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Osteoporosis does not affect bone mineral density change in the proximal humerus or the functional outcome after open reduction and internal fixation of unilateral displaced 3- or 4-part fractures at 12-month follow-up

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Background: The aim of this prospective study was to investigate bone mineral density (BMD) changes in the proximal humerus of the shoulder during a healing period of 12 months after displaced 3- or 4-part proximal humerus fractures treated with open reduction and internal fixation (ORIF) with an anatomic angular stable locking plate and the influence on fracture healing and functional outcomes.
Methods: In a prospective multicenter study, 36 patients (29F and 7M, age range: 38-83) with unilateral displaced 3- or 4-part proximal humerus fractures were included for ORIF. Dual-energy x-ray absorptiometry for osteoporosis status was employed. Postoperative and 6-week, 3-, 6-, and 12-month shoulder radiographs and dual-energy x-ray absorptiometry of the shoulder with BMD measures in 4 templated regions of interest (ROIs) were performed. Functional outcomes, Western Ontario Osteoarthritis of the Shoulder index, Constant score, visual analog scale pain (VAS), and 36-Item Short Form Survey, were collected.
Results: A total of 17 of 36 patients had osteoporosis. We found no differences in BMD changes, functional outcomes, radiology, or need for revision surgery between the osteoporosis and nonosteoporosis groups. The BMD values gradually declined from baseline to 3-month follow-up in all 4 ROIs of the operated shoulders. All 4 ROIs in the operated shoulder presented with a reduction in BMD at 3, 6, and 12 months compared with baseline, whereas no significant BMD changes were seen in the healthy shoulder during the study period. The functional outcomes displayed an increase in Constant score from 3 to 12 months, but a decrease in domains of the 36-Item Short Form Survey from preinjury to 12 months (physical functioning, general health, and bodily pain). Preinjury and 12-month Western Ontario Osteoarthritis of the Shoulder index, VAS pain at rest, and VAS pain at activity were comparable.

This study was approved by the Danish Research Ethics Committee (registration no. 2006-0166) and reported to the Data Protection Agency.

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Conclusion: BMD changes appeared swiftly in the proximal humerus, after the treatment of displaced 3- or 4-part fractures with ORIF, particularly affecting the proximal diaphysis of the humerus. Shoulder function was restored to preinjury levels for most of the patients. Osteoporosis may not be regarded as a contraindication for the treatment of displaced 3- or 4-part fractures with ORIF.

Level of evidence: Level I; Prospective Cohort Design; Prognosis Study

Keywords: Proximal humerus fracture; bone mineral density; angle stable locking plate; disuse osteoporosis; disuse osteopenia; functional outcomes

Proximal humerus fractures are one of the most common fracture types. The incidence increases with low bone mineral density (BMD), which is why women are more often affected than men.[3,4,13,22,24] Osteoporotic proximal humerus fractures account for approximately 250,000 fractures per year in Europe alone, constituting a sizeable burden for the health care system.[18]

Open reduction and internal fixation (ORIF) using an angular stable locking plate is a popular surgical treatment option for proximal humerus fractures because its design accounts for poor bone quality by providing screws pointing in different directions offering a strong bone fixation.[31] Sufficient fracture reduction and fixation is key to reducing the risk of hardware complications; however, osteoporotic fractures complicate surgical fixation because of their nature of comminution and fragile bone, which may influence the outcome.[3,6,16,24,28] Further, tendon sutures fixed to the plate reduce the tension on the bone fragments. Loss of fracture reduction is a dynamic process in the healing period and may partly be explained by the local disuse osteopenia/osteoporosis and stress shielding that is induced by insertion of an implant.[11] Loss of fracture reduction has previously been correlated with impaired postoperative shoulder function.[1,5] Little is known about changes in BMD during the healing period after ORIF with an angular stable locking plate. In addition to bone healing and complications, outcomes that matter to patients such as pain, shoulder function, and quality of life should be evaluated.

The aim of this prospective study was to investigate BMD changes in the proximal humerus during a healing period of 12 months after displaced 3- or 4-part proximal humerus fractures treated with ORIF and the influence on fracture healing and functional outcomes.

Materials and methods

This prospective multicenter study performed in 3 regional hospitals in the Central Denmark Region, Denmark. The Helsinki 2 declaration was followed. Oral and written informed consent was obtained from all patients.

