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Original article

Risk factors for secondary displacement in conservatively treated isolated greater tuberosity fractures: An analysis of 82 cases

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ABSTRACT

Introduction: The optimal treatment of isolated fractures of the greater tuberosity is an important topic of current surgical research. While non-displaced fractures are amenable to conservative treatment, displacement of the fragment can result in rotator cuff malfunction and impingement. For the present study, risk factors predicting secondary fragment displacement were analyzed.
Hypothesis: Certain risk factors determine a higher risk of secondary displacement in patients with greater tuberosity fractures.
Patients and methods: All patients diagnosed with a fracture of the greater tuberosity and initially treated non-surgically at our Level I trauma center between January 2008 and July 2015 were included in this retrospective analysis. Patients were grouped into: no secondary displacement (group 1) and secondary displacement at follow-up (group 2). The following risk factors were analyzed: age, gender, side of fracture, initial displacement, fragment/head ratio, fragment shape, dislocation, concomitant fractures and concomitant fractures to the same extremity.
Results: 82 patients (42 male, 40 female) were eligible for further analyses. Median follow-up was 8.0 ± 39.5 days. Patients with secondary displacement (group 2) were significantly older (group 1: 51.7 ± 15.5, group 2: 68.3 ± 14.3; $p < 0.001$) and had significantly more shoulder dislocations ($p = 0.024$), whereas gender ($p = 0.299$), side of fracture ($p = 0.189$) and fragment/head ratio ($p = 0.660$) showed no significant different distribution between both groups. Finally, split-type fractures increased the risk of secondary displacement.
Discussion: The present study identified age older than 65 years to be an important risk factor for secondary displacement in the conservative management of fractures of the greater tuberosity. Furthermore, fracture type and shoulder dislocations are factors associated with an increased relative risk for secondary displacement.
Level of proof: III, Retrospective comparative study.

1. Introduction

Isolated fractures of the greater tuberosity and their optimal treatment have seen an increase in clinical and scientific interest [1,2]. While they only represent 20% of all proximal humeral fractures, their clinical relevance is immense since the greater tuberosity is the insertion site of the rotator cuff [3] and current research has reported a high rate of concomitant soft tissue pathologies [2]. Furthermore, a percentage of cases of anterior shoulder dislocations is accompanied by fractures of the greater tuberosity [4]. Today, indications for surgical fixation remain to be controversial [3]. While recent guidelines recommend surgical fixation in cases with a displacement of 5 mm and more [5], there is a paucity of knowledge regarding the clinical course in conservatively managed patients with initial displacement of less than 5 mm. Here, the risk of secondary fragment displacement and subsequent poorer functional outcome due to delayed surgical treatment have been discussed [6].

The present study aimed to identify risk factors predicting secondary displacement in conservatively managed patients with

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isolated fractures of the greater tuberosity. We hypothesized that factors such as age, gender, fracture mechanism and fracture morphology increase the risk for secondary displacement in fractures of the greater tuberosity.

2. Patients and methods

All patients diagnosed with a fracture of the greater tuberosity at our Level I trauma center between January 2008 and July 2015 were included in this retrospective analysis. During the inclusion process all data was pseudonymized. Exclusion criteria were: nerve or vessel damage, minors, primary surgical treatment and incomplete radiologic data. The detailed inclusion and exclusion process is provided in Fig. 1. Fractures were visualized with a true a.p. radiograph standing in the upright position with an upper body rotation of 45° and an axial radiograph in the lying position with 90° abduction. In cases with a shoulder dislocation, repositioning was performed using the technique according to Arlt and the radiographs were repeated [7]. All radiographs were analyzed in a.p. view by 2 independent observers, both trauma surgeons at our centre. Displacement was measured with a protocol similar to the technique described by Foruria et al. [8]: the inferior tip of the fragment was identified. Then, the shortest distance between this tip and its origin at the humeral sheaf was measured and defined as displacement. Patients with a displacement of the fragment of more than 5 mm, which was measured directly and without calibration, were considered as primary displacement and were excluded from further analysis. Patients with less than 5 mm displacement were treated according to our standardized clinical algorithm. Conservative treatment included a three-stage concept. In the first period, the injured shoulder was immobilized in a Gilchrist sling for 3 weeks. During the second stage, pendular swinging and assisted exercises were commenced for another 3 weeks. In the third and last stage, active exercises were performed.

