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Buechel Pappas Resurfacing Shoulder Replacement: Evolution and over 40 Years of Clinical Experience

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Abstract

Background: Early exploration of the semi constrained "Floating-Socket" total shoulder replacement (TSR) in 1974 led to a proliferation of various unconstrained designs that allowed resection or retention of the humeral head, depending upon the pathological process involved. Degenerative glenohumeral arthritis with mild to moderate involvement of subchondral bone allowed for a resurfacing option, while severe humeral head involvement required a partial or full humeral head replacement attached to an intramedullary stem for fixation. All components evolved from cemented to cementless application by 1982. The purpose of this paper is to describe the progression of Buechel-Pappas (B-P) shoulder replacement development from the early 1970's in both cemented and cement less applications. **Methods:** Clinical evaluations of "Floating-Socket" TSR, followed by B-P stem-type, resurfacing types, bipolar-type and revision components, all of which comprise the B-P Shoulder Replacement System, were performed over a 49-year period. **Results:** "Floating-Socket" implants improved the results of simple, constrained ball-in-socket designs, but generally failed by glenoid component loosening in both chimpanzee and human applications. Unconstrained resurfacing-type components, both anatomical humeral head and full proximal humeral components, were quite successful, with minimal failures observed in long-term studies. Bipolar salvage implants, used for severe proximal deficiencies, revisions and massive rotator cuff arthropathy, were also very successful; providing overhead range of motion in many patients. **Conclusions:** Resurfacing hemiarthroplasty, in patients with intact or repairable rotator cuff mechanisms, gave the most satisfactory results and were the least technically complicated to perform, requiring minimal instrumentation. Resurfacing of full proximal humeral deficiencies, using femoral resurfacing components, gave similar clinical results to more complex semi-constrained devices, also with less technical difficulties and simple instrumentation.

Keywords

Total Shoulder Replacement, Resurfacing Shoulder Replacement

1. Background

Early shoulder replacement designs by Krueger [1] and Neer [2] established a venue for replacing the proximal humerus in the event of complex fractures or degenerative arthritis. As further pathologies evolved, requiring improved stability, more constrained and semi-constrained devices were developed [3] [4]. Fenlin developed a reverse-type shoulder replacement using a “ball & socket” mechanism in 1973 [3]. DePalma, the chairman of the orthopaedic department at NJ Medical School, recruited a mechanical engineer, Michael J Pappas, PhD, in 1974 to collaborate with his research resident, Frederick F Buechel, MD, to evaluate his initial constrained designs and develop a semi-constrained TSR that they called the “floating socket”, since it was comprised of a sphere within a sphere with an offset pivot center, creating a “floating socket”! (See **Figure 1**). This patented device had 120˚ of motion and was attached by snap rings to a fixed glenoid component; making it one of the first “reverse” TSR’s [5] [6] (see **Figure 2**). It was successful in both chimpanzee [7] and human [5] in the short term, but in the intermediate term (>3 years) it failed by glenoid component loosening, even though one device lasted for 17 years in a rheumatoid female patient, see **Figure 3**.

