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Locked plate osteosynthesis of humeral head–splitting fractures in young adults

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Background: Humeral head–splitting fractures occur in younger patients and can be associated with poor outcome. We aimed to study the functional outcome and complications in simple and complex humeral head–splitting fractures. We hypothesized that simple head-splitting fractures will perform better compared with complex head-splitting fractures.

Patients and methods: Records of 16 patients <55 years who underwent locked plating for humeral head–splitting fractures were reviewed. Five fractures were classified as simple (isolated head-splitting fractures) and 11 as complex fractures (associated tuberosity fractures). Union and quality of articular and tuberosity reduction were assessed radiologically. Shoulder and upper limb function was assessed by Constant and Disabilities of the Arm, Shoulder, and Hand (DASH) scores. Complications such as osteonecrosis, nonunion, and arthritic changes were also recorded.

Results: Of 15 fractures, 13 had united at a mean follow-up of 34 months (25-47 months). No osteonecrosis or nonunion was seen in simple fractures. In complex fractures, osteonecrosis was seen in 4 patients ($P = .01$), nonunion in 2 patients, and glenohumeral arthritis in 1 patient. The mean Constant score (66.5 [56-77]) and DASH score (21 [7.5-35.8]) showed significantly better outcomes in simple fractures (Constant score, $P = .02$; DASH score, $P = .029$).

Conclusion: Locked plating achieves satisfactory results in simple head-splitting fractures. Complex fractures are associated with higher rates of nonunion, avascular necrosis, and inferior shoulder function.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Proximal humerus fractures; head splitting; locked plating; osteosynthesis

Neer defined humeral head–splitting fractures as proximal humerus fractures in which the humeral head is split into more than one fragment with the fractured fragments measuring more than 20% of the articular surface.[13]

Isolated humeral head–splitting fractures are rare injuries. Head splitting can also occur as a part of complex proximal humerus fractures seen in high-velocity injuries in younger individuals. The glenohumeral joint is often found subluxated or dislocated. There may be associated impaction injuries to the humeral head and the glenoid.[5] Favorable results with osteosynthesis can be difficult to achieve because of the very proximal location of the head fracture and associated poor vascularity. Control of small articular fragments during reduction and maintenance of fixation in a

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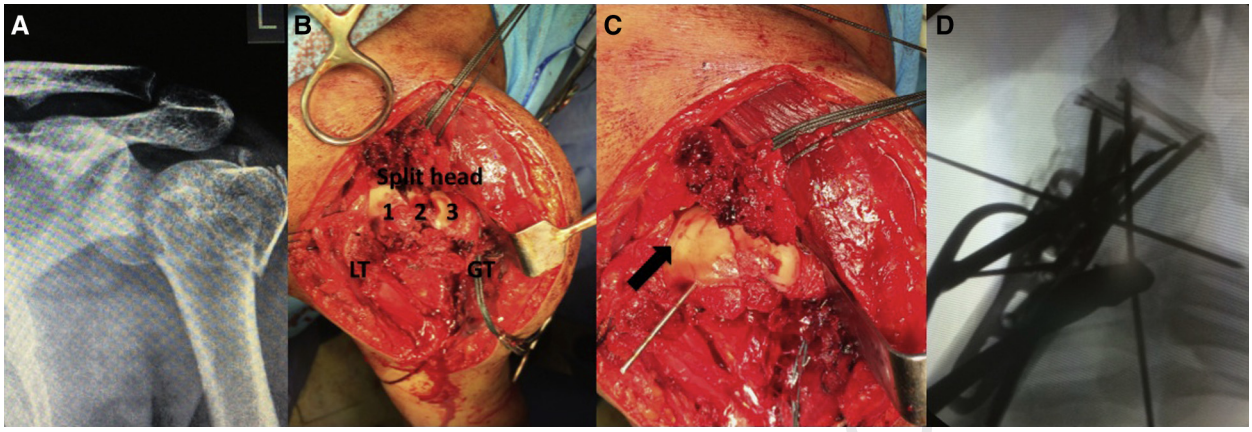

Figure 1 (**A**) Anteroposterior radiograph showing a complex head-splitting fracture with a subluxed head fragment. (**B**) Intraoperative image after reduction of the anteriorly subluxed head fragment shows the head split into 3 fragments and the tuberosities (*LT*, lesser tuberosity; *GT*, greater tuberosity) tagged with sutures. (**C**) After reduction of the head fragments and fixation with headless screws (*arrow*). (**D**) Axial fluoroscopy image shows the anatomic reduction of the head and tuberosities.

small fragment lacking soft tissues may also be difficult. Nevertheless, osteosynthesis is still favored because hemiarthroplasty in younger patients may be associated with an inferior functional outcome in the long term.[15] With this background, we reviewed our results of simple and complex head-splitting proximal humerus fractures in patients <55 years treated by locked plating between 2008 and 2010 with emphasis on functional outcome and complications. We hypothesized that simple fractures will have a better clinical and functional outcome compared with complex head-splitting fractures.

