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Short-term outcomes and survival of pyrocarbon hemiarthroplasty in the young arthritic shoulder

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Hypothesis: The purpose was to report the short-term outcomes and survival of hemiarthroplasty with a pyrocarbon head (HA-PYC) for the treatment of shoulder osteoarthritis in patients aged ≤ 60 years. We hypothesized that HA-PYC could be an alternative to hemimetal (avoiding the risk of rapid glenoid erosion) and total shoulder arthroplasty (TSA) (avoiding the risk of rapid glenoid loosening) in an active patient population.
Methods: Sixty-four consecutive patients (mean age, 53 years) who underwent HA-PYC for glenohumeral osteoarthritis were included. The primary outcome was revision to TSA or reverse shoulder arthroplasty. Secondary outcome measures included functional outcome scores; return to work and sports; and radiographic evaluation of humeral reconstruction quality using the "circle method" of Mears, as well as glenoid erosion severity and progression using the Sperling classification. Patients were reviewed and underwent radiography at an average follow-up of 33 months (range, 24-60 months).
Results: At last follow-up, the rate of survival of the HA-PYC prosthesis was 92%. Revision was performed in 5 patients, with a mean delay of 24 months (range, 15-37 months): 1 conversion to TSA and 4 conversions to reverse shoulder arthroplasty. The Constant score and Subjective Shoulder Value increased from 36 points (range, 26-50 points) to 75 points (range, 69-81 points) and from 35% (range, 20%-50%) to 80% (range, 75%-90%), respectively ($P < .001$). Postoperatively, 91% of the patients (42 of 46) returned to work and 88% (15 of 17) returned to sport. The severity of preoperative and postoperative glenoid wear (Sperling grade 3 or 4) had no influence on the functional results. Patients who underwent associated concentric glenoid reaming (n = 23) had similar Constant scores and Subjective Shoulder Values ($P = .95$) to other patients and did not show more progression of glenoid wear. Nonanatomic reconstruction of the proximal humerus (center of rotation of the prosthesis > 3 mm from the anatomic center) occurred in 29% (18 of 62 patients) and was associated with significantly lower functional and subjective results, more complications (subscapularis insufficiency and/or symptomatic glenoid erosion), and a higher risk of revision. The additional 1.5-mm thickness of the metal disc under the pyrocarbon head was found to be the main reason for oversizing of the prosthetic head.
Conclusion: HA-PYC is a reliable procedure to treat shoulder osteoarthritis and allows return to work and sports in a young (≤60 years) and active patient population. The severity of glenoid bone erosion or the association with glenoid reaming does not affect functional outcomes and failure risk. By contrast, nonanatomic reconstruction of the proximal humerus after HA-PYC (because of humeral head oversizing) occurred in one-third of the cases and is associated with lower functional outcomes, as well as higher risks of complications and revision.

Institutional review board approval was not required for this case series.

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The treatment of glenohumeral osteoarthritis (GHOA) in young (≤60 years) and active patients remains a dilemma for the surgeon: Hemiarthroplasty (HA) with metallic heads carries a risk of rapid glenoid erosion with functional deterioration, whereas total shoulder arthroplasty (TSA) carries a risk of rapid glenoid loosening. As a result, half of young patients (≤60 years) who have undergone shoulder arthroplasty of all sorts for osteoarthritis (OA) present unsatisfactory clinical and radiologic results.[13,22,31] At long-term follow-up, only 25% of patients with OA treated with HA-metal implants are satisfied with their outcomes.[22] Clinical studies have shown that TSA has outperformed HA regarding pain relief, shoulder function, and the revision rate in patients with primary OA.[3,6,7,11,15] However, a high risk of glenoid implant loosening and a high rate of revision have been reported after TSA in younger and active patients.[21,31] This major controversy surrounding the use of HA or TSA in young patients also has important economic impacts.[5,28]

Many young, active patients with OA have high physical demands, high expectations, and long life spans.[12,20] Alternative bearing surfaces, such as pyrocarbon, have been proposed to avoid glenoid erosion and deterioration of the functional results after HA.[14] Pyrocarbon has tribological qualities and elastic properties close to those of cortical bone,[10] and it has been thought that this material could be used for humeral head replacement and thus would potentially reduce glenoid wear. Indeed, pyrocarbon implants have demonstrated good results in hand surgery[27] and elbow surgery,[16] but to date, few data are available regarding shoulder OA.[2,13,15]

In patients with incongruent or biconcave glenoids, HA associated with concentric reaming (known as the "ream and run" procedure) has been popularized by Matsen[24] as an alternative technique for glenoid resurfacing.[23,29] Although some authors have reported good to excellent results with this technique,[23,24,29] a recent report has shown that up to 25% of patients required revision surgery at an average of 2.7 years after metallic-head HA and glenoid reaming.[18]

The questions we sought to answer were as follows: Could hemiarthroplasty with a pyrocarbon head (HA-PYC) be a reliable implant in younger patients with high demands? Would this new bearing surface prevent increased glenoid erosion with functional deterioration seen with metallic heads? Does the severity of the initial glenoid erosion affect the risk of failure of HA-PYC? Would associated concentric reaming increase the risk of deterioration of the functional and radiologic results? We hypothesized that HA-PYC would be a reliable procedure to treat GHOA and allow return to work and sports in a young (≤60 years) and active patient population. A second hypothesis was that the severity of glenoid bone erosion could affect functional outcomes and failure risk.