Between February 2012 and October 2015, patients with radiologically confirmed displaced 3- or 4-part proximal humerus fractures according to the Neer classification were included.[25] Inclusion criteria were age between 18 and 85 years, and a preinjury well-functioning shoulder. Exclusion criteria included the decision for surgical treatment that was not ORIF, for example, shoulder arthroplasty, and complicating circumstances that might affect healing or postoperative events such as simultaneous fractures, systemic corticosteroid treatment, or inability to participate in postoperative rehabilitation. A cohort of 36 patients was included.

Surgical technique

All patients were treated with the Winsta proximal humerus angular stable locking plate (Marquardt Medizintechnik, Spaichingen, Germany), which is a preshaped thin and elastic titanium plate with the option of placing screws at different angles allowing stable fracture fixation (Fig. 1).

The surgeries were performed by 5 experienced shoulder surgeons, with the patient under general anesthesia in a beach chair position. Prophylactic cefuroxime 1.5 g as a single dose was administered intravenously before surgery. A deltopectoral approach was used, and the fracture was disimpacted and reduced with the aid of fluoroscopy. Nonabsorbable suture 2-0 fiberwires (Arthrex, Naples, FL, USA) were attached to the rotator cuff tendons for tuberosity fixation. The angular stable locking plate was distally fixed with bicortical screws and proximally with locking screws. The nonabsorbable sutures were tied to the plate through suture holes. No bone transplants or bone void fillers were used. Subcutaneous tissue was closed with absorbable sutures (Vicryl 0) and the skin with nonabsorbable 3-0 nylon. Finally, the arm was placed in a fixed sling.

Rehabilitation

In the first 14 days, the arm was rested in a fixed sling and the patients were instructed in edema prophylaxis. During this period, the use of nonsteroidal anti-inflammatory drugs was not allowed. After 2 weeks, the fixed sling was replaced by an open sling (collar and cuff) and patients initiated passive motion exercises respecting pain limits. During weeks 6-12, the patients underwent physiotherapist-guided active motion exercises. After 3 months, loaded

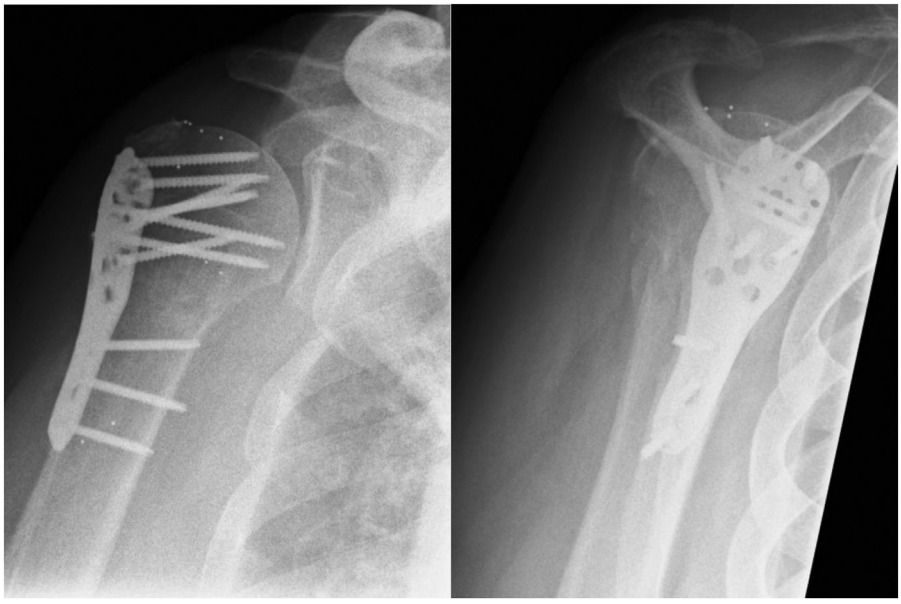

Figure 1 Representative postoperative x-rays from 1 patient demonstrating the Winsta proximal humerus angular stable locking plate.

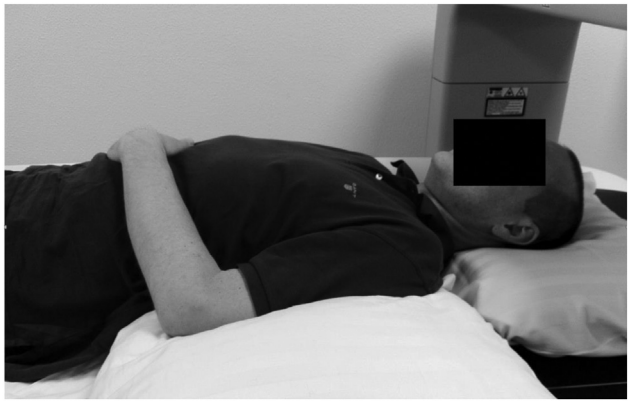

Figure 2 A comfortable position for the patient with internal shoulder rotation and flexed elbow was used for DXA scanning the proximal humerus. *DXA*, dual-energy x-ray absorptiometry.

exercises were introduced. Physiotherapist-led rehabilitation was continued until full range of motion was achieved or until it was considered that the maximum obtainable level of range of motion was reached.