Materials and methods

This was a retrospective single-center study. The medical records of adult patients treated for a head-splitting proximal humerus fracture at our hospital from January 2008 to December 2010 were retrieved from the hospital's prospectively maintained trauma database. Patients younger than 55 years presenting with a humeral head–splitting fracture were included. Patients with open physis and older than 55 years and patients with preoperative evidence of axillary nerve injury or associated brachial plexus injury were excluded. Head splitting was quantified on preoperative computed tomography (CT) scans, and fractures fitting Neer's definition (20% of the articular surface involvement) were included. Small articular fragments attached to the tuberosities and impaction injuries of the humeral head were not considered head-splitting fractures. During the study period, 18 patients with 18 head-splitting fractures were identified; 16 satisfied the inclusion criteria and were included in the study.

Preoperatively, all patients had undergone an anteroposterior radiograph of the injured shoulder and a 3-dimensional CT scan as part of the hospital protocol. Fractures were subclassified as simple (fracture line splitting the humeral head without associated tuberosity fractures) and complex (split humeral head with tuberosity fractures; the humeral head fragment has no residual attachment to the tuberosity fragments). Osteosynthesis with a precontoured fixed angle plate was performed in all patients.

Surgical technique

A deltoid split approach by a shoulder strap incision with superior extension if required[18] was the preferred surgical approach except in patients with an anterior fracture dislocation. Five heavy nonabsorbable sutures (No. 5 Ethibond; Ethicon, Chennai, India) were passed through the cuff to reduce tuberosity fragments and to get the head out of varus. Two sutures each were taken at the posterior and anterior cuff, and 1 suture was passed through the superior portion of the cuff. One anterior and 1 posterior suture were tied together to reduce and to hold the tuberosities together before plating. Remaining sutures were secured to the plate holes to augment the strength of fixation. The articular fragment, if dislocated/subluxated, was reduced into position by direct methods or with a cannulated 6.5-mm tap as a joystick. The split head fragments were reduced and provisionally held in place with threaded K-wires. The split head fragment, if small, was reduced to the main head fragment and fixed with 2.4-mm headless screws before plating. An intramedullary autograft fibula was used in 2 patients in whom the medial metaphysis was found to be comminuted. After reduction and preliminary fixation with K-wires, angle stable fixation was performed with the proximal humerus interlocking system (PHILOS; Synthes Medical Pvt Ltd., Gurgaon, Haryana, India). A minimum of 7 screws were used to fix the proximal portion of the plate, including at least 1 of the 2 inferomedial calcar screws (Fig. 1).

Patients were kept in a sling for 3 weeks. Pendulum exercises were started after control of pain. Passive range of motion exercises were started after 2 weeks, followed by active-assisted range of motion exercises at 4 weeks and active range of motion exercises and strengthening exercises at 6 weeks after surgery. Outpatient clinical and radiographic reviews were performed every 3 weeks until fracture union. Further regular follow-ups were conducted every 6 months until 2 years after surgery. Constant scores[4] and Disabilities of the Arm, Shoulder, and Hand (DASH)[11] scores were assessed at final follow-up. The Constant scores were adjusted for age and gender, and a normalized score was generated as described by Katolik et al.[12]

