 cases," *Radiology*, vol. 226, no. 2, pp. 366–372, 2003.

[6] C. Cooper, E. J. Atkinson, W. M. O'Fallon, and L. J. Melton III, "Incidence of clinically diagnosed vertebral fractures: a population-based study in Rochester, Minnesota, 1985–1989," *Journal of Bone and Mineral Research*, vol. 7, no. 2, pp. 221–227, 1992.

[7] S. Tanaka, M. Kubota, Y. Fujimoto, J. Hayashi, and K. Nishikawa, "Conus medullaris syndrome secondary to an li burst fracture in osteoporosis: a case report," *Spine*, vol. 18, no. 14, pp. 2131–2134, 1993.

[8] K.-Y. Ha, Y.-H. Kim, D.-G. Chang, I.-N. Son, K.-W. Kim, and S.-E. Kim, "Causes of late revision surgery after bone cement augmentation in osteoporotic vertebral compression fractures," *Asian Spine Journal*, vol. 7, no. 4, pp. 294–300, 2013.

[9] D. H. Kim and A. R. Vaccaro, "Osteoporotic compression fractures of the spine; current options and considerations for treatment," *Spine Journal*, vol. 6, no. 5, pp. 479–487, 2006.

[10] K. H. Bridwell, L. G. Lenke, K. W. McEnery, C. Baldus, and K. Blanke, "Anterior fresh frozen structural allografts in the thoracic and lumbar spine: do they work if combined with posterior fusion and instrumentation in adult patients with kyphosis or anterior column defects?" *Spine*, vol. 20, no. 12, pp. 1410–1418, 1995.

[11] J. A. Kozak, A. E. Heilman, and J. P. O'Brien, "Anterior lumbar fusion options. Technique and graft materials," *Clinical Orthopaedics and Related Research*, no. 300, pp. 45–51, 1994.

[12] K. Kaneda, S. Asano, T. Hashimoto, S. Satoh, and M. Fujiya, "The treatment of osteoporotic-posttraumatic vertebral collapse using the kaneda device and a bioactive ceramic vertebral prosthesis," *Spine*, vol. 17, no. 8, pp. 295–303, 1992.

[13] M. Reinhold, K. Schwieger, J. Goldhahn, B. Linke, C. Knop, and M. Blauth, "Influence of screw positioning in a new anterior spine fixator on implant loosening in osteoporotic vertebrae," *Spine*, vol. 31, no. 4, pp. 406–413, 2006.

[14] H. Sudo, M. Ito, K. Kaneda et al., "Anterior decompression and strut graft versus posterior decompression and pedicle screw fixation with vertebroplasty for osteoporotic thoracolumbar vertebral collapse with neurologic deficits," *Spine Journal*, vol. 13, no. 12, pp. 1726–1732, 2013.

[15] M. Kanayama, T. Ishida, T. Hashimoto et al., "Role of major spine surgery using kaneda anterior instrumentation for osteoporotic vertebral collapse," *Journal of Spinal Disorders and Techniques*, vol. 23, no. 1, pp. 53–56, 2010.

[16] A. Shawky and M. Kroeber, "Shortening spinal column reconstruction through posterior only approach for the treatment of unstable osteoporotic burst lumber fracture: a case report," *Archives of Orthopaedic and Trauma Surgery*, vol. 133, no. 2, pp. 167–169, 2013.

[17] T. Suzuki, E. Abe, N. Miyakoshi et al., "Anterior decompression and shortening reconstruction with a titanium mesh cage through a posterior approach alone for the treatment of lumbar burst fractures," *Asian Spine Journal*, vol. 6, no. 2, pp. 123–130, 2012.

[18] P. A. Robertson, H. J. Rawlinson, and A. T. Hadlow, "Radiologic stability of titanium mesh cages for anterior spinal reconstruction following thoracolumbar corpectomy," *Journal of Spinal Disorders and Techniques*, vol. 17, no. 1, pp. 44–52, 2004.

[19] H. Nakashima, S. Imagama, Y. Yukawa et al., "Comparative study of 2 surgical procedures for osteoporotic delayed vertebral collapse: anterior and posterior combined surgery versus posterior spinal fusion with vertebroplasty," *Spine*, vol. 40, no. 2, pp. E120–E126, 2015.

[20] H. Kim, B. S. Chang, and C. K. Lee, "Considerations in surgical treatment for osteoporotic spinal fracture: surgical indication, approach, fixation, and graft material—review article," *Journal of Korean Society of Spine Surgery*, vol. 23, no. 1, pp. 34–45, 2016.

[21] M. Kanayama, B. W. Cunningham, C. J. Haggerty, K. Abumi, K. Kaneda, and P. C. McAfee, "In vitro biomechanical investigation of the stability and stress-shielding effect of lumbar interbody fusion devices," *Journal of Neurosurgery*, vol. 93, no. 2, pp. 259–265, 2000.

[22] S. Okuda, T. Oda, R. Yamasaki, T. Haku, T. Maeno, and M. Iwasaki, "Surgical outcomes of osteoporotic vertebral collapse: a retrospective study of anterior spinal fusion and pedicle subtraction osteotomy," *Global Spine Journal*, vol. 2, no. 4, pp. 221–226, 2012.

[23] W. Z. Ray and M. H. Schmidt, "Thoracoscopic vertebrectomy for thoracolumbar junction fractures and tumors: surgical technique and evaluation of the learning curve," *Clinical Spine Surgery*, vol. 29, no. 7, pp. E344–E350, 2016.

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Clinical Study

Minimally Invasive Treatment of Displaced Proximal Humeral Fractures in Patients Older Than 70 Years Using the Humerusblock

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Background. Surgical treatment of proximal humeral fractures (PHF) in osteoporotic bone of elderly patients is challenging. The aim of this retrospective study was to evaluate the clinical and radiological outcome after percutaneous reduction and internal fixation of osteoporotic PHF in geriatric patients using the semirigid Humerusblock device. *Methods.* In the study period from 2005 to 2010, 129 patients older than 70 years were enrolled in the study. After a mean follow-up of 23 months, a physical examination, using the Constant-Murley score and the VAS pain scale, was performed. Furthermore radiographs were taken to detect signs of malunion, nonunion, and avascular necrosis. *Results.* The recorded Constant-Murley score was 67.7 points (87.7% of the noninjured arm) for two-part fractures, 67.9 points (90.8%) for three-part fractures, and 43.0 points (56.7%) for four-part fractures. In ten shoulders (7.8%) loss of reduction and in four shoulders (3.1%) nonunion were the reason for revision surgery. Avascular humeral head necrosis developed in eight patients (6.2%). *Conclusions.* In two- and three-part fractures postoperative results are promising. Sufficient ability for the activities of daily living was achieved. In four-part fractures the functional results were less satisfying regarding function and pain with a high postoperative complication rate. In those patients other treatment strategies should be considered. *Study design.* Therapeutic retrospective case series (evidence-based medicine (EBM) level IV).

1. Introduction

Proximal humeral fractures (PHF) are common in elderly patients, with a six times higher incidence in patients above 70 years compared to younger patients [1]. Usually, treatment is often more difficult, than in a younger age group, due to preexisting osteopenia, osteoarthritis, and rotator-cuff lesions along with various systemic comorbidities [2, 3]. Therefore treatment of PHF in elderly patients is a challenge for the treating physicians.

In nondisplaced and minimally displaced fractures conservative treatment seems to be the preferable therapy rendering a good functional outcome [4]. In complex PHF results after conservative treatment in advanced aged patients are significantly worse. Therefore, surgical treatment is recommended [4, 5]. However, insufficient reduction of displaced fractures can lead to nonunion or malunion of the fragments leading to poor functional results.

Even though there are many studies, reporting on the outcome after surgically treated PHF in elderly patients, no clear treatment guidelines exist. Some studies favour osteosynthesis [6, 7] and some prosthetic replacement [8–10].

In this retrospective single centric study the technical feasibility as well as clinical and radiological outcome after minimally invasive, percutaneous reduction and internal fixation (CRIF) of displaced PHF in the elderly using the semirigid Humerusblock device is analyzed.

2. Patients and Methods

In the study period from January 2005 to December 2010, 261 PHF in patients above 70 years were surgically treated at an urban level I trauma center. The decision for surgical instead of conservative treatment was made according to modified Neer II criteria [11] and comprised displacement of the tuberosities greater than 5 mm or misalignment of the head fragment greater than 30 degrees.

232 fractures were treated using the minimally invasive Humerusblock device (Synthes, Oberdorf, Switzerland). Cannulated screws (Stryker Leibinger Micro Implants, Freiburg, Germany) were used to fix the tuberosity fragments. In 16 cases an intramedullary nail was implanted. A reversed shoulder arthroplasty (RSA) was performed in 12 shoulders (6 head split fractures, 4 fracture dislocations, and 2 four-part fractures). Although in our department we do not use routinely angular stable plates for treating PHF, in 1 patient open reduction and internal fixation with an angular stable plate was performed. In that patient the procedure was demonstrated as life operation during a convention by an experienced shoulder surgeon, who was not part of our medical staff.

In this study all patients above 70 years at the time of injury, who were treated with the Humerusblock device for PHF, were included in the study. Patients with injury-unrelated musculoskeletal impairment of the involved shoulder, neurologic diseases impairing shoulder function, and comorbidities preventing a clinical and radiological follow-up were excluded from this study.

Out of the 232 patients treated with the Humerusblock device, 207 patients were included. The mean age was 79.8 years (range, 70–101). The injury mechanism was simple fall in 191 patients (92.3%), skiing accident in nine patients (4.3%), bicycle accident in five patients (2.4%), and traffic accident in two patients (1%).

43 patients (20.8%) died and were lost to follow-up. Six patients (2.9%) came from abroad and were not available for clinical and radiological examination; 29 patients (14%) could not be reached for follow-up.

129 patients (62.3%) could be evaluated clinically and radiographically after a mean of 22.9 months (range, 6–79) postoperatively. There were 105 women (81.4%) and 24 men (18.6%). Ten of these patients were evaluated separately and included in the complication analysis as they had undergone revision surgery using a different technique.

The surgical treatment was performed 2.2 days after trauma on average (range, 0–19 days).

Radiological follow-up was completed at 2, 4, and 6 weeks postoperatively and at final follow-up. Radiographs were taken in anteroposterior (AP) and axial path of rays to evaluate signs of malunion, nonunion, and avascular necrosis (AVN).

The clinical outcome was evaluated using the Constant-Murley score [12]. The pain was assessed using a visual analogue scale (VAS). The ability to complete activities of daily living was rated on a 20-point scale. The range of motion (maximum 40 points) was evaluated using a goniometer in 5° increments. A force meter (IsoForceControl, MDS Medical Device Solutions AG, Oberburg, Switzerland) was utilized to measure the power in 90° of abduction (maximum 25 points). The overall outcome was compared to the uninjured arm and related to age- and gender-matched normal values.

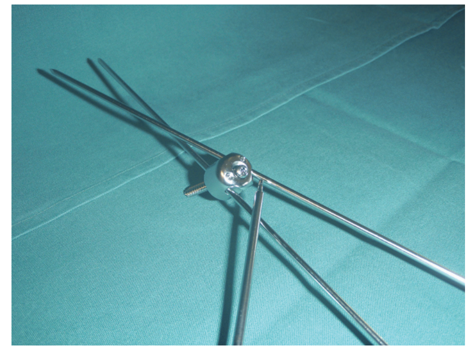

Figure 1: The Humerusblock device with the cannulated, self-tapping screw and two 2.2 mm k-wires.