Follow-up

Radiology

Preoperative standard shoulder x-ray imaging with the patient standing and a computed tomography scan of the proximal humerus were performed according to the trauma protocol. Preoperative, postoperative, and 12-month x-ray evaluation were conducted to assess fracture reduction and complications including humeral head necrosis, joint penetrating screws, and loss of reduction. If indicated, x-rays were subsequently available by the discretion of the treating clinician.

Other postoperative complications were looked for in the electronical medical records until 12-month follow-up.

Dual energy x-ray absorptiometry

Within 1 week from surgery (baseline) and at 6 weeks, 3, 6, and 12 months, dual-energy x-ray absorptiometry (DXA) scans (iDXA; GE Healthcare, Chicago, IL, USA) of the proximal humerus of both shoulders were performed for BMD measurement. During all scans, the operated shoulder was placed on a pillow in a comfortable and reproducible position, with the shoulder in internal rotation, the elbow flexed, and a longitudinal placement of the humerus parallel with the scanner bed (Fig. 2). The nonfractured shoulder was positioned similarly during scans. No determined software for shoulder DXA scans was available; therefore, the ''femur'' scan mode was used with settings of a thin tissue layer (7-13 cm). The scan window was 18 cm wide and 20.5 cm long. Smart scan (automatic region reduction) was enabled, allowing for similar information for dynamic tissue thresholding. The scan was started 2 cm medial to the armpit, approximately at the nipple level. It was recorded in a distal-proximal direction and stopped just after passing the acromion. Analysis of DXA scans was performed by 1 experienced technician using the enCORE software, version 16 (iDXA; GE Healthcare). When necessary, tissue label correction was performed ($<15\%$ of scans). The area near the humeral bone, including some of the scapula, was labeled as a neutral zone. The plate and screws were marked as implant and automatically removed from the measured bone area. A project specific template was designed, with 4 interconnected regions of interest

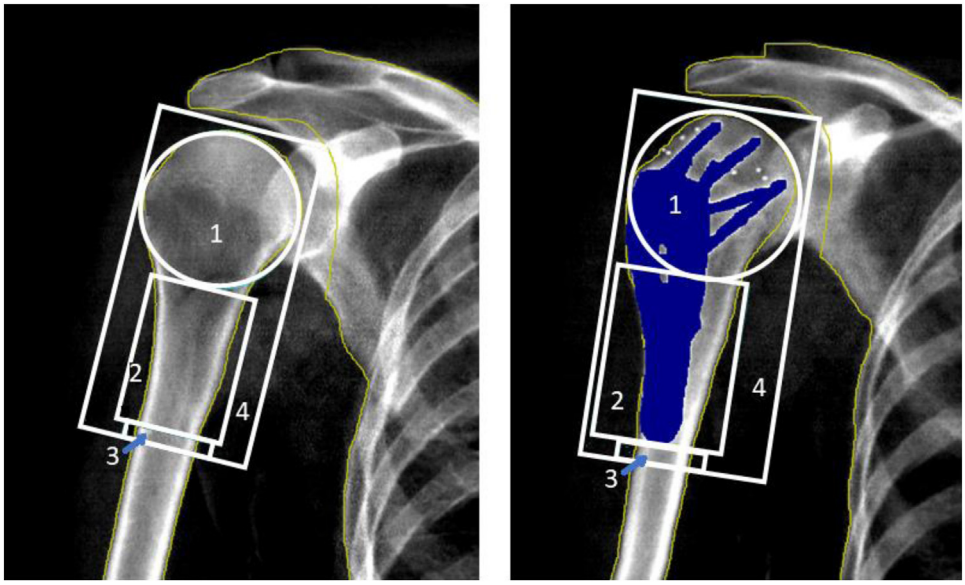

Figure 3 The 4 interconnected regions of interest (ROIs) marked in a healthy shoulder (*left*) and an operated shoulder (*right*). The metal in the plate and screws was marked and subtracted from the BMD measurement. ROI 1 was circular and included the humeral head. ROI 2 was square and included the metaphysis from the lower border of the humeral head to the lower end of the angular stable locking plate and was the same length in the healthy contralateral shoulder. ROI 3 was a narrow square box distal to the angular stable locking plate. ROI 4 was a box that included all of ROIs 1-3. *BMD*, bone mineral density.

