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Fracture of pyrocarbon humeral head resurfacing implant: a case report

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We report a case of a pyrocarbon humeral head resurfacing implant fracture, occurring 6 years after its implantation, without any obvious trauma or dislocation. Initial radiographs showed a proud and oversized pyrocarbon resurfacing implant. On clinical examination, the patient had a painful and pseudoparalyzed shoulder with subscapularis insufficiency. Imaging studies confirmed implant fracture and severe fatty infiltration (Goutallier, grade 4) of the subscapularis muscle. Intraoperatively, the implant was found to be fractured with multiple pyrocarbon debris in the glenohumeral joint. The implant was loose, and gross inspection showed no visible bony adhesion or ongrowth. Histologic analysis showed multiple seats of metallosis in the synovial tissue and cancellous bone of the humeral head. Successful management of this complication was managed with a thorough débridement and irrigation and revision to reverse shoulder arthroplasty. Our observation put into question the use of pyrocarbon as a humeral head resurfacing implant. The material seems to be too fragile to be used as a resurfacing implant and cannot achieve fixation of the implant to bone.

Keywords: Shoulder; pyrocarbon; resurfacing humeral head; implant fracture

Metallic humeral head resurfacing arthroplasty was initially developed by Dr. S. A. Copeland and first used clinically in about 1986. The implant consists of a thin-wall, spherical, dome-shaped metal shell having a central tapered and fluted stem intended to achieve fixation of the implant to bone. It has been claimed that humeral head resurfacing implants have many benefits compared with stemmed humeral head replacements, including less bone removal, easier humeral head positioning and location (making more easily the preservation of the individual anatomy), reduced risk of fat embolus or hypotension because substantial intramedullary reaming is not required, and no possibility of intraoperative humeral diaphyseal fracture.[14] Furthermore, the absence of a stem prevents humeral shaft bone lysis due to stress shielding and fracture at the tip of the prosthesis due to a stress riser effect. Initially, this less traumatic and more conservative procedure looked promising.

Shoulder hemiarthroplasty (HA) with metal (cobalt-chrome) humeral heads has good long-term clinical outcomes and reliably relieves pain and shoulder dysfunction in glenohumeral osteoarthritis.[21,22,24,25] However, several long-term follow-up studies have demonstrated a moderate rate, 15%-20%, of revision of HA due to glenoid erosion and painful glenohumeral arthritis.[22,25] Recently, pyrolytic carbon (PyC; commonly referred to as pyrocarbon) HA has been investigated as an alternative to metal humeral head replacement. Several recent studies have shown good clinical outcomes, low rates of glenoid erosion, and low complications rates at short-term follow-up with the use of

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PyC implants for shoulder hemiarthroplasty (HA-PyC) and PyC interpositional arthroplasty (PISA).[1,6,7] Alternatively, PyC humeral head resurfacing arthroplasty (PyC-HHRA) has been proposed as an alternative to metal ones to prevent glenoid erosion.

PyC is a material initially introduced in the 1970s in the field of cardiology with bi-leaflet mechanical heart valves. Several in vitro and in vivo (explanted) heart valve studies confirmed the safety and durability of PyC with low wear rates.[11,15] This led to the expansion of applications in orthopedic surgery, with successful use in hand small joint arthroplasty and radial head replacement.[2,5,8,20] In vitro studies have clearly demonstrated the superior tribologic properties of PyC over cobalt-chrome and metal alloys, including the lower coefficient of friction with boundary layer lubrication. Klawitter et al[13] performed an in vitro study in 2018 in which they compared bone wear for shoulder HA and found that PyC produced significantly less bone wear compared with a chrome-cobalt prosthesis. They explain their results by pointing out that the elastic modulus of PyC (26.9 GpA) is nearer to the bone elastic modulus (20.4 GpA) than that of chrome-cobalt (200 GpA). Additionally, a study in canines evaluated the gross and histologic specimens of acetabula after implantation of hip HA prostheses with articulating surfaces of low-temperature isotropic (LTI) PyC, cobalt-chromium-molybdenum alloy, and titanium alloy for periods ranging from 2 weeks to 18 months. The authors found a 92% probability of survival for cartilage articulating with LTI PyC at 18 months, compared with only a 20% probability of survival for cartilage articulating with use of the metallic alloys.[4]

Although fractures of PyC implants have been reported in hand small joint arthroplasty[23,26] and radial head arthroplasty,[10] there are currently no published data concerning fracture of PyC shoulder implants. We report here the case of a patient who underwent PyC HHRA at an outside institution and sustained an atraumatic implant fracture that required revision to reverse shoulder arthroplasty after implant and debris removal. Additionally, we present a comprehensive review of the literature regarding the use of PyC implants in shoulder surgery.

