Outcome and revision rate of shoulder resurfacing arthroplasty after 7,5 years

Fanny Manauté[1], Gabriel Lateur[1], Dominique Saragaglia[1]

[1] Department of Orthopaedic Surgery and Sport Traumatology,
Grenoble South Teaching Hospital,
38130 Échirolles, France

Fanny Manauté: fmanaute@chu-grenoble.fr

ABSTARCT

Introduction: The main objective of this study was to evaluate the long-term survival rate of shoulder arthroplasties by humeral resurfacing prosthesis. The secondary objectives were to evaluate the clinical and radiological results and complications of our technique.

Materials and methods: 65 patients (75 shoulders) with a mean age of 69,1 years underwent shoulder resurfacing arthroplasty (Copeland Humeral Resurfacing Head™ then Aequalis® Resurfacing Humeral Head) between 2003 and 2017. Radiographic factors were evaluated on front view and Lamy view in preoperative and post-operative and on CT-arthrography. Functional results at the last follow-up were evaluated by Constant score, Disability Arm Shoulder and Hand score (DASH), pain on Visual analog scale and active range of motion. At the final follow-up complications were registered.

Results: At the mean follow-up of 7.5 year we reviewed 32 patients with a survival rate was of 79%. 8 patients need a surgical revision. We obtained a significant difference between pre-operative and post-operative Absolute Constant score, adjusted Constant score, antepulsion and abduction. The mean inclination of proximal humerus after prothesis was + 4,2° varus (p=0,09). We fund that indication for post-traumatic osteonecrosis is higher in complication group than in non-complication one (p=0,018). On the contrary indication for osteoarthrosis was higher in non-complication group (p=0,019).

Conclusion: This study confirmed that SRA improved considerably functional score and especially range of motion and pain but there is a significant rate of revision.

Level of evidence: Level IV, case series, therapeutic study.

Keywords: Shoulder resurfacing, hemiarthroplasty, glenohumeral arthropathy, surface replacement, shoulder prosthesis.

INTRODUCTION

Glenohumeral osteoarthritis (OA) is a common cause of shoulder pain and loss of function [1]. When conservative treatment fails, joint replacement is often considered because of its predictable pain relief and improvement of shoulder function.

Shoulder resurfacing arthroplasty (SRA) was introduced in Scandinavia in the early 1980s to treat rheumatoid shoulders[2,3] but was subsequently developed by S. Copeland [4–9.]. SRA has the theoretical advantages of a cementless surface replacement respecting humeral head anatomy for all variations of version, offset and angulation which would be expected to promote favorable glenohumeral kinetics and optimal periarticular muscle function. Therefore, there is no requirement for intra-medullary canal reaming or cementation and this is a less traumatic procedure than total shoulder arthroplasty. Revision surgery to a stemmed prosthesis can be performed easily as there is no loss of bone stock and no cement to retrieve from within the humeral shaft. Several advantages of CSRA have been postulated including shorter operation time and lower risk of periprosthetic fractures[1].

The results of surface replacement, as in any other shoulder replacement, depend on the indications and diagnosis [4]. The best results are achieved in osteoarthritis with an intact cuff, and the worst results in cuff tear arthropathy and post-traumatic arthritis.

The main objective of this study was to evaluate the long-term survival rate of shoulder arthroplasties by humeral resurfacing prosthesis. The secondary objectives were to evaluate the clinical and radiological results and complications of our technique.

Our primary criterion was surgical revision for totalization of arthroplasty. Our secondary criteria were the results for the functional scores: Constant[10,11], DASH[12] and radiological measurement.

MATERIALS AND METHODS

Study

We realized a single-center transversal observational single surgeon cohort study in our department of Orthopedic and Traumatology Surgery in the South Teaching Hospital of Grenoble.

Patients (table 1)

We reviewed all the patients who benefited from a resurfacing humeral prosthesis between 2003 and 2017.

During this period, 65 patients (75 shoulders) were operated. The dominant arm was operated in 63,2% of cases (43 shoulders). There were 18 men and 47 women with an average age of 69,1 years [32 - 88] at the time of surgery.