Table I Patient demographics

Age, mean (range)	63 (38-83)
Sex	29F, 7M
BMI, mean (SD)	23.2 (4.6)
Operated side	15 dxt, 21 sin

BMI, body mass index; *SD*, standard deviation; *dxt*, dexter (right); *sin*, sinister (left).

(ROIs): ROI 1, humeral head; ROI 2, metaphysis; ROI 3, diaphysis distal to plate; and ROI 4, total (Fig. 3). These were manually placed on the first scan and then copied to successive scans including the outline of the bone border, where overlay of the bone borders minimized variation of template placement.

At the 6-month follow-up, double DXA scans were performed with reposition of the patient in between scans in order to assess the combined precision error of the scan, the patient positioning, and the manual image analysis.

T-score

At 3-month follow-up, all patients had a dual-hip and lumbar spine DXA scan to assess T-score for WHO grading of bone quality as normal, osteopenia, or osteoporosis.[17] If a patient met the criteria for osteoporosis (T-score ≤ -2.5 standard deviation [SD]), they were referred to a medical follow-up for treatment. Patients with osteopenia were recommended oral supplement of calcium and vitamin D. Bone quality grading was performed at 3 months, as this was not a part of the primary end point.

Functional outcomes

Four questionnaires were used: (1) The Western Ontario Osteoarthritis of the Shoulder index (WOOS) measures quality of life and is specific for shoulder pathology: it focuses on physical symptoms, sport/recreation/work function, lifestyle function, and emotional function. It consists of 19 questions, answered using a visual analog scale (VAS) with a possible score range from 0 to 100, resulting in a total score range from 0 to 1900 (0 = best). A Danish validated version of WOOS was used, and the score was normalized to 0-100 (100 = best).[20,23] (2) The Constant score (CS) measures shoulder pain, motion, strength, and function and is divided into a subjective part including daily activities and an objective clinical part, ensuing a score range from 0 to 100 (100 = best).[19] (3) VAS for measuring general shoulder pain intensity in activity and at rest.[15] (4) The 36-Item Short Form Survey (SF-36) is a generic questionnaire measuring 8 scales ranging from functional ability and well-being to the overall health, resulting in 2 concepts measured: physical and mental component score.[14] On admission and before surgical treatment, all patients completed questionnaires for a subjective assessment of their preinjury shoulder function (WOOS, VAS, and SF-36). On all follow-up occasions, the questionnaires were repeated, supplemented with CS at 3, 6, and 12 months.

Statistical analyses

Normality of data was assessed using quantile-quantile plots. We grouped patients as either osteoporotic or