2.1. Operative Technique. The operative technique of CRIF for PHF using the Humerusblock has been widely described in the past [13–16]. The surgery is performed in beach-chair position and fluoroscopy is utilized for visualization of the reduction and fixation steps. A delta split approach of 3 cm is performed about 4 to 5 cm below the fracture site at the lateral aspect of the humerus. Then the Humerusblock is brought in and fixed to the shaft of the humerus by a 3.5 mm self-tapping, cannulated screw. It is very important to hold the arm in neutral rotation during introductions of the Humerusblock. Two k-wires are introduced to the humeral shaft through a guiding device (Figures 1 and 2). The two k-wires are brought in at an angle of 35° to the shaft and 25° to each other. This allows the k-wires to cross over each other and diverge in the humeral head. Before reduction the k-wires are drilled up to the subcapital fracture level. Then the fracture is reduced manually by traction and/or percutaneously by using an elevator via small stab incisions. In 3-part fractures the head fragment is derotated using a bone hook. After anatomical reduction the head fragment is fixed by introducing the two k-wires up to the subchondral bone. Finally the k-wires are locked within the Humerusblock. Additionally, displaced tuberosities are reduced with small bone hooks, introduced via stab incisions. After reduction the tuberosities are fixed with 3.0 mm cannulated screws (Figures 3–5).

2.2. Postoperative Treatment. Postoperatively the upper arm is immobilized in a standard shoulder sling for three to four weeks. Beginning from the first postop day passive mobilization is recommended. Active movement is started after the fourth postoperative week. The removal of the Humerusblock is advised following bony healing after approximately six weeks.

3. Results

In patients with two-part fractures a mean postoperative Constant-Murley score of 67.7 points (range, 25–90) was

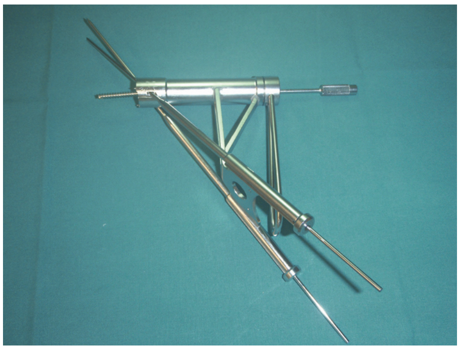

Figure 2: The aiming device. The k-wires are inserted percutaneously through the guiding sleeves.

Figure 3: Radiograph of a 3-part proximal humeral fracture of a 96-year-old woman.

recorded which accounted for 87.7% of the contralateral side. Compared with age- and gender-matched normal values, this equated to 100.6% of the anticipated score.

In patients with three-part fractures the mean postoperative Constant-Murley score was 67.9 points (range, 36–90), accounting for 90.8% of the noninjured arm, which results in 99.5% of the age- and gender-correlated score. In patients with four-part fractures the mean Constant-Murley score was 43.0 points (range, 18–62), which represents 56.7% compared to the noninjured side. The age- and gender-correlated Constant-Murley score was 63.7%.

The mean pain score for two-part fractures was 13.6 points (range, 5–15), for three-part fractures 13.5 points (range, 8–15), and for four-part fractures 12.2 points (range, 5–15).

The average achievable range of motion is illustrated in Table 2.

The mean operating time was 51.3 ± 29.5 min in the investigated patients. The mean total hospital stay was eight days (range, 3–20 days). The mean intraoperative fluoroscopy time was 183.4 ± 93.3 seconds.

Types of fracture of the included patients according to the AO/OTA and Neer classification are shown in Table 1.

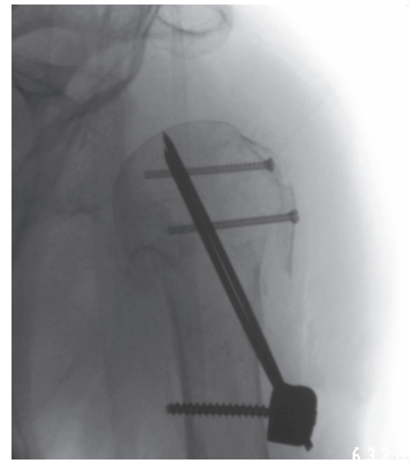

Figure 4: Intraoperative X-ray after reduction and stabilization using the Humerusblock.

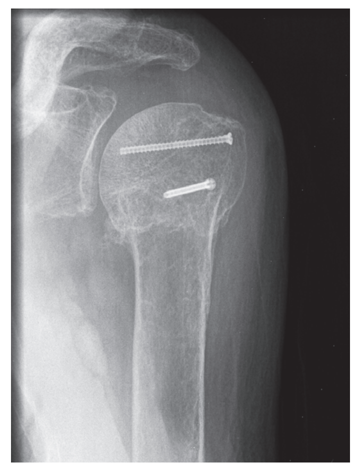

Figure 5: At time of follow-up 15 months after minimally invasive stabilization bony healing with a relative Constant-Murley score of 97% was observed.

Table 1: Fracture division according to modified Neer's criteria and AO/OTA classification.

	Number of patients	Percent of total
Neer classification		
Two-part	63	52.9%
Three-part	47	39.5%
Four-part	9	7.6%
AO/OTA classification		
A-type	63	52.9%
B-type	39	32.8%
C-type	17	14.3%

3.1. Complications and Revisions. 100 (77.5%) of all fractures treated with the Humerusblock showed primary bony union without complications. Secondary dislocation was recorded in ten patients (7.8%). In four of those patients, revision surgery, using the Humerusblock again was performed. The

Table 2: Values of range of motion and corresponding points according to the constant score.

Direction (medium, range)	Two-part ($n = 63$)	Three-part ($n = 47$)	Four-part ($n = 9$)
Flexion (°)	143 (45–180)	139 (80–180)	81 (40–115)
Abduction (°)	138 (50–175)	131 (50–175)	78 (40–115)
Internal rotation (points)	6.2 (2–10)	6.1 (0–10)	4.0 (0–6)
External rotation (points)	7.8 (0–10)	7.4 (0–10)	4.0 (0–8)

Table 3: Complication overview and therapy.

Complication	N	%	Therapy
Dislocation	10	7.8%	Reosteosynthesis with HB: 4 RSA: 4 Blade-plate: 1 Intramedullary nail: 1
Nonunion	9	7.0%	RSA: 3 Blade-plate: 1 No further surgery: 5
AVN	8	6.2%	No further surgery: 8
Infection	1	0.8%	Conservative
Arm thrombosis	1	0.8%	Conservative

patients were included in the clinical follow-up. In four patients RSA, in one patient intramedullary nail, and in one patient an angular stable plate was used for revision surgery. Nine (7%) nonunions were observed; in four of those patients surgical revision was performed (three RSA, one blade-plate). One superficial, postoperative wound-infection was treated conservatively with intravenous antibiotics. In one patient deep vein thrombosis of the operated arm was observed. AVN of the humeral head occurred in eight shoulders (6.2%). Five (3.9%) showed partial necrosis and three (2.3%) showed complete collapse of the humeral head.

Table 3 shows an overview of all complications and corresponding therapies.

4. Discussion

In advanced age above 60 years, especially in women, bone density of the humeral head decreases significantly [2]. In PHF, the head fragment is usually very fragile with small amounts of subchondral bone, which often gives the impression of an "egg shell" [17]. Treatment of fractures in patients with weak bone is challenging. The aim of this study was to evaluate the functional and radiological outcome of surgical treatment of osteoporotic PHF in elderly patients, using a minimally invasive, semirigid device.

Surgical treatment strategies for severely displaced PHF comprise joint preserving methods, such as plate osteosynthesis, intramedullary nailing, k-wire based methods, and anatomical and reverse arthroplasty (RSA).

Hemiarthroplasty (HA) has long been the gold-standard in treating severely displaced PHF [10, 18, 19]. However, outcome after HA is strongly dependent on tuberosity healing [20, 21]. High rates of tuberosity resorption and bad functional outcome after HA for primary fractures treatment are reported [22, 23]. Due to its biomechanical features, functional outcome after RSA is more independent from tuberosity healing. Therefore, RSA gained popularity in fracture treatment of severely displaced PHF in elderly patients [22]. In a recently published systemic review, the authors found significantly better results for RSA than for HA in the treatment of PHF. However, complication rate was not significantly different [22, 24].

In a recent matched-pair analysis comparing RSA and CRIF using the Humerusblock for the treatment of three- and four-part fractures significantly better results were found in the CRIF group [16].

Alternative strategies to treat PHF are ORIF using plates as well as intramedullary nailing. Often, fixed-angled locking-plates are used, giving a sufficient primary stability in young patients for early mobilization of the shoulder. In osteoporotic bone secondary perforation or cut-out of the screws is reported in up to 43% [25–27]. This can lead to secondary loss of reduction and damage to the glenoid surface. Another risk of rigid implants such as fixed-angled locking-plates is the lack of flexibility not allowing sufficient sintering of the fragments. This potentially increases the secondary displacement rate and decreases the rate of bony union [28]. In osteoporotic bone, flexible implants, which reduce the forces on the implant-bone interface, show advantages in biomechanical studies [29, 30].

A fundamental principle of the Humerusblock is dynamic stabilization. So a guided sintering of the fragments along the k-wires to assure a continuous contact of the fracture fragments can be achieved. Consequently humeral head perforation of the k-wires is not unusual. In these cases, in order not to jeopardise the glenoid surface, shortening of the k-wires is necessary before starting active movements. In our patients, retrieval of perforating k-wires was necessary in 21.8%. Of course this leads to another operation and even though this can be done in a local anesthesia it still shows a disadvantage of the procedure.

In general a higher rate of AVN is described in literature after ORIF, mainly due to compromising soft tissue and the blood supply of the humeral head during surgery [31]. In closed reduction soft tissue bridges can be preserved. Periosteal bridges between shaft and head fragment especially are not disturbed through this technique. They often present the only left perfusion for the humeral head. This is validated in our data where we found a humeral head necrosis rate of 6.2% compared to 10% in open reduction techniques of a collective with an average age of 62 years [32]. 75% of all AVN were found in the group of four-part fractures. This suggests the consideration of primary arthroplasty in those special cases.

In the presented study all tuberosities healed. This is a better prerequisite if conversion to secondary arthroplasty will be necessary after occurrence of AVN. With anatomically healed tuberosities and an intact rotator cuff, anatomical shoulder replacement can be considered.

A revision rate of 10.9% in patients with the average age of 80 is compared to other implants in the lower range [32]. Taking a look at four-part fractures the reoperation rate increases to 35.7%. A conversion to RSA due to secondary displacement was necessary in four patients. In one case nonunion was treated with a blade-plate. The clinical results of four-part fractures treated with the Humerusblock are far below those of two- and three-part fractures.

A disadvantage in all semirigid implants is the necessity of immobilizing the shoulder. In younger patients an immobilization for about three weeks is adequate; in advanced age immobilization needs to be extended to four weeks. However, passive mobilization is started immediately after surgery.

Some limiting factors of the present study have to be mentioned. The main limitation is its retrospective design. Furthermore, a follow-up rate of only 62% could be achieved. However, all patients were of advanced age and most of them have comorbidities, which can explain the high dropout rate. Another limitation is the missing comparison group to other implants like angle-stable plates or intramedullary nails. A multicentre study is projected to compare different options of operative treatment of PHF in elderly patients.