Patients were followed in our outpatient department and the same imaging routine was repeated. Median follow-up was 8.0 ± 39.5 days. Patients presenting with a secondary displacement of > 5 mm were treated surgically. Representative radiographs of cases with and without secondary displacement are provided in Fig. 2.

A retrospective risk factor analysis of two groups was performed: patients without secondary displacement (group 1) and patients with secondary displacement (group 2). The following risk factors were analyzed: age, gender, side of fracture, initial displacement, fragment/head ratio (measured as the maximal length of the fragment divided by the maximal length of the humeral head diameter in the a.p. radiograph by two independent observers), fragment shape as described by Mutch et al. [9] (type I – avulsion, type II – split, type III – depression), confirmed dislocation of the shoulder, concomitant fractures to the same extremity and number of concomitant fractures.

2.1. Ethics

Designed as a retrospective pseudonymized study no ethical review statement was required.

2.2. Statistics

Results were documented in an Excel database (Mircosoft Excel 2010, Microsoft, Redmont, USA). After a baseline analysis, a bivariate analysis of the dichotomous and numeric parameters was performed using IBM SPSS statistics 22 (Statistical Package for the Social Science, IBM Cooperation, Armonk, no.Y., USA). Normal distribution was evaluated by using the Kolmogorov–Smirnov test. To compare the parameters, analysis of variance (ANOVA) and Chi-square tests were used. If normal distribution was not given, Mann–Whitney-U tests were used. Relative risks were determined for factors with significantly different distributions between group 1 and 2.

Additionally, a Pearson correlation analysis was performed to assess the interrelationship between the above named risk factors and the affiliation to either group. Then, a bivariate logistic

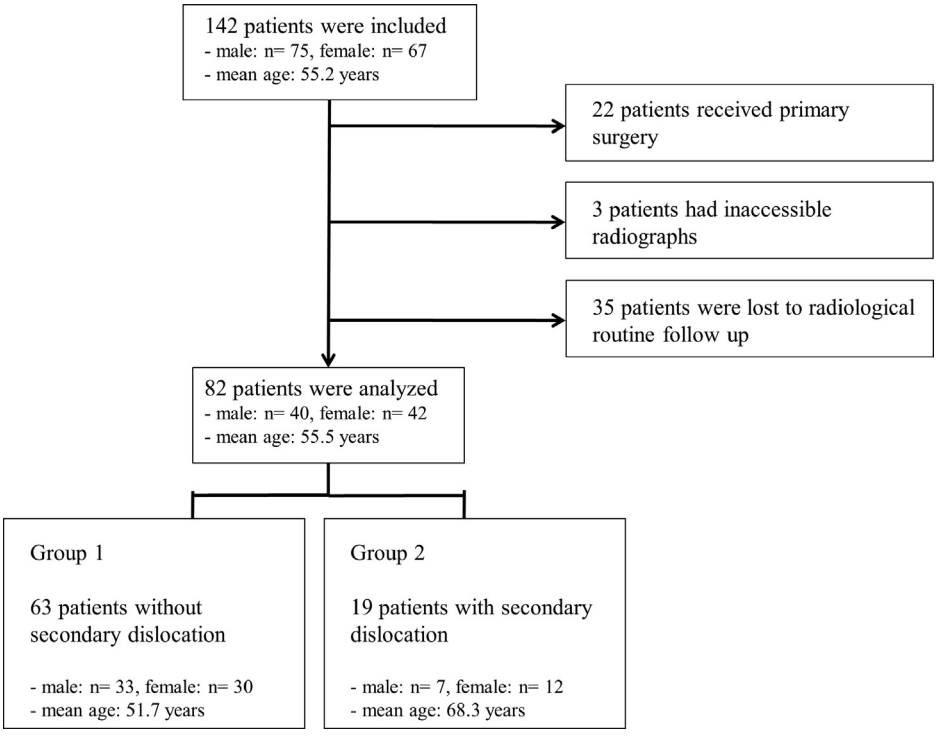

Fig. 1. Flowchart depicting the inclusion/exclusion process.