Methods

Study design

We included patients aged ≤ 60 years who underwent HA-PYC for the treatment of symptomatic GHOA and were reviewed with a minimum follow-up period of 2 years. We included patients with either primary arthritis, post-instability arthritis, rheumatoid arthritis, or post-traumatic arthritis. Patients with previous surgery for cuff pathology, instability, or fracture fixation were included. All types of glenoid erosion according to Walch (A, B, or C) were accepted. We excluded patients who underwent previous shoulder arthroplasty. All patients gave their informed consent to be included in this study.

Patient population

Between November 2013 and March 2017, 64 shoulders (62 patients) received HA-PYC in 5 tertiary shoulder centers and were included in the analysis. The average follow-up period was 33 months (range, 24-60 months). Demographic data are summarized in Table I.

Surgical procedure

The surgical procedure was performed with the patient under general and local anesthesia through a deltopectoral approach. The subscapularis tendon was detached from the lesser tuberosity using a peel-off technique (32 cases) or a tenotomy (32 cases). Tenotomy or tenodesis of the long head of the biceps was systematically performed. Humeral head osteotomy was performed at the anatomic neck level after osteophyte removal. The Aequalis Ascend Flex stem (Tornier-Wright, Memphis, TN, USA) was implanted in all patients. All but 3 stems were uncemented. The diameter of the pyrocarbon head varied between 39 and 50 mm and had 2 mm more thickness in HA-PYC compared with a hemimetal head because of a 2-mm-thick metal disc under the pyrocarbon head. At the end of the procedure, the subscapularis tendon was reattached with transosseous sutures. Associated concentric glenoid reaming was performed in 23 patients (36%) either to smoothen the glenoid surface in type A glenoids (5 cases) or to correct retroversion in type B or C glenoids (18 cases).

Table I Demographic characteristics (N = 64)

Parameter	Data
Age at surgery, yr	53 (25-60)
Female/male, n (%)	20 (31)/44(69)
Right/left, n	45/19
Dominant side, n (%)	55 (86)
Smoking, n (%)	13 (20.3)
Diabetes, n (%)	3 (5)
Body mass index, kg/m^2	27 (23-29)
ASA class, n (%)	
1	21 (33)
2	33 (52)
3	5 (8)
4	0 (0)
Physical activity at work, n (%)	
No manual labor	18 (28)
Light manual labor	19 (30)
Heavy manual labor	22 (34)
Retired	5 (8)
Practice of sport before symptom onset, n (%)	17 (29)
Pathology, n (%)	
Primary osteoarthritis	20 (31)
Instability arthritis	15 (23)
Post-traumatic arthritis	13 (20)
Aseptic osteonecrosis	13 (20)
Rheumatoid arthritis	3 (5)
Previous surgical treatment, n (%)	35 (55)
Arthroscopic cuff repair	3 (5)
Long head of biceps tenotomy (n = 2) or tenodesis (n = 4)	6 (9)
Graft jacket	1 (2)
Proximal fracture fixation	8 (13)
Stabilization procedure	
Anterior Bankart	3 (5)
Latarjet	10 (16)
Posterior Bankart	1 (2)
Prosthetic humeral head size, mm	48 (43-50)
Type of glenoid erosion according to Walch classification, n (%)	
A1	3 (15)
A2	1 (5)
B1	7 (35)
B2	7 (35)
B3	1 (5)
C	1 (5)

ASA, American Society of Anesthesiologists.

Clinical and radiologic outcome assessment

The primary outcome was revision to TSA or reverse shoulder arthroplasty. Secondary outcome measures included subjective (Subjective Shoulder Value [SSV]) and functional (Constant score[9,19]) outcome scores; shoulder active mobility; return to work and sports; and radiographic evaluation of humeral reconstruction quality using the "circle method" of Mears et al,[25] as well as glenoid erosion severity and progression using the Sperling classification.[32]

Standard anteroposterior (AP) radiographs (in neutral, internal, and external rotation) were obtained before the intervention, the day after the surgical procedure, and at last follow-up. The glenoid morphology was determined on the preoperative computed tomography (CT) scan based on the modified Walch classification.[4] The radiographs were retrospectively analyzed independently by 4 observers (3 shoulder surgeons and 1 radiologist). A consensus among the 4 observers was sought regarding the following parameters.

Severity of glenoid erosion

The severity of glenoid erosion was assessed and graded on preoperative, immediate postoperative, and last follow-up AP radiographs using the method proposed by Sperling et al.[32] Glenoid erosion was graded as none (grade 1), mild (grade 2; erosion into subchondral bone), moderate (grade 3; medialization past the subchondral bone with hemispheric deformation), or severe (grade 4; complete deformation or destruction of the glenoid or hemispheric deformation until or beyond the base of the coracoid) (Fig. 1).