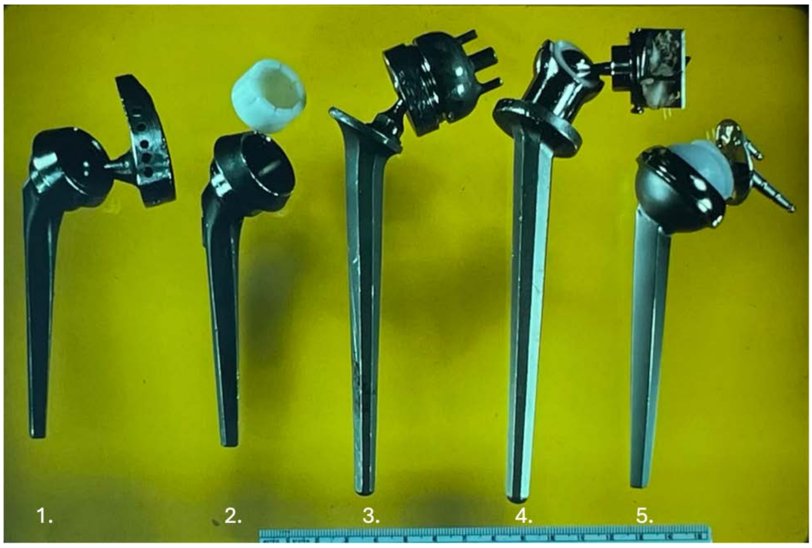


Figure 1. DePalma-inspired total shoulder joint replacement designs 1973-1975 (left to right): 1. Simple metal-metal ball-socket, 2. Simple ball-socket with poly insert, 3. DePalma (Michael Reese) metal-poly, 4. Universal Joint type metal-poly, 5. “floating socket” TSR.

Figure 2. Floating socket TSR cemented in dry bones 1975.

Figure 3. Cemented floating socket 17 years post-op in a rheumatoid female patient.

The lesson learned from the "floating-socket" device was that even semi-constrained devices can loosen by repetitive torque on glenoid fixation. This knowledge gave rise to minimizing or eliminating torque on fixation elements in our future designs. By uncoupling the humeral component from the glenoid component, and minimizing constraint in favor of soft tissue stabilization, component loosening in either cemented or cementless fixation was minimized.

Of interest, our initial cementless cobalt chrome resurfacing TSR, implanted in 1982, remained functional for over 26 years, until wear through of the ultra high molecular weight polyethylene (UHMWPe) bearing caused osteolysis and failure, see Figure 4.

In 1989, we changed from cobalt-chromium alloy to titanium nitride (TiN) ceramic coated titanium alloy resurfacing and stem-type components with porous coating for cementless fixation and created a system of stem-type and revision component as well (B-P Shoulder System, Figure 5). These highly polished and biocompatible components gave reasonable congruity to the arthritic glenoid surface and were surprisingly pain free. After observing wear failures of total stem-type TSR after 15 years using standard UHMWPe, see Figure 6, it stimulated the concept of hemiarthroplasty rather than TSR to avoid glenoid bearing

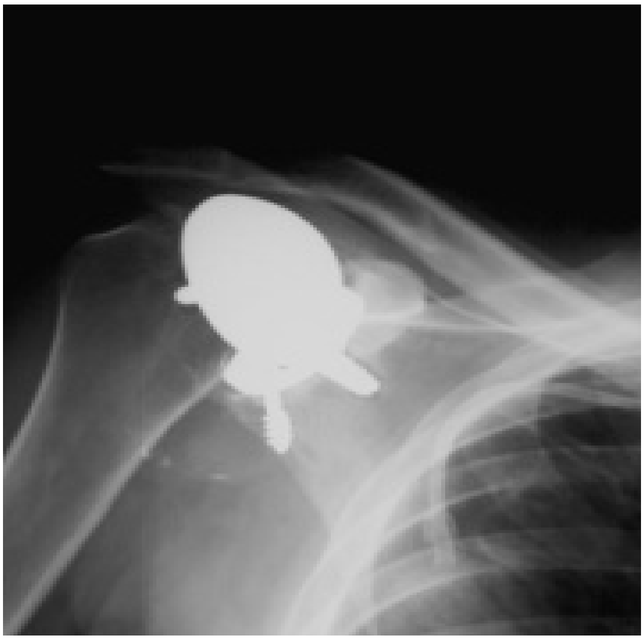


Figure 4. Cementless CoCr resurfacing TSR 26 years post-op in a male patient with avascular necrosis.