Case report

A healthy 62-year-old right hand–dominant male presented to our department with a chief complaint of right shoulder pain and dysfunction. His surgical history revealed shoulder stabilization with open Latarjet procedure at an outside institution in 1992. Following this procedure, the shoulder was stable and pain-free for 20 years. In 2012, the patient developed symptomatic glenohumeral osteoarthritis and was reoperated at an outside institution. Glenohumeral osteoarthritis was confirmed and the screws fixing the coracoid bone block were removed; a PyC humeral head resurfacing prosthesis (Integra, Plainsboro Township, NJ, USA) was implanted and a biceps tenodesis were performed. At the end of the procedure, the subscapularis tendon, which was described as particularly thin, was reinserted. The patient reported significant pain relief and satisfactory shoulder function following this PyC HHRA.

Figure 1 Early postoperative anteroposterior radiograph, taken 3 months after pyrocarbon humeral head resurfacing implantation (2012). Notice that the implant is oversized and too proud, thereby "overstuffing" the glenohumeral joint.

In December 2018, approximately 6 years after the PyC HHRA, the patient developed a sudden onset of shoulder pain and limited motion. He first noted it while lying in bed on December 30, 2018. The pain and limited shoulder motion persisted despite conservative treatment, which consisted of rest and activity modification. No trauma or dislocation of the shoulder were reported. On physical examination, the patient presented no evidence of supraspinatus, infraspinatus, or deltoid muscle atrophy. The shoulder was painful, with popping and cracking at mobilization. Active forward elevation was limited to 90°, whereas external rotation with the arm was –10° and internal rotation was allowed to reach only the greater trochanter. Subscapularis insufficiency was obvious with positive belly-press and lift-off tests, but not decrease of strength in external rotation. The biology (sedimentation rate, C-reactive protein [CPR]) did not show any evidence of inflammation.

Retrospective analysis of immediate postoperative radiographs showed that anatomic reconstruction of the

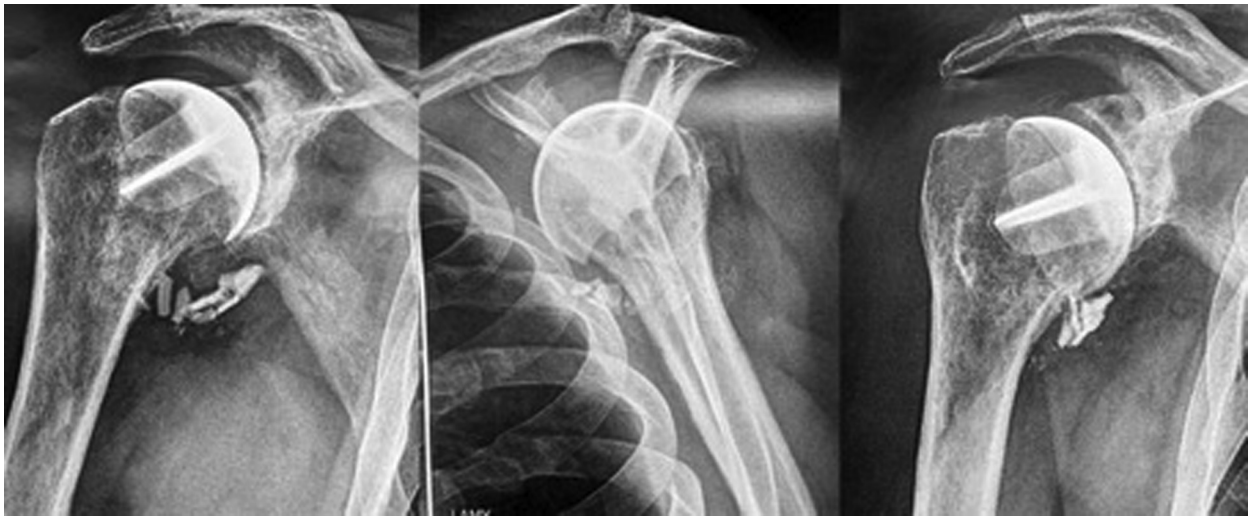

Figure 2 Anteroposterior and lateral radiographs, taken 6 years after the index surgery, demonstrating fracture of the resurfacing implant with pyrocarbon debris in the axillary pouch (2019).