Quality of humeral reconstruction

The quality of the humeral reconstruction was evaluated on preoperative and postoperative AP radiographs using the humeral head circle-fit method described by Alolabi et al[1] and Mears et al.[25,30] Three independent surgeons (C.C., P.B., and M.O.G.) compared the center of rotation of the prosthesis with the native center of rotation. A circle fit to the articular margin of the humeral head was manually drawn to determine whether the implant was too proud or the prosthetic head was oversized (or the contrary). If the center of rotation of the prosthesis was >3 mm from the anatomic center, the humeral reconstruction was considered "nonanatomic."[1,25,30]

Data collection

Data were retrospectively collected using electronic and paper medical records, as well as the computer software programs Ortho+ (version 17) and Clinicom (version 2019). Imaging data were collected from picture archiving and communication system software, as well as Easymedstat software.

Statistical analysis

Categorical data were expressed as the number of patients and percentage, and continuous variables were expressed as the median and interquartile range. Group differences were compared by a nonparametric Mann-Whitney test for continuous variables. The Fisher exact test was used for categorical data. A 2-sided P value $< .05$ was considered significant. A Kaplan-Meier curve was used to assess the survival of patients free from revision. Statistical analyses were performed using GraphPad Prism software (version 7.00; GraphPad Software, La Jolla, CA, USA).

The reproducibility of the Sperling classification was determined using radiographs and was analyzed by calculating the intraclass correlation coefficient and 95% confidence interval of the mean difference among 4 observers (C.C., M.O.G., J.L.R., and H.V.). The intraclass correlation coefficient and 95% confidence interval were calculated between the 2 analyses performed at

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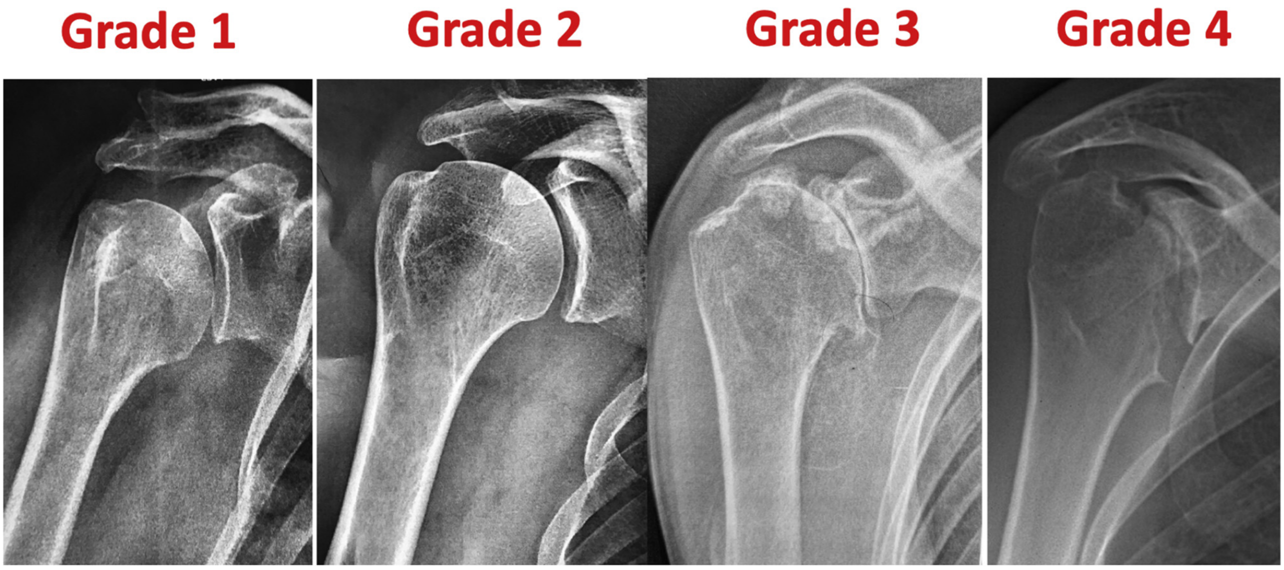

Figure 1 Grading of preoperative glenoid erosion according to Sperling classification: grade 1, no erosion; grade 2, subchondral erosion; grade 3, medialization; and grade 4, medialization until base of coracoid.

2-week intervals by a single observer (C.C.) to assess the intra-observer reliability.

Results

Prosthesis survival

At last follow-up, the rate of survival of the HA-PYC prosthesis was 92% (Fig. 2). Revision was performed in 5 patients (8%); the mean delay to revision was 24 months (range, 15-37 months). One patient with painful glenoid erosion underwent conversion of the HA to a TSA and had good pain relief. Four patients had postoperative cuff deficiency (3 subscapularis tears and 1 supraspinatus tear) and underwent conversion to a reverse shoulder arthroplasty. Among the 3 subscapularis tears, 2 were traumatic (1 heavy worker and 1 rheumatoid patient); the third was associated with early infection after HA-PYC for a fracture sequela.

