

Anatomic placement of shoulder prosthesis for complex proximal humerus fractures: A modified method for hemiarthroplasty

Wanfu Wei

Tianjin Hospital

Jian'an Li (✉ jjanan12210@163.com)

Tianjin Hospital <https://orcid.org/0000-0002-0894-4060>

Guoyun Bu

Tianjin Hospital

Tao Yang

Tianjin Hospital

Technical note

Keywords: Proximal humeral fracture; Distance; Anatomic reference; Treatment; Surgery; Shoulder arthroplasty; Hemiarthroplasty

Posted Date: May 4th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-24174/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background

The placement of shoulder prosthesis used for reconstruction of a complex proximal humerus fractures is challenging. To achieve the anatomical placement of prosthesis, we introduced a new operative technique to determine the humerus height and humeral head retroversion. Herein, we retrospectively investigated the clinical and radiographic outcomes of our procedure.

Method

34 patients, treated by shoulder arthroplasty for 4-part or 3-part proximal humeral fracture during the period between June 2016 and December 2018, were enrolled in the study. Eventually 29 patients, 18 women and 11 men with an average age of 68.4 years (range 58–85 years), were followed up successfully. Of which 13 patients treated with classic method were matched to 19 of the 29 new method treated patients by operation time, blood loss, pain, range of motion, Constant-Murley score and radiologic features.

Results

There was significant difference between the two treatment groups in operation time ($p = 0.024$), while there was no significant difference in blood loss ($p = 0.078$). No significant difference was found between the two treatment groups in Visual Analog scale ($p = 0.225$), Constant-Murley score ($p = 0.930$), and radiological outcomes ($p = 0.504$). There was linear regression and correlation between Constant-Murley score and age ($p = 0.027$), while there was no linear relationship between status of tuberosity and the function of the shoulder joint ($p = 0.931$).

Conclusion

We introduce a new operative technique to determine the humerus height and humeral head retroversion for shoulder arthroplasty operation. Based on the data, there is linear regression and correlation between Constant-Murley score and age, while there is no linear relationship between status of tuberosity and the function of the shoulder joint. Our present analyses reveal that our protocol is personalized, easy, effective and feasible.

Trial registration: <https://doi.org/10.1186/ISRCTN28175069>.

Background

The proximal fracture of humerus is one of the most common fractures in elderly patients, and it is usually comminuted because of poor bone quality. There is general agreement that most of these fractures can be treated nonoperatively. Most surgeons trend to investigate operation for complex humeral fractures with or without glenohumeral dislocation or splitting of the head (1–3). However, the optimal treatment of complex

proximal humeral fractures in older people has not yet been established (4, 5). Four part fractures and 3 part fracture/dislocations in elderly patients often require management with prosthetic arthroplasty(6).

When arthroplasty is being performed, the management of proper humeral height and version represents a significant reconstructive challenge for surgeons. The important of intraoperatively restoring anatomic humeral height, humeral version, and tuberosity reconstruction were highlighted to improve outcomes after hemiarthroplasty for shoulder fracture(6, 7).The nonanatomic reduction of the tuberosity in the horizontal may result in insurmountable postoperative motion restriction (8). There are some published methods of restoring the appropriate humeral length for arthroplasty, such as preoperative plan according to the calcar of non-injured extremity, landmark using medial calcar of proximal humeral fracture, reference using pectoralis major tendon, and the Gothic arch based on radiographs (9–11). However, there are some obstructions during surgery: preoperative anteroposterior radiographs of the injured and the contralateral humerus, the break off of pectoralis major tendon for exposure of fracture, repeated intraoperative radiographs.

Methods

In this work, we introduced a new operative technique to determine the humeral height and humeral head retroversion, and conducted a retrospectively study to examine the clinical results of hemiarthroplasty performed at our institute.