Our indication for RSA were patients with osteoarthritis, osteonecrosis or polyarthritis. The exclusion criteria before surgery were an active infection, a neurological lesion, and an acute fracture at the time of surgery.

Figure 1: Flow chart

Table 1: Patient characteristics

Operative technique

We successively used the Copeland Humeral Resurfacing Head (Zimmer-Biomet Orthopedic®, Warsaw, Indiana, USA) then the Aequalis® Resurfacing Humeral Head (Tornier®, Stafford, Texas, USA).

Patient was placed in beach chair position, deltopectoral approach was used and subscapularis tenotomy was performed 1 cm from the insertion onto the lesser tuberosity and reinserted at the end of surgery, by simple tendon-to-tendon suture or transosseous has it is described by Copeland[4].

Sling immobilization was maintained for 30 days. Passive rehabilitation and self-rehabilitation pendulum exercises were allowed immediately but external rotation greater than 30°degres and active internal rotation were forbidden for one month.

Patients evaluation

All the patients got pre-operative radiographs: anterior-posterior view in three rotations and Lamy view to measure size, inclination and position of humeral head. A CT-arthrography was sometimes realized to specify humeral head morphology, glenoid version according to Walch classification[13], muscular trophicity rotator cuff tendon state. In post-operative, only front view in neutral rotation and Lamy view

were performed just after surgery and at the last follow-up to compare evolution. An independent assessor performed the last radiological and clinical reviews of the patient.

The principal assessment criterion was prosthetic survival rate evaluated by any surgical revision.

The secondary assessments criteria were radiologic prognostic factors measured on the anterior-posterior view at last follow-up: correct position of the implant, Radius curvature of the humeral head (RC), humeral head height (H), humeral head diameter (HD), the inclination angle of proximal humerus (CCD), deepness of the glenoid (GD), acromio-humeral distance (AHD). Oversizing was considered present when the diameter of the implanted transcended the diameter of the anatomical humeral head. Progression of glenoid erosion was evaluated by comparing the depth of the glenoid cavity preoperatively.

Functional results at the last follow-up were evaluated by Constant score[10,11], Disability Arm Shoulder and Hand score (DASH)[12,14], pain on Visual analog scale and active range of motion (Anterior elevation, abduction and rotations). Excellent results were defined by a Constant score between 100 and 91, good results between 76 and 90, average results between 75 and 51 and poor result under 50. At the final follow-up complications were registered.

Statistical analysis was performed using XL stat (2016 version). Quantitative variables were analyzed using Student's t test. Alpha was set at 0.05 to reach statistical significance.

This study was conducted in lines with the principles of the Helsinki declaration and all patients provided consents for their participation in the study. We didn't need ethic committee consent because it is a normal follow-up with no extra imaging examination. The STROBE Checklist was used to structure the article.

RESULTATS

At the mean follow-up of 7.5 year [2;16] we reviewed 32 patients (9 men and 23 women) consisting in 36 shoulders, representing a review rate of 50% (table 2).

Survival rate and complications

Our survival rate was 79%.

8 patients (21,6%) need surgical revision after a mean of 3,5 years [0;8]. Two patients presented a fracture of humerus head associated with prosthesis loosening. 4 patients had glenoid erosion with pain and limited range of motion and two patients had pain and limited range of motion but without radiological abnormality.

Furthermore, at last follow up we noticed that 2 patients presented complications with no need of new surgery. One patient presented a fracture of the superior extremity of humerus 50 days after surgery and a rotator cuff tear 8 month after. One patient had signs of glenoid erosion and implant oversizing on the radiography. There was no significant difference in clinical and radiological results with patients without complications and this was also true when each complication was analyzed separately.

We didn't report any infection or hematoma in all the patients. One patient in the group of failed prosthesis had a brachial plexus injury that had a full recovery in 3 months. This was probably a neurapraxia induced by stretching during surgery.

Number of people operated for post-traumatic osteonecrosis was higher in the complication group and this difference was significant (p=0,018) in contrary number of people operated for osteoarthrosis was higher in the group without complication with significant difference (p= 0,019).