Functional outcomes

We evaluated the functional outcomes and range of motion of the 59 patients who still had their prostheses in place at last follow-up. Table II summarizes the results and shows that all the parameters of the Constant score improved significantly. With the number available, we observed that sex, age, diagnosis, and glenoid wear did not significantly affect final shoulder function or SSVs.

Return to work and sports participation

Among the 46 patients who were active workers before the intervention, 38 (83%) were able to go back to work with

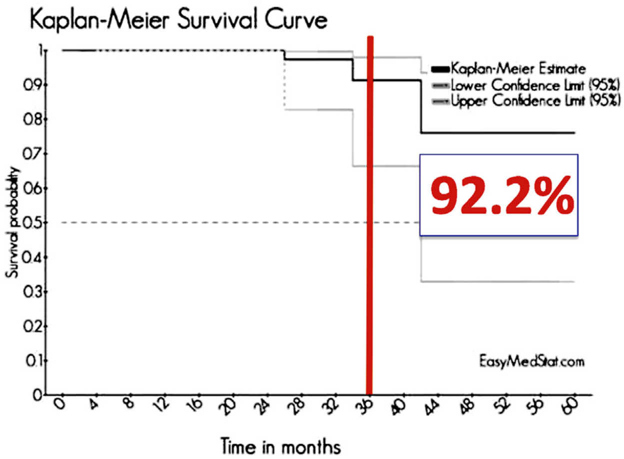

Figure 2 Kaplan-Meier survival curve of patients free from reintervention (N = 64).

the same working conditions, 4 (9%) needed an adaptation of the working conditions, and 4 (9%) did not return to work. Before the intervention, 17 patients (29%) practiced sports; among them, 15 (88%) returned to sport after the intervention (Table III).

Glenoid erosion

The reproducibility of the Sperling classification was determined using radiographs, and we found a linear correlation between the 4 observers (C.C., M.O.G., J.L.R., and H.V.; $P < .001$). Preoperatively, 24 patients (45%) had moderate or severe glenoid erosion (Sperling grade 3 or 4) vs. 28 patients (52%) postoperatively and 41 patients (70%) at last follow-up (Fig. 3). The evolution of glenoid erosion is summarized in Figure 4.

Table II Functional outcomes after pyrocarbon hemiarthroplasty (n = 59)

	Preoperative	Last follow-up (33 ± 6 mo)	*P* value
Active forward elevation, °	90 (80-130)	160 (140-160)	<.0001
Active external rotation, °	10 (0-30)	40 (30-50)	<.0001
Active internal rotation, points	4 (2-6)	7 (6-8)	<.0001
Subjective Shoulder Value (of 100), %	35 (20-50)	80 (75-90)	<.0001
Constant score (of 100), points	36 (26-50)	75 (69-81)	<.0001
Pain (of 15)	5 (3-8)	12 (12-15)	<.0001
Activity (of 20)	10 (6.8-12)	18 (16-19)	<.0001
Mobility (of 40)	18 (10-22)	34 (32-36)	<.0001
Strength (of 25)	4.5 (2-8.5)	11 (7-15)	<.0001

Data are presented as median (interquartile range).

Table III Evolution of lifestyle after pyrocarbon hemiarthroplasty

	n (%)
Return to work	
No active work before surgery	13 (22)
Work before surgery	46 (78)
Return to work with same working conditions	38 (83)
Return to work with adaptation	4 (9)
No return to work owing to physical disability	1 (2)
No return for another reason	3 (7)
Return to sport	
No practice of sport before surgery	42 (71)
Practice of sport before surgery	17 (29)
Return to sport at same level	11 (65)
Return to sport at lower level	4 (24)
No return to sport	2 (12)

The global proportion of patients with Sperling grade 4 significantly increased between immediate postoperative and last follow-up (33% to 12%, P = .0074). At final follow-up, glenoid erosion had evolved in 23 glenoids (39%), either to correct posterior humeral subluxation (18 cases) or to improve congruency (5 cases). The severity of glenoid erosion had no influence on the functional outcome at last follow-up. The 23 patients who underwent concentric glenoid reaming had similar Constant scores and SSVs to the other patients ($P > .9$) and did not show significantly more progression of glenoid wear ($P = .47$).

Quality of humeral reconstruction

Nonanatomic humeral reconstruction was identified in 18 cases (28%) because of a proud prosthesis and/or oversized prosthetic head (Fig. 5). At last follow-up, 4 of these needed a revision to reverse shoulder arthroplasty because of glenoid erosion and subscapularis insufficiency. We also found that there was 2 mm more thickness in HA-PYC compared with hemi-metal (Fig. 6) because of a 2-mm-thick metal disc under the pyrocarbon head. In the nonanatomic reconstruction group, the clinical results were inferior, with a higher revision rate, more subscapularis tears, and a tendency toward increased glenoid erosion. The results are presented in Table IV.