We undertook a descriptive, prospective study that included 34 consecutive patients, treated by shoulder arthroplasty for proximal humeral fracture during the period between June 2016 and December 2018. At the very beginning, the height of humerus was determined and planned on from the non-injured extremity (7, 10, 12). The surgeons involved in this study stopped using this method and switched to our method in September 2017. One of these patients died for reasons not related to shoulder surgeries, and four patients were lost to follow-up. The complete clinical data of the remaining 29 patients with Shoulder arthroplasty were available for this retrospective analysis: 18 women and 11 men with an average age of 68.4 years (range 58–85 years). Of the 29 cases, 27 cases were 4-part and 2 cases were 3-part fractures of the proximal humerus according to Neer classification, and 22 cases combine with dislocation of glenohumeral joint. The mean time between the patient's accident and his or her surgery was 10.6 days (range 4–57 days). The mechanism of damage in all patients was a low energy injury to the upper extremity. The average follow-up period after surgery was 27.6 months (range 11–42 months). Demographic information is included in Table 1. This retrospective study was approved by the institutional review board. All the patients gave their consent to participate in the study.

Surgical technique

The patients are placed in supine position with the injured shoulder joint raised about 30 degrees. A deltopectoral incision is used to provide an internervous plane into the glenohumeral joint. The deltoid and the cephalic vein are retracted laterally, and the proximal humerus is exposure. The smaller branches of the cephalic vein are coagulated or tied. After the fracture fragment of greater tuberosity and the tendon of

supraspinatus are pulled out from under the acromion of the scapula, the tuberosity can be tagged at the tendon bone by non-absorbable sutures (Ethibond Excel6™) ready for further use. And then the lesser tuberosity is pulled with another suture after the recognizing of the long head of the biceps tendon. The articular segment of the humeral head was then identified and removed. The normal anatomy of fracture is reduced according to medial calcar and intertubercular sulcus (Fig. 1), and control the anatomy by provisional Kirschner wire fixation. On the opposite side of the humeral head a hole, drilled in the lateral cortical bone of the metaphysis, is set as the marker for restoration of humeral height and approximately 30° of retroversion (Fig. 2). The distance between the most proximal point of the humeral head and the hole is tested and set as the height of the prosthesis (Fig. 3). The humeral canal is then reamed manually and proper stem is selected based on the final model number of the reamer. Two holes are drilled in the lateral cortical bone of the diaphysis to pass two non-absorbable sutures (Ethibond Excel6™) ready for final suture of the tuberosities. Proper artificial head is selected whose diameter is about 2 mm smaller than the reduced humeral head. Adjustment of the retroversion and of the length of the humerus is carried out according to previous test after a trial reduction to test the laxity and stability of the joint (Fig. 4). The tuberosity fragments are reduced anatomically and fixed to the prosthesis, to each other and to the humeral shaft. All rotator cuff injuries are repaired with non-absorbable suture and the long head of the biceps tendon is cut and sutured to united tendon with tension.

Postoperatively, the shoulder was immobilized in sling for 6 weeks. On postoperative days 1 through 42, passive range of motion of shoulder joint was taught by a therapist and continued by the patient. Active range of motion was initiated at 6 weeks after operation, and strengthening was added at 3 months postoperatively. Clinical and radiographic prospective evaluations are made preoperatively and postoperatively at 6 weeks, 3, 6, 12 months, and then yearly. The primary outcome measure in this study is Constant-Murley score (CMs). Clinical evaluations also include a visual analog scale (VAS), and range of motion. Radiologic evaluations include anteroposterior, scapular Y, and axillary views, and the status of tuberosities is defined as healing, malunion, migration, and resorption.

Statistical analysis

The statistical software used was IBM SPSS 22.0 software (IBM-SPSS, Armonk, NY). Means, standard deviations (SD), frequencies and proportions were used to describe the study sample. Fisher test was used to compare the incidence of two groups of data. The Kolmogorov–Smirnov test was used to determine the normal distribution of data. The Mann-Whitney test was used for unpaired groups. The Spearman rank correlation and Pearson correlation coefficient were applied to correlate different variables. P values of < 0.05 were considered significant.

Results

Before matching there was a statistically significant difference between the two groups (Table 1). The mean operation time of classic method group was 145.15 ± 31.67 min (range 105 min-210 min), while that of new method group was 120.63 ± 23.16 min (range 90 min-1800 min). There was significantly difference

($p = 0.024$). The mean blood loss was 402.31 ± 151.0 ml (range 240 ml-700 ml) and 252.5 ± 68.85 ml (range 200 ml -400 ml), respectively.