5. Conclusion

Minimally invasive fracture treatment can be demanding especially in a poor bony situation. Of course this procedure has a certain learning curve. For complex PHF an experienced surgeon is needed to achieve the best possible outcome. Recognising the "personality" of the fracture before entering the operation is crucial to be able to identify the fragments and its periosteal bridges [33]. Subsequently the course of action is planned. To make planning easier we recommend a CT scan with 3-dimensional reconstructions preoperatively.

Analyzing the results of this study pain-free shoulder mobility with good range of motion can be achieved in a great number of patients after minimal invasive PHF treatment using the Humerusblock. In highly unstable four-part fractures a sufficient stabilization can be hardly achieved. Due to the high rate of AVN and the risk of secondary dislocation a RSA should be considered in this patient group.

Abbreviations

PHF: Proximal humeral fractures
CRIF: Closed reduction and internal fixation
RSA: Reversed shoulder arthroplasty
AP: Anteroposterior
AVN: Avascular necrosis
VAS: Visual analogue scale
HA: Hemiarthroplasty.

Competing Interests

The authors declare that there are no competing interests regarding the publication of this paper.

References

[1] J. A. Baron, M. Karagas, J. Barrett et al., "Basic epidemiology of fractures of the upper and lower limb among americans over 65 years of age," *Epidemiology*, vol. 7, no. 6, pp. 612–618, 1996.

[2] F. Barvencik, M. Gebauer, F. T. Beil et al., "Age- and sex-related changes of humeral head microarchitecture: histomorphometric analysis of 60 human specimens," *Journal of Orthopaedic Research*, vol. 28, no. 1, pp. 18–26, 2010.

[3] K. Okike, O. C. Lee, H. Makanji, M. B. Harris, and M. S. Vrahas, "Factors associated with the decision for operative versus nonoperative treatment of displaced proximal humerus fractures in the elderly," *Injury*, vol. 44, no. 4, pp. 448–455, 2013.

[4] C. Torrens, M. Corrales, G. Vilà, F. Santana, and E. Cáceres, "Functional and quality-of-life results of displaced and nondisplaced proximal humeral fractures treated conservatively," *Journal of Orthopaedic Trauma*, vol. 25, no. 10, pp. 581–587, 2011.

[5] I. R. Murray, A. K. Amin, T. O. White, and C. M. Robinson, "Proximal humeral fractures: current concepts in classification, treatment and outcomes," *Journal of Bone and Joint Surgery—Series B*, vol. 93, no. 1, pp. 1–11, 2011.

[6] D. M. Friess and A. Attia, "Locking plate fixation for proximal humerus fractures: a comparison with other fixation techniques," *Orthopedics*, vol. 31, no. 12, 2008.

[7] A. E. Handschin, M. Cardell, C. Contaldo, O. Trentz, and G. A. Wanner, "Functional results of angular-stable plate fixation in displaced proximal humeral fractures," *Injury*, vol. 39, no. 3, pp. 306–313, 2008.

[8] G. Kontakis, C. Koutras, T. Tosounidis, and P. Giannoudis, "Early management of proximal humeral fractures with hemiarthroplasty: a systematic review," *The Journal of Bone & Joint Surgery—British Volume*, vol. 90, no. 11, pp. 1407–1413, 2008.

[9] H. A. Vallier, "Treatment of proximal humerus fractures," *Journal of Orthopaedic Trauma*, vol. 21, no. 7, pp. 469–476, 2007.

[10] K. Zyto, W. A. Wallace, S. P. Frostick, and B. J. Preston, "Outcome after hemiarthroplasty for three- and four-part fractures of the proximal humerus," *Journal of Shoulder and Elbow Surgery*, vol. 7, no. 2, pp. 85–89, 1998.

[11] C. S. Neer II, "Displaced proximal humeral fractures. I. Classification and evaluation," *Journal of Bone and Joint Surgery—Series A*, vol. 52, no. 6, pp. 1077–1089, 1970.

[12] C. R. Constant and A. H. G. Murley, "A clinical method of functional assessment of the shoulder," *Clinical Orthopaedics and Related Research*, vol. 214, pp. 160–164, 1987.

[13] E. Aschauer, H. Resch, and C. Hübner, "Percutaneous osteosynthesis of humeral head fractures," *Operative Orthopädie und Traumatologie*, vol. 19, no. 3, pp. 276–293, 2007.

[14] R. Bogner, C. Hübner, N. Matis, A. Auffarth, S. Lederer, and H. Resch, "Minimally-invasive treatment of three- and four-part fractures of the proximal humerus in elderly patients," *Journal of Bone and Joint Surgery—Series B*, vol. 90, no. 12, pp. 1602–1607, 2008.

[15] H. Resch, C. Hübner, and R. Schwaiger, "Minimally invasive reduction and osteosynthesis of articular fractures of the humeral head," *Injury*, vol. 32, supplement 1, pp. 25–32, 2001.

[16] R. Ortmaier, G. Mattiassich, M. Pumberger et al., "Comparison between reverse shoulder arthroplasty and Humerusblock in three- and four-part proximal humerus fractures in elderly patients," *International Orthopaedics*, vol. 39, no. 2, pp. 335–342, 2014.

[17] D. Ring, "Current concepts in plate and screw fixation of osteoporotic proximal humerus fractures," *Injury*, vol. 38, no. 3, supplement, pp. 59–68, 2007.

[18] R. T. Goldman, K. J. Koval, F. Cuomo, M. A. Gallagher, and J. D. Zuckerman, "Functional outcome after humeral head replacement for acute three- and four-part proximal humeral fractures," *Journal of Shoulder and Elbow Surgery*, vol. 4, no. 2, pp. 81–86, 1995.

[19] C. S. Neer II, "Articular replacement for the humeral head," *The Journal of bone and joint surgery. American volume*, vol. 37, no. 2, pp. 215–228, 1955.

[20] P. Boileau, S. G. Krishnan, L. Tinsi, G. Walch, J. S. Coste, and D. Molé, "Tuberosity malposition and migration: reasons for poor outcomes after hemiarthroplasty for displaced fractures of the proximal humerus," *Journal of Shoulder and Elbow Surgery*, vol. 11, no. 5, pp. 401–412, 2002.

[21] F. Kralinger, R. Schwaiger, M. Wambacher et al., "Outcome after primary hemiarthroplasty for fracture of the head of the humerus," *Journal of Bone and Joint Surgery—Series B*, vol. 86, no. 2, pp. 217–219, 2004.

[22] D. J. Cuff and D. R. Pupello, "Comparison of hemiarthroplasty and reverse shoulder arthroplasty for the treatment of proximal humeral fractures in elderly patients," *The Journal of Bone & Joint Surgery—American Volume*, vol. 95, no. 22, pp. 2050–2055, 2013.

[23] F. Reuther, B. Mühlhäusler, D. Wahl, and S. Nijs, "Functional outcome of shoulder hemiarthroplasty for fractures: a multicentre analysis," *Injury*, vol. 41, no. 6, pp. 606–612, 2010.

[24] S. Namdari, J. G. Horneff, and K. Baldwin, "Comparison of hemiarthroplasty and reverse arthroplasty for treatment of proximal humeral fractures: a systematic review," *The Journal of Bone & Joint Surgery—American Volume*, vol. 95, no. 18, pp. 1701–1708, 2013.

[25] F. Brunner, C. Sommer, C. Bahrs et al., "Open reduction and internal fixation of proximal humerus fractures using a proximal humeral locked plate: a prospective multicenter analysis," *Journal of Orthopaedic Trauma*, vol. 23, no. 3, pp. 163–172, 2009.

[26] B. D. Solberg, C. N. Moon, D. P. Franco, and G. D. Paiement, "Locked plating of 3- and 4-part proximal humerus fractures in older patients: the effect of initial fracture pattern on outcome," *Journal of Orthopaedic Trauma*, vol. 23, no. 2, pp. 113–119, 2009.

[27] K. C. Owsley and J. T. Gorczyca, "Fracture displacement and screw cutout after open reduction and locked plate fixation of proximal humeral fractures," *The Journal of Bone and Joint Surgery. American*, vol. 90, no. 2, pp. 233–240, 2008.

[28] S. Carbone, P. Moroder, V. Arceri, R. Postacchini, and S. Gumina, "The amount of humeral head impaction of proximal humeral fractures fixed with the Humerusblock device," *International Orthopaedics*, vol. 38, no. 7, pp. 1451–1459, 2014.

[29] H. Lill, P. Hepp, J. Korner et al., "Proximal humeral fractures: how stiff should an implant be? A comparative mechanical study with new implants in human specimens," *Archives of Orthopaedic and Trauma Surgery*, vol. 123, no. 2-3, pp. 74–81, 2003.

[30] F. Kralinger, M. Gschwentner, M. Wambacher, V. Smekal, and C. Haid, "Proximal humeral fractures: what is semi-rigid? Biomechanical properties of semi-rigid implants, a biomechanical cadaver based evaluation," *Archives of Orthopaedic and Trauma Surgery*, vol. 128, no. 2, pp. 205–210, 2008.

[31] F. Kralinger, A. Irenberger, C. Lechner, M. Wambacher, K. Golser, and G. Sperner, "Comparison of open versus percutaneous treatment for humeral head fracture," *Unfallchirurg*, vol. 109, no. 5, pp. 406–410, 2006.

[32] R. C. Sproul, J. J. Iyengar, Z. Devcic, and B. T. Feeley, "A systematic review of locking plate fixation of proximal humerus fractures," *Injury*, vol. 42, no. 4, pp. 408–413, 2011.

[33] H. Resch, P. Povacz, R. Fröhlich, and M. Wambacher, "Percutaneous fixation of three- and four-part fractures of the proximal humerus," *The Journal of Bone & Joint Surgery—British Volume*, vol. 79, no. 2, pp. 295–300, 1997.

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Clinical Study

Clinical Effects of the Probing Method with Depth Gauge for Determining the Screw Depth of Locking Proximal Humeral Plate

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Background. The use of locking plates has gained popularity to treat proximal humeral fractures. However, the complication rates remain high. Biomechanical study suggested that subchondral screw-tip abutment significantly increased the stability of plant. We present a simple method to obtain the proper screw length through the depth gauge in elderly patients and compared the clinical effects with traditional measuring method. *Methods*. 40 patients were separated into two groups according to the two surgical methods: the probing method with depth gauge and the traditional measuring method. The intraoperative indexes and postoperative complications were recorded. The Constant and Murley score was used for the functional assessment in the 12th month. *Results*. Operative time and intraoperative blood loss indicated no statistical differences. X-ray exposure time and the patients with screw path penetrating the articular cartilage significantly differed. Postoperative complications and Constant and Murley score showed no statistical differences. *Conclusions*. Probing method with depth gauge is an appropriate alternative to determine the screw length, which can make the screw-tip adjoin the subchondral bone and keep the articular surface of humeral head intact and at the same time effectively avoid frequent X-ray fluoroscopy and adjusting the screws.

1. Introduction

Proximal humeral fractures represent approximately 5% of all fractures and 10% of these patients are older than 65 years [1–4]. As the population ages there is an increase in the number of people in poor general condition with an increased risk of falls on fragile bones [5]. Although most patients can be treated by nonsurgical management [6], many patients require surgical treatment. With the development of fixation techniques, especially the locking plates, open reduction and internal fixation has gained popularity to treat proximal humeral fractures [5, 7, 8].