Discussion

The results of this study confirm our first hypothesis: HA-PYC is a valuable option for the treatment of GHOA in a young (≤60 years), active, demanding population. At short-term follow-up, HA with this new bearing surface provides improved pain relief and shoulder function, as well as high rates of return to work and sports. Overall, 90% of the patients were satisfied with their outcomes, and the subjective value of the shoulder was reported to be, on average, 80% of a normal shoulder. The results reported in our study with HA-PYC are similar to those observed after standard HA with metallic heads[22,26] or even after TSA.[8]

The survival rate free from revision after HA-PYC for OA found in our series is promising (92% at 3 years), although it is not different, at this follow-up, from the rates reported for hemi-metal and TSA.[22,33] Our data confirm the survival rate reported by Garret et al[14] with the same implant (95% at 2 years' follow-up). In our series, 5 patients (8%) underwent revision surgery mainly for cuff insufficiency or subscapularis tearing.[14] We found that revision to TSA (1 case) or reverse shoulder arthroplasty (4 cases) was facilitated by humeral stem conservation and convertibility.

Our second hypothesis—that the severity of glenoid bone erosion could affect the functional results and the failure risk—is not confirmed. The Sperling grade increased in 39% of patients, whereas Garret et al[14] found that at the 2-year follow-up, glenoid erosion progressed slightly in 14% of patients. In our study, the severity of preoperative and immediate postoperative glenoid wear (Sperling grade 3 and 4) had no influence on the functional results at last follow-up. Among the 33 patients with no or minor glenoid erosion preoperatively (grade 1 or 2

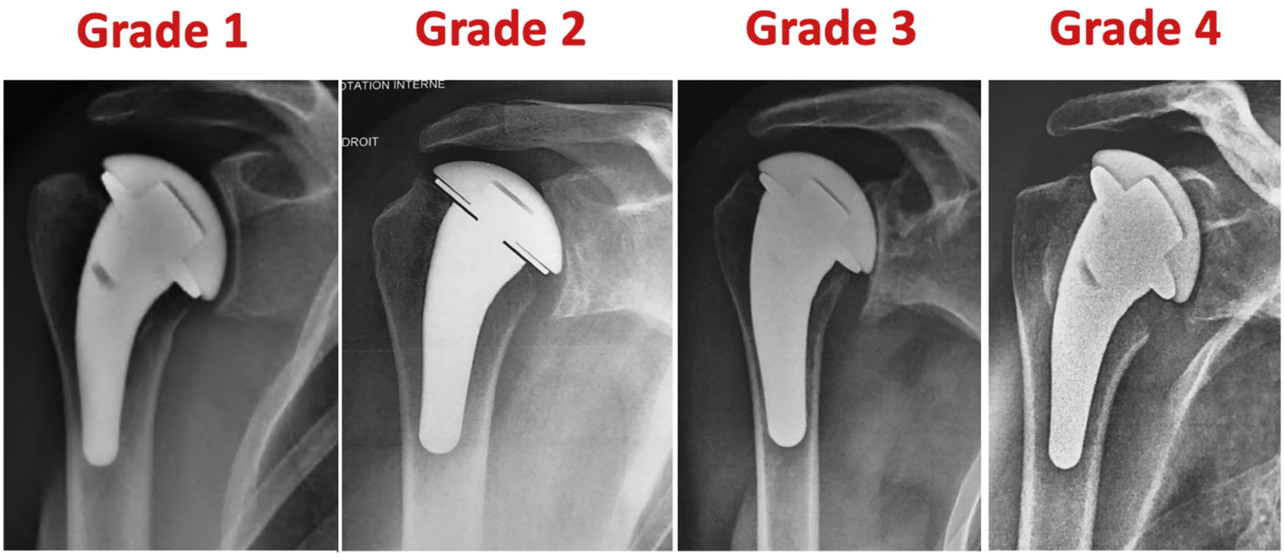

Figure 3 Grade of erosion at last follow-up according to Sperling classification: grade 1, no erosion; grade 2, subchondral erosion; grade 3, medialization; and grade 4, medialization until base of coracoid.