Table 2 demonstrates outcomes of the two groups. The mean postoperative VAS score of classic method group and new method group was 0.69 ± 1.1 (range 0–3) and 1.5 ± 1.9 (range 0–7), respectively. The mean postoperative active forward flexion was $79.23^\circ \pm 17.05^\circ$ (range 60° – 110°) and $83.75^\circ \pm 18.21^\circ$ (range 60° – 110°), respectively. The mean postoperative active extension was $36.92^\circ \pm 9.47^\circ$ (range 30° – 60°) and $37.5^\circ \pm 5.77^\circ$ (range 30° – 50°), respectively. The mean postoperative active abduction was $78.46^\circ \pm 14.05^\circ$ (range 60° – 100°) and $81.86^\circ \pm 12.23^\circ$ (range 60° – 100°), respectively. The mean postoperative active adduction was $34.62^\circ \pm 5.19^\circ$ (range 30° – 40°) and $35.63^\circ \pm 5.12^\circ$ (range 30° – 40°), respectively. The mean Constant-Murley score was 60.08 ± 7.41 (range 44–70) and 60.19 ± 7.45 (range 48–72), respectively.

The parametric study on the Constant-Murley score, performed by radiologic outcomes, had shown that there was no linear relationship between radiologic outcomes and Constant-Murley score ($p = 0.931$, Fig. 5A). However, there is linear regression and correlation between CMs and age ($p = 0.027$, Fig. 5B).

We noted no radiolucency or evidence of component migration. Of the 29 patients, four had a resorption of the greater tuberosity but had satisfactory ROM. One patient had a malunion of the greater tuberosity. There were no postoperative infections, hematomas, or dislocations. There were no periprosthetic fractures noted. One patient suffered from moderate to severe pain and a painkiller was needed in the daily life. No complications resulted in reoperation.

Discussion

Complex fractures of the proximal humerus are usually comminuted because of poor bone quality or high-energy trauma. These kind of fractures treated with open reduction and internal fixation (ORIF) are at the high risk of malunion, screw cutout, osteonecrosis and revision surgery. The integrity of the medial hinge, and the length of the dorsomedial metaphyseal extension have been described as key prognostic factors for humeral head vascularity which may lead to the necrosis of humeral head (13, 14). The most important indication of arthroplasty is fracture type, including head-splitting patterns, fracture dislocations, and displaced three- and four-part fractures not amenable to surgical fixation (12, 15). However, most surgeons tend to choose hemiarthroplasty in the patients ≤ 65 years, and tend to choose reverse total shoulder arthroplasty in old patients with lower-demand or teared rotator cuff (16–20). Arthroplasty for proximal humeral fracture is performed with the aim of restoring normal biomechanics, achieving adequate range of movement and providing a painless functional joint to the patients. The best advantage of arthroplasty is a reliable procedure for pain relief. Hemiarthroplasty can provide satisfactory functional results, but depends on correct height of the implant and tuberosity union (6).

Clinical studies have shown that anatomical recreation of proximal humerus fractures can affect the clinical consequences of hemiarthroplasty (7). It is a technically demanding procedure that requires proper humeral height, correct retroversion of the stem, and anatomical reconstruction of the tuberosities. The lengthening humeral height more than 10 mm and shortening more than 15 mm is unacceptable in the