Functional results (table 3)

At last follow-up, the mean absolute constant score was 70,9 +/- 10,9 [40-90] and the mean adjusted constant on age and sex was 99,9 +/- 10,1 [69-118] (Figure 2).

The mean DASH score was 17,5 +/-11,4 [1,6-55,8].

Statistical analysis showed a significant difference between pre-operative and post-operative absolute Constant score, adjusted Constant score, antepulsion and abduction but there was no significant difference for external rotation in position 1 (p=0,7).

Radiological results (table 4)

The mean inclination of proximal humerus after prothesis was + 4,2° varus but the difference with pre-operative measurement was not significant (p=0,09) like for other radio measurements.

At the last follow-up there were no significant difference with pre-operative measurement in the acromial-humerus distance (p=0,06) and of the glenoid depth (p=0,3).

DISCUSSION

The aim of this study was to evaluate the long-term survival of SRA prothesis. In our study we had a survival rate of 79% at a mean follow up of 7,5 years [2-16]. Our results showed a higher revision rate after SRA than the current literature where it ranges from 3.0 to 15.0% after a follow-up of 3–22 years[1]. Our result is probably due to a longer mean follow up though we get similar results than Geervliet et al. who had a survival rate of 77% after a mean follow up of 6,5 years[15]. In most of studies, the indication for SRA was primary glenohumeral osteoarthritis unlike our study covering a wide range of etiologies.

However, concerning the functional score our results was similar with the literature (table 5).

A radiologic analysis by Thomas et al.[16] demonstrated that the Copeland resurfacing implant restored near-normal anatomic landmarks. Radius of curvature of the humeral head was reduced by about 3.5%; lateral offset increased by about 5 mm (22%) over pre-operative values. Subsequently, Hammond et al. likewise reported that resurfacing prostheses reproduced the geometric center of the humeral head more precisely than 3rd generation hemiarthroplasty[17]. Our results are in lines with these studies. Moreover, as Mansat et al. we found that the implant was mainly in varus postoperatively compared with preoperative values but that it had no influence on functional results[2].

As we expected our study confirmed that osteoarthrosis is the best indication for SRA and that post-traumatic osteonecrosis is the worst, in lines with Copeland et al[4].

Having only one senior operator strengthened the results of our study because it avoided learning bias. Despite our mean follow up was longer than most of studies.

The first limit was the number of lost patients probably due to the mean age of this population, that is higher than the mean age of review patients respectively 82 years [47-97] and 76,3 years [59-90] (p=0,013).

The second limit was the small size of the cohort that was probably not enough to highlight significant differences.

Unfortunately, only few patients get à CT-arthrography in pre-operative, so the condition of glenoid cartilage was unknown and degenerative cartilage could explain remaining pain after surgery that disappears after totalization of prosthesis.

Regarding the other options for glenohumeral arthropathy, Verstraelen et al.[1] resume current literature and say that with Total Shoulder Arthroplasty there is a prevalence of glenoid component loosening after 10 years of 80% and in 15% of cases, loosening of components leads to revision. Modern hemiarthroplasty might provide comparable clinical results without this risk of glenoid component failure. In hemiarthroplasty, both stemmed and stemless options are available, and both show good clinical and radiological results.

Lebon et al. found that stemmed hemiarthroplasty had better survival rate than SRA[18] though functional results are the same[2,17,18].

Since a few years, anatomic stemless shoulders prothesis are become more popular, and a major competitor of the SRA. In a long-term study Hawi et al.[19] found that outcomes are comparable to that of third- and fourth-generation standard shoulder prosthesis. The Constant Score improved significantly from 52% to 79%[19]. These results are similar to those of SRA. To go further a comparative study should be done, but from what we know, there is none.

Recently, Pyrolytic carbon humeral head, have been developed to limit the glenoid erosion in hemiarthroplasty. Garret et al. [20] report interesting results with a post-operative Constant improvement of 44,4 points (from 31,0 to 74,8) that seems to be better than our results for SRA but their clinical follow-up was short (only 25,9 +/- 33 months) and their population was younger 59,7 +/- 13,3 years.