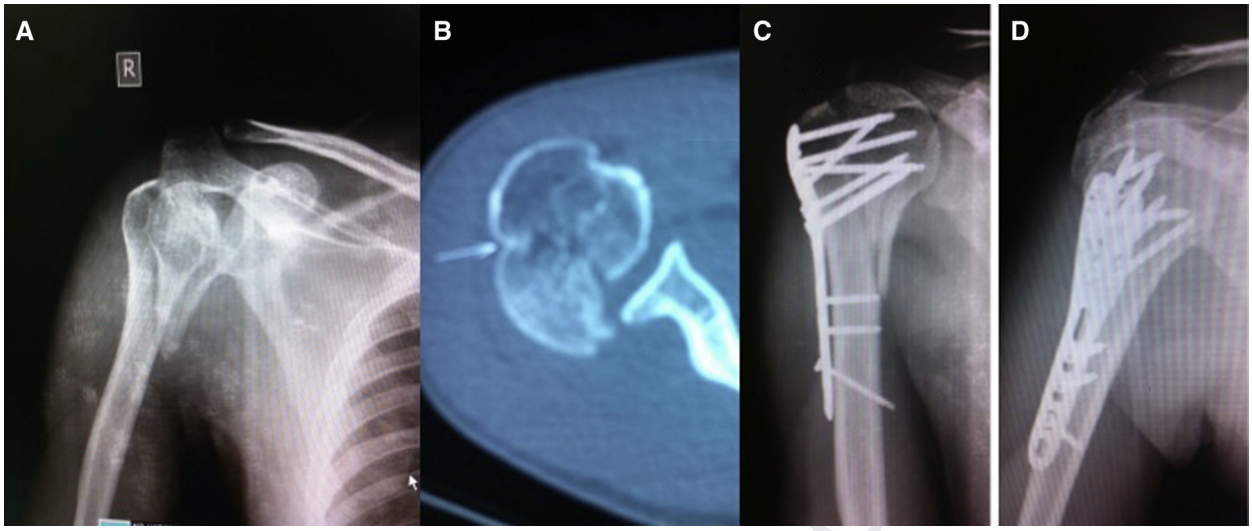

Figure 2 (**A**) Anteroposterior radiograph of a simple head-splitting fracture depicting a double head sign. (**B**) Axial CT shows the extent of the head split and a subluxed head fragment. (**C** and **D**) Follow-up radiographs show good reduction of the head and progressing union.

Follow-up radiographs were assessed for union, loss of reduction and fixation, intra-articular screw violation, presence of avascular necrosis (AVN), and arthritic changes at the glenohumeral joint. Head reduction was classified as anatomic, good (<2 mm step), and poor (>2 mm step). Head-shaft alignment was classified as normal, varus (head-shaft angle < 120°), or valgus malalignment (>150°). Tuberosity malreduction was documented as poor if displacement was more than 5 mm in any plane. Radiographic interpretation was made by a radiologist and an author (A.S.G.) together.

Statistical analysis

Statistical analysis was performed with SPSS 16 for Windows (Chicago, IL, USA). Constant scores, DASH scores, and major complications were compared between simple and complex fracture patterns. Categorical variables were tested for significance by the Pearson χ^2 test, and continuous variables were tested by *t* tests. The level of significance was set at $P \leq .05$. We performed a post hoc power analysis based on the study data, which showed that the response within each subject group was normally distributed with standard deviation of 4. If the true difference in the experimental and control means is 10, we needed to study 5 experimental subjects and 3 control subjects to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability (power) 0.8. The type I error probability associated with the test of this null hypothesis is 0.05.

Results

There were 11 men and 5 women. The mean age was 38 years (21-54 years). The mode of violence was a high-velocity road traffic accident in 13 patients, a fall from a height in 2 patients, and an industrial accident in 1 patient. Impaction injuries to the humeral head on CT were seen in 2 patients (<25% of the articular surface). The head fragment was found dislocated or subluxated in 9 patients (60%). The dislocation/subluxation was anterior in 3 patients and posterior in 6 patients. The fracture pattern was simple in 6 patients (Fig. 2) and complex in 10 patients (Figs. 3 and 4). The mean time from injury to surgery was 4 days (1-13 days). The mean follow-up was 34 months (25-47 months). The final analysis included 15 patients, including 1 patient who dropped out after diagnosis of a nonunion and secondary arthritis at 8 months; 1 patient with a simple fracture could not be located for follow-up assessment (Table I).

Union was achieved in 13 patients at a mean time of 15 weeks (9-18 weeks). Articular reduction was classified as anatomic in 9 patients, good in 4 patients, and poor in 2 patients. The head-shaft angle was classified as normal in 13 patients, valgus in 1 patient, and varus in 1 patient. Tuberosity fractures were reduced satisfactorily in 9 of 10 patients. Varus collapse (>10°) was seen in 2 patients. At last follow-up, the mean Constant score was 66.5 (56-77), and the normalized Constant score was 72 (63.8-87.5). The Constant score was graded as good in 2 patients, fair in 11 patients, and poor in 1 patient. The mean DASH score was 21 (7.5-35.8). Both the DASH and Constant scores were significantly better in patients with simple fractures compared with patients with complex fractures ($P = .029$ for DASH score and .02 for Constant score) (Table II).