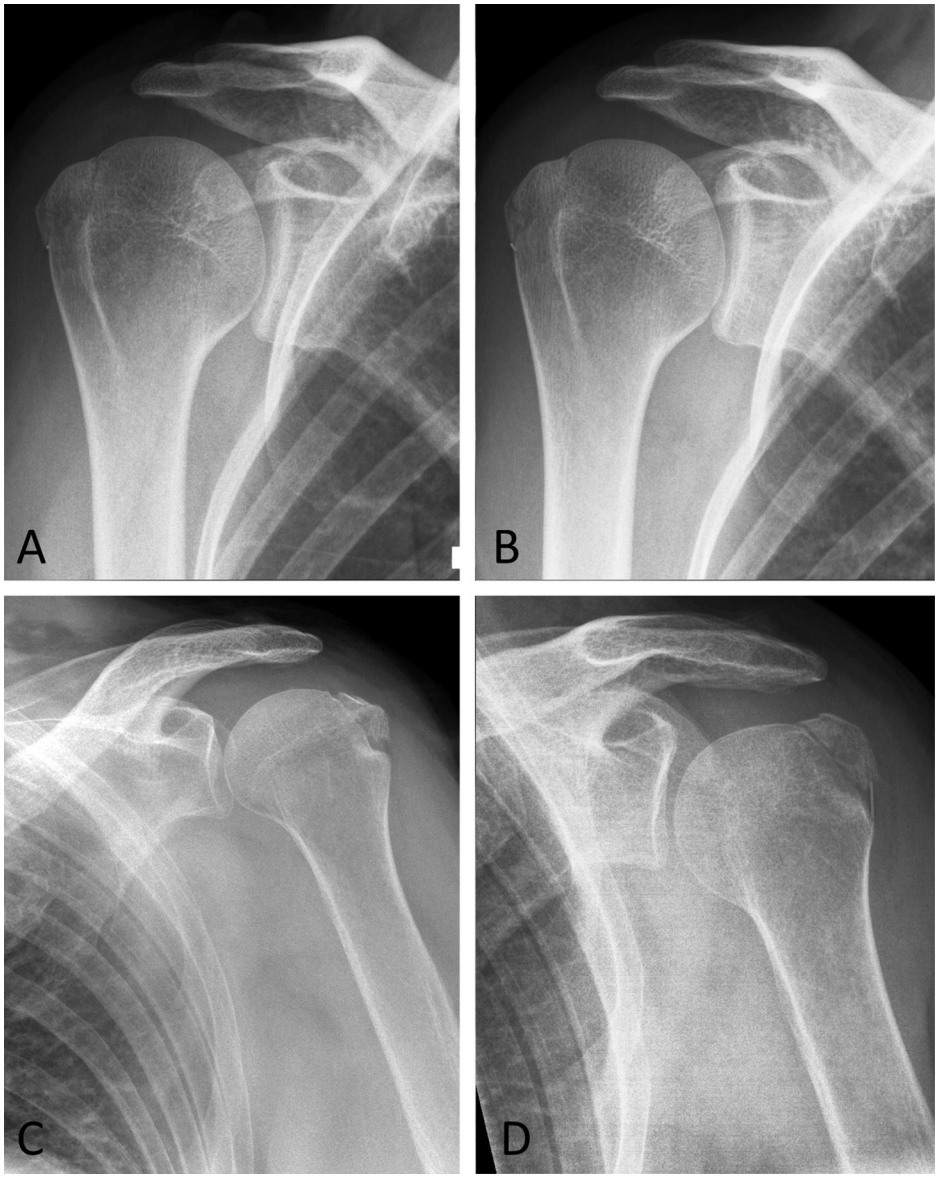

Fig. 2. Radiographs of representative cases. Posttraumatic (A) and (B) follow-up radiographs of a non-displaced case (distance: 1 mm), compared to a patient presenting with secondary displacement (distance: 7 mm) between trauma (C) and follow-up at 10 days (D).

regression was performed to evaluate the effect of the respective factors on the secondary displacement risk.

A p-value < 0.05 was considered statistically significant.

3. Results

Between January 2008 and July 2015, 142 patients presented at our trauma center with a fracture of the greater tuberosity. Sixty patients had to be excluded, resulting in 82 available cases (the detailed inclusion/exclusion process is provided in Fig. 1). Group 1 consisted of 63 patients, group 2 of 19 patients. In 4 patients included in group 2 no surgical fixation was performed due to patient's refusal ($n = 1$) or severe comorbidities. The age of patients who showed a primary displacement at first follow-up and were excluded was 64.5 ± 17.9 years and did not differ from the remaining 82 patients ($p = 0.061$). Their initial displacement was 12.4 mm ± 7.8 mm, which is significantly higher when compared to patients from group 1 and 2 ($p < 0.001$).