Resurfacings have been used in younger individuals with a higher demand on their shoulders as a procedure to 'buy time' before conversion to total shoulder arthroplasty because of conservation of bone sock. However, access to glenoid is more difficult because of the exposition. Only add a glenoid component on a SRA prosthesis is challenging. In a stemmed hemiarthroplasty, a resection of humeral head is realized and provide an easy access to the glenoid. In our study, all the patients who need revision surgery get a resurfacing prosthesis removal before the TSA or the reverse TSA.

We did not highlight factors that could influence the risk of revision unlike Odquist et al. [23] that found that age at surgery was the main factor that influence the risk of revision and that a lower age increased it. This was true for SRA and stemmed prosthesis. Earlier studies have found that younger age is also a risk factor in Total Shoulder Arthroplasty. In a study by Singh et al.[21], younger age gave a significantly higher risk for revision after primary TSA. This age-related risk might influence the choice of primary type of implant, if a revision is expected to be a likely outcome in the future (Chillemi et al.[22]).

Since revision surgery after SRA seems easier than after stemmed hemiarthroplasties, it has been argued that resurfacing is a good option in young and active patients where the risk for a future revision might be higher (Levy et al. [23]) and can be a reason of the higher revision rate.

Shoulder resurfacing arthroplasty is as an alternative to conventional shoulder arthroplasty for the treatment of glenohumeral arthropathy. Those advantages are minimal bone resection, a short operative time, low prevalence of humeral periprosthetic fractures, maintenance of head shaft angle, and an ease of revision to a conventional total shoulder replacement[2,22,24] .

CONCLUSION

This study confirmed that SRA improved considerably functional score and especially range of motion and pain but there is a significant rate of revision. It also confirmed that osteoarthrosis is the best indication for SRA and post-traumatic osteonecrosis is the worst.

LEVEL OF EVIDENCE: Level IV, case series, therapeutic study.

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Conflict of interest: the authors declare that they have no conflict of interest.

Table 1: Population characteristic’s

	Total population
Number of shoulders/patients	75/68
Mean Age at surgery(years)	69,1 (32-88)
Male/Female	20 (29 %) / 48 (71%)
Dominant side	43 (63,2%)
Prothesis	
Copeland	12 (33,3%)
Aequalis®	24 (66,6%)

Table 2: Pre-operative characteristics of Review patients

	Total population	No complications	Complication	P value
Number of shoulders/patients	36/32	26 / 222	10/12	
Mean Age at surgery (years)	67,9 (55-86)	66,9 (55-86)	70 (55-75)	0,29
Male/Female	9(28,1%) / 23(71,8%)	7(31,8%) / 15 (68,1%)	2 (20%) / 8(80%)	0,6/0,2
Dominant side	21 (58,3%)	11 (43,3%)	9 (90%)	0,009
Mean follow-up (years)	7,5 (1-16)	7,2	6,5	
Manual Work	20 (62,5%)	16 (72,7%)	4 (40%)	0,12
Samislon classification				
1	4 (11,1%)	1 (3,8%)	3	0,025
2	7 (19,4%)	6 (23%)	1	0,38
3	23 (63,9%)	19 (73%)	4	0,013
Walch Classification	(23 shoulders)	(18 shoulders)	(5 shoulders)	
A1	9 (25%)	6 (23%)	3	0,67
A2	5 (13,9%)	4 (17,4%)	1	0,68
B1	6 (16,7%)	5 (21,7%)	1	0,51
B2	3 (8,3%)	3 (13%)		0,27
C	0	0		1
Indications				
Primary osteoarthritis	31 (86,1%)	24 (92,3%)	6 (60%)	0,019
Post-trauma osteoarthritis	2 (5,5%)	1 (3,8%)	1 (10%)	0,48
Idiopathic osteonecrosis	1 (2,7%)	1 (3,8%)	0	0,54
Post-trauma osteonecrosis	1 (2,7%)	0	2 (20%)	0,018
Polyarthritis	1 (2,7%)	0	1 (10%)	0,11
Cuff tear	5 (13,9%)	4 (15,4%)	2 (20%)	0,74
Prothesis				
Copeland	12 (33,3%)	10 (38,5%)	2 (20%)	0,30
Aequalis®	24 (66,6%)	16 (61,5%)	8 (80%)	0,30
Rx characteristics				
Head diameter (mm)	52,3 (+/-)	52 (+/-4,9)	52,9 (+/-8,3)	0,73
Cervical angle (°)	131,3 (+/-11,5)	131,1 (+/-10,2)	133,9 (+/-15,2)	0,57
Sub acromial space (mm)	8,9 (+/-5,4)	10,4 (+/-5,5)	5,1 (+/- 2,2)	0,024
Functional score				
Constant pre-operative	38,5 (+/- 13,7)	40 (+/-10)	34,8 (+/-19,8)	0,32
Pain		5,9 (3-10)	6,6 (4-10)	0,32
Function		8 (6-10)	8,3 (6-12)	0,75
Mobility		21,5 (12-36)	23,5 (14-32)	0,48
Strength		4,5 (0-12)	5 (0-10)	0,76
Constant p	55 (+/- 13,2)	53,4	58,9 (+/-12,8)	0,36
VAS rest		4,8(0-8)	5,1 (3-7)	0,74
VAS activity		7,8 (6-9)	7,6 (6-8)	0,52
Range of motion (°)				
Antepulsion	118,3 (+/-33,3)	117,5 (+/-32,6)	121,2 (+/-35,2)	0,79
Abduction	106 (+/-30,7)	107 (30,5)	102,5 (+/-31,1)	0,72
External rotation	48,8 (+/- 18,6)	48,9 (+/-20,3)	48,8 (+/-11,7)	0,99