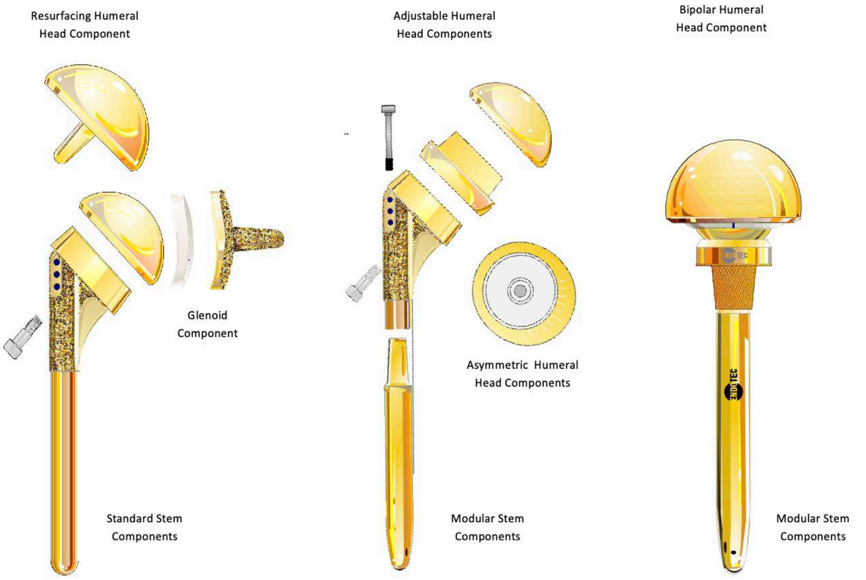
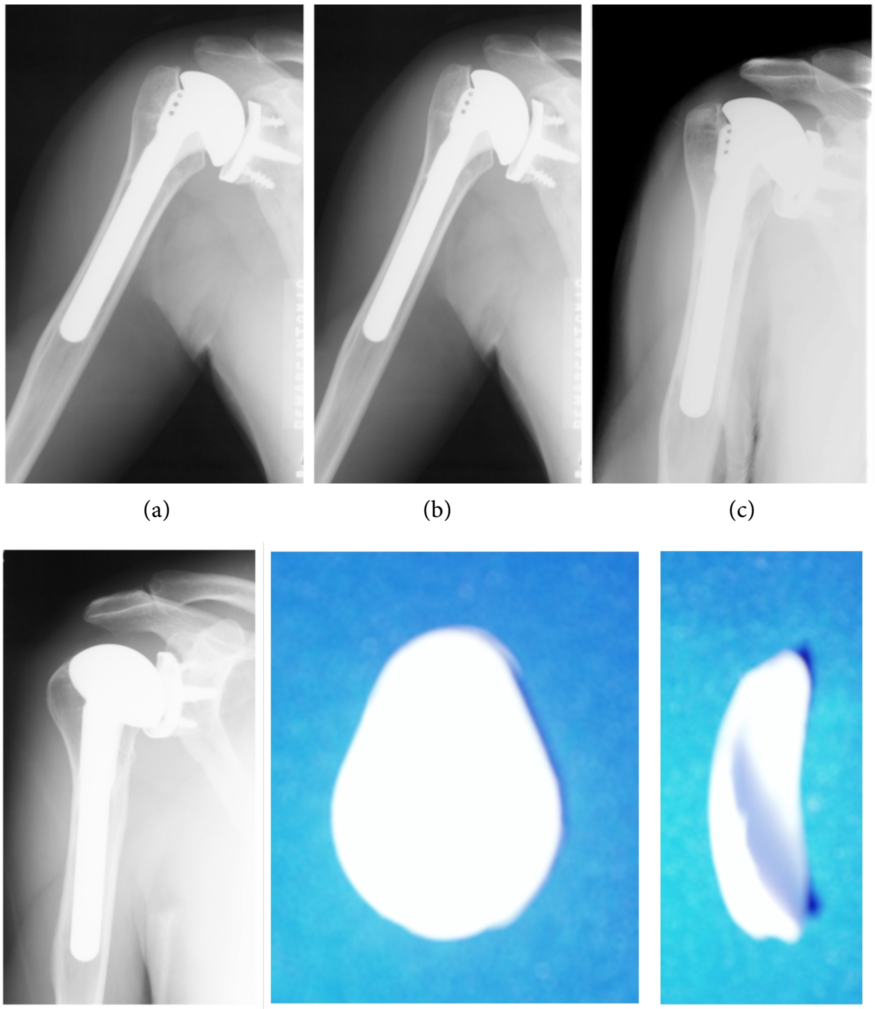