Displacement of the individual patients is provided in Fig. 3A–C. The Kolmogorov–Smirnov test showed no normal distribution for age ($p = 0.046$), initial displacement ($p < 0.001$), fragment/head ratio ($p < 0.001$), concomitant fractures ($p < 0.001$) and concomitant fractures to the same extremity ($p < 0.001$). Patients with secondary displacement had a higher initial displacement at first examination (group 1: 1.4 mm ± 1.5 mm; group 2: 2.6 mm ± 1.7 mm; $p = 0.007$), a significantly higher age (group 1: 51.7 ± 15.5, group 2: 68.3 ± 14.3; $p < 0.001$), whereas gender (group 1: 30 women, 33 men; group 2: 12 women, 7 men; $p = 0.299$) and fracture side (group 1: 27 left, 36 right; group 2: 12 left, 7 right; $p = 0.189$) showed no significant differences (Table 1). While, no predominant fracture pattern was observed in both groups (Mutch I: 33 in group 1, 7 in group 2, $p = 0.299$; Mutch II: 21 in group 1, 10 in group 2, $p = 0.178$, Mutch III: 9 in group 1, 2 in group 2, $p = 1.000$), an increased relative risk of secondary displacement was found for type II fractures (Table 2). Shoulder dislocation as the underlying trauma mechanism (group 1: 48 without dislocation, 15 with dislocation; group 2: 9 without dislocation, 10 with dislocation; $p = 0.024$) was seen more frequently in group 2. Patients with secondary displacement presented with an increased number of concomitant injuries ($p = 0.181$) or concomitant injuries to the same extremity ($p = 0.060$;

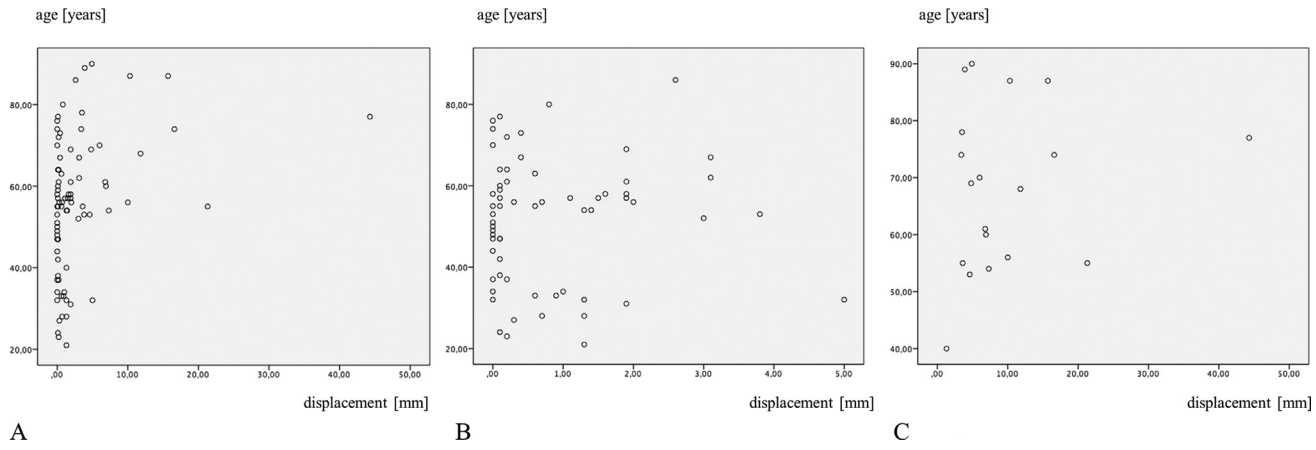

Fig. 3. Scatter plot showing dislocation [mm] depending on age [years] for all patients (A), group 1 (B) and Group 2 (C).

Table 1
Distribution of risk factors between non-displaced (group 1) and displaced (group 2) greater tuberosity fractures.