Table 3: Clinical results of reviewed patients

	Pre-op	Post-op		
	Mean	Mean	%	p value
Abduction (°)	105,9	146,3	+27,6	<0,0001
Antepulsion(°)	115,9	160,0	+27,6	<0,0001
External rotation 1	48,4	50,2	+3,6	0,71
Constant	40,4	70,9	+43,4	<0,0001
Pain	6	13,5	+55,6	<0,0001
Function	8	14,8	+46	<0,0001
Mobility	22	32,5	+32,3	<0,0001
Strength	4,3	10,1	+57,4	0,0003
Constant p	54,6	99,9	+45,3	<0,0001
DASH		17,5		
VAS at rest	4,9	1,1	-77,6	<0,0001
VAS in activity	7,8	2,0	-74,4	<0,0001

Table 4: Radiological results of reviewed patients

	Pre-operative				Immediately Post-operative			
	Total population	P without c	Complications	P value	Total population	P without c	Complication	P value
RC (mm)	30,7	29,78 (20,41)	30,8 (24-43)	0,6	31,4	30,6 (21-40)	30,6 (21-39)	0,98
HD (mm)	51,9	51,78 (40-63)	53,3 (43,67)	0,51	52	51 (42-61)	54 (42-68)	0,22
LO (mm)	10,3	9,57 (0-18)	15,8 (6-23)	0,0078	10,3	8,7 (0-21)	13,54 (5-26)	0,003
CCD (°)	129,7	130,78 (112-158)	134,1 (100-150)	0,46	125,5	126,2 (104-152)	124,45 (112-140)	0,61
AHD (mm)	10	10,39 (4-26)	5,3 (1-11)	0,011	9,6	9,83 (1-21)	9,27 (5-13)	0,75

RC: Radius Curvature of the humeral head
HD: Humeral Head Diameter
CCD: inclination angle of proximal humerus (CCD)
AHD: Acromio-Humeral Distance (AHD)

Table 5: Literature on Constant and absolute Constant score after SRA

	Levy 2004	Thomas 2005	Al-Hadithy 2012	Gieverliet 2014	Verstraelen 2015	Current Study 2019
Number of patients	37	48	50	49	33	32
Follow-up (years)	4,4	2,8	4,2	2	7,3	7,5
Mean age of population	73,4	68	69	69	67,7	67,9
Constant score evolution	+32,7 (25,3 to 58,1)	+37,6 (16,4 to 54)	+38,2 (24,2 to 62,4)	-	+36,2 (20,2 to 56,4)	+30,5 (40,4 to 70,9)
Adjust Constant score evolution	+ 51 (40 to 91)	-	36,6 (38,5 to 75,1)	+ 30 (49 to 79)	+ 51,5 (25 to 76,5)	+ 45,3 (54,6 to 99,9)