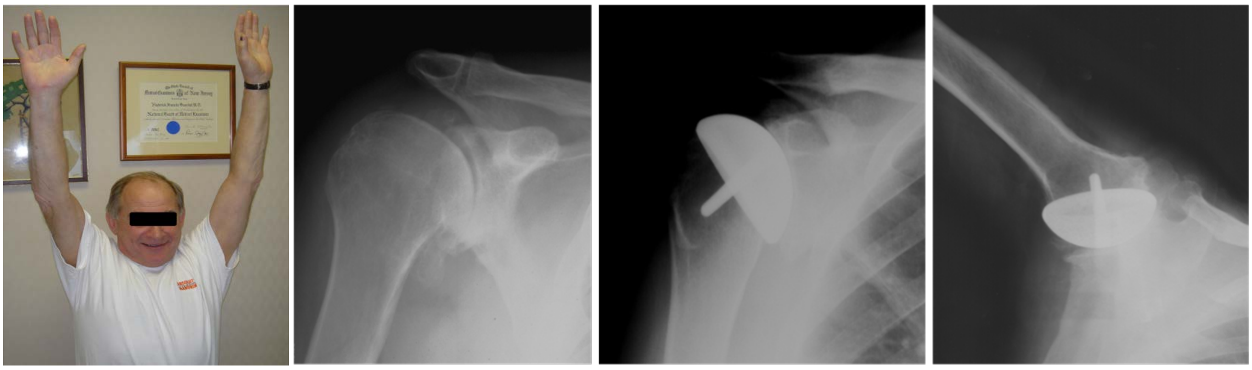
Figure 5. B-P total shoulder system 1989.



(a) (b) (c)

(d) (e)

Figure 6. X-rays of a 41-year-old male, osteoarthritic patient who developed wear failure of UHMWPE bearing After 15.5 years. (a) Immediate post-op; (b) 5 years post-op; (c) 15.5 years post-op; (d) 23 years post-op new bearing: 6 years; (e) worn bearing insert 15.5 years



(a) (b) (c) (e)

Figure 7. Example of a right shoulder B-P hemiathroplasty in a 60-year-old male patient with osteoarthritis and a functional rotator cuff. (a) Range of motion of right shoulder at 10 years post-op; (b) pre-op AP x-ray; (c) years post-op AP x-ray; (d) years post-op abduction AP x-ray.

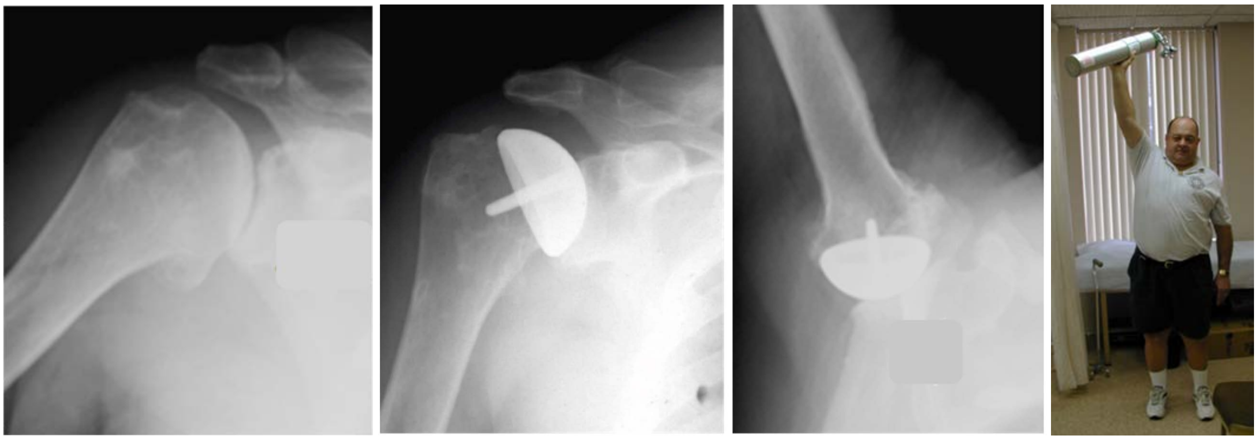

(a) (b) (c)