Complications

In complex fractures, nonunion was seen in 2 patients, glenohumeral arthritis was seen in 1 patient, and AVN was seen in 4 patients (Fig. 5). Two patients with AVN also had

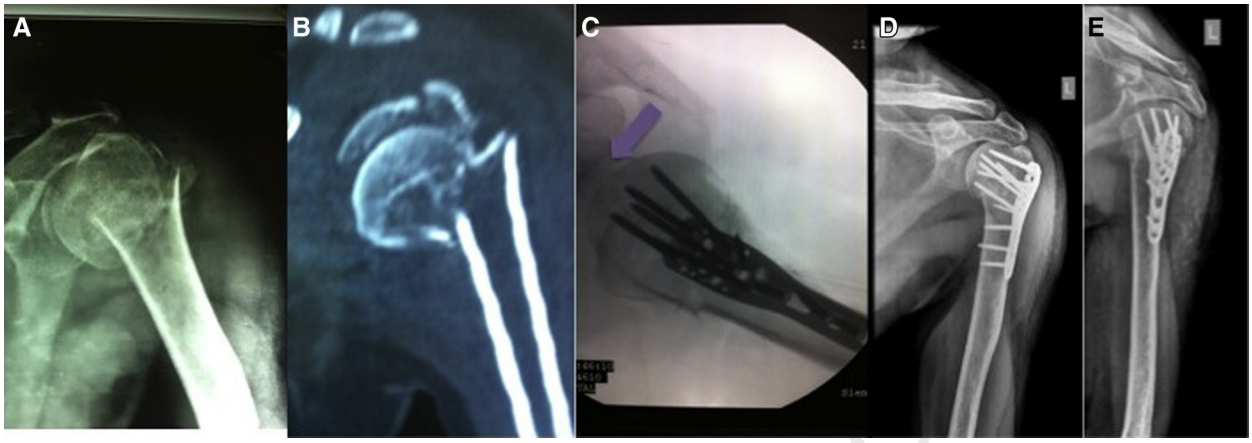

Figure 3 (**A** and **B**) Radiograph and CT image show a complex head-splitting fracture. (**C**) Intraoperative fluoroscopy image shows a satisfactory reduction of the split humeral head (*arrow*). (**D** and **E**) At 2-year follow-up, radiographs show union, maintenance of reduction, and a vascular head.

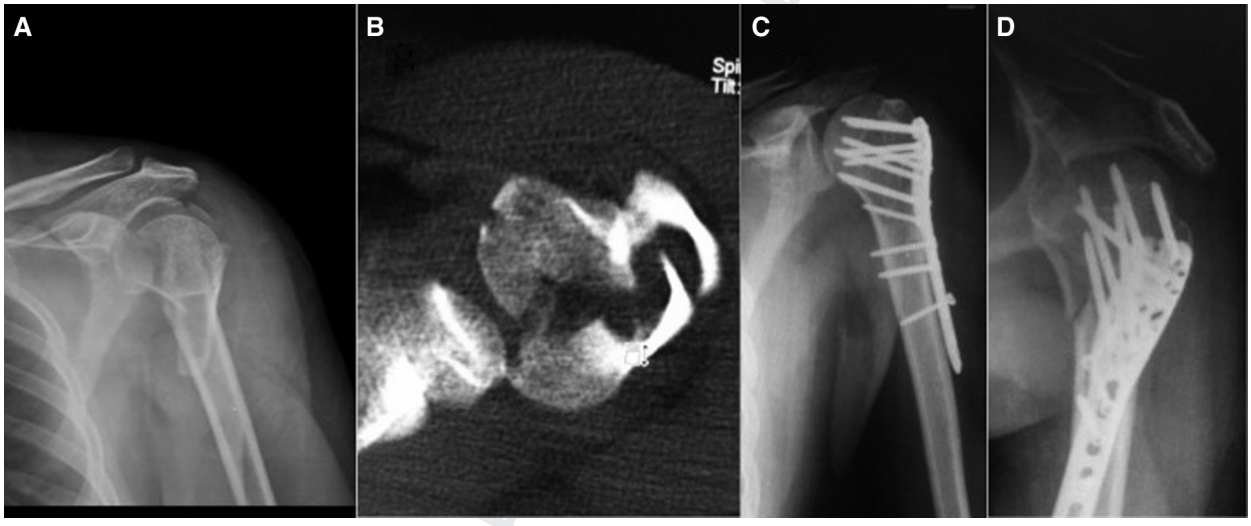

Figure 4 (**A** and **B**) Complex head-splitting fracture with a posteriorly dislocated head fragment. (**C** and **D**) At 6-week follow-up, radiographs show excellent reduction and fixation.