Figure 1: Flow chart

Figure 2: Representation of post-operative absolute Constant score

Excellent: Constant score between 100 and 91
Good: score between 76 and 90
Average: score between 75 and 51
Poor: score under 50

REFERENCES

1. Verstraelen FU, Horta LA, Schotanus MGM, Kort NP, Samijo SK, Jansen EJP. Clinical and radiological results 7 years after Copeland shoulder resurfacing arthroplasty in patients with primary glenohumeral osteoarthritis: an independent multicentre retrospective study. *Eur J Orthop Surg Traumatol Orthop Traumatol*. 2018;28(1):15-22. doi:10.1007/s00590-017-2023-8

2. Mansat P, Coutié A-S, Bonnevialle N, Rongières M, Mansat M, Bonnevialle P. Resurfacing humeral prosthesis: do we really reconstruct the anatomy? *J Shoulder Elbow Surg*. 2013;22(5):612-619. doi:10.1016/j.jse.2012.07.014

3. Rydholm U, Sjögren J. Surface replacement of the humeral head in the rheumatoid shoulder. *J Shoulder Elbow Surg*. 1993;2(6):286-295. doi:10.1016/1058-2746(93)90074-Q

4. Copeland SA, Levy O, Brownlow HC. Resurfacing Arthroplasty of the Shoulder. *Tech Shoulder Elb Surg*. 2003;4(4):199.

5. Copeland S. The continuing development of shoulder replacement: "reaching the surface." *J Bone Joint Surg Am*. 2006;88(4):900-905. doi:10.2106/JBJS.F.00024

6. Levy O, Copeland SA. Cementless surface replacement arthroplasty of the shoulder. 5- to 10-year results with the Copeland mark-2 prosthesis. *J Bone Joint Surg Br*. 2001;83(2):213-221.

7. Levy O, Funk L, Sforza G, Copeland SA. Copeland surface replacement arthroplasty of the shoulder in rheumatoid arthritis. *J Bone Joint Surg Am*. 2004;86-A(3):512-518.

8. Levy O, Copeland SA. Cementless surface replacement arthroplasty (Copeland CSRA) for osteoarthritis of the shoulder. *J Shoulder Elbow Surg*. 2004;13(3):266-271. doi:10.1016/S1058274604000229

9. Deladerrière J-Y, Szymanski C, Vervoort T, Budzik J-F, Maynou C. Geometrical analysis results of 42 resurfacing shoulder prostheses: A CT scan study. *Orthop Traumatol Surg Res OTSR*. 2012;98(5):520-527. doi:10.1016/j.otsr.2012.03.010

10. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop*. 1987;(214):160-164.

11. Constant CR, Gerber C, Emery RJH, Søjbjerg JO, Gohlke F, Boileau P. A review of the Constant score: modifications and guidelines for its use. *J Shoulder Elbow Surg*. 2008;17(2):355-361. doi:10.1016/j.jse.2007.06.022

12. Angst F, Schwyzer H-K, Aeschlimann A, Simmen BR, Goldhahn J. Measures of adult shoulder function: Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH) and its short version (QuickDASH), Shoulder Pain and Disability Index (SPADI), American Shoulder and Elbow Surgeons (ASES) Society standardized shoulder assessment form, Constant (Murley) Score (CS), Simple Shoulder Test (SST), Oxford Shoulder Score (OSS), Shoulder Disability Questionnaire (SDQ), and Western Ontario Shoulder Instability Index (WOSI). *Arthritis Care Res*. 2011;63 Suppl 11:S174-188. doi:10.1002/acr.20630

13. Vo KV, Hackett DJ, Gee AO, Hsu JE. Classifications in Brief: Walch Classification of Primary Glenohumeral Osteoarthritis. *Clin Orthop*. 2017;475(9):2335-2340. doi:10.1007/s11999-017-5317-6

14. Beaton DE, Wright JG, Katz JN, Upper Extremity Collaborative Group. Development of the QuickDASH: comparison of three item-reduction approaches. *J Bone Joint Surg Am*. 2005;87(5):1038-1046. doi:10.2106/JBJS.D.02060