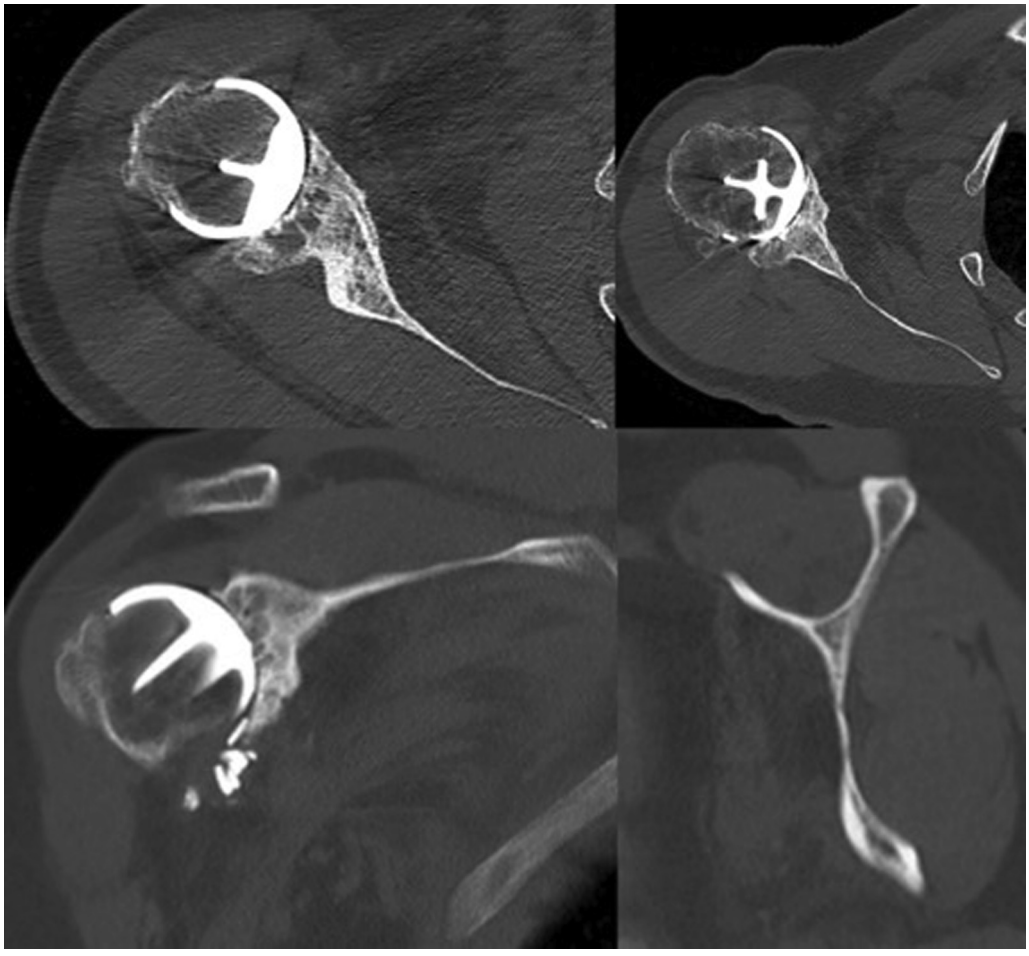

Figure 3 2D CT scan images demonstrating the fracture of the pyrocarbon implant, located at the anterior edge with PyC debris in the axillary fold. Notice that there is glenoid erosion with cysts of hyperpressure and severe fatty infiltration (Goutallier stage 4) of the subscapularis muscle. *CT*, computed tomographic; *PyC*, pyrolytic carbon.

Figure 4 3D CT scan showing multiple pyrocarbon debris in the axillary pouch. *CT*, computed tomographic.

proximal humerus was not restored because of proud and oversized PyC resurfacing implant (Fig. 1). Radiographs of the shoulder, taken 6 years after humeral head resurfacing, demonstrated a fracture of the resurfacing implant with numerous PyC particles in the axillary pouch (Fig. 2). The computed tomographic scan images showed a fracture of the PyC implant and confirmed subscapularis insufficiency with severe (Goutallier stage 4) fatty infiltration (Figs. 3 and 4).

