Open Journal of Orthopedics, 2023, 13, 435-442
https://www.scirp.org/journal/ojo
ISSN Online: 2164-3016
ISSN Print: 2164-3008

Cementless Buechel-Pappas Resurfacing Total Hip Replacement: A 45-Year Personal Journey to Overcome Wear, Osteolysis, Loosening and Femoral Neck Fractures

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How to cite this paper: Buechel, Sr. F.F. (2023) Cementless Buechel-Pappas Resurfacing Total Hip Replacement: A 45-Year Personal Journey to Overcome Wear, Osteolysis, Loosening and Femoral Neck Fractures. *Open Journal of Orthopedics*, **13**, 435-442.
https://doi.org/10.4236/ojo.2023.1310043

Received: September 6, 2023
Accepted: October 24, 2023
Published: October 27, 2023

Abstract

Background: Resurfacing-type total hip replacement (THR) has been successfully developed over the past 50 years through collaborative efforts between engineers and surgeons. Much of the development was pursued by individuals or groups, each of which participated in adding further refinements to the implants, instruments and surgical procedures, thus minimizing the serious problems of wear, osteolysis, loosening and femoral neck fractures. The purpose of this study is to explore the development process to optimize the resurfacing total hip replacement into its current application. **Methods:** In the early 1980s, cementless resurfacing implants were developed using "thin shell" technology to minimize bony resection of the acetabulum and femoral head. Femoral components utilized short, non-porous coated, tapered straight stems to reduce shear stresses in the femoral neck to prevent fractures and stress shielding, while mechanically stabilizing and aligning the components. Acetabular components were anatomically designed to be recessed inside bony borders to avoid neck-cup impingement and loosening. Initially, ultrahigh molecular weight polyethylene (UHMWPE) was used as a bearing, but due to high levels of wear and osteolysis, it was replaced by wear-resistant highly crossed-linked polyethylene (HXLPE) in 2008. **Results:** Use of HXLPE as a bearing material in both Co-Cr-Mo and titanium nitride (TiN) ceramic- coated resurfacing implants has led to excellent patient outcomes for more than 10 years. In clinical studies, 87% of patients with bilateral total hip replacements prefer their resurfacing-type total hip over their stem-type total hip. The author's own personal resurfacing total hips, now at 8 and 5 years, respectively, provide "normal" function and no radiographic osteolysis. **Conclusions:** After 45 years of active evaluation, including mechanical design considerations, prosthetic design development, clinical and radiographic analysis of results, as well as availability of components cleared by the FDA 510 K process, the author has stated a personal preference for the BP Resurfacing Hip System. His excellent mid-term results in both of his resurfaced hips are similar to the long-term results presented in published studies.

Keywords

Resurfacing Total Hip Replacement

1. Background

Resurfacing-type total hip replacement has had a long, generally unfavorable, history of intermittent success, interspersed with significant failures over the past 50 years. Most of the early failures were due to loosening of the cemented polyethylene acetabular cup in devices that used a hemispherically designed component. These devices developed "impingement torque" during an extreme range of motion, which caused loosening of the acetabular cup. Neck-cup impingement on the overhanging cup gave rise to excessive shear stresses on cement fixation, resulting in loosening failures in devices such as the ICLH [1] and the Indiana Conservative Hip. [2]

Recessing the cup within the borders of the acetabulum, as seen in the THARIES design, [3] improved acetabular stability, but gave way to osteolysis and femoral neck fractures, because of excessive wear and blood supply interruption from use of a trans-trochanteric approach, as well as thermal necrosis of the femoral head from a thickened layer of bone cement.

Cementless fixation of the acetabular component, as seen in the early Birmingham [4] [5] and New Jersey [6] resurfacing components, gave reasonable stability to the socket, but wear debris osteolysis from metal-metal or metal-polyethylene bearing surfaces gave unpredictable longevity to these devices, even though some lasted more than 20 years.