an anterior dislocation. The incidence of AVN was significantly high in complex fractures ($P = .01$), but the incidence of nonunion ($P = .28$) and glenohumeral arthritis ($P = .43$) was not statistically different across fracture patterns. Primary intra-articular screw placement was seen in 1 patient and was revised postoperatively. Secondary articular screw penetration was evident in 2 patients after AVN and secondary collapse. One patient underwent acromioplasty and subacromial decompression for symptomatic impingement. In all patients, the axillary nerve was intact and there was no evidence of a wound infection.

Discussion

The available evidence on optimal treatment of head-splitting fractures is scarce. Apart from case reports, only a single case series has been published exclusively on osteosynthesis of isolated simple head-splitting fractures.[2,3,17] The authors described good results with internal fixation in simple head-splitting fractures in 3 of the 8 patients who were young (19-41 years) and opted for hemiarthroplasty in patients >55 years.[2] In our study, all patients were younger than 55 years, and the majority of the fractures were complex, indicating higher energy violence and possibly more disruption of the humeral head blood supply. Most of our complications were seen in complex fracture patterns. A nonunion rate of 20% and AVN rate of 40% in complex fractures compared with none in isolated head-splitting fractures indicate the inherent severity of these injuries.

Previous reports have recommended hemiarthroplasty for these fractures on the basis of increased risk for AVN and arthritis secondary to articular impaction injuries.[7]

Table I Patient and clinical data

Patient (fracture type)	Age/sex	Follow-up (months)	DASH score	Raw Constant score	Constant score, normalized	Adverse events
1 (simple)	29/M	47	20	72	75.7	
2 (simple)	47/M	33	17.5	73	76	
3 (complex)	21/M	25	23.3	66	69.4	Impingement due to poor plate placement
4 (complex)	39/F	28	35.8	59	67.8	AVN, secondary IA screw penetration
5 (simple)	28/F	35	7.5	77	87.5	
6 (complex)	51/M	42	23.3	60	63.8	
7 (complex)	33/M	30	18.3	68	71.5	
8 (simple)	40/F	36	15	69	80.2	
9 (complex)	27/M	35	21.7	62	65.2	AVN
10 (complex)	37/M	8 (treatment failure)				Nonunion, glenohumeral arthritis
11 (complex)	28/F	30	17.5	60	68	
12 (simple)	47/M	38	10.8	76	79	
13 (complex)	54/M	40	25.8	64	68	AVN
14 (complex)	50/M	34	24.2	69	73.4	
15 (complex)	45/F	26	33.4	56	65	Nonunion, AVN, secondary IA screw penetration

AVN, avascular necrosis; *IA*, intra-articular.

Table II Fracture-specific functional results and complications

	Simple fractures (n = 5)	Complex fractures (n = 10)	*P* value
Nonunion	0	2	.28
Avascular necrosis	0	4	.01
Constant score	73.4 ± 3.2	62.6 ± 4.3	.02
DASH score	14.16 ± 5	24.8 ± 6.1	.029
Forward elevation	144 ± 16.7	112 ± 18.5	.8
Lateral elevation	140 ± 18.7	102 ± 17.8	.28
Varus collapse	0	2	.283
Glenohumeral arthritis	0	1	.43

Patients in our study were young compared with the average age of patients undergoing shoulder arthroplasty as a primary treatment.[6,8] Patients with simple head-splitting fractures in our series had very good results even in the presence of a dislocation. Although a previous study indicated good results with screws alone in simple head-splitting fractures in 3 patients,[2] the authors had to immobilize the shoulder for 3 weeks. We used a locked plate in all our patients to achieve stable fixation and to enable early mobilization (Table III). Although complications such as AVN and nonunion necessitating further treatment were seen in 5 of 10 patients (50%) with complex fractures, we recommend osteosynthesis in this population of young patients, focusing on anatomic head, tuberosity reduction, and union, which either provides the best outcome or will facilitate a future arthroplasty procedure.[1] In a study by Greiwe et al,[10] the functional outcome with hemiarthroplasty was much superior in simple head-splitting fractures compared with 3- and 4-part proximal humerus fractures involving fractured tuberosities.