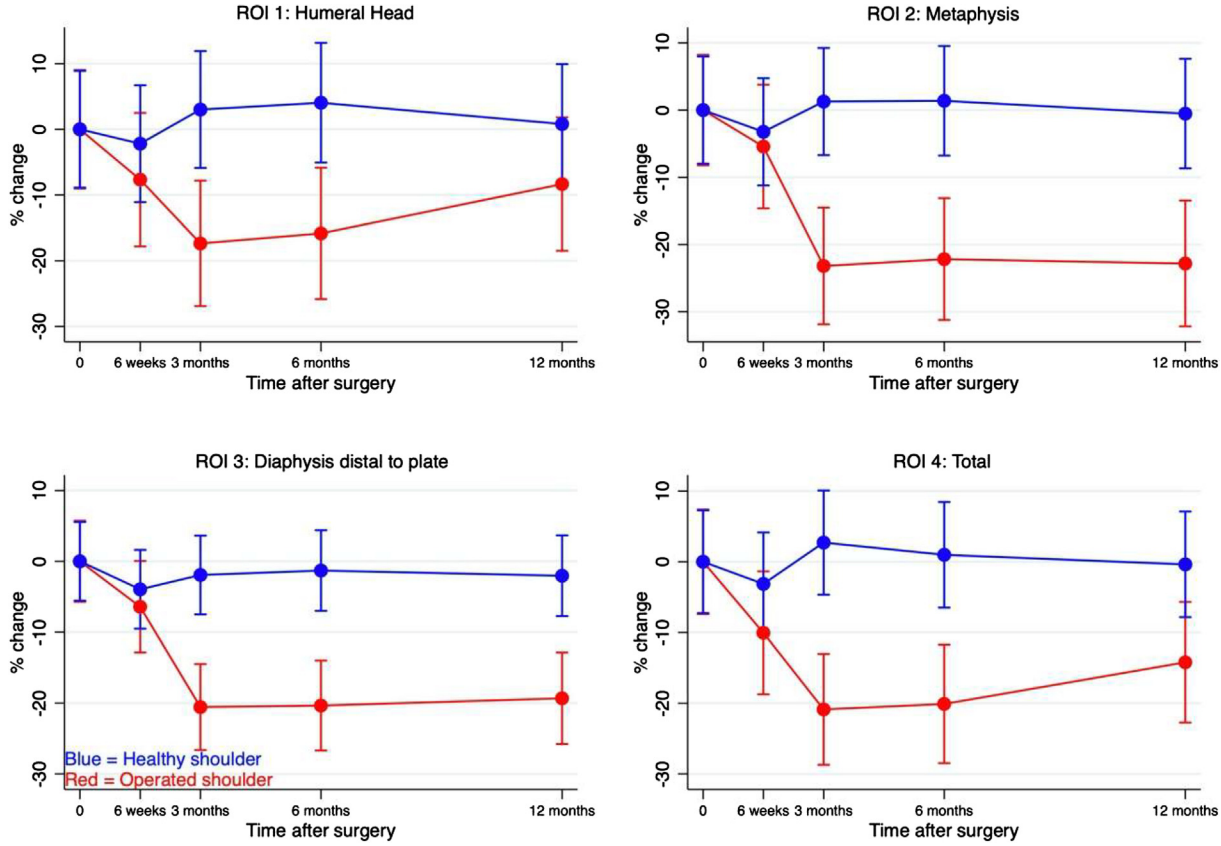

Figure 4 Mean % BMD change in ROIs 1-4 for both the operated (*red*) and healthy (*blue*) shoulder. The bars represent 95% confidence intervals. *BMD*, bone mineral density; *ROI*, region of interest.

nonosteoporotic based on the T-score limit of −2.5 SD and tested for group differences. Mixed model analysis was used to assess the WOOS point change and BMD % change at all follow-ups. WOOS or BMD was modeled as the dependent variable, with T-score ≤ -2.5 as an independent variable. Mixed model data distribution assumptions were controlled using model residual quantile-quantile plots and residuals vs. fitted plots. If no between-group difference was found, the osteoporotic and nonosteoporotic groups were pooled for further analysis. We conducted an analysis of the method precision by a 6-month double DXA scanning at each of the 4 ROIs for both the operated and the healthy control shoulder. These are presented using % mean difference, % SD, % min and % max, and coefficient of variation (%SD difference/% mean difference).

The change in the subscales of SF-36 and VAS measured shoulder pain from baseline to 12 months postoperatively was analyzed using the Wilcoxon signed-rank test. CS changes from 3 to 12 months postoperatively were analyzed using the paired *t*-test.

The statistical analyses were performed using STATA, Version 15 IC (Stata Corp., College Station, TX, USA), with a significance level of .05.

Results

A total of 36 patients (29F, age range: 39-83; and 7M, age range: 38-72) were included. Patient demographics are provided in Table I.

Bone mineral density

A total of 17 patients (14F and 3M, age range: 56-83 [5 patients <65 years], mean [SD] body mass index: 25.7 [3.3]) were diagnosed with osteoporosis (mean [SD] T-score: −3.4 [0.9] at 3-month follow-up), and 19 patients (15F and 4M, age range: 39-75 [11 patients <65 years], mean [SD] body mass index: 21.0 [4.6]) were non-osteoporotic (mean [SD] T-score: −1.5 [0.7] at 3-month follow-up). There was no difference in BMD % changes until 12-month follow-up of the fractured proximal humerus between the osteoporosis and nonosteoporosis groups, and all patients were therefore pooled for further analysis.

For the operated shoulders

The BMD values gradually declined from baseline to 3-month follow-up in all 4 ROIs. At 6 weeks, ROI 4 (total)

Table II Method precision at the 6-month double DXA scanning

	ROI 1 humeral head	ROI 2 metaphysis	ROI 3 diaphysis distal to plate	ROI 4 total
Operated shoulder				
Mean (%)	6.6	9.4	9.9	7.2
Std. dev. (%)	33.3	31.9	25.9	30.4
Minimum (%)	−40.0	−33.8	−21.7	−35.3
Maximum (%)	109.5	106.6	104.5	84.5
Coefficient of variation (%)	5.0	3.4	2.6	4.2
Healthy shoulder				
Mean (%)	2.9	3.8	1.4	3.1
Std. dev. (%)	27.2	28.9	20.4	26.1
Minimum (%)	−58.5	−50.1	−39.4	−54.2
Maximum (%)	103.2	136.3	88.0	113.6
Coefficient of variation (%)	9.4	7.6	1.5	8.4

DXA, dual-energy x-ray absorptiometry; *ROI*, region of interest; *Std. dev.*, standard deviation.
Percentage mean difference, standard deviation, minimum difference, and maximum difference between 2 DXA bone mineral density measurements in the 4 ROIs.