Further refinement of the polished Co-Cr-Mo metal-metal articulation of the Birmingham resurfacing THR has given reasonable success, but ALVAL osteolysis [7] and femoral AVN from thermal necrosis [8] remain challenging problems.

Metal-polyethylene articulation using standard ultra-high-molecular weight polyethylene (UHMWPE) has given inferior wear results over time, resulting in significant osteolysis in both the pelvis and femoral head. [9] Even ceramic on standard UHMWPE failed to improve wear resistance, resulting in advanced osteolysis in 5 to 10 years. [6] [9] Recently, highly cross-linked UHMWPE (HXLPE) has become available for use in hip replacement bearings. [10] This new material has made a dramatic difference in wear resistance over the past 10 - 15 years, making it the bearing material of choice for either metal-poly or ceramic-poly bearings. This paper documents the 45-year journey of the author in development and utilization of multiple bearing surfaces, before discovering and exploring ceramic-HXLPE as a superior THR bearing articulation. This journey established this new technique as not only valuable, but also exceptional in restoring normal hip function in extremely active patients.

2. Methods

In 1982, the cementless New Jersey (NJ) Resurfacing Hip Replacement (Endomedics, Inc, South Orange, NJ) was developed to replace the modified, cemented Indiana Conservative Hip Replacement (DePuy, Warsaw, Indiana) that used a less than hemispherical UHMWPE acetabular component and a non-stemmed femoral resurfacing cap made from Co-Cr-Mo alloy. The cementless NJ components used an uncoated short, straight femoral stem to align the component in the femoral neck and protect it from a shear stress fracture. The NJ acetabular component, also made from Co-Cr-Mo alloy and porous coating, was less than a hemisphere to avoid neck-cup impingement, see Figure 1(a). These NJ components developed stable cementless fixation, but went on to develop acetabular and femoral osteolysis, which helped solve the mystery of "cement disease", in that no cement was used, but osteolysis was still seen, similar to that seen in cemented total hips. [9] [10]

In 1989, the NJ Resurfacing hip program was advanced to the Buechel-Pappas (B-P) Resurfacing THR System (Endotec, Inc., Orlando Florida) by the use of Ti_6Al_4V alloy, coated with titanium nitride ceramic and porous coating, while using a standard UHMWPE bearing, see Figure 1(b). These devices were

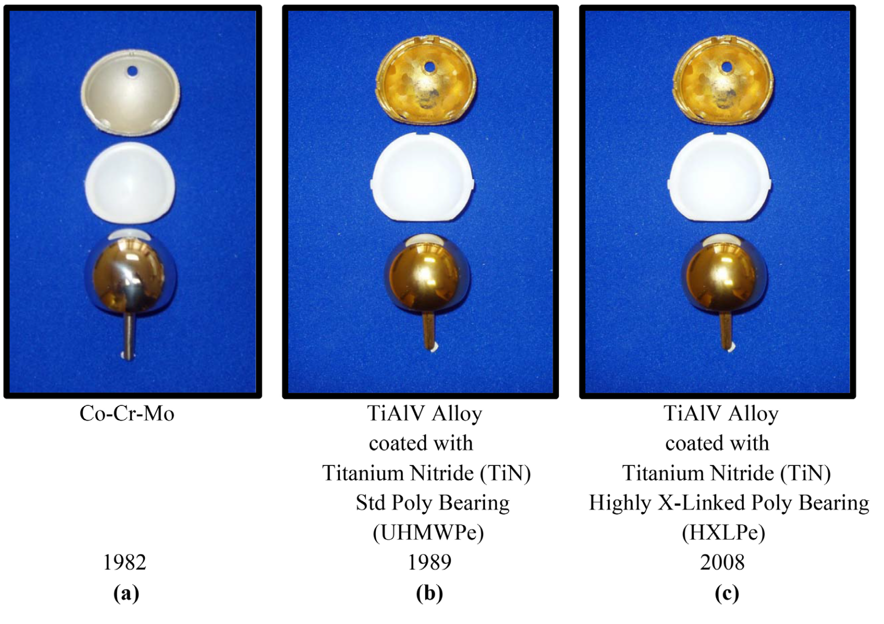


Figure 1. B-P resurfacing total hip development program.

mechanically simulated for nearly 50 million cycles with minimal wear noted, [11] giving hope to improved clinical success. Unfortunately, these devices failed to give predictable long term clinical results because of "similar osteolysis" to their Co-Cr-Mo counterparts. Improved polishing of the femoral component counterfaces gave moderate improvement in wear properties, but until 2008, when UHMWPE was changed to HXLPE, further improvement was minimal.