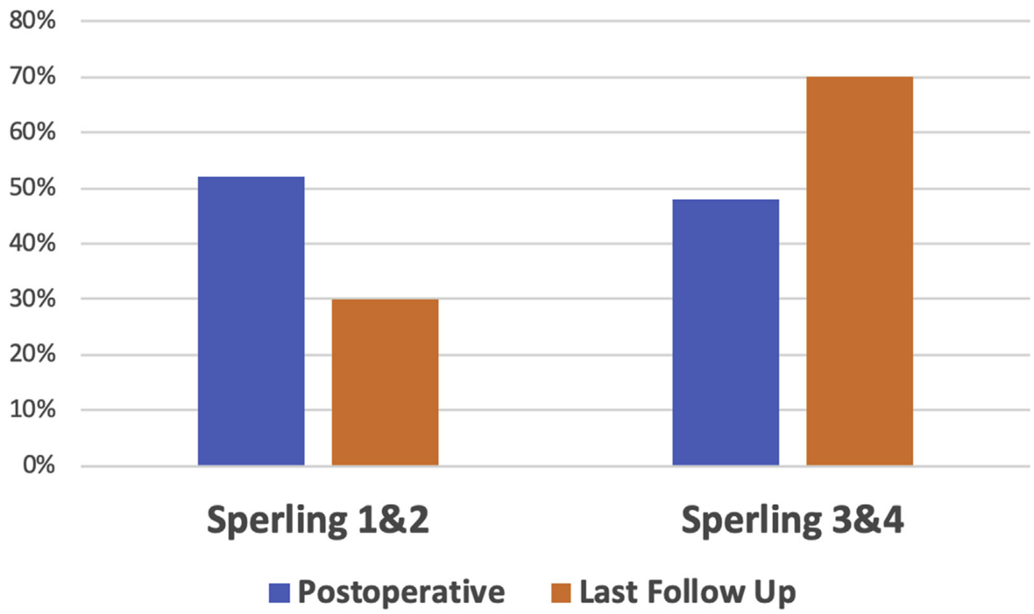

Figure 4 Evolution of hemiarthroplasty with pyrocarbon head with glenoid erosion (n = 59).

according to the Sperling classification), 14 (42%) showed the development of some glenoid erosion (grade 3 or 4) at the last follow-up. Increased glenoid erosion had no influence on the pain scores and functional results in our series. In contrast to HA-metal implants, glenoid erosion after HA-PYC has no influence on pain scores and functional results at short-term follow-up. Although longer follow-up is needed to confirm these results, our data suggest that HA-PYC does not fully prevent glenoid erosion over time but that this increased glenoid erosion is not painful or is less painful.

It must be emphasized that HA with a pyrocarbon head has been approved for clinical use in Europe and Australia but is not yet available in the United States. The mechanical properties of the pyrocarbon bearing surface material (modulus of elasticity and density) are very similar to those of cortical bone, which makes it ideal for implant-bone stress transfer.[27] In an experimental study performed in canines, it was shown that pyrocarbon articulated well against bone, cartilage, and soft tissues, generating 10 times less cartilage wear than cobalt-chromium and 6 times fewer microscopic subchondral cracks than cobalt-chromium.[10]

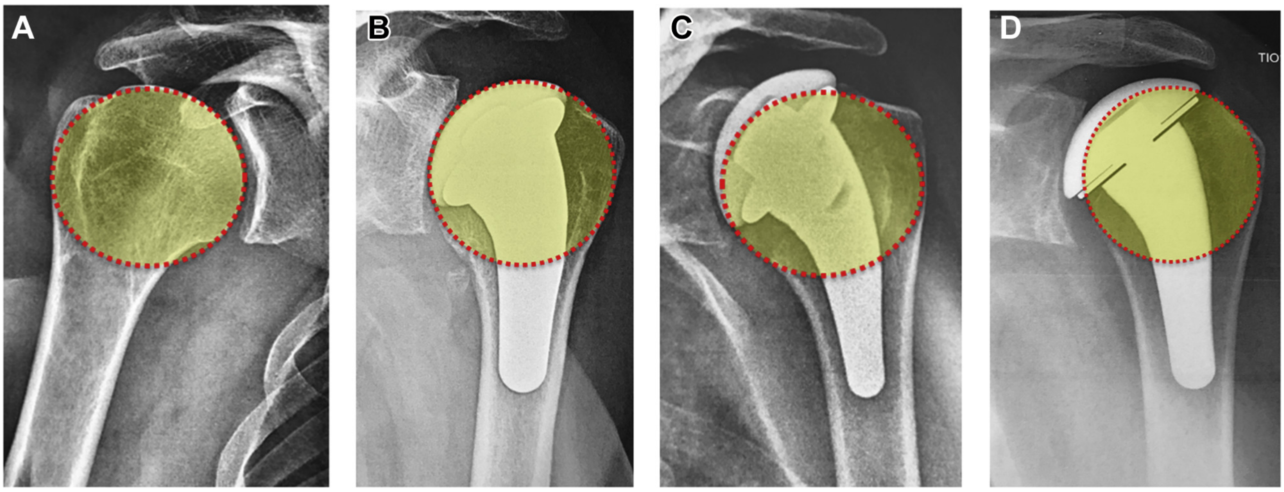

Figure 5 Evaluation of humeral reconstruction quality using circle method according to Mears et al.[25] (**A**) Native humerus. (**B**) Postoperative radiograph showing anatomic humeral reconstruction. **(C)** Postoperative radiograph showing nonanatomic humeral reconstruction because of proud prosthesis. (**D**) Postoperative radiograph showing nonanatomic humeral reconstruction because of oversized prosthetic head.