	N	Average	Standard deviation	95% confidence interval for mean		Minimum value	Maximum value
				Lower limit	Upper limit		
Age							
Group 1	63	51.67	15.50	47.76	55.57	21.00	86.00
Group 2	19	68.26	14.34	61.35	75.18	40.00	90.00
Total	82	55.51	16.71	51.84	59.18	21.00	90.00
Fragment/head ratio							
Group 1	63	0.56	0.22	0.50	0.61	0.24	1.42
Group 2	19	0.58	0.24	0.46	0.69	0.18	1.12
Total	82	0.56	0.22	0.51	0.61	0.18	1.42
Concomitant injuries							
Group 1	63	0.10	0.30	0.02	0.17	0.00	1.00
Group 2	19	0.21	0.42	0.01	0.41	0.00	1.00
Total	82	0.12	0.33	0.05	0.19	0.00	1.00
Concomitant injuries to same extremity							
Group 1	63	0.06	0.25	0.00	0.13	0.00	1.00
Group 2	19	0.21	0.42	0.01	0.41	0.00	1.00
Total	82	0.10	0.30	0.03	0.16	0.00	1.00

Table 2
Relative risks of age, fracture type and concomitant injuries for secondary displacement.

Risk factor	Relative Risk
Age > 65 years	3.75
Mutch I	0.61
Mutch II	1.83
Mutch III	0.76
Concomitant fractures	1.92
Concomitant fractures to the same extremity	2.47
Dislocation	2.53

Table 1). However, concomitant injuries to the same extremity showed a relevant increase in the relative risk. The relative risks of secondary displacement for the analyzed variables are given in Table 2.

To further evaluate the influence of the above named risk factors, the Pearson correlation coefficients (r) were evaluated and a bivariate regression analysis was performed. A strong correlation was found for age > 65 years ($r = 0.385$, $p < 0.001$) and dislocation as fracture mechanism ($r = 0.264$, $p = 0.016$), while only a weak correlation was found with fracture type (Mutch I: $r = -0.131$, $p = 0.240$; Mutch II: $r = 0.168$, $p = 0.132$; Mutch III: $r = -0.047$, $p = 0.678$), concomitant injuries ($r = 0.149$, $p = 0.183$) and concomitant injuries to same extremity ($r = 0.209$, $p = 0.059$).

The bivariate regression analysis confirmed the significant influence of age ($p = 0.022$), while dislocation as fracture mechanism did not reach significance ($p = 0.055$). Again, fracture type (Mutch I: $p = 0.239$; Mutch II: $p = 0.116$; Mutch III: $p = 1.000$), concomitant injuries ($p = 0.999$) and concomitant injuries to same extremity ($p = 0.999$) showed no significant influence on secondary displacement.

4. Discussion

The aim of this study was to identify risk factors predicting secondary fragment displacement during the non-surgical treatment of greater tuberosity fractures of the shoulder.

Fractures of the greater tuberosity can cause functional limitations due to the close anatomic relation to the rotator cuff and subacromial space [3]. Current surgical concepts include both, open surgical repair via suture or screw fixation and minimal invasive arthroscopic techniques [10]. In cases of displacement of more than 5 mm, surgical treatment has been recommended, especially in young and active patients performing overhead activities [10]. In cases with very little or even no displacement, non-surgical treatment with temporary immobilization is usually preferred [11,12]. Importantly, failure of the non-surgical treatment has been associated with poor functional outcome. In cases with osseous consolidation in malposition after secondary displacement, an impingement syndrome may develop [6,13].

Data on risk factors predicting secondary displacement of isolated greater tuberosity fractures is scarce. Be that as it may, the size of the fragment has been proposed to be a critical adverse factor, since larger fragments are expected to impinge more

easily and result in a higher mechanical strain of the abductors [6,11]. Duparc described the lack of stability of the fragment, which is indicated by secondary displacement, as a central mechanism leading to malunion; however, this observation was not specifically limited to isolated tuberosity fractures [14].

In our study, we identified higher age as the most important risk factor for secondary displacement. While a higher grade of immobilization could be expected in older patients, insufficient passive and active stabilizing mechanisms might increase the risk of secondary displacement with age. Furthermore, shoulder dislocations as the underlying trauma mechanism were more frequently observed in group 2 and showed an increased relative risk for secondary displacement of the greater tuberosity. This finding might also be explained by a general instability due to injuries to the capsula after shoulder joint dislocation facilitating unphysiological translation of the proximal humerus. This finding confirms data of Hebert-Davies et al. reporting higher rates of secondary displacement following dislocation of the shoulder [15].