Patients treated with locking plate can be mobilized earlier and get better functional recovery. However, the complication rates remain high [9–12], such like failure of reduction, avascular necrosis, varus collapse, subacromial impingement, and screw cutout of the articular surface [10, 11, 13]. Due to the characteristics of osteoporosis, stable fixation with plate and screw of such fractures remains a challenge, and more and more attention has been attracted. Biomechanical study suggested that subchondral screw-tip abutment significantly increased the stability of plant [14]. Therefore, obtaining an ideal screw length is important. Obviously, short screw cannot afford enough holding force [14]. The long screw penetration of the humeral head can occur as an original complication or secondary to fracture settling caused by medial instability [15]. However, the incidence of original penetration into the glenohumeral joint has been reported up to 10%–15% [5, 13], which will cause the destruction and chondrolysis of the articular cartilage [16–18].

In the traditional surgical method, the depth of drilling mostly depended on the tactile feedback from the drill bit against the subchondral bone. Given the characteristics of osteoporotic patients, a surgical method that was called "sounding" was reported in the literature [19]. They firstly used a drill bit to perforate the lateral cortex of the desired locking screw slot, then the blunt tip of a Kirschner wire was used to be inserted by hand until feeling a firm end point which indicated the blunt tip against the subchondral bone, and thus a more accurate and safer depth was obtained. In our study, a depth gauge was used instead of Kirschner wire and we called it "probing method."

A clinical trial was performed to compare the clinical effects of management of proximal humeral fractures with either our probing method with depth gauge or traditional surgical method in geriatric patients. We hypothesized that an ideal screw length and good bone purchase will be obtained through probing method.

2. Patients and Methods

The study was approved by the Ethics Committee of the Third Hospital of Hebei Medical University and all aspects of the study comply with the Declaration of Helsinki. Between August 2012 and February 2013, we treated 40 patients with proximal humeral fractures based on the following criteria: (1) age > 55; (2) acute fracture, and the patients received the treatment of surgery within 2 weeks after an injury; (3) osteoporosis. We excluded patients based on the following conditions: (1) inability to cooperate with the informed consent, such like mental disorders; (2) preexisting disabling disorder; (3) open or pathological fractures; (4) existing neurovascular impairment; (5) rehabilitation unable to be performed as required; and (6) contraindication to surgery.

The mean age was 64.95 (57–72), including 15 male patients and 25 female patients. 28 fractures were caused by falls, and another 12 fractures were caused by traffic injuries. Based on the Neer classification system [20], all the fractures contained 3 two-part fractures, 32 three-part fractures, and 5 four-part fractures.

Patients were randomly divided into two groups according to the following management strategies: traditional measuring method (20 patients) and probing method with depth gauge (20 patients). A standard surgical procedure was performed by two experienced orthopaedic trauma surgeons from our institution. The patient was placed supine on a radiolucent operating room table. A deltopectoral approach was used to expose the fracture. Once the fracture was reduced, the locking plate was positioned and provisionally stabilized. Depending on the fracture pattern, screw insertion may begin either proximally or distally. During the proximal locking screws insertion, a drill bit was utilized to perforate the lateral cortex of the desired locking screw slot firstly.

In the traditional measuring method group, the drill bit advanced after perforating the lateral cortex and the depth of drilling was determined by the tactile feedback from the drill bit against the subchondral bone. In the probing method group, after perforating the lateral cortex, we predrilled additional length of the cancellous bone with the locking drill sleeve to form a screw track with right direction and then removed the sleeve; the depth gauge was used to be advanced by hand until a firm end point was felt, which indicated that the tip reached the area close to subchondral bone, and then we measured the depth directly. The position of the depth gauge tip can be verified with fluoroscopy (Figure 1). The locking plate was fixed by 4–6 proximal locking screws and 2-3 distal conventional screws. The lesser tubercle fracture or rotator cuff injury can be repaired by absorbable sutures. Rotator cuff sutures can be tied to the locking plate to enhance the stability.

The same postoperative rehabilitation protocol was performed for all the patients. Firstly, the arm was placed in a sling. Active mobilization of elbow, wrist, and hand may begin on the first day after surgery. Pendulum exercises could be carried out early. Once the patient was comfortable, gentle passive motion of the shoulder was started. Active motion of shoulder should start at 4 to 6 weeks, and strengthening exercises were carried out from 12 weeks on.

Operative time, blood loss, and X-ray exposure time (1 X-ray fluoroscopy was recorded as 1 second) were recorded. CT examination was routinely used to assess the screw length and detect whether there is a path through the articular surface. The screw path penetrating the articular cartilage was recorded. During 12-month follow-up, complications were recorded and the Constant and Murley score (CMs) [21] was used for the assessment of all patients in the 12th month by experienced orthopaedic surgeon. The CMs was graded as excellent (86–100), good (71–85), moderate (56–70), or poor (0–55) [21], and the fineness rate (the percentage of the excellent and good grades) was compared between the two groups.

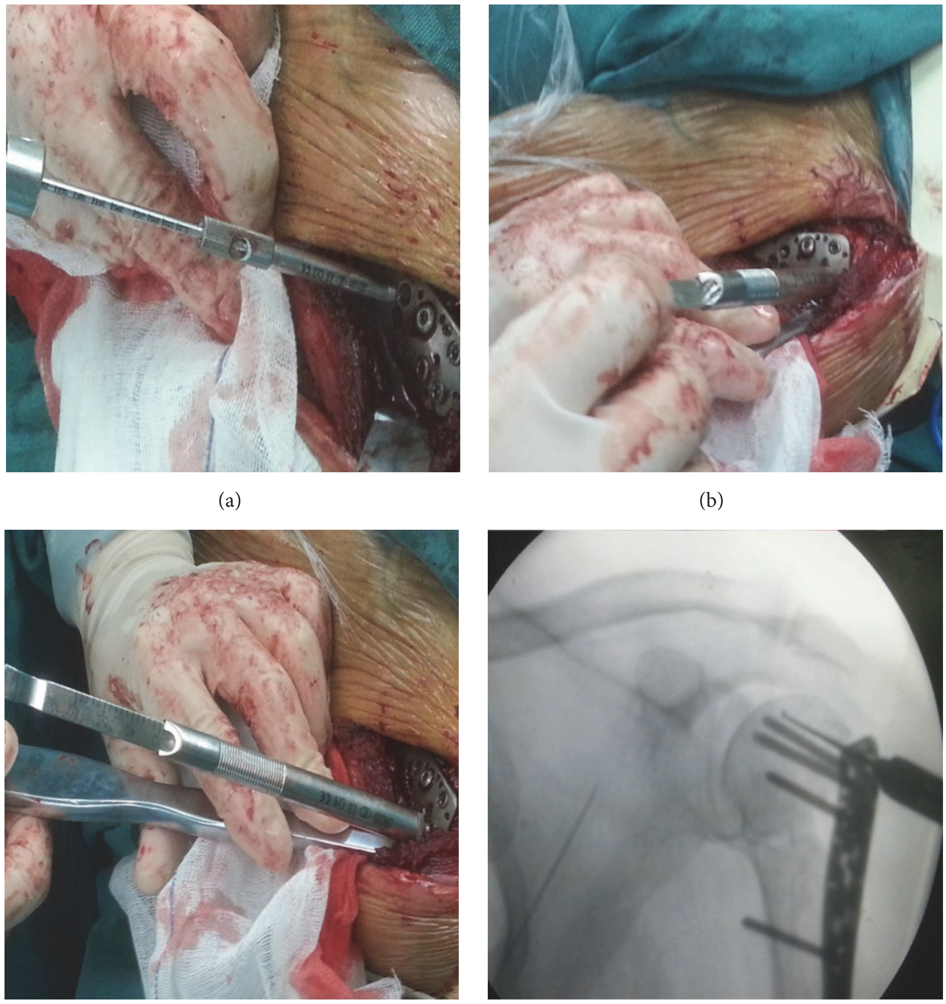
The statistical analysis was performed using the SPSS 21.0 statistical software. 2-independent-sample t-test, Chi-square test, or Fisher exact test were applied to all outcome analyses, where appropriate. Statistical significance was defined as $p < 0.05$.

3. Results

Operative time (110.55 ± 9.36 min versus 107.05 ± 8.22 min, $p = 0.217$) and intraoperative blood loss (156.50 ± 33.13 mL versus 146.50 ± 29.78 mL, $p = 0.322$) indicated no statistical differences between two groups. X-ray exposure time (13.15 ± 2.13 s versus 11.50 ± 1.73 s, $p = 0.011$) and the patients with screw path penetrating the articular surface (6 versus 0, $p = 0.027$) significantly differed (Figure 2); probing method showed the absolute advantage. During the 12-month follow-up, no one had nonunion. In the traditional group, 1 case had humeral head necrosis, 1 case had screw loosening, and 2 cases had screw penetration (Figure 3). In the probing group, 2 cases had screw loosening; 1 case had subacromial impingement (Table 1). There were no statistically significant differences in complication rates between patients treated with either traditional measuring method or probing with depth gauge. In the 12th month function evaluation, the score of traditional group was 76.30 ± 8.69, including 2 excellent, 13 good, 4 moderate, and 1 poor; the score of probing group was 77.05 ± 7.73, including 3 excellent, 13 good, and 4 moderate. The score ($p = 0.775$) and fineness rate (80% versus 75%, $p = 1.000$) showed no statistical differences (Table 2).

4. Discussion

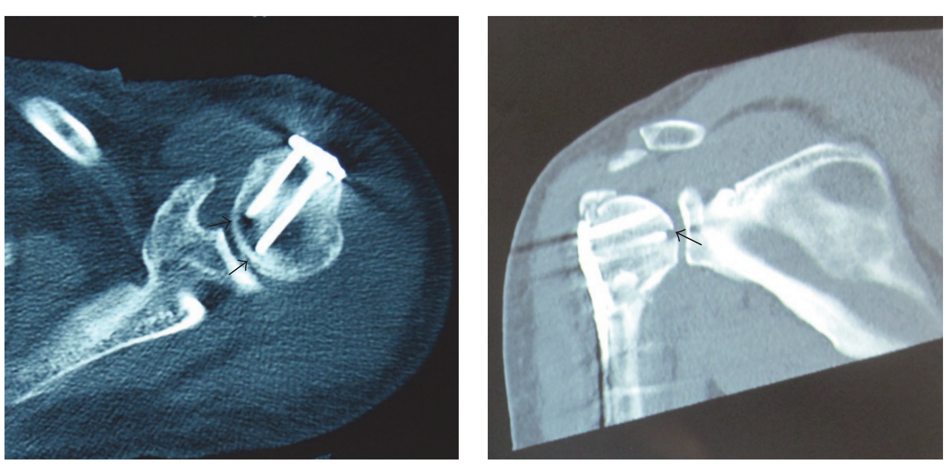
Most displaced proximal humeral fractures can be treated with locking plate. Locking plate has made a great progress in treating displaced proximal humeral fractures, which



(a) (b)

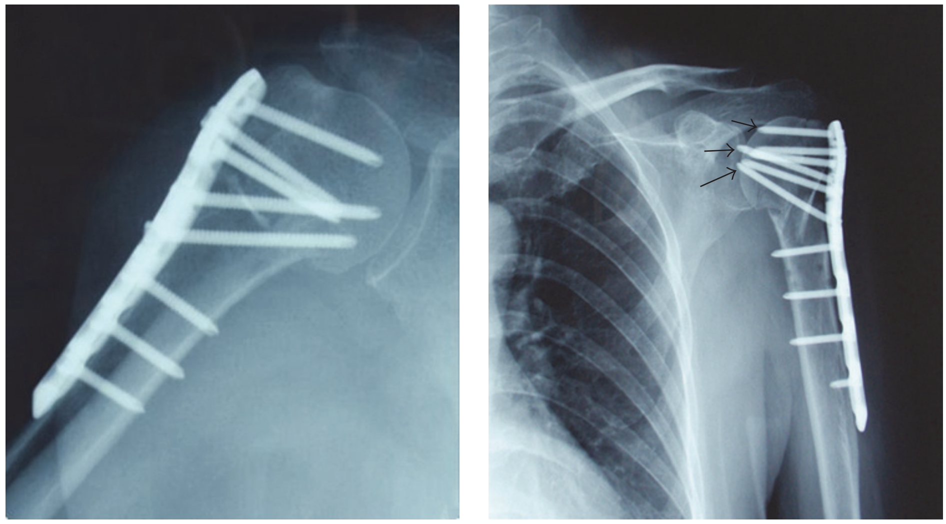
(c) (d)

Figure 1: Probing method with depth gauge: (a) after perforating the lateral cortex, predrilling additional length of the cancellous bone with the locking drill sleeve to form a screw track with right direction; (b) removing the sleeve, the depth gauge was used to be advanced by hand; (c) a firm end point was felt, which indicated the tip reached the area close to subchondral bone; (d) verifying the position of the depth gauge with fluoroscopy.