Figure 8. Example of a right shoulder B-P hemiathroplasty in a 60-year-old male patient with osteoarthritis and a functional rotator cuff. (a) Pre-op AP x-ray; (b) 10 years post-op AP and abduction x-rays; (c) range of motion of shoulder at 10 years post-op.

revision. This appealing concept allowed minimal contouring of the proximal humerus and gave long term (>10 years) results that were equal to or superior to TSR, see **Figure 7** and **Figure 8**.

This historical context of design rationale and reviewing clinical results was essential to one understanding of loading concepts in the pursuit of refining implant design to compensate for stable or compromised rotator cuff mechanisms. Also, salvage situations required proximally porous coated stem-type fixation components to avoid stress shielding the humeral shaft. Overall, our early experience with constrained and semi-constrained devices led to loosening failures, which logically led us to unconstrain our implants in favor of soft tissue and anatomical constraints, rather than mechanical constraints.

2. Methods

The B-P Shoulder Replacement System, see **Figure 5**, evolved from the “floating socket” TSR, see **Figure 2**, developed in 1974 [5] [6]. This initial device was modified and implanted in an adult male chimpanzee in 1975 (see **Figure 9**), and followed for 3 years, when the animal died from complications of Crohn’s disease; the device was retrieved from the primate center post-mortem. The first human “floating socket” TSR was implanted in 1975 and was also followed for 3 years, when the 60 year old osteoarthritic male patient died from complications of liver cirrhosis; the device was retrieved with permission post-mortem.

B-P Resurfacing shoulder replacements were extensively studied by Pritchett [8] [9] in both anatomic hemiarthroplasty and full proximal humeral hemiarthroplasty conditions, using femoral resurfacing implants, see **Figure 10**. Bipolar shoulder replacements were studied by Worland [10] [11] and used in salvage situations involved in loss of proximal humeral bone stock (see **Figures 11-12**).

(a) (b) (c)

Figure 9. 6-year-old adult male chimpanzee with left "floating socket" TSR. (a) 2 weeks post-op AP x-ray left shoulder; (b) 2 years post-op AP x-ray demonstrating glenoid & humeral component loosening; (c) 2 years post-op anesthetized chimpanzee with arms overhead.

AP X-ray of an osteoarthritic right shoulder with rotator cuff arthropathy in a 67-year-oldman

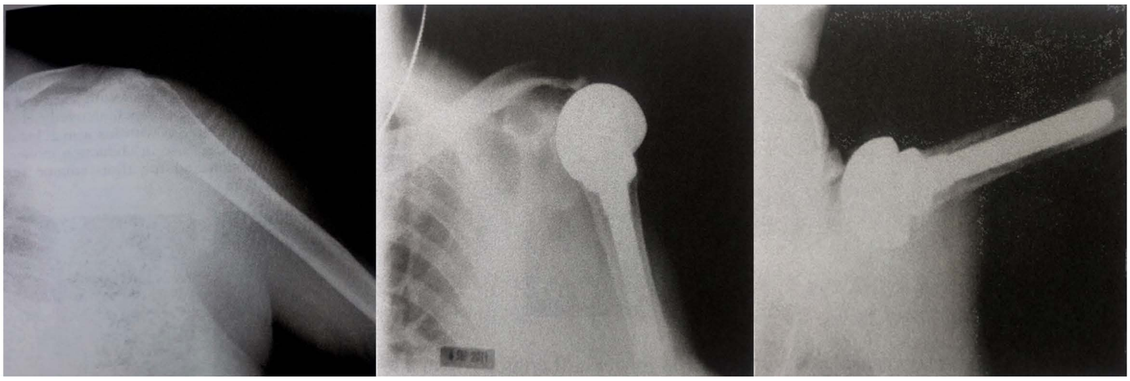
Figure 10. AP x-ray after 4 years using a femoral hip resurfacing component to achieve full humeral head coverage and stable, painless articulation in the subacromial space.