3. Results

After the introduction of HXLPE into the BP Resurfacing THR System, long-term improvement in wear resistance and decrease in osteolysis was reported by Pritchett. [12] [13] [14] In the meantime, refusal of the manufacturing company to supply product to its distributors led to an essential closure of Endotec, Inc and loss of the FDA 510 K status supporting its United States manufacturing and sales of its devices. [15]

In an attempt to salvage the B-P Resurfacing THR System, Biocore 9, a product development company located in Whippany, NJ, spent 4 years reclaiming an FDA 510 K status for the B-P Resurfacing THR System, which had already been in clinical use for over 30 years. Aside from unchanged design and engineering specifications, a new 5 million cycle mechanical simulation study and new specific "lever out" studies were mandated to assure stability of the HXLPE bearing in the ceramic coated acetabular cup. Both the femoral resurfacing components and the acetabular components were independently cleared by the FDA 510 K process for commercial sale and distribution in the United States by 2022. [16] [17]

A review of the work of resurfacing hip replacement developers, including Smith-Petersen, [18] Charnley, [19] Wagner, [20] Freeman, [21] Judet, [22] Hedley, [23] Amstutz, [3] McMinn, [5] Townley [24] and Buechel [6] led the author to consider the B-P Resurfacing THR for his own personal use, when he developed osteoarthritis of both hips, from late stage femoro-acetabular-impingement (FAI). [25] Prior to his hip replacement surgery, the author had been a highly successful Division I collegiate wrestler, an avid scuba diver for over 40 years and a motivated squash player for more than 50 years, aside from being an active joint replacement surgeon and implant designer for the past 45 years.

At the age of 70 in 2015, the author had his left hip resurfaced, followed by a right B-P Resurfacing Hip Replacement in 2018. He recovered uneventfully, with only an overnight hospital stay for both arthroplasties. He was partial weight bearing for 4 weeks, used a cane in the opposite side until his abductors were strong enough to allow normal walking without an abductor lurch (about 4 - 6 weeks). Thereafter, he returned to playing squash twice weekly and continued his orthopaedic surgical practice until his retirement in 2023. His bilateral Harris Hip Scores were 100 points out of 100 points (excellent) at last follow-up. **Figure 2** shows post-op A-P and lateral x-rays of both hips.

Anterior-Posterior (A-P) X-Ray
5 Years 8 Years
(a)

Lateral X-Ray
Right Hip (5 Yrs)
(b)

Lateral X-Ray
Left Hip (8 Yrs)
(c)

Figure 2. X-Rays of a 78 year-old orthopaedic surgeon with bilateral B-P resurfacing hip replacements.

4. Discussion

Resurfacing total hip replacement has been an ideal reconstructive concept for restoring normal hip function in severely arthritic joints for nearly a century. Recent analysis over the past 45 years has led the author and colleagues to incorporate several important contributions from prior authors to advance the concept into its present form.