(a) (b)

Figure 2: (a) Patient in the probing group without the articular cartilage disruption; (b) patient in the traditional group with screw path penetrating the articular cartilage, which was caused by accidental penetration during operation.



(a) (b)

Figure 3: During the follow-up period, (a) patient from the probing group had a good screw length; (b) screw penetration complication occurred in the traditional measuring method group (black arrows).

Table 1: Intraoperative characteristics.

Parameters	Traditional group (n = 20)	Probing group (n = 20)	p value
Operative time (min)			0.217
Range	96–135	90–120	
Mean ± SD	110.55 ± 9.36	107.05 ± 8.22	
Blood loss (mL)			0.322
Range	90–220	90–200	
Mean ± SD	156.50 ± 33.13	146.50 ± 29.78	
X-ray exposure time (s)			0.011*
Range	9–16	8–15	
Mean ± SD	13.15 ± 2.13	11.50 ± 1.73	
Original penetration, n (%)	6 (30%)	0	0.027*

*Statistically significant difference ($p < 0.05$).

Table 2: Postoperative characteristics.

Parameters	Traditional group (n = 20)	Probing group (n = 20)	p value
Complications			
Humeral head necrosis, n (%)	1 (5%)	0	1.000
Screw loosening, n (%)	1 (5%)	2 (10%)	1.000
Screw penetration, n (%)	2 (10%)	0	0.468
Subacromial impingement, n (%)	0	1 (5%)	1.000
CMs			0.775
Range	53–90	59–92	
Mean ± SD	76.30 ± 8.69	77.05 ± 7.73	
CMs grades, n (%)			
Excellent (86–100)	2 (10%)	3 (15%)	
Good (71–85)	13 (65%)	13 (65%)	
Moderate (56–70)	4 (20%)	4 (20%)	
Poor(0–55)	1 (5%)	0	
CMs fineness rate (71–100), n (%)	15 (75%)	16 (80%)	1.000

CMs: Constant and Murley score.

makes the joint-preserving surgery method more successful in elderly osteoporotic patients [22]. Compared to standard plates, locking plates were found to provide better stiffness and torsional fatigue resistance [23], as well as significantly greater holding power of the humeral head [24]. In theory locking plate has a lower rate of implant failure or fixation loosing due to more stable fracture fixation, thus allowing earlier mobilization. However, the overall complication rate remains high [9–12]. A retrospective analysis of locking plate in the treatment of proximal humeral fracture reported that the failure rate is as high as 13.7% [25]. In addition, intraoperative complications are also common; screw joint perforation is one of the most common complications, especially the iatrogenic penetration into the glenohumeral joint during operation [5, 13]. Kettler et al. [26] found that the incidence of intraoperative penetration of screws was 11%. Two other large series have reported intraoperative screw penetration rates of 11% and 14%, respectively [17, 18]. Although the penetrating screws are caused by secondary collapse or cutout [11, 27], we and some other authors believe that a certain proportion of penetration occurs during operation [10, 19, 28].

Several factors may result in the original penetration, such as the spherical surface of the humeral head and the diverging and converging characteristics of locking screws, which make assessing the position of the screw tip difficult on orthogonal views. Additionally the poor bone quality of osteoporosis patients limits the sensitivity of the tactile feedback of drill bit. So it is challenging to detect the screw penetration with the 2-dimensional C-arm fluoroscopy, even though the live fluoroscopy was taken during passive range of motion [28]. Strategies to minimize such complication are being developed in recent years. Weil et al. [29] introduced the use of C-InSight (Mazor Surgical Technologies, Caesarea, Israel), which allowed the use of a conventional 2-dimensional C-arm fluoroscope, coupled with a target array, to capture and produce 3-dimensional fluoroscopic images. More sophisticated intraoperative imaging devices have appeared that enabled producing 3-dimensional images, such as O-arm fluoroscopy [30]. These advanced devices were very useful in verifying the reduction of intra-articular fracture [30–32] but also assisted in detecting accidental destruction of articular surface by screws [33]. However, it was not routinely available in clinical practice, maybe because of the high cost and the large amount of radiation exposure during each scan [34].

However, the accidental penetration during operation, even when recognized and replaced, may disrupt the overall integrity of articular surface of the humeral head and more likely cause cutout and varus collapse. It is known that the subchondral bone of the humeral head offers the best grip, and it has a mean width of 5 mm [14]. For elderly patients, the quality of the subchondral bone is typically poor. As a result, it is difficult to distinguish the tactile feedback between cancellous bone and the thin subchondral bone during drilling. Therefore, the traditional measuring method with advancing the drill bit is unreliable, which may result in high accidental penetration rate.

To solve the above-mentioned problem, Bengard and Gardner [19] used a blunt-tipped Kirschner wire to verify the tactile feedback of the bone to get the screw tip location. In our study, we used a depth gauge instead of the Kirschner wire. When bone is osteoporoticly changed, cortical bone is thinner and cancellous bone is built of thin trabeculae, so the bone tissue is fragile due to lower density and changed trabecular built. As a result, the depth gauge can easily penetrate the cancellous bone by hand until the subchondral bone. Compared to the Kirschner wire, the depth gauge was easy to hold when it was advanced by hand and provided a more clearly tactile feedback; in addition, the depth can be measured directly. In our experience, the metal strength of the depth gauge was enough to penetrate the cancellous bone of osteoporotic patients to the subchondral bone without bending deformation, which was confirmed by the fluoroscopy. In addition, probing with depth gauge will decrease the disruption of the cancellous bone compared to the drill bit; thus the screw will have a better compression effect on the surrounding bone during screw insertion, like the PFNA blade, which improves the stability of the fixation. Therefore, even if the depth gauge tip cannot reach the subchondral bone in the patients with relatively hard bone, the compression effect may provide enough holding force to avoid looseness.

According to our own findings, even though there were no statistical differences between the two groups, operative time and intraoperative blood loss were less in the probing group, which showed the decreasing trend. The probing method just offered help to the procedure of getting the screw length, which may not significantly influence the overall operative time. Even so, the probing method showed obvious advantage in decreasing the X-ray exposure time. In traditional measuring method, more fluoroscopy times were needed to verify whether the screw-tip had penetrated the articular surface, even using the live fluoroscopy. Replacing improper locking screws would also increase exposure time. Through probing method, the ideal screw length can be quickly obtained without frequent fluoroscopy. At the same time, the probing method significantly decreased the risk of accidental perforation during drilling the screw path, which preserved the integrity of articular cartilage.

The other complications between two groups had no statistical differences. Compared to the traditional group, no screw penetration occurred in the probing group during the follow-up period. Even though there was no statistic difference, our results still showed some advantage in protecting the articular surface and the stability of screw fixation. The CMs is a common and objective evaluation index for the shoulder's function. Many factors may affect the functional outcome, such as fracture type, function before injury, and rehabilitation. According to our findings, the mean score and fineness rate in the probing group were both higher, indicating some advantage.

Although the follow-up time in our study was relatively short, the results demonstrate several benefits of the probing method with depth gauge. A limitation of the study is the small number of patients; future study with large sample may have a better result. Another limitation is that our probing method with depth gauge is more applicable to geriatric patients with osteoporosis. It will bring difficulty to advance the depth gauge to the ideal position in the younger patients with strong bone quality, so patient selection is important.

5. Conclusions

Given the characteristics of osteoporosis, probing with depth gauge is an effective method to get the accurate depth of locking screws to humeral head. Probing method with depth gauge significantly decreased the radiation exposure and effectively avoided the accidental penetration during operation. We therefore recommend the use of the probing method with depth gauge in the treatment with locking plate for proximal humeral fractures of osteoporotic patients.

Competing Interests

All authors have no conflict of interests regarding this paper.

References

[1] C. M. Court-Brown and B. Caesar, "Epidemiology of adult fractures: a review," *Injury*, vol. 37, no. 8, pp. 691–697, 2006.

[2] C. M. Court-Brown, A. Garg, and M. M. McQueen, "The translated two-part fracture of the proximal humerus. Epidemiology and outcome in the older patient," *Journal of Bone and Joint Surgery B*, vol. 83, no. 6, pp. 799–804, 2001.

[3] C. M. Court-Brown, A. Garg, and M. M. McQueen, "The epidemiology of proximal humeral fractures," *Acta Orthopaedica Scandinavica*, vol. 72, no. 4, pp. 365–371, 2001.

[4] C. M. Court-Brown and M. M. McQueen, "Two-part fractures and fracture dislocations," *Hand Clinics*, vol. 23, no. 4, pp. 397–414, 2007.

[5] D. Aaron, J. Shatsky, J. C. S. Paredes, C. Jiang, B. O. Parsons, and E. L. Flatow, "Proximal humeral fractures: internal fixation," *Instructional Course Lectures*, vol. 62, pp. 143–154, 2013.

[6] M. M. Lefevre-Colau, A. Babinet, F. Fayad et al., "Immediate mobilization compared with conventional immobilization for the impacted nonoperatively treated proximal humeral fracture. A randomized controlled trial," *Journal of Bone and Joint Surgery A*, vol. 89, no. 12, pp. 2582–2590, 2007.

[7] M. B. Berkes, M. T. M. Little, and D. G. Lorich, "Open reduction internal fixation of proximal humerus fractures," *Current Reviews in Musculoskeletal Medicine*, vol. 6, no. 1, pp. 47–56, 2013.

[8] T. M. Gregory, E. Vandenbussche, and B. Augereau, "Surgical treatment of three and four-part proximal humeral fractures," *Orthopaedics & Traumatology, Surgery & Research*, vol. 99, no. 1, supplement, pp. S197–S207, 2013.

[9] N. Aksu, A. Gögüs, A. N. Kara, and Z. U. Işiklar, "Complications encountered in proximal humerus fractures treated with locking plate fixation," *Acta Orthopaedica et Traumatologica Turcica*, vol. 44, no. 2, pp. 89–96, 2010.