Figure 11. AP x-ray 3 years post-op showing a failed cemented left Neer-type TSR in a 57-year-old man with rheumatoid polyarthropathy.

Figure 12. AP x-ray 9 years post-op after revision with a B-P cementless bipolar long-stem TSR in the same patient as **Figure 11**.

3. Results

Resurfacing Shoulder Arthroplasty, using polished TiN ceramic coated implants, has been extensively studied by Pritchett [8] [9]. He recently reported on 428 patients with intact or reconstruct able rotator cuff mechanisms that received a hemiarthroplasty and were followed for 5 to 30 years (mean 11 years), as well as 67 patients with rotator cuff arthropathy that received a hemiarthroplasty using a femoral resurfacing component, and were followed for a minimum of five years. He found that 94% of the former group had good to excellent results, while 90% preferred their resurfacing arthroplasty to a stem-type prosthesis already implanted in their contralateral shoulder. In the latter group, there were 9 patients with a reverse TSR in their opposite shoulder; bipolar shoulder replacements were quite useful for severe proximal humeral deficiency or rotator cuff arthropathy, since the outer shell of the bipolar component filled the subacromial space, which provided stability and a fulcrum to allow stable abduction, see **Figure 13**. No glenoid component was



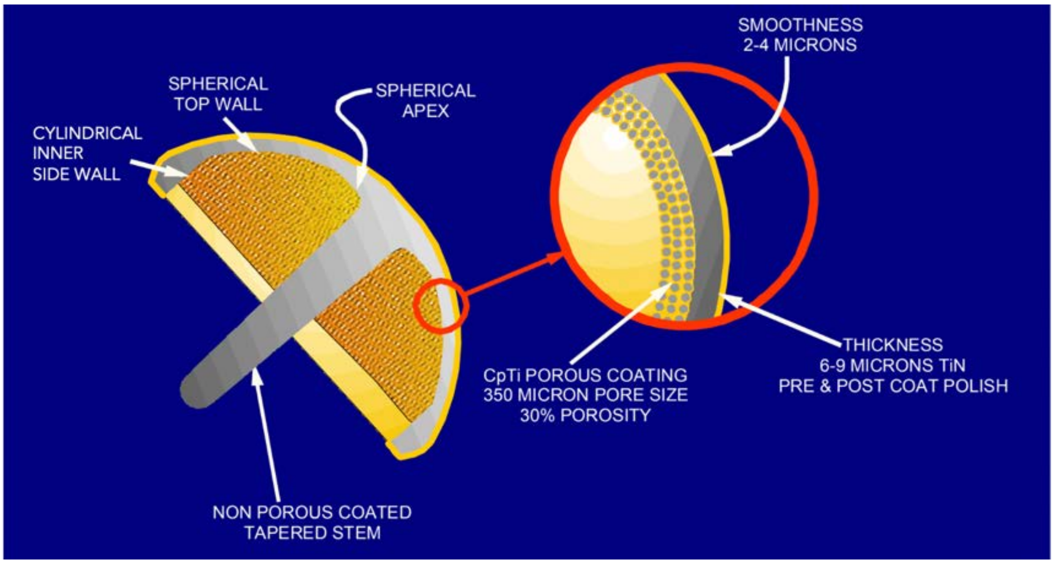
(a) (b)

Figure 13. Bipolar shoulder replacement used in rotator cuff arthropathy. (a) AP X-Ray of an osteoarthritic left shoulder with rotator cuff arthropathy in a 64-year-old man; (b) AP and overhead elevation left shoulder X-Rays with a cementless B-P Bipolar shoulder replacement in the same patient after 7 years.