clinical practice(6, 7). To date, pre-operative templating with comparison of both arms remains the only objective evaluation to assess for the correct parameters of the arm at the time of arthroplasty. The technique is based on exact measurement according to the medial calcar of the fracture prior to the operation(10). In clinical practice there are some obstacles, repeated X-ray exposure before operation, and complicated pre-operation design. Joel et al. introduced the distance at 5.5 cm between the pectoral major tendon insertion and top of the humeral head as a landmark for proper placement of hemiarthroplasty in fractures of the proximal humerus(21). And the method is proved to be a useful and reliable reference for optimal humeral height during hemiarthroplasty for proximal humerus fractures in Asian populations(9). However, the technique is not individual. The distance between the pectoral major tendon insertion and top of the humeral head is different in population due to the height and gender of patients. To prepare the glenoid and exposure the fracture ends, the upper one-third of the pectoralis tendon can be tenotomized routinely. The specific height of prosthesis still needs to be adjusted repeatedly according to the intraoperative joint tension. Sumant et al. (7)restored the proper height by recovery the Gothic Arch (The joining of outline the medial calcar of the proximal humeral and the lateral border of the scapula creates a classical "vaulted" arch or Gothic arch shape). The incorrect prosthetic height, broken medial calcar, or too large head may lead to the failure construction of Gothic arc in the standard lateral position. However, to achieve the arch, the humerus must be rotate to the most lateral offset position which may need repeated X-ray exposure during surgery. Another previous study described a method. If the height was proper, the distance between the lateral margin of the artificial head and medial calcar of the fracture was about 2–3 mm larger than the diameter of the head (10). The technique is based on the integrality of medial calcar.

In our protocol,the height and retroversion of prosthesis are determined through the hole in metaphysis after the anatomical reduction of tuberosities and head of humerus. There is no need additional X-ray exposure pre-operation and intra-operation. The mean operation time and the blood loss have no significant difference between two methods which means that the protocol is easy and convenient. The version of the artificial head is selected whose diameter is about 2 mm smaller than the reduced humeral head. It is our practice that the smaller diameter and the anatomical reduction of humeral head can allow the tuberosities to be easily pulled down around the shaft of the prosthesis. The humeral head is 10 mm higher than the greater tuberosity, which can lead to satisfactory clinical outcome(12).

The previous literature suggests that the success of the surgery depends on the ability of the tuberosities to heal themselves and on the reduction to the humeral shaft in anatomic positions surrounding the implant (8, 22). In the present study, the clinical outcome of new method is similar to that of the typical method. The outcome of radio graphical assessment suggests that there was no linear relationship between the presence of tuberosity and the function of the shoulder joint. The bone union rate and clinical results were comparable to those of the previous studies. The result of a meta-analysis also demonstrates that the percentage of healed tuberosities did not correlate with the Constant score(23). The possible reason is a small number of specimens. Another possible reason is tuberosity fragments are fixed to each other, to prosthesis and to the humeral shaft. As it is mentioned, stable fixation of the tuberosities is imperative to maximize functional results and decrease the risk of instability regardless of the arthroplasty technique chosen (24).

One strength of our operative technique is that it is based on the idea of fracture treatment. Another strength is that it is personalized, easy and convenient. Thirdly, it is suitable for most proximal humeral fractures unless there is humeral head comminution or with comminuted fracture of the humeral shaft.

Our study has some limitations. Firstly, this study was conducted with a small number of specimens, and studies with much larger samples are needed to confirm the findings. Secondly, it is a retrospective and not randomized study. A randomized controlled trial with a larger number of patients is needed. While we believe our minimum follow-up time of 38.1 months (range 25–55 months) is sufficient to assess the function of shoulder, it still represents only short-term follow-up.

Conclusions

In this work, we introduce a new method to determine the humerus height and humeral head retroversion in the operation of shoulder arthroplasty. We examine the clinical results and radiologic outcomes of the technique by a retrospectively study. For the analyzed case control study, it was found that there were no significant difference between the two treatment groups in clinical outcomes and radiological appearance, while there is linear regression and correlation between CMs and age. Our present analyses reveal our protocol is personalized, easy, effective and feasible.

Abbreviations

CMs Constant-Murley score.

VAS visual analog scale.

SD standard deviations.

ORIF open reduction and internal fixation.

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the institutional review board (approval no. 2020-006).

Consent for publication

All patients gave their approval for participation.

Availability of data and materials

All data generated or analysed during this study are included in this published article

Competing interests

None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete *Disclosures of Potential Conflicts of Interest* submitted by authors are always provided with the online version of the article.

Funding

There is no funding available.

Authors' contributions

Wanfu Wei and Jian

anLi contributed equally → this work or k. Wanfu Wei carried out the operations. Jianan Li, Tao Yang and Guoyun Bu followed up the patients and collected the data. Jian

anLi and Wanfu Wei analysed the data, interpreted the results and wrote the manuscript. Jianan Li supervised all the retrospective study.