The 28% incidence of AVN seen in this study is higher than the described risk of 5% to 17% reported by previous studies involving nonhomogeneous fracture patterns.[16] The risk factors for AVN noted in the current study include the complex fracture pattern, the presence of anterior dislocation, the associated soft tissue injury (all anterior dislocations were complete, whereas the posterior dislocations were only partial subluxations), and the choice of surgical approach (deltopectoral approach, used in the study for all anterior fracture-dislocations, has been shown to be associated with a higher incidence of AVN).[9,19] Similarly, Ogawa et al[14] reported that the split head fragment in a posterior fracture-dislocation remained in good contact with an intact inferomedial attachment in 90% of the cases, and hence the risk of AVN is low with head-splitting fractures associated with a posterior dislocation.

This is the largest study to focus exclusively on the outcomes after osteosynthesis in head-splitting humeral head fractures. The study was retrospective with a small sample size, but the fracture subtypes were homogeneous, with a high follow-up rate and a mean follow-up period of 34 months. The post hoc power analysis showed that the study is adequately powered to draw conclusions, but the lack of controls is a significant limitation of this study.

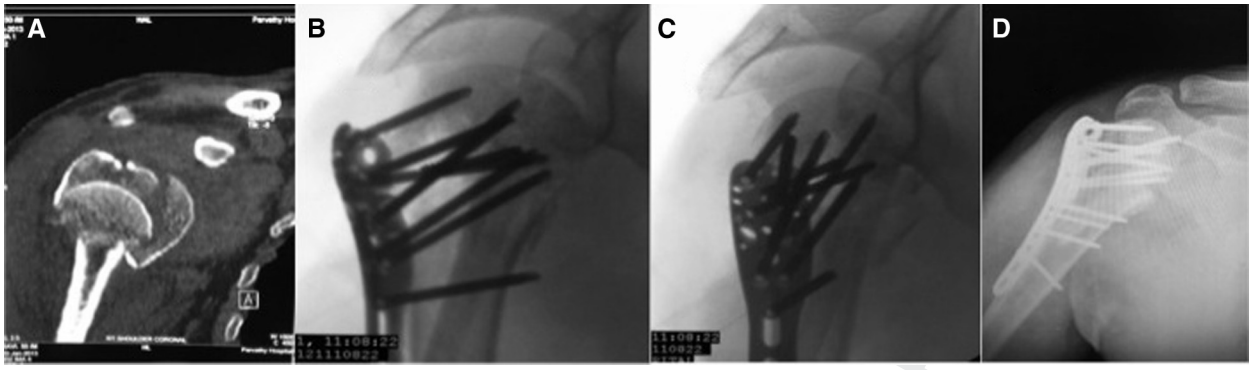

Figure 5 (**A**) Coronal CT shows a 4-part head-splitting fracture at the level of the anatomic neck. (**B** and **C**) Postoperative radiographs show satisfactory reduction. (**D**) At 18-month follow-up, radiograph shows avascular necrosis, collapse of the humeral head, and intra-articular screw penetration.

Table III ■■■ Published data on head split fractures Q1

Study	Patients	Mean age (years)	Fracture type	Associated subluxation	Intervention	ASES score	Constant score	AVN or other complications
Chesser et al[2] (2001)	8	39 ± 15.8	Simple: 7 Complex: 1	7/8	Screw fixation: 3 Hemiarthroplasty: 1 Closed reduction: 1 Missed: 3		68.25 ± 28	AVN: 0 Ankylosis in 3 patients
Griewe et al[10] (2013)	8	67 ± 12	NA	4/8	Hemiarthroplasty	68 ± 33		NA
This study (2014)	15	38 ± 10.3	Simple: 5 Complex: 10	9/15	Osteosynthesis: locked plating ± headless screws		66.5 ± 7	Simple: 0 Complex: 4

ASES, American Shoulder and Elbow Surgeons; *AVN*, avascular necrosis; *NA*, not available.

The rates of AVN and nonunion are high compared with published data on proximal humerus fractures but not surprising as our study was isolated to head-splitting fractures.

Conclusions

Satisfactory reduction with stable fixation achieves excellent and predictable results in simple head-splitting fractures. Complex head-splitting fractures are associated with the higher rate of nonunion, AVN, and reduced shoulder outcomes.

Disclaimer

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