Table III Reported mean (95% CI) for WOOS, Constant scores, VAS rest, and VAS activity at preinjury, and 6 weeks, 3, 6, and 12 months postoperatively

	Preinjury	6 weeks	3 months	6 months	12 months
WOOS, mean (CI 95%)*	81.7 (68.5-94.9)	51.6 (44.7-58.6)	66.0 (57.5-74.5)	75.4 (67.2-83.6)	78.6 (70.2-87.0)
Constant score†	–	–	43.8 (39.2-48.3)	55.3 (49.0-61.6)	63.2 (58.0-68.5)
VAS rest, mean (CI 95%)	10.8 (1.7-19.9)	20.9 (8.8-3.3)	20.7 (12.6-28.8)	11.5 (4.7-18.3)	14.0 (4.3-23.6)
VAS activity, mean (CI 95%)	20.3 (4.7-35.9)	45.3 (32.1-58.5)	38.6 (26.8-50.3)	27.9 (17.7-38.0)	25.7 (12.0-39.4)

CI, confidence interval; *WOOS*, Western Ontario Osteoarthritis of the Shoulder index; *VAS*, visual analog scale.
* WOOS different at 6 weeks and 3 months from preinjury ($P \leq .001$).
† Constant score increase from 3 months to 12 months ($P < .001$).

displayed a BMD reduction of −10.0% (95% confidence interval: −19.9; −0.17) compared with baseline ($P = .046$). From 6 weeks to 3 months, there was a BMD reduction in the range between −9.7% and −17.8% for all 4 ROIs ($P < .05$). The BMD loss ceased after the initiation of loaded shoulder rehabilitation 3 months after surgery. All 4 ROIs displayed a BMD reduction at 3, 6, and 12 months as compared with baseline ($P < .05$) (Fig. 4).

For the healthy shoulders

No significant changes in BMD were seen during the 12-month study period (Fig. 4).

Coefficient of variation range of the double DXA scans/measurements at 6 months was 1.5%-9.4% (Table II).

Functional outcomes

Reply rates were 96% for WOOS, 97% for CS, 84% for VAS, and 90% for SF-36. There were no differences in the functional outcomes between the osteoporosis and non-osteoporosis groups, and all patients were therefore pooled for further analysis. Reported mean (95% confidence interval) WOOS, CS, VAS rest, and VAS activity at preinjury, 6 weeks, 3, 6, and 12 months postoperatively are presented in Table III. WOOS displayed an increase from preinjury to 6 weeks and 3 months ($P \leq .001$), but returned to preinjury levels at 6 months and 12 months (Fig. 5). The mean CS increased from 3 months to 12 months ($P < .001$). VAS rest and activity mean scores reported a small, albeit statistically insignificant increase in pain from preinjury to 12 months. SF-36 comparisons between preinjury, at 12-month follow-up, and full health are depicted in Fig. 6, displaying a decrease in physical functioning, general health, and bodily pain from preinjury to 12 months ($P < .03$).

Radiology

Descriptive preoperative and postoperative x-ray measurements are reported in Table IV. Four patients were varus impacted postoperatively.

Complications

Within 12-month follow-up, 5 patients experienced complications that required additional surgery. Two patients had

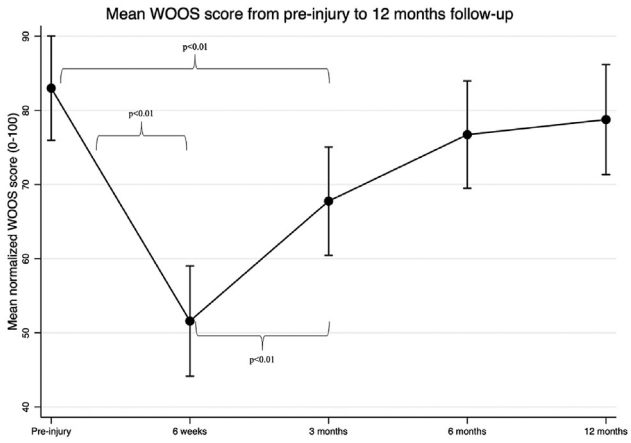

Figure 5 Mean WOOS score from preinjury to 12-month follow-up. The bars represent 95% confidence intervals. *WOOS*, Western Ontario Osteoarthritis of the Shoulder index.