Because of the subscapularis insufficiency and severe glenoid erosion, it was decided to revise the failed PyC HHRA to a reverse shoulder arthroplasty. The prior deltopectoral approach incision was used. The subscapularis was found to be totally thin and could not be repaired at the end of the procedure. After dislocation of the humeral head, the fractured PyC humeral head was visualized (Fig. 5, *A*). Multiple implant fracture fragments were spread in the whole joint, and it was apparent that the humeral bone and capsular and synovial tissues contained a significant amount of black PyC debris (Fig. 5, *B*).

The humeral resurfacing implant was loose and easily removed without the need of an extractor. A thorough débridement of the humeral bone and soft tissues was performed. The retrieved PyC implant was examined by means of visual inspection (Fig. 6). The fracture involved multiple cracks extending mainly along the anterior edge of the resurfacing head component. The cruciform peg was not broken, but there was no evidence of any bony adhesion to the PyC or ingrowth. Histologic samples of soft tissues and bone were sent to the laboratory for microscopic analysis. Histologic analysis showed multiple seats of metallosis within the synovial tissue and the bone marrow (Figs. 7 and 8)

After complete cleaning of the joint, a reverse shoulder arthroplasty (Aequalis Ascend Reversed; Wright Medical, Memphis, TN, USA) was implanted (Fig. 9). Postoperatively, the patient was placed into a shoulder immobilizer in neutral rotation for 4 weeks. Physiotherapy was allowed the day after surgery with pendulum exercises. Formal physiotherapy was started at 1 month after the surgery. The early functional result after revision in our patient was satisfactory with recovery of a pain-free functional shoulder. At last follow-up, the shoulder was pain free, mobile, and stable.

Discussion

We report here the first case of fracture of PyC humeral head resurfacing implant, occurring 6 years after implantation without any obvious trauma or dislocation. The PyC resurfacing arthroplasty was performed in a 62-year-old patient for osteoarthritis, 20 years after open Latarjet procedure for recurrent instability. Postoperatively, the shoulder was pain free and functional for at least 5 years. Progressively, the shoulder became painful and nonfunctional. Clinical examination showed subscapularis insufficiency, and imaging studies showed a fractured implant with multiple PyC debris inside the joint and severe fatty infiltration (Goutallier, grade 4) of the muscle. Intraoperatively, the implant was found to be loose and gross inspection showed no visible bony adhesion or ongrowth. Histologic analysis showed multiple seats of metallosis in the synovial tissue and cancellous bone of the humeral head. Successful management of this complication was managed with a thorough débridement and irrigation and revision to reverse shoulder arthroplasty.

The first question brought by our observation is, What could be the mechanism of such late fracture of a PyC implant? When retrospectively analyzing the initial radiographs, it was obvious that restoration of the proximal humerus anatomy was not achieved because of a proud and oversized resurfacing implant (Fig. 1). Both clinical examination and computed tomographic scan images confirmed a subscapularis insufficiency with severe fatty infiltration (Goutallier stage 4) of the muscle (Fig. 3). The absence of restoration of the center of rotation may have created glenohumeral joint ‘‘overstuffing,’’ with secondary failure of the subscapularis. We hypothesize that subscapularis insufficiency may have potentially created micro-instability, leading to recurrent subluxations, not perceived by the patient, and eventual catastrophic failure of the PyC resurfacing implant.