15. Geervliet PC, van den Bekerom MPJ, Spruyt P, Curvers M, van Noort A, Visser CPJ. Outcome and revision rate of uncemented glenohumeral resurfacing (C.A.P.) after 5-8 years. *Arch Orthop Trauma Surg*. 2017;137(6):771-778. doi:10.1007/s00402-017-2688-9

16. Thomas SR, Sforza G, Levy O, Copeland SA. Geometrical analysis of Copeland surface replacement shoulder arthroplasty in relation to normal anatomy. *J Shoulder Elbow Surg*. 2005;14(2):186-192. doi:10.1016/j.jse.2004.06.013

17. Hammond G, Tibone JE, McGarry MH, Jun B-J, Lee TQ. Biomechanical comparison of anatomic humeral head resurfacing and hemiarthroplasty in functional glenohumeral positions. *J Bone Joint Surg Am*. 2012;94(1):68-76. doi:10.2106/JBJS.I.00171

18. Lebon J, Delclaux S, Bonnevialle N, et al. Stemmed hemiarthroplasty versus resurfacing in primary shoulder osteoarthritis: a single-center retrospective series of 78 patients. *Orthop Traumatol Surg Res OTSR*. 2014;100(6 Suppl):S327-332. doi:10.1016/j.otsr.2014.05.012

19. Hawi N, Magosch P, Tauber M, Lichtenberg S, Habermeyer P. Nine-year outcome after anatomic stemless shoulder prosthesis: clinical and radiologic results. *J Shoulder Elbow Surg*. 2017;26(9):1609-1615. doi:10.1016/j.jse.2017.02.017

20. Garret J, Harly E, Le Huec J-C, Brunner U, Rotini R, Godenèche A. Pyrolytic carbon humeral head in hemi-shoulder arthroplasty: preliminary results at 2-year follow-up. *JSES Open Access*. 2019;3(1):37-42. doi:10.1016/j.jses.2018.09.002

21. Singh JA, Sperling JW, Cofield RH. Revision surgery following total shoulder arthroplasty: analysis of 2588 shoulders over three decades (1976 to 2008). *J Bone Joint Surg Br*. 2011;93(11):1513-1517. doi:10.1302/0301-620X.93B11.26938

22. Chillemi C, Franceschini V. Shoulder Osteoarthritis. Arthritis. doi:10.1155/2013/370231

23. Levy O, Tsvieli O, Merchant J, et al. Surface replacement arthroplasty for glenohumeral arthropathy in patients aged younger than fifty years: results after a minimum ten-year follow-up. *J Shoulder Elbow Surg*. 2015;24(7):1049-1060. doi:10.1016/j.jse.2014.11.035

24. Burgess DL, McGrath MS, Bonutti PM, Marker DR, Delanois RE, Mont MA. Shoulder resurfacing. *J Bone Joint Surg Am*. 2009;91(5):1228-1238. doi:10.2106/JBJS.H.01082

Figure 1: Flow chart

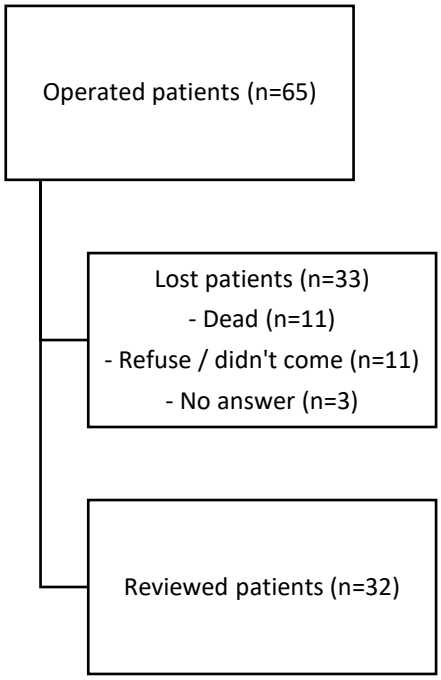

Figure 2: representation of post-operative absolute constant score