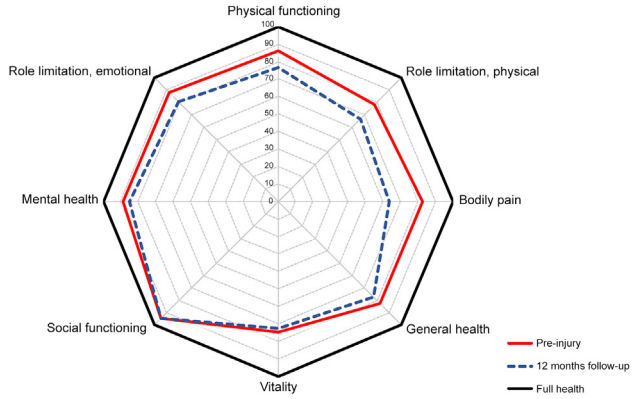

Figure 6 SF-36 preinjury at 12-month follow-up compared with preinjury. Physical functioning, general health, and bodily pain were different at 12-month follow-up compared with preinjury ($P < .03$). *SF-36*, 36-Item Short Form Survey.

the plate removed after 6 and 7 months due to humeral head necrosis and subacromial impingement, respectively. Three patients had pain associated with a joint penetrating screw and had each one screw removed at 6 weeks, 7 weeks, and 6 months, respectively. Excluding the patient with humeral head necrosis, the remaining 4 patients requiring additional surgery displayed no difference in any of the investigated functional outcomes in comparison to the remaining cohort at 12-month follow-up. The mean number of inserted locking screws in the humeral head was 5.9 (range: 4-8). Seven patients had a minimum of 1 joint penetrating screw displayed at minimum 1 follow-up occasion. No associations between osteoporosis, postoperative varus impaction, and hardware removal or screw penetration were found. No infections were encountered in any of the patients at 12-month follow-up. All fractures were radiographically healed at the final follow-up, and none of the fractures showed major loss of reduction, except for the 1 patient with humeral head necrosis. No patients were lost to follow-up.

Discussion

In this prospective multicenter study, we found no differences between osteoporotic and nonosteoporotic patients in local shoulder BMD changes and functional outcomes during a healing period of 12 months after displaced 3- or 4-part proximal humerus fractures were treated with ORIF. The BMD values gradually declined from baseline to 3-month follow-up in all 4 ROIs of the operated shoulders. All 4 ROIs presented with a significant reduction in BMD at 3, 6, and 12 months compared with baseline, whereas no significant BMD changes were seen in the healthy shoulder during the study period. The functional outcomes displayed an increase in CS score from 3 to 12 months, but a decrease in elements of SF-36 from preinjury to 12 months (physical functioning, general health, and bodily pain). Preinjury and 12-month WOOS, VAS pain at rest, and VAS pain at activity were comparable.

Osteopenia and osteoporosis are determined by measurements of low BMD and indicate weakened bone microarchitecture and increased risk of fragility fractures.[7,8] Moreover, low BMD may complicate fracture reduction,[10] and biomechanical studies have previously suggested that local disuse osteopenia/osteoporosis results in reduced fracture and screw fixation.[12,32] However, this correlation has not been shown in clinical studies[12,21] and consistently not found in our study as no associations between osteoporosis and hardware removal or screw penetration were found. Bone mineral resorption and formation is balanced through a net exposure of bone loading such as muscle contractions and physical activity of a functional limb.[7] Upper limb sparing with other injuries than fractures, for example, isolated rotator cuff tears, also leads to a decrease in BMD in the proximal humerus.[26] The presented BMD reductions in all 4 ROIs during 3 months of immobilization of the operated shoulder were therefore merely expected rather than surprising. Interestingly, the largest decreases in BMD at 3 months were found in the humerus diaphysis from the lower border of the humeral head to the lower end of the angular stable locking plate (ROI 2) and just distal to the angular stable locking plate (ROI 3). This decrease may be explained by local stress shielding induced by the angular stable locking plate through a load shift away from the bone. At 3 months, with the initiation of loaded shoulder rehabilitation, the BMD loss ceased, positively correlating supervised active and increasingly loaded rehabilitation of the shoulder with maintained or increased BMD in the proximal humerus. However, the BMD did not return to baseline levels at 12-month follow-up. All patients meeting the criteria for osteoporosis on a DXA scan of systemic BMD at 3-month follow-up were referred to a medical follow-up for osteoporosis treatment.