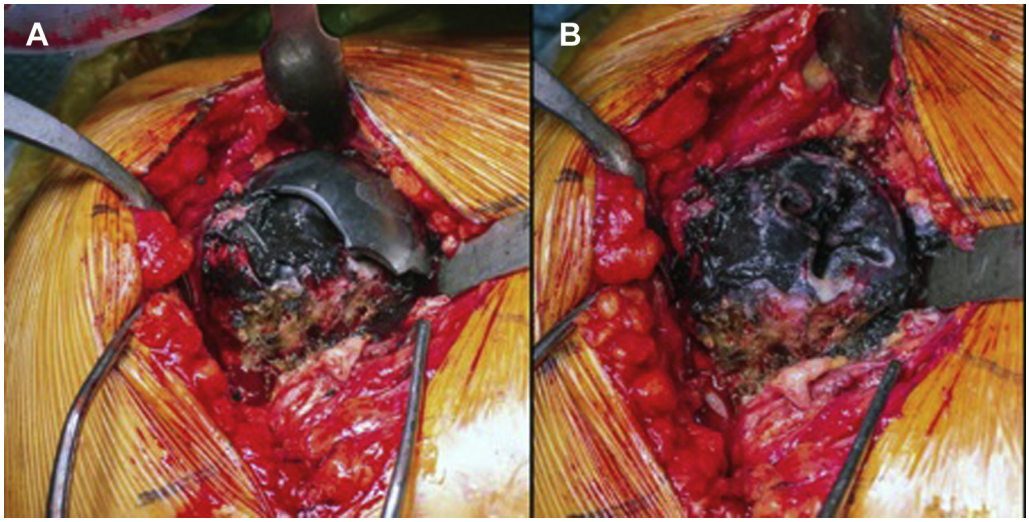

Figure 5 **(A)** Intraoperative images demonstrating the fractured pyrocarbon resurfacing implant. **(B)** After removal of the implant, note the black carbon debris in the bone of the remaining humeral head and in synovial and capsular soft tissues.

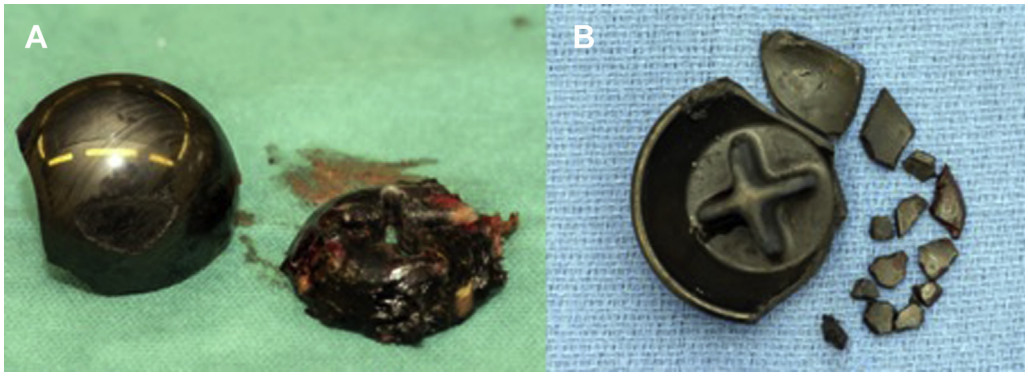

Figure 6 **(A)** Retrieved resurfacing implant with the cut humeral head with black cancellous bone and **(B)** the multiple pieces of the broken pyrocarbon implant. Notice that the cruciform stem is not broken, but there is no evidence of any bony adhesion or ongrowth.

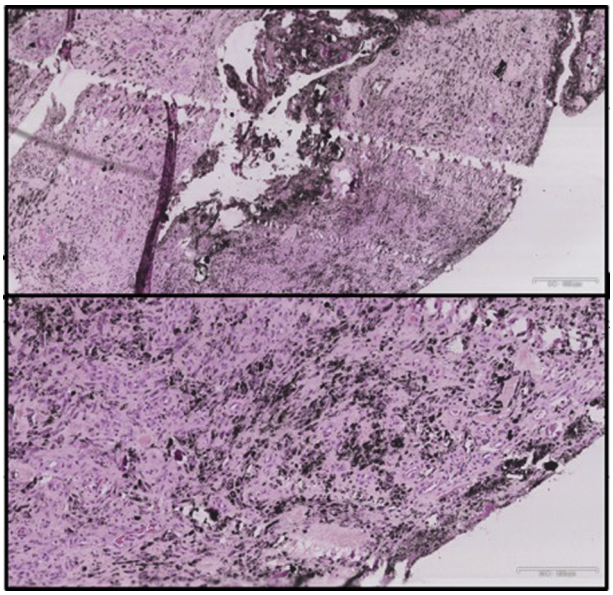

Figure 7 Histologic images showing seats of metallosis in the synovial tissue.

The difficulties to reconstruct the anatomy of the proximal humerus with metallic resurfacing implants has been emphasized by many authors.[17] Shoulder arthroplasty registries are showing progressive abandon of this type of implants because of the high rates of failures and revision for glenoid erosion and rotator cuff or subscapularis tears.[3,9,12,16,19] Jaiswal et al[12] described 26 cases of revision after failed resurfacing humeral implants: 42% of the patients were revised for glenoid erosion and/or 31% for rotator cuff tear. Natera et al[18] described the same types of complications, with 82% for rotator cuff tear and 13% for glenoid erosion. The soft issue insufficiency seen after humeral head resurfacing is related to their frequent proudness, leading to ''overstuffing'' of the glenohumeral joint. As shown by our observation, this is also true with a PyC humeral head resurfacing implant.