Acknowledgements

Not applicable.

References

1. Brouwer M, Reininga I, El Moumni M, Wendt K. Outcomes of operative and nonoperative treatment of 3- and 4-part proximal humeral fractures in elderly: a 10-year retrospective cohort study. *Eur J Trauma Emerg Surg.* 2017;45(1):131–8.
2. Boyer E, Menu G, Loisel F, Saadnia R, Uhring J, Adam A, et al. Cementless and locked prosthesis for the treatment of 3-part and 4-part proximal humerus fractures: prospective clinical evaluation of hemi- and reverse arthroplasty. *European journal of orthopaedic surgery traumatology: orthopedie traumatologie.* 2017;27(3):301–8.
3. Peters PM, Plachel F, Danzinger V, Novi M, Mardian S, Scheibel M, et al. Clinical and Radiographic Outcomes After Surgical Treatment of Proximal Humeral Fractures with Head-Split Component. *The Journal of bone joint surgery American volume.* 2020;102(1):68–75.
4. Boyle M, Youn S-M, Frampton C, Ball C. Functional outcomes of reverse shoulder arthroplasty compared with hemiarthroplasty for acute proximal humeral fractures. *Journal of shoulder elbow surgery.* 2012;22(1):32–7.
5. Chivot M, Lami D, Bizzozero P, Galland A, Argenson JN. Three- and four-part displaced proximal humeral fractures in patients older than 70 years: reverse shoulder arthroplasty or nonsurgical treatment? *J Shoulder Elbow Surg.* 2019;28(2):252–9.

6. Wiesel B, Nagda S, Williams G. Technical Pitfalls of Shoulder Hemiarthroplasty for Fracture Management. *The Orthopedic clinics of North America*. 2013;44:317–29.
7. Krishnan S, Bennion P, Reineck J, Burkhead W. Hemiarthroplasty for Proximal Humeral Fracture: Restoration of the Gothic Arch. *The Orthopedic clinics of North America*. 2008;39:441 – 50, vi.
8. Hiranaka T, Nishida K, Konishiike T, Ozaki T, Mikasa M. Tuberosity-overlapping Fixation of the Humeral Shaft in Humeral Head Replacement Surgery. *Acta Med Okayama*. 2019;73:299–305.
9. Kim B-S, Kim D-H, Song K-S, Min B-W, Bae K-C, Cho C-H. Is the pectoralis major tendon a reliable reference for restoration of humeral length with fracture hemiarthroplasty? *J Shoulder Elbow Surg*. 2017;27(2):e45-e9.
10. Hromádka R, Aleš Antonín K, Šmíd M, Popelka S. Medial calcar of proximal humeral fracture as landmark in restoration of humeral length in case of hemiarthroplasty. *Surgical radiologic anatomy*. 2013;36(5):473–9.
11. Sahu D, Jagiasi JD, Valavi AS, Ubale T. The Distance between the Pectoralis Major Tendon Insertion and the Top of the Humeral Head is a Reliable Landmark: An Anatomic Study. *Joints*. 2019;7(2):37–40.
12. Jones R. Hemiarthroplasty for Proximal Humeral Fractures Indications, Pitfalls, and Technique. *Bulletin of the Hospital for Joint Disease*. 2013;71:60–3.
13. Chambers L, Dines J, Lorich D, Dines D. Hemiarthroplasty for proximal humerus fractures. *Curr Rev Musculoskelet Med*. 2013;6(1):57–62.
14. Hertel R, Hempfing A, Stiehler M, Leunig M. Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. *Journal of shoulder elbow surgery*. 2004;13:427–33.
15. Doursounian L, Gaillard J, Cambon-Binder A, Zbili D, Sautet A. Hemiarthroplasty for proximal humerus fractures with conservation of the whole humeral head as autograft: does it improve greater tuberosity healing? *Int Orthop*. 2018;43(5):1155–64.
16. Roberson T, Bentley J, Griscom J, Kissenberth M, Tolan S, Hawkins R, et al. Outcomes of total shoulder arthroplasty in patients younger than 65 years: A systematic review. *J Shoulder Elbow Surg*. 2017;26(7):1298–306.
17. Sebastiá-Forcada E, Cebrián-Gómez R, Lizaur Utrilla A, Gil-Guillén V. Reverse shoulder arthroplasty versus hemiarthroplasty for acute proximal humeral fractures. A blinded, randomized, controlled, prospective study. *Journal of shoulder elbow surgery*. 2014;23(10):1419–26.
18. Gallinet D, Clappaz P, Garbuio P, Tropet Y, Obert L. Three or four parts complex proximal humerus fractures: Hemiarthroplasty versus reverse prosthesis: A comparative study of 40 cases. *Orthopaedics and traumatology, surgery and research*. 2009;95:48–55.
19. Thon SG, Seidl AJ, Bravman JT, McCarty EC, Savoie FH, Frank RM. Advances and Update on Reverse Total Shoulder Arthroplasty. *Curr Rev Musculoskelet Med*. 2019.
20. Rugg CM, Coughlan MJ, Lansdown DA. Reverse Total Shoulder Arthroplasty: Biomechanics and Indications. *Curr Rev Musculoskelet Med*. 2019;12(4):542–53.