[10] S. Brorson, J. V. Rasmussen, L. H. Frich, B. S. Olsen, and A. Hróbjartsson, "Benefits and harms of locking plate osteosynthesis in intraarticular (OTA Type C) fractures of the proximal humerus: a systematic review," *Injury*, vol. 43, no. 7, pp. 999–1005, 2012.

[11] K. A. Egol, C. C. Ong, M. Walsh, L. M. Jazrawi, N. C. Tejwani, and J. D. Zuckerman, "Early complications in proximal humerus fractures (OTA types 11) treated with locked plates," *Journal of Orthopaedic Trauma*, vol. 22, no. 3, pp. 159–164, 2008.

[12] R. C. Sproul, J. J. Iyengar, Z. Devcic, and B. T. Feeley, "A systematic review of locking plate fixation of proximal humerus fractures," *Injury*, vol. 42, no. 4, pp. 408–413, 2011.

[13] B. Jost, C. Spross, H. Grehn, and C. Gerber, "Locking plate fixation of fractures of the proximal humerus: analysis of complications, revision strategies and outcome," *Journal of Shoulder and Elbow Surgery*, vol. 22, no. 4, pp. 542–549, 2013.

[14] A. S. L. Liew, J. A. Johnson, S. D. Patterson, G. J. W. King, and D. G. Chess, "Effect of screw placement on fixation in the humeral head," *Journal of Shoulder and Elbow Surgery*, vol. 9, no. 5, pp. 423–426, 2000.

[15] M. J. Gardner, Y. Weil, J. U. Barker, B. T. Kelly, D. L. Helfet, and D. G. Lorich, "The importance of medial support in locked plating of proximal humerus fractures," *Journal of Orthopaedic Trauma*, vol. 21, no. 3, pp. 185–191, 2007.

[16] B. D. Solberg, C. N. Moon, D. P. Franco, and G. D. Paiement, "Surgical treatment of three and four-part proximal humeral fractures," *Journal of Bone and Joint Surgery—Series A*, vol. 91, no. 7, pp. 1689–1697, 2009.

[17] F. Brunner, C. Sommer, C. Bahrs et al., "Open reduction and internal fixation of proximal humerus fractures using a proximal humeral locked plate: a prospective multicenter analysis," *Journal of Orthopaedic Trauma*, vol. 23, no. 3, pp. 163–172, 2009.

[18] N. Südkamp, J. Bayer, P. Hepp et al., "Open reduction and internal fixation of proximal humeral fractures with use of the locking proximal humerus plate. Results of a prospective, multicenter, observational study," *Journal of Bone and Joint Surgery—Series A*, vol. 91, no. 6, pp. 1320–1328, 2009.

[19] M. J. Bengard and M. J. Gardner, "Screw depth sounding in proximal humerus fractures to avoid iatrogenic intra-articular penetration," *Journal of Orthopaedic Trauma*, vol. 25, no. 10, pp. 630–633, 2011.

[20] C. S. Neer II, "Displaced proximal humeral fractures. I. Classification and evaluation," *Journal of Bone and Joint Surgery A*, vol. 52, no. 6, pp. 1077–1089, 1970.

[21] J.-M. Björkenheim, J. Pajarinen, and V. Savolainen, "Internal fixation of proximal humeral fractures with a locking compression plate: a retrospective evaluation of 72 patients followed for a minimum of 1 year," *Acta Orthopaedica Scandinavica*, vol. 75, no. 6, pp. 741–745, 2004.

[22] R. A. Meier, P. Messmer, P. Regazzoni, W. Rothfischer, and T. Gross, "Unexpected high complication rate following internal fixation of unstable proximal humerus fractures with an angled blade plate," *Journal of Orthopaedic Trauma*, vol. 20, no. 4, pp. 253–260, 2006.

[23] D. M. Weinstein, D. R. Bratton, W. J. Ciccone II, and J. J. Elias, "Locking plates improve torsional resistance in the stabilization of three-part proximal humeral fractures," *Journal of Shoulder and Elbow Surgery*, vol. 15, no. 2, pp. 239–243, 2006.

[24] S. Walsh, R. Reindl, E. Harvey, G. Berry, L. Beckman, and T. Steffen, "Biomechanical comparison of a unique locking plate versus a standard plate for internal fixation of proximal humerus fractures in a cadaveric model," *Clinical Biomechanics*, vol. 21, no. 10, pp. 1027–1031, 2006.

[25] J. Agudelo, M. Schürmann, P. Stahel et al., "Analysis of efficacy and failure in proximal humerus fractures treated with locking plates," *Journal of Orthopaedic Trauma*, vol. 21, no. 10, pp. 676–681, 2007.

[26] M. Kettler, P. Biberthaler, V. Braunstein, C. Zeiler, M. Kroetz, and W. Mutschler, "Treatment of proximal humeral fractures

with the PHILOS angular stable plate. Presentation of 225 cases of dislocated fractures," *Unfallchirurg*, vol. 109, no. 12, pp. 1032–1040, 2006.

[27] K. C. Owsley and J. T. Gorczyca, "Displacement/screw cutout after open reduction and locked plate fixation of humeral fractures," *Journal of Bone and Joint Surgery—Series A*, vol. 90, no. 2, pp. 233–240, 2008.

[28] P. Hernigou and W. Germany, "Unrecognized shoulder joint penetration during fixation of proximal fractures of the humerus," *Acta Orthopaedica Scandinavica*, vol. 73, no. 2, pp. 140–143, 2002.

[29] Y. A. Weil, S. Beyth, A. Abu-Ahmad, A. Khoury, M. Liebergall, and O. Safran, "Use of three-dimensional fluoroscopy to determine intra-articular screw penetration in proximal humeral fracture model," *Journal of Shoulder and Elbow Surgery*, vol. 23, no. 8, pp. 1150–1155, 2014.

[30] A. A. Theologis, S. Burch, and M. Pekmezci, "Placement of iliosacral screws using 3D image-guided (O-Arm) technology and Stealth Navigation: comparison with traditional fluoroscopy," *The Bone & Joint Journal*, vol. 98, no. 5, pp. 696–702, 2016.

[31] J. Geerling, D. Kendoff, M. Citak et al., "Intraoperative 3D imaging in calcaneal fracture care—clinical implications and decision making," *Journal of Trauma—Injury, Infection and Critical Care*, vol. 66, no. 3, pp. 768–773, 2009.

[32] D. Kendoff, M. Citak, M. J. Gardner, T. Stübig, C. Krettek, and T. Hüfner, "Intraoperative 3D imaging: value and consequences in 248 cases," *The Journal of Trauma*, vol. 66, no. 1, pp. 232–238, 2009.

[33] K. Atesok, J. Finkelstein, A. Khoury et al., "The use of intraoperative three-dimensional imaging (ISO-C-3D) in fixation of intraarticular fractures," *Injury*, vol. 38, no. 10, pp. 1163–1169, 2007.

[34] C. Rock, D. Kotsianos, U. Linsenmaier et al., "Studies on image quality, high contrast resolution and dose for the axial skeleton and limbs with a new, dedicated CT system (ISO-C-3 D)," *RoFo*, vol. 174, no. 2, pp. 170–176, 2002.

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Research Article

The Prevalence of Fragility Fractures in a Population of a Region of Southern Italy Affected by Thyroid Disorders

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In the literature there is no clear evidence of a relationship between thyropathies and fragility fractures. The aim of our study is to define the prevalence of thyroid disease in a study sample made up of subjects with fragility fractures and from the same geographical area. We retrospectively studied the "hospital discharge records" (HDR) in the Apulian Database for the period 2008–2013 in order to identify all those patients with fragility fractures that required hospitalization. After detecting the prevalent population, we identified the patients affected by thyroid disease. We observed that, between 2008 and 2013 in Apulia, 16,636 patients were affected by hyperthyroidism. In the same period there were 92,341 subjects with hypothyroidism. The incidence of fragility fractures was 4.5% in the population with hyperthyroidism. As regards the population with hypothyroidism, the incidence of fragility fractures was 3.7%. Furthermore, we assessed the statistical connection between thyroid disease and fragility fractures revealing a higher incidence in patients with hyperthyroidism and clinical hypothyroidism.

1. Introduction

Osteoporosis is currently the most common metabolic disease of the skeleton in the world, with an estimated prevalence of approximately 200 million people. The prevalence of the disease increases with an aging population and it is estimated that 30% of European women in menopause are suffering from osteoporosis [1]. The complications of osteoporosis are a major cause of disability and constitute one of the largest items in the budget of health expenditure in several countries, surpassing, according to some authors, myocardial infarction [2]. Fragility fractures (femoral, vertebral, humerus, wrist, tarsus, and metatarsus) are lesions due to mechanical stress not ordinarily resulting in fracture. Moreover, these lesions are caused by low-energy trauma according to National Institute for Health and Care Excellence. Fragility fractures are the most frequent complications of osteoporosis. However, numerous studies have shown that, in patients with low bone mass, all types of fractures are quite frequent. Furthermore, regardless of the skeletal segment concerned, the fracture event increases by 50–100% the likelihood of a subsequent fracture in a different location [3].

In the elderly population, the incidence of fragility fractures and chronic diseases is increasing [4]. In literature there are various works in which the authors have defined the association between osteoporosis and chronic diseases such as diabetes, hypertension, heart disease, and thyroid disease. As for the latter, in many works the association between hyperthyroidism and osteoporosis has been highlighted [5–7], while studies on the relationship between osteoporosis and hypothyroidism [8–10] are controversial and limited. In particular, some authors report an increased incidence of fragility fractures in hypothyroid patients on hormone replacement therapy (levothyroxine) [10, 11]. Thyroid diseases are responsible for metabolic changes that interfere with cardiovascular, psychic, intestinal, muscle, and bone functions [12].

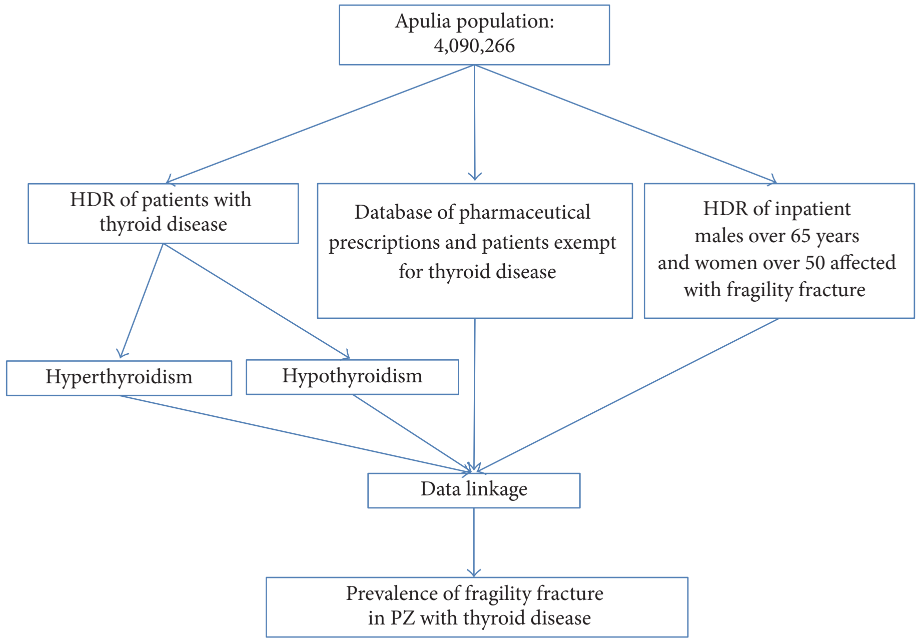

Figure 1: A flow-chart to describe the selection of patients in the period 2008–2013.