Our observation put into question the use of PyC as a humeral head resurfacing implant for at least 2 reasons. First, the fragility of the thin layer of PyC material precludes sufficient impaction of the implant, making

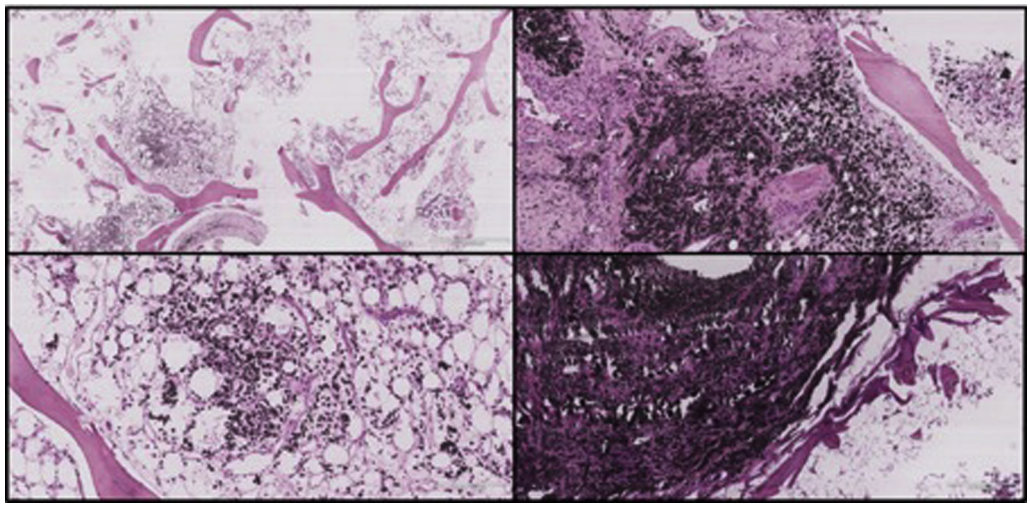

Figure 8 Histologic images showing seats of metallosis in of bone marrow.

Figure 9 Postoperative anteroposterior radiograph of shoulder following revision with a reverse shoulder arthroplasty.

reconstruction of the proximal humerus anatomy difficult, if not impossible, and leading to secondary subscapularis/cuff tear or insufficiency and glenoid erosion due to joint overstuffing. Second, the nature of the PyC material itself precludes bone cell adhesion or ongrowth to the implant, making secondary fixation of the implant to bone impossible, leading to implant loosening.

The few clinical studies that have investigated the short-term outcomes of PyC implants for shoulder reported encouraging results and did not report implant fractures. Garret et al[7] performed a multicenter prospective study evaluating the outcomes of 65 consecutive patients who underwent PyC shoulder HA. Sixty-one patients were available for follow-up at a mean of 25.9 months. The mean Constant score increased from 31.0 ± 15.8 points preoperatively to 74.6 ± 17 points at final follow-up. Radiographic analysis revealed that 86% of glenoids remained unchanged, whereas a slight erosion was present in 14%. There were no implant fractures. The same authors also investigated the outcomes of PISA[6] for osteoarthritis at a minimum follow-up of 2 years. This was a prospective multicenter study at 9 centers with 67 consecutive patients. Revision surgery was needed in 7 (10%) patients. Of the 55 patients who were available for the Constant scores, all of them improved significantly. Radiographs revealed erosion in 6 glenoids and thinning of 3 humeral tuberosities. Recently a study with longer follow-up has been published concerning PISA: Barret et al[1] described a series including 58 PISA at 47 months of follow-up. Survival of the prosthesis was 90% at final follow-up. Revisions were due to glenoid erosion in 2 cases and humeral erosion with greater tuberosity fracture in 4 cases. Again, no implant fractures were reported. Although short- to midterm outcomes are encouraging, long-term studies are still needed to definitely conclude.

Conclusion

We report a case of a PyC humeral head resurfacing implant fracture, which occurred 6 years following its implantation, without any trauma. Successful management of this complication was accomplished with a thorough débridement and irrigation and revision to reverse shoulder arthroplasty. Our observation put into question the use of PyC as a humeral head resurfacing implant. The material seems to be too fragile to be used

as a resurfacing implant and cannot achieve fixation of the implant to bone.

Disclaimer

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