21. Murachovsky J, Ikemoto Y, Nascimento L, Bueno R, Stroese E, Almeida L. The Distance Between the Pectoral Major Tendon Insertion and the Top of the Humeral Head as a Landmark for Proper Placement of Hemiarthroplasty in Fractures of the Proximal Humerus. *Tech Shoulder Elbow Surg.* 2008;9:66–9.
22. Voos J, Dines J, Dines D. Arthroplasty for Fractures of the Proximal Part of the Humerus. *Instr Course Lect.* 2011;60:105–12.
23. Nijs S, Broos P. Outcome of shoulder hemiarthroplasty in acute proximal humeral fractures: A frustrating meta-analysis experience. *Acta orthopaedica Belgica.* 2009;75:445–51.
24. Aaron D, Parsons B, Sirveaux F, Flatow E. Proximal humeral fractures: prosthetic replacement. *Instr Course Lect.* 2013;62:155–62.

Tables

Table 1. Demographic characteristics of two groups

Characteristic	Classic method	New method	P value
Patients	13	16	
Age at injury (years)	68.6	68.2	0.982
Gender			
Female	8	10	0.628
Male	5	6	
Fracture classification			
3-part	1	1	0.704
4-part	12	15	
Affected shoulder			
Right	8	7	0.282
Left	5	9	
Dislocated shoulder joint			
Yes	9	13	0.374
No	4	3	
Time from accident to Operation (days)	10.7	10.5	0.641
Follow up time (months)	34.38	22.06	0.00

Table 2. Clinical outcomes of two groups

Clinical outcomes	Classic method	New method	P value
Operation time (mean/ min)	145.15	120.63	0.024
Blood loss (mean / ml)	402.31	252.5	0.078
VAS (mean)	1.5 (0-7)	0.69 (0-3)	0.225
Flexion (mean °)	79.23	83.75	0.472
Extension (mean °)	36.92	37.5	0.467
Abduction (mean °)	78.46	81.86	0.393
Adduction (mean °)	34.62	35.63	0.502
CMs (mean)	60.08	60.19	0.930
Radiologic outcomes			
Healing (N)	10	14	0.504
Malunion (N)	1	0	
Migration (N)	0	0	
Resorption (N)	2	2	

Figures



Figure 1

The proximal humerus is exposed in supination. The normal anatomy of fracture is reduced according to medial calcar and intertubercular sulcus. The achieved reduction can be temporarily fixed with several 1.6-mm K-wires.



Figure 2

A hole is drilled in the lateral cortical bone of the metaphysis (arrow). It is set as the marker for restoration of humeral height and approximately 30° of retroversion.



Figure 3

The keyhole is located in the lateral cortex of metaphysis, about 2 cm away from the fracture line. The distance between the most proximal point of the humeral head and the hole is tested and set as the height of the prosthesis.



Figure 4

The height of prosthesis is confirmed according to the distance between the most proximal point of the humeral head and the hole. The retroversion of humeral head is set according to the hole.