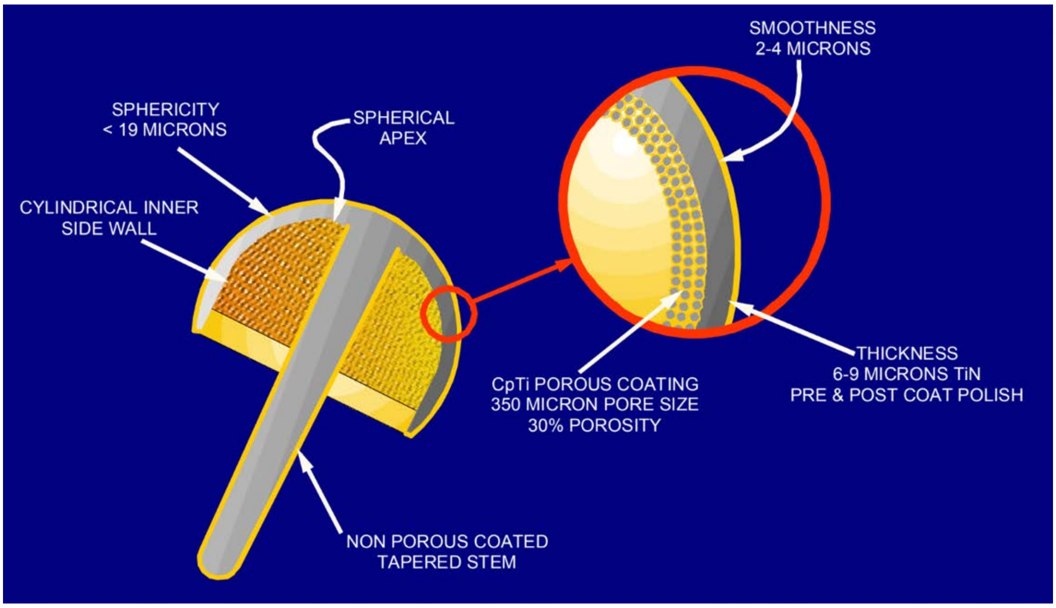
needed for this articulation, in contrast to the "Reverse TSR" [4] that uses a semi-constrained large gleno-sphere, stabilized by multiple screws, which are constantly exposed to torquing forces.

4. Discussion

Resurfacing shoulder replacement has been proven to be an effective surgical procedure to restore function and relieve pain. Extensive studies by Pritchett [8] have shown that polished TiN ceramic implants cause minimal wear on the native glenoid surface and are more wear-resistant than similar cobalt chromium devices, based on simulator and retrieval analyses.



(A) Proximal humeral resurfacing component used for anatomic coverage of proximal humerus.



(B) Femoral resurfacing component used for full coverage of proximal humerus.

Figure 14. Fabrication details of resurfacing shoulder implants.

His comparative studies of patients with bilateral shoulder replacements demonstrate the superiority of resurfacing implants over stem-type implants by patient preference [9].

The journey of implant design from "floating-socket" to stem-type to the simplistic resurfacing type has required diligence and engineering expertise. The specific details of fabrication of the resurfacing humeral component and the resurfacing femoral component (Biocore9, Whippany, NJ) are shown in **Figure 14**. Both devices have been cleared by the FDA 510K process [12] [13] [14].

Despite the complexity of resurfacing surgery, it is less invasive than implanting stem-type or reverse-type shoulder prostheses. There is also a lower infection rate and less overall complications using resurfacing implants [8]. In surgery, the old adage of "doing the least to gain the most" certainly applies to resurfacing shoulder arthroplasty.

5. Conclusions

Resurfacing shoulder hemiarthroplasty in patients with intact or reconstruct able rotator cuff mechanisms had 94% good or excellent results at 5 - 30 years, meaning 11 years.

Rotator cuff arthropathy patients that were reconstructed with femoral resurfacing components had results that were equal to, or better than, reverse TSR at a minimum of 5 years.

Resurfacing shoulder replacement surgery was observed to have fewer infections and fewer complications than stem-type shoulder replacements.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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