Femoral resurfacing geometry is best reproduced by a spherical element which should be thin enough to allow for the retention of the viable femoral head and neck, thus allowing resection of only the arthritic boney surface and retention of much of the subchondral supporting bone, as seen in the Smith-Peterson, [18]

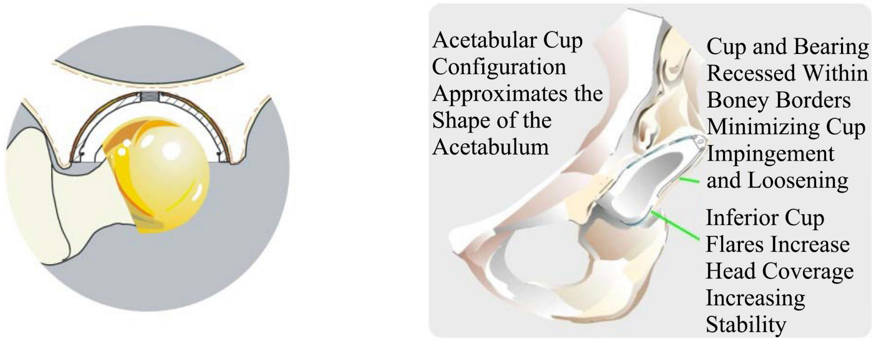
Tharies, [3] Wagner, [20] Eicher, [2] ICLH, [21] Townley, [24] Birmingham [4] [5] and B-P [6] [14] femoral components.

A short, central fixation stem, as seen in the Judet prosthesis, [22] can help to prevent a shear stress fracture of the femoral neck, whereas a longer metaphaseal curved stem, as seen in the Townley device, [24] can cause stress shielding. Similarly, a short porous-coated stem, as seen in Hedley's dog studies, [23] can cause stress shielding and should be avoided in a cementless femoral component. For these reasons, the B-P femoral component uses a short, straight, tapered, non-porous-coated central stem to provide alignment and early stability, while reinforcing the region of highest shear stresses in the femoral neck, without fear of stress shielding, see **Figure 1(c)**.

The acetabular component geometry of the B-P resurfacing hip system, like the femoral component, uses thin shell technology [27] and less than a hemisphere to avoid neck-cup impingement, while providing anatomical inferior flares and a cut-out to increase stability, while avoiding contact with the iliopsoas tendon during flexion and extension, see **Figure 3**.

Additionally, a "thin shell" allows for a thicker HXLPE bearing, which equates to less acetabular bone removal, thus allowing a standard acetabular preparation while maximizing the femoral component head size.

These subtle design features, which include flexible, peripheral locking tabs, anti-rotational tabs and increased bearing thickness in the superior weight-bearing portion of the HXLPE bearing, allow for minimal overall thickness of the porous coated ceramic-poly-ceramic composite to simulate the articular cartilage-subchondral plate overall thickness in the normal hip.



Recessed Acetabular Cup Avoids Neck Impingement

(a)

Anatomical Fit of the B-P Fixed Acetabular Components

(b)

Figure 3. The design of the B-P acetabular cup avoids neck impingement and increases head coverage.

The early studies of Freeman [27] demonstrated that the arthritic hip vasculature became increasingly intraosseous, which allowed full exposure of the femoral neck, without fear of impending avascular necrosis. However, when using methyl methacrylate to cement the femoral component, temperature as high as 100˚C can be reached, [28] which can cause thermal necrosis of the femoral head, leading to neck fracture failure. [8] This important consideration leads to the preferential use of ingrowth fixation for the femoral component, rather than cement fixation.

In fact, over the past 30 years of use, routine cementless fixation of the B-P Resurfacing Hip Replacement has been quite reliable, only to be overshadowed by excessive wear and osteolysis problems associated with UHMWPE.

Considerimg all of these years of evolution, the current optimized resurfacing total hip replacement, using HXLPE bearings, can finally stand up to (or even replace) the conventional stem-type THR in selected high activity patients.

5. Conclusion

After 45 years of active evaluation, including mechanical design considerations, prosthetic design and instrument development, clinical and radiographic analysis of results, as well as availability of components cleared by the FDA 510 K process, the author has a personal preference for the B-P Resurfacing THR System. He has regained full range of motion in both of his resurfaced hips, with restoration of his ability to play competitive squash and perform complex joint replacement surgery. Excellent mid-term results of 8 and 5 years, respectively, reproduce the long term excellent results presented in similar patient applications.

Conflicts of Interest

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

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