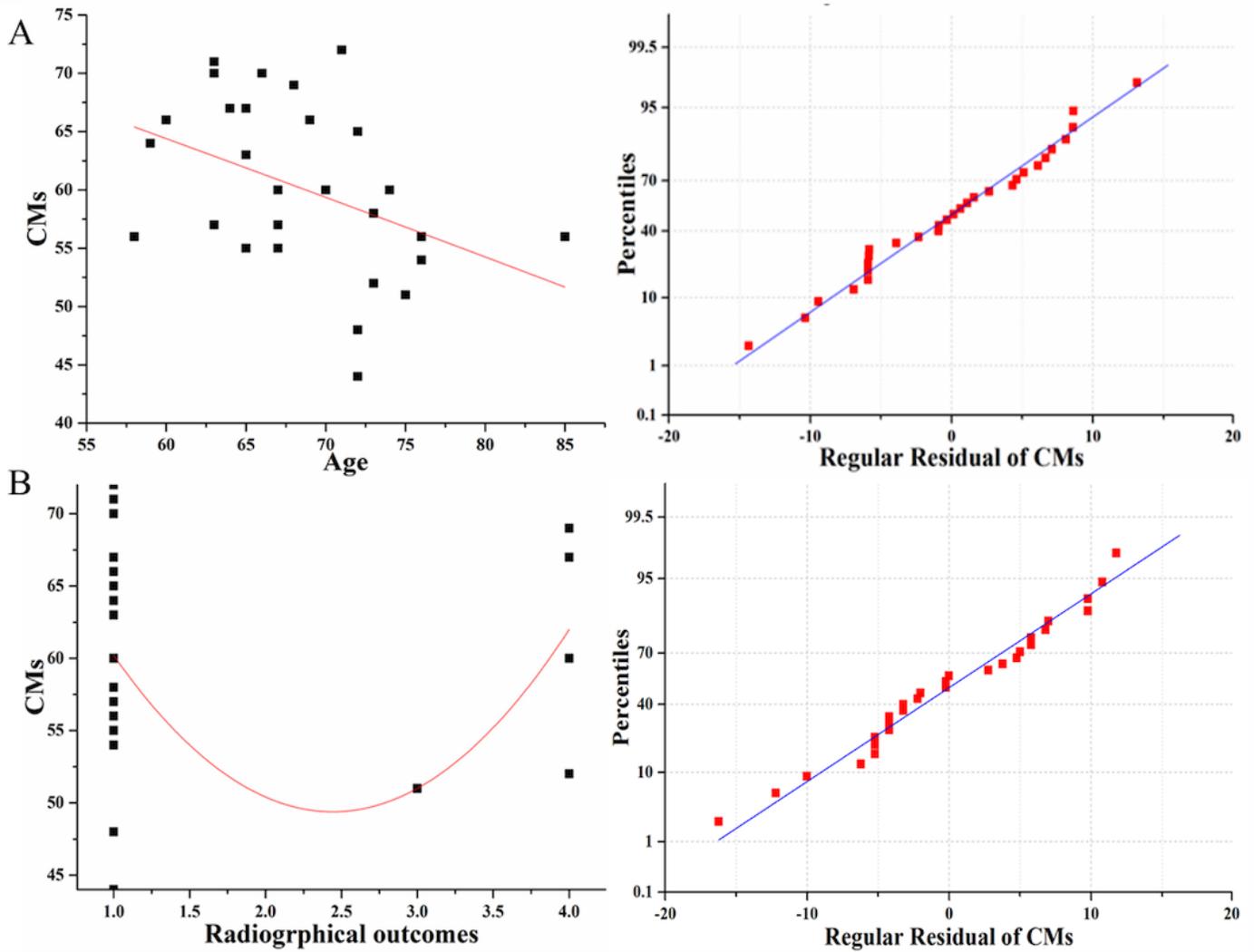


Figure 5

(A) This scatter plot with fit demonstrates linear regression and correlation CMS to age ($p=0.027$). (B) This scatter plot with fit demonstrates correlation CMS to radiographical outcomes. There was no linear relationship between the status of tuberosity and the function of the shoulder joint ($p=0.931$).