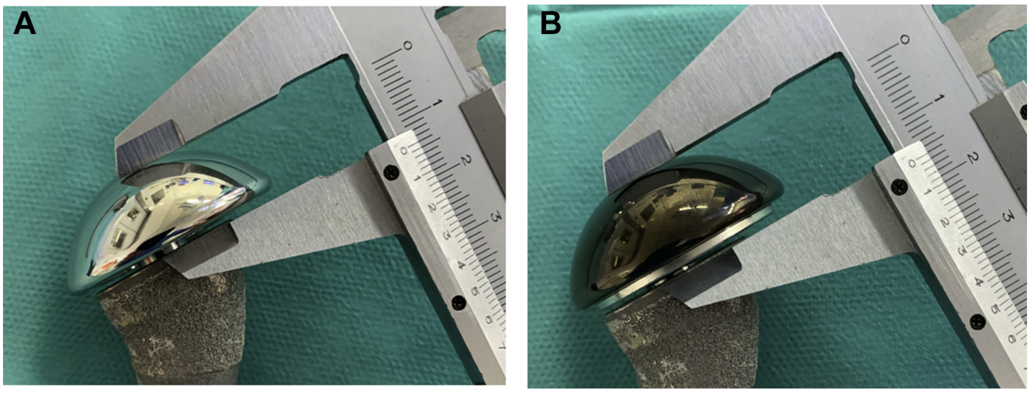

Figure 6 For the same diameter (39 mm in this case), the pyrocarbon head (**B**) is 2 mm thicker than the metallic head (**A**) (16 mm vs. 14 mm) because of the metallic tray needed to support the pyrocarbon head.

Table IV Comparison of clinical and radiologic results between anatomic and nonanatomic humeral reconstruction

	Anatomic reconstruction (n = 46)	Nonanatomic reconstruction (n = 18)	*P* value
Active forward elevation, °	154	111	.005
Active external rotation, °	46	28	.004
Active internal rotation, points	7	4	.002
Constant score, points	78 (14-100)	48 (14-72)	.003
Subjective Shoulder Value, %	83	58	.004
Progressive glenoid erosion, %	37	61	.07
Subscapularis tear, n	1	3	.04
Revision rate, %	2.2	22	.019

Pyrocarbon, initially developed for nuclear energy applications, is remarkably resistant to fatigue because, at ambient and body temperatures, the crystallographic mechanisms for crack initiation and damage propagation are negligible. Furthermore, pyrocarbon wears very little when sliding against itself or against bone or cartilage and is considered nearly ‘‘non-wearable.’’

Associated concentric glenoid reaming was mainly performed either to smoothen an irregular glenoid surface in type A glenoids (5 cases) or to correct retroversion and