As regards the functional aspect of thyroid diseases, we recognize hypo- and hyperfunctioning. The relationship between thyroid function and phosphocalcium metabolism was reported for the first time in 1891 by Von Recklinghausen, who described hyperthyroidism in osteoporosis [13].

The patient affected with hyperthyroidism characterized by low serum levels of the hormone TSH (≤0.1 IU/L) has an increased risk of vertebral and nonvertebral fractures, respectively, 4.5 and 3.2 times more than those unaffected [14]. The pathogenesis is due to hypofunctioning of pituitary gland. The patients with hyperthyroidism suffer from a wide range of symptoms, for example, anxiety, palpitation, ophthalmopathy, sweating, and slimming while in the patients with hypothyroidism we may describe bradycardia, increased perception of cold, impairment of memory, goiter, lymphoedema of arms, and obesity. In the first case, there emerged hyperproduction of thyroid hormone due to different causes. In the case of hypothyroidism there is a lack of thyroid hormone synthesis with an increase of TSH hormone. The prevalence of hypothyroidism varies between about 0.1 and 2% [15]. The effect of thyroid hormone therapy on BMD shows conflicting results [16–18].

Several authors have underlined the role of replacement therapy as being responsible for the reduction of serum TSH levels which in turn adversely affects bone mineral density. As explained above, it is clear how important it is to define the epidemiological data of the national and regional territory in order to understand in terms of primary prevention and secondary and health economics the problem of fragility fractures in the thyreopatic population. The aim of our study is to determine the prevalence of thyroid disease in the study sample represented by individuals with fragility fractures and from the same geographical area.

2. Materials and Methods

We requested the consent of the local ethics committee, and we designed a retrospective observational clinical study. The authors conducted an epidemiological survey on patients who were admitted in different hospitals of the Orthopedics and Traumatology Unit of the Apulia Region. Apulia is a region of Southern Italy with a number of 4,090,266 inhabitants (given Istat updated to 31 December 2013). In order to identify all patients with fragility fractures that required hospitalization, we evaluated the hospital discharge record (HDR) in the period 2008–2013.

In particular, we selected all the Apulia inpatient males over 65 years of age and women over the age of 50 years whose HDR reported domestic accidents (low-trauma energy) in the "trauma field" and who did not die in hospital.

The database of patients with fragility fractures was analyzed using a key linkage individual sanitary code and eliminating all duplicates. This database represented the prevalent population used for the study. The definition of proportion of subjects with fragility fracture and thyroid disease was the primary outcome of the study.

The data sources were HDR: database of pharmaceutical prescriptions of medications band A and the database of the Regional Health Service of Apulia regarding patients exempt from paying medications for thyroid disease (Figure 1). A mining algorithm to select the subjects prevailing cohorts suffering from thyroid disease in 2008 was created, considering every person who, in that year, was hospitalized for thyroid disease or reported a prescription charge exemption for the disease or at least a prescription for a tracer drug.

The extracted records were then linked with the "tax code" field; the processing of the data was performed through the WAS MP11 software.

For the definition of the event, the thyroid diseases were reported according to the ICD-IX codes.

In particular, patients with hyperthyroidism were defined as follows:

(i) Every subject of the prevailing population who was hospitalized for a main cause correlated with hyperthyroidism, as follows.

HDR Code of Hyperthyroidism

242.0 DIFFUSE TOXIC GOITER

242.1 NODULAR TOXIC GOITER

242.2 MULTINODULAR TOXIC GOITER

242.3 ASPECIFIC NODULAR TOXIC GOITER

(ii) Every subject with at least one of the following prescription drugs (ATC A010) ascertained through data linkage with the regional database of pharmaceutical prescriptions and those with the exemption code: 035 (BASEDOW DISEASE AND OTHER FORMS OF HYPERTHYROIDISM) as follows.

Drugs Prescribed for Hyperthyroidism

H03B ANTI THYROID DRUGS

H03BA THIOURACIL

H03BA01 METIL THIOURACIL

H03BA02 PROPYL THIOURACIL

H03BA03 BENZYL THIOURACIL

H03BB IMIDAZOLE CONTAINING SULFUR

H03BB01 CARBIMAZOLE

H03BB52 TIAMAZOL

H03BC PERCHLORATE

H03BC01 POTASSIUM PERCHLORATE

H03BX OTHER ANTI THYROID PREPARATIONS

H03BX01 DIIODOTYROSINE

H03BX02 DIBROMOTYROSINE

H03CA IODIOTHERAPY

Similarly, patients with hypothyroidism were defined as follows.

(i) Every subject of the prevailing population who was hospitalized for a main cause correlated with hypothyroidism, as follows.

HDR Code of Hypothyroidism

243 CONGENITAL HYPOTHYROIDISM

244.1 OTHER HYPOTHIROIDISM TYPE DUE TO THYROID ABLATION

244.2 HYPOTHYROIDISM DUE TO IODIO

244.3 OTHER IATROGEN HYPOTHIROIDISM TYPE

244.8 OTHER ACQUIRED HYPOTHIROIDISM TYPE

Table 1: Prevalence of hyperthyroidism, by sex and age group. Apulia, years 2008–2013.

Year class	M	F	Total
50–54	426	1.816	2.242
55–59	584	1.863	2.447
60–64	658	1.799	2.457
65–69	664	1.550	2.214
70–74	611	1.452	2.063
75–79	622	1.599	2.221
80–84	440	1.317	1.757
≥85	212	1.023	1.235
Total %	4.217 (25%)	12.419 (75%)	16.636 100 (%)

(ii) Every subject with at least one of the following prescription drugs (ATC A010) ascertained through data linkage with the regional database of pharmaceutical prescriptions and those with the exemption code: 027 (congenital hypothyroidism, SEVERE ACQUIRED HYPOTHYROIDISM) (TSH values greater than 10 mU/L) as follows.

Drugs Prescribed for Hypothyroidism

H03AA01 LEVOTHYROXINE SODIUM

H03AA02 LIOTHYRONINE SODIUM

H03AA03 COMBINATION OF LEVOTHYROXINE AND LIOTHYRONINE

H03AA04 TIRATRICOL

H03AA05 THYROID GLAND PREPARATIONS

Furthermore, the authors defined the subject affected by hypothyroidism who was detected simultaneously in both the HDR database codes and the exemption codes but not in the drug prescription database; the subjects present in database 3 were defined as patients with hypothyroidism in treatment. The databases were linked using as a key linkage individual sanitary code and eliminating all duplicates. Data were stratified by age (50–54 years, 55–59 years, 60–64 years, 65–69 years, 70–74 years, 75–79 years, 80–84 years, and ≥85 years) and by gender (male and female).

3. Results

In Apulia, for the period between 2008 and 2013, we revealed 16,636 patients with hyperthyroidism of which 75% were female. The analysis by year class shows a greater distribution in 60–64 years of age range (Table 1).

In the study period, we revealed 92,341 patients with hypothyroidism in Apulia. 84% were female, while the stratification by age showed a greater distribution in the 55–59 years' class (Table 2). In the population of patients affected by hypothyroidism (92,341), 95.1% (87,842) presented clinical hypothyroidism while 4.9% (4,499) presented subclinical hypothyroidism and so were not in drug treatment.

For the period in question, the analysis of data of fragility fractures in the population with hyperthyroidism allowed us

Table 2: Prevalence of hypothyroidism, by sex and age group. Apulia, years 2008–2013.

Year class	M	F	Total
50–54	2051	14.078	16.129
55–59	2360	14.833	17.193
60–64	2546	14.186	16.732
65–69	2317	11.437	13.754
70–74	1976	9.384	11.360
75–79	1559	6.996	8.555
80–84	1076	4.262	5.338
≥85	666	2.614	3.280
Total %	14.551 (16%)	77.790 (84%)	92.341 (100%)

Table 3: Incidence of fragility fractures in patients with hyperthyroidism, by sex and year class. Apulia, years 2008–2013.

Year class	M	F	Total
50–54	3	24	27
55–59	9	37	46
60–64	16	49	65
65–69	10	68	78
70–74	14	68	82
75–79	18	138	156
80–84	25	134	159
≥85	14	114	128
Total	109	632	741

Table 4: Incidence of fragility fractures in patients with hypothyroidism, by sex and year class. Apulia, years 2008–2013.

Year class	M	F	Total
50–54	12	231	243
55–59	40	277	317
60–64	40	371	411
65–69	38	404	442
70–74	42	504	546
75–79	60	553	613
80–84	59	461	520
≥85	51	307	358
Total	342	3.108	3.450

to detect an incidence value of 4.5% (741). The most frequent year class was 80–84 years and gender analysis showed a higher incidence in females than in males (85% versus 15%) (Table 3).

As regards the population affected by hypothyroidism, the incidence of fragility fractures was 3.7% (3,450); the most frequent age group was 75–79 years. According to gender analysis, we found a higher incidence in females than in males (90% versus 10%) (Table 4). The incidence of pathologic fractures in patients with subclinical hypothyroidism was 2.6% (118), and in subjects with clinical hypothyroidism it was 3.8% (3,332). The most frequent year class for the former was 60–64 years and for the latter 75–79 years (Table 5). Analyzing the data of fractures regarding the site, the order of frequency did not change between the two groups (hyper- and hypothyroid) (Table 6).

Table 5: Incidence of fragility fractures in patients with hypothyroidism, subclinical and clinical, by year class. Apulia, years 2008–2013.

Year class	Subjects with subclinical hypothyroidism	Subjects with clinical hypothyroidism	Total
50–54	8	235	243
55–59	17	300	317
60–64	29	382	411
65–69	20	422	442
70–74	11	535	546
75–79	20	593	613
80–84	8	512	520
≥85	5	353	358
Total	118	3332	3450

Table 6: Percentage of fragility fractures in patients with hypothyroidism and hyperthyroidism according to the fracture site. Apulia, years 2008–2013.

Fracture side	Patients with hypothyroidism	Patients with hyperthyroidism
Femur	42.9%	55.9%
Humerus	15.2%	13.6%
Forearm	12.8%	10.1%
Lumbar spine	11.2%	9.5%
Tibial pilon	10.4%	5.3%
Dorsal spine	5.6%	4.9%
Tarsus and metatarsus	1.5%	0.5%
Sacrum spine	0.4%	0.2%

4. Discussion

The aim of our study was to determine through observation of a numerically significant sample the real influence of thyroid disease in the Apulian population affected by fragility fractures.

The relationship between hyperthyroidism and bone tissue was defined for the first time in 1890 by the author Von Recklinghausen who described the clinical history of a patient with hyperthyroidism and multiple fractures [19]. By observation of the Apulian population with hyperthyroidism, we defined a gender difference in favour of females and a higher incidence of this disease in the year class 60–64 (Table 1). In accordance with literature, we verified an increase of the incidence value in the first age classes with the maximum value in the range 60–64 [20].

The etiological relationship has been recently confirmed by several authors, who found that the secondary hyperthyroidism in Graves' disease, toxic multinodular goiter, and adenoma of Plummer may modify mineral density and increase risk fracture [21, 22].