Table IV Descriptive preoperative and postoperative radiographical x-rays measurements

Preoperative: 36 patients	
Fracture type	
3-part fracture	33
4-part fracture	3
Head-shaft displacement	
<50%	33
≥50%	3
Inclination AP	
Valgus impacted	23
Varus impacted	11
Neutral (135° ± 10°)	2
Inclination scapula-Y	
<45°	20
≥45°	16
Postoperative: 36 patients	
Inclination AP	
Valgus impacted	1
Varus impacted	4
Neutral (135° ± 10°)	31
Inclination scapula-Y	
<45°	28
≥45°	8

AP, anteroposterior.

Although bone antiresorptive medical treatment for osteoporosis introduced a possible bias in the following BMD evaluations in comparison to the nonosteoporotic group, this approach was applied for ethical reasons and because it is the clinical standard.

The postoperative rehabilitation may be affected by various factors, including shoulder pain, which may relate to fracture complexity and soft tissue damage including rotator cuff tears.[2] Simultaneous injuries may increase the likelihood of sparing the affected shoulder, directly leading to risk of further BMD loss. We observed a decrease in SF-36 elements (physical functioning, general health, and bodily pain) along with an increase in VAS shoulder pain score at rest/activity during the first 3 months, which support that the BMD loss was related to reduced physical activity and shoulder pain. At 12 months, WOOS and VAS shoulder pain at rest/activity were not different from preinjury. CS steadily increased from 3 to 12 months. Interestingly, the 2 subjective specific shoulder assessments (WOOS and CS) did not directly correlate with the SF-36. Overall, the presented functional outcomes indicate that shoulder function returned to preinjury levels for most of the patients during this follow-up period.

Secondary surgery with plate or screw removal was performed in 14% of the patients (n = 5), which is lower than the reported reoperation rate of 28%-30% in studies of comparable proximal humerus fractures treated with locking plate applications.[9,27] Importantly, follow-up times are different (12 months in the present study vs. mean 36-42 months in the reported studies). Moreover, the patient groups (age, sex, trauma, and bone quality) are rather heterogeneous, and the indication for use of locking plates for proximal humerus fractures is wide, which all may contribute to these differences. The cause for secondary surgeries in the present study were mechanical issues related to the osteosynthesis only within the first 12 months, that is, screw penetration and 1 humeral head necrosis (no infection encountered), and were not associated with osteoporosis.

This study has several limitations. The included patients represented a heterogeneous and genuine cohort of patients with displaced 3- or 4-part proximal humerus fractures operated at 3 different centers by 5 different surgeons, in which ORIF was considered the best treatment option. As such, our results should be generalizable to most institutions. Moreover, the follow-up time of 12 months limits any evaluation of late complications. We found no difference in BMD changes, complications, or hardware failures between the osteoporosis and nonosteoporosis groups, and in spite of an even group distribution, our study population may have been too small to exploit any true differences. We included no control group of conservatively treated displaced 3- or 4-part proximal humerus fractures, limiting any evaluation of the sole influence of ORIF surgery on the BMD outcome. Also, a less restrictive rehabilitation program may have affected the functional outcomes and postoperative BMD changes. The applied functional outcomes were not able to assess how the patients changed their normal postoperative daily activities. Another questionnaire, interview, or application of an activity monitor (on both upper and lower extremity) might have addressed this issue. Finally, although comparable to a previous study on humeral head resurfacing arthroplasty,[29] the method precision at the 6-month double DXA scanning demonstrated that reproducible positioning of an operated upper extremity is more challenging than for lower extremities.[30] This calls for further standardization of patient position and maybe user of specific positioners in future studies.

Conclusion

BMD changes appeared swiftly in the proximal humerus after treatment of displaced 3- or 4-part fractures with ORIF, particularly affecting the proximal diaphysis of the humerus. BMD changes followed the amount of load strain of the operated shoulder during postoperative rehabilitation but did not return to baseline level at 12-month follow-up. Preinjury and 12-month WOOS and VAS shoulder pain at rest and activity were comparable, suggesting return of preinjury shoulder functions for most of the patients. In the present study, osteoporosis at

the time of surgery and the subsequent loss of local BMD in the proximal humerus after surgery and immobilization did not affect the failure risk or functional outcomes after treatment of displaced 3- or 4-part fractures with ORIF. Therefore, osteoporosis may not be regarded as a contraindication for treatment of displaced 3- or 4-part fractures with ORIF.

Disclaimers:

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Conflicts of interest: The Winsta proximal humerus ASLPs by Marquardt Medizintechnik was the standard osteosynthesis plate for the proximal humerus in the department. The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2022.07.008.

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