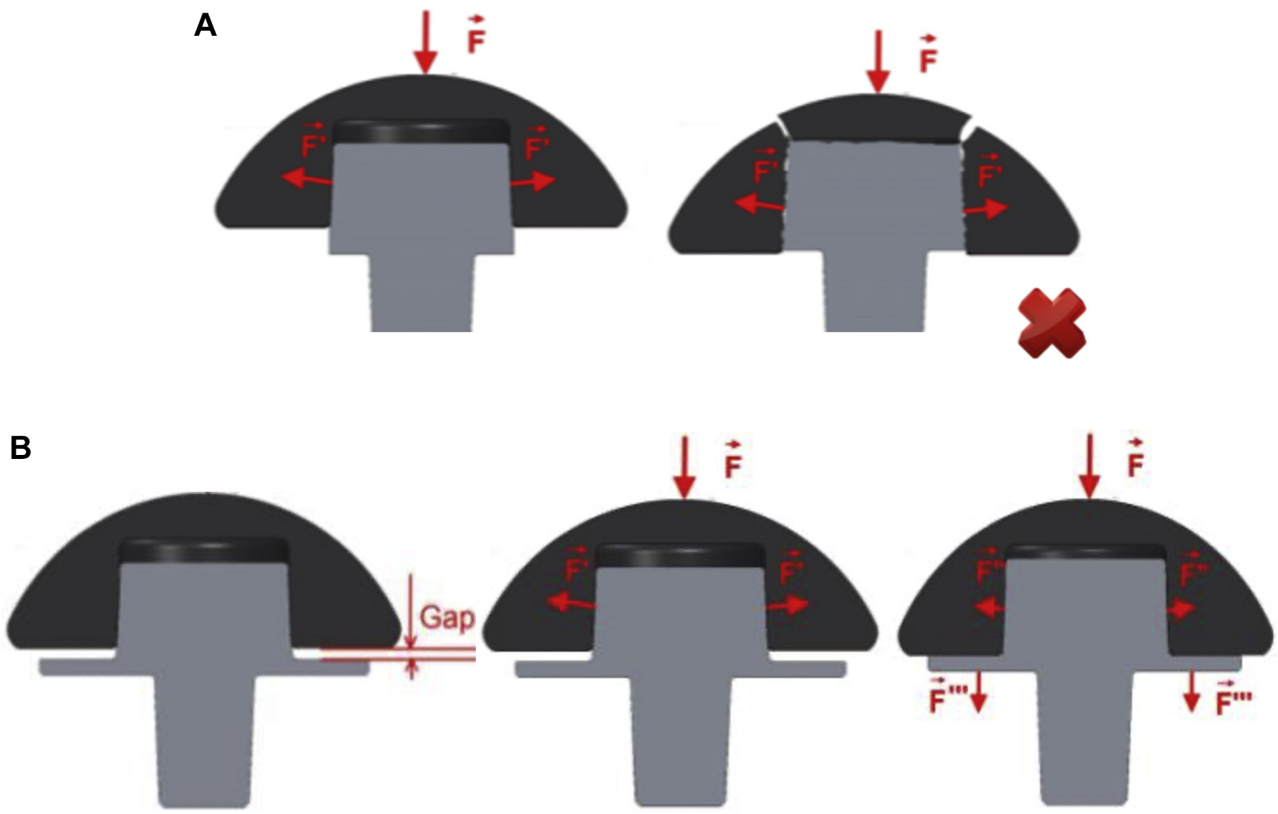

Figure 7 The Aequalis Ascend Flex pyrocarbon humeral head is created by combining a pyrocarbon bearing surface and a cobalt-chromium *(CoCr)* double taper neck. The pyrocarbon bearing surface is assembled on its CoCr double taper neck in the factory. No breakage of the Aequalis Ascend Flex pyrocarbon humeral head has occurred since its launch on the market in 2013. (**A**) A classical Morse taper cannot be used with a pyrocarbon head because of its low Young modulus and poor resistance to traction: When applying a force of impaction *(F)*, the risk of breakage of the pyrocarbon is too high. (**B**) To make the Morse taper reliable and safe, an abutment is added to stop the pyrocarbon bearing surface translation at an appropriate level. The addition of a metallic plate (1.5 mm in thickness) allows division of the force *(F)* into 2 parts: *F"* and *F'"*. Before mounting, there is a gap between the pyrocarbon head and the metallic plate. At the beginning of assembly, the force F" is enough to keep the pyrocarbon bearing surface in place (pullout and torque-out strength) but remains under the limit of breakage of graphite and pyrocarbon in traction. At the end of assembly, the force F'" is transmitted through the head to the metallic plate, which is a CoCr alloy and provides resistance.

attempt to re-center the humeral head in type B (biconcave erosion) or type C (dysplastic) glenoids (18 cases). An interesting finding in our study was that patients who underwent associated concentric glenoid reaming (n = 23) had similar Constant scores and SSVs to the other patients and did not show more progression of glenoid wear. Again, longer follow-up is needed to make definitive conclusions about the potential benefit of this associated procedure needed in some patients. Furthermore, CT scan studies will be needed to see if the humeral head remains centered after concentric reaming in type B2 or B3 glenoids.

Proper reconstruction of the proximal humeral anatomy is of primary importance to maximize patient outcomes after shoulder arthroplasty.[17] Using the radiologic method described by Alolabi et al[1] and Mears et al,[25,30] we found that one-third of the patients had a nonanatomic humeral reconstruction. More important, nonanatomic reconstruction of the proximal humerus was associated with lower functional results, more complications (subscapularis insufficiency and/or symptomatic glenoid erosion), and a higher risk of surgical revision. Looking for the reasons for such a high rate of nonanatomic reconstruction, we found that the prosthesis was oversized and/or too proud.

In fact, pyrocarbon heads are about 2 mm thicker than the metallic heads for the same diameter. This increased thickness is related to the addition of a metallic tray to support the pyrocarbon head (+1.5 mm) plus the void under the metallic plate (+0.5 mm) to accommodate the inferior Morse taper (Fig. 5). The metallic plate acts as an abutment to stop the bearing surface translation at an appropriate level and prevent any breakage of the pyrocarbon head (Figs. 6 and 7). Like any new implant, the HA-PYC implant has a learning curve, and this increased thickness of pyrocarbon heads should be taken into account by surgeons when choosing the head size. We now systematically downsize (by 1 size) the humeral pyrocarbon head to prevent any overstuffing of the cuff tendons and overpressure on the glenoid surface.

This study has several limitations, mainly related to its multicenter design, its insufficient follow-up, the variety of indications for surgery, and the lack of a control group that would have enabled more direct comparisons of outcomes. Knowing that patients with HA experience deterioration of results over time, longer follow-up is needed to draw definitive conclusions. Another weakness of our study is that, at the current follow-up, we did not perform CT scans to measure preoperative and postoperative glenoid wear and posterior humeral subluxation. However, this is the first study to analyze humeral reconstruction with HA-PYC.

Conclusion

At short-term follow-up, HA-PYC is a reliable procedure to treat shoulder OA and allows return to work and sports in a young (≤60 years) and active patient population. The severity of glenoid bone erosion or the association with glenoid reaming does not affect functional outcomes and failure risk. By contrast, nonanatomic reconstruction of the proximal humerus after HA-PYC is not rare (one-third of the cases) and is associated with lower functional outcomes, as well as higher risks of complications (subscapularis insufficiency and/or symptomatic glenoid erosion) and revision. Surgeons should be aware of the increased thickness of the pyrocarbon heads, related to the addition of a metallic plate (+1.5 mm in thickness) under the bearing surface to prevent any breakage of the pyrocarbon head plus the void (+0.5 mm) needed to accommodate the double Morse taper. For proper reconstruction of the proximal humeral anatomy and optimal outcomes, we are now downsizing (by 1 size) the pyrocarbon head thickness.

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