Other studies have reported that the effects of hyperthyroidism on metabolism and bone mass are due to an imbalance between osteoblast and osteoclast activity and negative calcium intake. Imbalance causes a reduction of the remodeling process and decreases osteogenesis [23]; negative calcium intake is responsible for decreasing PTH and so modifying the hydroxylation of vitamin D [24].

As for the sample of subjects affected by hypothyroidism, in the period of observation, we found a higher number of subjects than those with hyperthyroidism (92,341 versus 16,636). Also in this case, the females were the most represented (84%), and regarding age, the highest number of cases was in the 55–59 years of age class and so younger than patients with hyperthyroidism, in accordance with the literature [25] (Table 2).

In literature the relationship between hypothyroidism and fragility fracture is not well defined. The role of TSH is controversial; in fact different authors report contradictory effects on bone tissue. In the congenital hypothyroidism, there emerged a decrease in bone development and thyroid hormone administration increased bone ingrowth and mineral density [26, 27]. In other studies, the effects of hormone replacement therapy are contradictory [16, 28].

It is important to distinguish subclinical hypothyroidism and clinical hypothyroidism since in the latter, the subject is under hormone replacement treatment.

Furthermore, we assessed the relationship between thyroid disease and fragility fractures. In the subjects with hyperthyroidism, the incidence of fractures was 4.5%. The gender most represented was the female (Table 3). According to the data of literature we confirm the increased risk of fragility fractures in patients with hyperthyroidism [5]. Moreover in our study we confirm a gender difference in favour of females (Table 3).

As for the sample of the subjects with hypothyroidism, we verified a higher incidence of fractures in the subjects with clinical hypothyroidism with respect to subjects with subclinical hypothyroidism. This value was 3.8% versus 2.6%, respectively. In consideration of the limited difference between the two values, one might believe that this difference is not important; instead by careful analysis there emerged a high difference, in terms of sample number, between two groups. The group of subjects with clinical hypothyroidism is greater than the group with subclinical hypothyroidism (3,332 versus 118) (Table 5).

In the literature, it is reported that, in the presence of high values of TSH (condition of hypothyroidism) or in cases of suppressed TSH (condition of hypothyroidism in treatment), there is an increased risk of fragility fractures [29]. From the data of our study, in consideration of the differences, in terms of increased incidence of fragility fractures in patients with clinical hypothyroidism compared to subclinical, we highlight the importance of the role of hormone replacement therapy. In fact, we may correlate the action of substitution treatment to the increased incidence of fractures and reduced importance of TSH. From our study, there emerged a direct relationship between hyperthyroidism and fragility fractures, confirming the different works in the bibliography; also for the sample of hypothyroidism, there emerged a direct correlation between hypothyroidism and fragility fractures. The authors believe the latter may be due to the lack of screening of osteoporosis in subjects with hypothyroidism. Indeed, while on the one hand, the increased risk of osteoporosis and fragility fractures in the patients with hyperthyroidism is known and for this reason the patients are screened, on the other hand the data in the literature are not yet clear and well defined for subjects with hypothyroidism. As emerged from the observation of our results, the subjects with hypothyroidism are nevertheless affected by fragility fractures. For this reason they should be considered affected by osteoporosis but not under treatment.

The observation of the fracture sites, in both samples, did not show any difference. Moreover the authors found the same order of fracture sites and that the femur represents the main site of fragility fractures in terms of statistical results for both groups.

5. Conclusion

Our study is the first that defines the prevalence of fragility fractures in relation to thyroid disease in a population of the same geographical area. The authors, by reaching the main objective and the observation of the Apulian population, confirm the role of thyroid disease as a risk factor in the onset of fragility fractures.

The data confirmed the increased risk of fragility fractures in the population affected by hyperthyroidism and hypothyroidism under treatment. The data also confirm that, besides TSH, hormone replacement therapy also plays an important role in inducing the alterations in bone mineral density. Furthermore, we define an increased risk of fragility fractures in hypothyroidism under treatment. The latter data were interpreted considering the hypothyroid patients with fragility fractures as subjects never screened for osteoporosis and thus affected by osteoporosis but never treated. In consideration of this, it is important to consider also the subjects with hypothyroidism have a risk for the onset of osteoporosis and therefore should be introduced to the diagnostic iter for osteoporotic disease.

Competing Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

[1] J.-Y. Reginster and N. Burlet, "Osteoporosis: a still increasing prevalence," *Bone*, vol. 38, no. 2, pp. S4–S9, 2006.

[2] P. Piscitelli, G. Iolascon, F. Gimigliano et al., "Incidence and costs of hip fractures compared to acute myocardial infarction in the Italian population: a 4-year survey," *Osteoporosis International*, vol. 18, no. 2, pp. 211–219, 2007.

[3] National Osteoporosis Foundation (NOF), *America's Bone Health: The State of Osteoporosis and Low Bone Mass in Our Nation*, National Osteoporosis Foundation, Washington, DC, USA, 2002.

[4] J. A. Kanis, N. Burlet, C. Cooper et al., "European guidance for the diagnosis and management of osteoporosis in postmenopausal women," *Osteoporosis International*, vol. 19, no. 4, pp. 399–428, 2008.

[5] P. Vestergaard and L. Mosekilde, "Hyperthyroidism, bone mineral, and fracture risk—a meta-analysis," *Thyroid*, vol. 13, no. 6, pp. 585–593, 2003.

[6] A. Svare, T. I. L. Nilsen, T. Bjøro, S. Forsmo, B. Schei, and A. Langhammer, "Hyperthyroid levels of TSH correlate with low bone mineral density: the HUNT 2 study," *European Journal of Endocrinology*, vol. 161, no. 5, pp. 779–786, 2009.

[7] M. D. Sarezky, D. J. Corwin, V. S. Harrison, and C. Jacobstein, "Hyperthyroidism presenting with pathologic fractures," *Pediatrics*, vol. 137, no. 2, Article ID e20150169, 2016.

[8] P. Vestergaard and L. Mosekilde, "Fractures in patients with hyperthyroidism and hypothyroidism: a nationwide follow-up study in 16,249 patients," *Thyroid*, vol. 12, no. 5, pp. 411–419, 2002.

[9] B. Abrahamsen, H. L. Jørgensen, A. S. Laulund et al., "The excess risk of major osteoporotic fractures in hypothyroidism is driven by cumulative hyperthyroid as opposed to hypothyroid time: an observational register-based time-resolved cohort analysis," *Journal of Bone and Mineral Research*, vol. 30, no. 5, pp. 898–905, 2015.

[10] M. S. Morris, "The association between serum thyroid-stimulating hormone in its reference range and bone status in postmenopausal American women," *Bone*, vol. 40, no. 4, pp. 1128–1134, 2007.

[11] J. M. Coindre, J. P. David, L. Rivière et al., "Bone loss in hypothyroidism with hormone replacement. A Histomorphometric Study," *Archives of Internal Medicine*, vol. 146, no. 1, pp. 48–53, 1986.

[12] E. Puxeddu and F. Santeusanio, "Malattie della tiroide," in *Trattato di Medicina Interna*, vol. 3 of *Malattie delle Ghiandole Endocrine, del Metabolismo e della Nutrizione*, Piccin Nuova Libraria, 2011.

[13] D. S. Ross and J. E. Muldr, "Bone disease with hyperthyroidism and thyroid hormone therapy," 2014, http://www.Uptodate.com/home/index.html.

[14] G. Martini, L. Gennari, V. De Paola et al., "The effects of recombinant TSH on bone turnover markers and serum osteoprotegerin and RANKL levels," *Thyroid*, vol. 18, no. 4, pp. 455–460, 2008.

[15] M. Devdhar, Y. H. Ousman, and K. D. Burman, "Hypothyroidism," *Endocrinology and Metabolism Clinics of North America*, vol. 36, no. 3, pp. 595–615, 2007.

[16] M. Amashukeli, E. Giorgadze, M. Tsagareli, N. Nozadze, and N. Jeiranashvili, "The impact of thyroid diseases on bone metabolism and fracture risk," *Georgian Medical News*, no. 184-185, pp. 34–39, 2010.

[17] C. A. M. Kulak and D. W. Dempster, "Bone histomorphometry: a concise review for endocrinologists and clinicians," *Arquivos Brasileiros de Endocrinologia & Metabologia*, vol. 54, no. 2, pp. 87–98, 2010.

[18] R. W. Flynn, S. R. Bonellie, R. T. Jung, T. M. MacDonald, A. D. Morris, and G. P. Leese, "Serum thyroid-stimulating hormone concentration and morbidity from cardiovascular disease and fractures in patients on long-term thyroxine therapy," *The Journal of Clinical Endocrinology and Metabolism*, vol. 95, no. 1, pp. 186–193, 2010.

[19] F. D. Von Recklinghausen, "Die Fibröse oder deformierende Ostitis, die 1," in *Osteomalazie und die Osteoplastische Carzinose in Ihren Gegenseitigen Beziehungen*, vol. 1, p. 1, Festchrift Rudolf Virchow. George Reimer, Berlin, Germany, 1891.

[20] M. P. J. Vanderpump, "The epidemiology of thyroid disease," *British Medical Bulletin*, vol. 99, no. 1, pp. 39–51, 2011.

[21] S. H. Toh, B. C. Claunch, and P. H. Brown, "Effect of hyperthyroidism and its treatment on bone mineral content," *Archives of Internal Medicine*, vol. 145, no. 5, pp. 883–886, 1985.

[22] S. Fraser, D. A. Smith, J. B. Anderson, and G. M. Wilson, "Osteoporosis and fractures following thyrotoxicosis," *The Lancet*, vol. 297, no. 7707, pp. 981–983, 1971.

[23] L. Mosekilde, E. F. Eriksen, and P. Charles, "Effects of thyroid hormones on bone and mineral metabolism," *Endocrinology and Metabolism Clinics of North America*, vol. 19, no. 1, pp. 35–63, 1990.

[24] B. Jastrup, L. Mosekilde, F. Melsen, B. Lund, B. Lund, and O. H. Sørensen, "Serum levels of vitamin D metabolites and bone remodelling in hyperthyroidism," *Metabolism*, vol. 31, no. 2, pp. 126–132, 1982.

[25] S. Kalra, A. Kumar, P. Jarhyan, and A. G. Unnikrishnan, "Indices of thyroid epidemiology," *Indian Journal of Endocrinology and Metabolism*, vol. 19, no. 6, pp. 844–847, 2015.

[26] C. J. Newland, P. G. F. Swift, and A. C. Lamont, "Congenital hypothyroidism—correlation between radiographic appearances of the knee epiphyses and biochemical data," *Postgraduate Medical Journal*, vol. 67, no. 788, pp. 553–556, 1991.

[27] J. Leger, J.-C. Ruiz, J. Guibourdenche, C. Kindermans, M. Garabedian, and P. Czernichow, "Bone mineral density and metabolism in children with congenital hypothyroidism after prolonged L-thyroxine therapy," *Acta Paediatrica*, vol. 86, no. 7, pp. 704–710, 1997.

[28] G. R. Williams, "Actions of thyroid hormones in bone," *Endokrynologia Polska*, vol. 60, no. 5, pp. 380–388, 2009.

[29] M. Karimifar, M. Karimifar, A. Salari, F. Esmaili, Z. Faragzadegan, and A. Kachuei, "Effects of Levothyroxine and thyroid stimulating hormone on bone loss in patients with primary hypothyroidism," *Journal of Research in Pharmacy Practice*, vol. 3, no. 3, pp. 83–87, 2014.