In the current study, patients with concomitant injuries to the same extremity showed an increased relative risk for displacement, which was not confirmed in the Pearson correlation and regression analysis. A recent study by Muhm et al. screened the amount of concomitant injuries in greater tuberosity fractures in patients younger than 65 years. Their group found a high incidence of relevant soft tissue pathologies, especially in patients with glenohumeral dislocation [16]. This finding underlines the high impact of concomitant injuries in this fracture.

The increased relative risk as described in our work can be caused by a higher level of immobilization on the respective side, which leads to a consecutive lack of mobility and reduces the ability to participate in rehabilitation programs. This hypothesis is in line with a study by Foruria et al. demonstrating that fracture fragments in proximal humeral fractures settle under conservative treatment when using a home program of passive and active assisted range of movement exercise [8].

Fracture morphology is known to substantially influence the surgeon's decision-making [9]. Three types of fragment shapes have been described by Mutch et al. [9]. Here, avulsion type fractures (type I as described by Mutch et al.) are often caused by the same mechanism such as rotator cuff tears, causing a bony avulsion instead of a soft tissue rupture. In general, these fractures can be treated conservatively. In case of secondary displacement, the fracture can be considered as a subtype of a rotator cuff tear, and suture bridge techniques are commonly used [17]. Split-type and depression type fractures (type 2 and 3 as described by Mutch et al.) are commonly linked with glenohumeral dislocations or subluxations and further evaluation of labrum integrity, especially in younger patients has been advocated [9,11]. In the present study, split-type fractures showed an increased relative risk for failure after initial conservative treatment.

The authors are aware of the limitations of the study. The retrospective study design limits the number of analyzed risk factors. Especially for patients of group 1, longer follow-up would have been helpful. If patients did not show displacement after few days, treatment was usually continued at an ambulatory healthcare center according to our local treatment algorithm. Thus, the vast majority of patients from group 1 was not followed up at our hospital any further. However, few displacements are seen after this crucial period [18] resulting in a long-term displacement rate of only 6% [15] for patients without initial shoulder dislocation. Keeping this in mind, the authors are convinced to have covered the majority of displacements during the first 8 days.

A pre-hoc power analysis was performed upon commencing this study. Taking into account the data presented by Foruria et al. [8] for the distance between the greater tuberosity and the acromion in posteromedial impaction fractures of the proximal humerus, a power of 0.5 and a type I error rate of 10% leads to a sample size of 68 patients per group, if the sampling ratio is 1/1. To reach a power of 0.8 and a type I error rate of 5%, groups of 256 patients each are needed. This can only be achieved in large prospective trials. Second, the anatomical measurements were evaluated in a.p. radiographs. Here, the use of MRI or CT scans could have resulted in an increased precision and additional information regarding concomitant soft tissue pathologies [19]. Third, we did not evaluate the functional outcome of the analyzed cohort. Thus, the clinical consequences of the radiological displacement remain to be clarified. Finally, we are not able to report on patients' compliance and performed physical therapy.

The major strength of the study represents the relatively large cohort of patients presenting with this relative rare injury. To the best of our knowledge, this is also the first study aiming to identify the risk factors predicting the failure of the non-operative treatment of these lesions in the context of the fracture morphology. Finally, a thorough statistical analysis was performed, including the calculation of relative risks and subgroup specific differences. For a multivariate analysis, a logistic regression was carried out. Although this analysis has limited usability due to the sample size, it still adds helpful information to our work. To fully address the problem of secondary displacement, as mentioned above, conducting a prospective study with a large cohort and a consecutive logistic regression might be considered. But in the current retrospective design of this study, we see the logistic regression as a positive addition, even with the small cohort.

5. Conclusion

The present study identified age of more than 65 years as an important risk factor for secondary displacement in the conservative management of fractures of the greater tuberosity. Thus, the initial hypothesis of our study could be proven. Furthermore, fracture type and shoulder joint dislocations were factors associated with show increased relative risks for secondary fragment displacement.

Disclosure of interest

CK Boese is employee of Smith & Nephew GmbH Germany, is consulting for Medicad HecTec GmbH and may be eligible for royalties in the future. The other authors declare that they have no competing interest.

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None.

Authors' contribution

Benjamin Bockmann designed the study, collected data, analyzed and interpreted data, and prepared the manuscript.

Philipp Lechler designed the study, analyzed and interpreted data, and revised the manuscript.

Christoph K Boese designed the study, analyzed and interpreted data and revised the manuscript.

Rene Aigner collected data, analyzed and interpreted data, and revised the manuscript.

Steffen Ruchholtz designed the study and revised the manuscript.

Michael Frink designed the study, analyzed and interpreted data, and prepared the manuscript.

References

[1] Gillespie RJ, Johnston PS, Gordon VA, Ward PJ, Getz CL. Using plate osteosynthesis to treat isolated greater tuberosity fractures. Am J Orthop 2015;44:E248–51.
[2] Maman E, Dolkart O, Chechik O, Amar E, Rak O, Rath E, et al. Arthroscopic findings of coexisting lesions with greater tuberosity fractures. Orthopedics 2014;37:e272–7.
[3] Gruson KI, Ruchelsman DE, Tejwani NC. Isolated tuberosity fractures of the proximal humeral: current concepts. Injury 2008;39:284–98.
[4] Atef A, El-Tantawy A, Gad H, Hefeda M. Prevalence of associated injuries after anterior shoulder dislocation: a prospective study. Int Orthop 2016;40:519–24.
[5] DeBottis D, Anavian J, Green A. Surgical management of isolated greater tuberosity fractures of the proximal humerus. Orthop Clin North Am 2014;45:207–18.
[6] Bono CM, Renard R, Levine RG, Levy AS. Effect of displacement of fractures of the greater tuberosity on the mechanics of the shoulder. J Bone Joint Surg Br 2001;83:1056–62.
[7] Mordeja J. The reposition of shoulder dislocation, according to v Arlt. Z Orthop Ihre Grenzgeb 1968;104:161–75.
[8] Foruria AM, Marti M, Sanchez-Sotelo J. Proximal humeral fractures treated conservatively settle during fracture healing. J Orthop Trauma 2015;29:e24–30.
[9] Mutch J, Laflamme GY, Hagemeister N, Cikes A, Rouleau DM. A new morphological classification for greater tuberosity fractures of the proximal humerus: validation and clinical implications. Bone Joint J 2014;96–b:646–51.
[10] George MS. Fractures of the greater tuberosity of the humerus. J Am Acad Orthop Surg 2007;15:607–13.
[11] Bahrs C, Lingenfelter E, Fischer F, Walters EM, Schnabel M. Mechanism of injury and morphology of the greater tuberosity fracture. J Shoulder Elbow Surg 2006;15:140–7.
[12] Kim SH, Ha KI. Arthroscopic treatment of symptomatic shoulders with minimally displaced greater tuberosity fracture. Arthroscopy 2000;16:695–700.
[13] Verdano MA, Aliani D, Pellegrini A, Baudi P, Pedrazzi G, Ceccarelli F. Isolated fractures of the greater tuberosity in proximal humerus: does the direction of displacement influence functional outcome? An analysis of displacement in greater tuberosity fractures. Acta Biomed 2013;84:219–28.
[14] Duparc F. Malunion of the proximal humerus. Orthop Traumatol Surg Res 2013;99:S1–11.
[15] Hebert-Davies J, Mutch J, Rouleau D, Laflamme GY. Delayed migration of greater tuberosity fractures associated with anterior shoulder dislocation. J Orthop Trauma 2015;29:e396–400.
[16] Muhm M, Arend S, Winkler H, Ruffing T. Associated injuries with greater tuberosity fractures: mechanism of injury, diagnostics, treatment. Unfallchirurg 2017;120:854–64.
[17] Park MC, Murthi AM, Roth NS, Blaine TA, Levine WN, Bigliani LU. Two-part and three-part fractures of the proximal humerus treated with suture fixation. J Orthop Trauma 2003;17:319–25.
[18] Bogdan Y, Gausden EB, Zbeda R, Helfet DL, Lorich DG, Wellman DS. An alternative technique for greater tuberosity fractures: use of the mesh plate. Arch Orthop Trauma Surg 2017;137:1067–70.
[19] Collin P, Yoshida M, Delarue A, Lucas C, Jossaume T, Ladermann A. Evaluating postoperative rotator cuff healing: prospective comparison of MRI and ultrasound. Orthop Traumatol Surg Res 2015;101:S265–8.