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Adventure sports and sexual freedom hip replacement: the tripolar hip

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Abstract Certain athletic activities and lifestyles require a completely stable and very mobile hip. Total hip replacement with a natural femoral head size and two mobile-bearing surfaces (i.e., a "tripolar" prosthesis) is the most stable prosthesis. Elegant design and wear-resistant bearing surfaces are the keys to long-term implant survivorship. The hypothesis is that a ceramic-coated tripolar prosthesis using highly cross-linked polyethylene can provide full function and complete stability with low wear. This study sought to determine: (1) patient-reported outcomes, (2) functional outcomes, (3) implant survivorship and complications, and (4) postoperative sexual limitations. Between 1998 and 2011, the author performed 160 primary total hip replacements using tripolar prostheses in patients participating in adventure sports and other physically demanding activities. The institutional review board approved this study. The inclusion criteria were patients who needed unrestricted activity and who were not candidates for or did not choose hip resurfacing. Patients were followed every second year and assessed with radiographs, Harris Hip Score, WOMAC, SF-12, and UCLA functional outcome scores. Patients were asked about symptoms of instability and satisfaction with their hip replacement. Patients were asked both preoperatively and 2 years postoperatively four questions about their sexual activity. Mean follow-up was 11 years. At 2 years' postoperatively, 98% of patients reported their satisfaction as excellent or good and 99% were not limited for sexual activity following surgery. Seventy-four percent of patients reported they were recovered within 6 weeks of surgery. There were no dislocations. There were three revision procedures for implant loosening, infection, and periprosthetic fracture, but there were no failures of the tripolar articulation. The mean postoperative UCLA score was the highly athletic score of 8. There were no signs of osteolysis, wear, or metal sensitivity reactions. The range of motion achieved, sexual, and functional outcomes were higher than with other types of total hip replacement. This ceramic-coated tripolar prosthesis using highly cross-linked polyethylene provides full function, complete stability, and low wear to younger, active patients, thus confirming the hypothesis and clinical relevance.

Keywords Total hip replacement · Athletic patients · Adventure sports · Sexual activity

Introduction

The design goals of total hip replacement (THR) prostheses are to restore range of motion, provide for complete implant stability, and create low wear surfaces. To assure low wear and frictional torque, conventional THR utilizes a smaller than natural size femoral head. However, the smaller femoral head comes with the penalty of reduced stability [1, 2]. There have been several attempts to increase stability, but the most successful has involved creating two articulating surfaces sharing the same motion center. In such a prosthesis, a second polyethylene head captures the smaller metal or ceramic femoral head attached to the stem. Thus, there is motion between both femoral heads and at the acetabular articulating surface [3–6].

If the second polyethylene femoral head is metal backed and intended for articulation with the native acetabular

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cartilage, it is termed a "bipolar" prosthesis [3, 6]. If the bipolar prosthesis, in turn, articulates with a polyethylene acetabular component, it is termed a "tripolar" prosthesis [3, 7, 8]. The first use of a tripolar prosthesis was to treat femoral neck fracture after a hip resurfacing procedure while retaining the well-fixed polyethylene acetabular component [8]. If the second polyethylene head is not metal backed and is intended to articulate with a one- or two-piece metal acetabular component, it is called a "dual-mobility" prosthesis [5].

Some patients participate in demanding adventure sports that require a full range of stable motion under the heaviest loads and in the most awkward positions. In addition, 40–75% of patients with hip arthritis are limited in their sexual activity [1–3, 9–22]. The most common reason for a patient to feel sexually limited after conventional THR is fear of dislocation, followed by the surgeon's advice to limit some positions [19, 22, 23]. An implant and procedure beyond the usual offerings are essential for patients who want no limits on their postoperative athletic and sexual activities. Choosing an implant or technique that requires any restriction for adventure sports or sexual activity may be an unnecessary concession to tradition and surgical convenience.

Hip resurfacing has been an excellent option for some patients, but it is demanding both in terms of the bone health over time and in terms of surgical effort and experience to perform the procedure [11, 24]. In addition, hip resurfacing cannot be offered to all patients because of their bone quality or geometry at presentation [24]. Also, on the uncommon occasion that bone health suffers, the resurfacing procedure may require revision [8, 25]. For young, active, carefully selected patients, hip resurfacing has superior survivorship and function compared to conventional THR [11].

Some surgeons have attempted to achieve full stability by utilizing different surgical approaches, such as the direct anterior or superior approach [9, 26]. However, it has never been proven that a surgical approach or technique alone can overcome the inherent issues of providing a stable hip in all circumstances [26]. The superior approach has the advantage of no postoperative restrictions, and it does not put the lateral femoral cutaneous nerve at risk of injury as does the anterior approach [9]. Other attempts to provide a stable THR by using large diameter metal-on-metal surfaces, modular neck prostheses, large diameter conventional and constrained implants have failed mechanically or by the accumulation of wear debris either at the head/neck junction or at the bearing surface [10, 12, 13, 27, 28].

Two-piece acetabular components with polyethylene offer the most versatility for acetabular component insertion and allow possible screw fixation. Even the most challenging dysplasia and revision situations can be addressed successfully. With cross-linked polyethylene, durability has improved greatly [29, 30]. The availability of improved polyethylene for the inner bearing of a bipolar component coupled with a very low wear ceramic-coated metal outer bearing has improved the resistance to wear of a bipolar prosthesis [10, 30, 31].

This study's hypothesis and clinical relevance are that a ceramic-coated tripolar prosthesis using highly cross-linked polyethylene can provide full function and complete stability, with low wear. This study sought to answer these questions: (1) What are the patient-reported outcomes? (2) What are the functional outcomes? (3) What are the implant survivorship and complications? I also asked specific questions about sexual limitations.

Methods

This was a prospective institutional review board-approved study of 160 patients undergoing THR using a tripolar prosthesis between 1998 and 2011. The inclusion criteria for primary THR procedures were patients who needed unrestricted activity and who were not candidates for/did not choose hip resurfacing. If patients had a healthy femoral head and neck and favorable geometry, a resurfacing procedure was offered. Table 1 shows patient demographic data and presenting diagnoses. The exclusion criterion was body mass index ≥ 40 kg/m^2. The study excluded 96 procedures that were performed as revision procedures and procedures performed before the availability of highly cross-linked polyethylene. Approximately 5% of patients presenting to the author's practice received a tripolar prosthesis.

Patients were followed every second year, and the operated hips were assessed with radiographs. Harris Hip Score, WOMAC, SF-12, and UCLA functional outcome scores were completed at each visit. A physical therapist and an exercise physiologist not involved in the patients' care questioned and examined the patients postoperatively to determine the time and extent of ultimate recovery, range of motion, and clinical scores. Patients were asked about any symptoms of instability (giving way or feeling of instability) and whether they were satisfied with their hip replacement. Only those who were highly or completely satisfied were considered satisfied with all other answers considered unsatisfied [32].

The operating surgeon asked patients both preoperatively and 2 years postoperatively four questions about their sexual activity: (1) Is your sexual activity limited or affected by your hip? (2) Is your concern about pain, limitations in position for sexual activity, or other? (3) Has your frequency of sexual activity increased, decreased, or remained the same after hip replacement surgery? (4) What

Table 1 Patient demographic data

n patients = 160	Mean age (years)	Age range (years)
Men = 76	45	23–71
Women = 84	42	19–76
Preoperative diagnoses		
Osteoarthritis = 76		
Severe dysplasia = 29		
Post-traumatic arthritis = 27		
Osteonecrosis = 19		
Inflammatory arthritis = 9		

were or are your concerns with sexuality following hip replacement: dislocation, limitations in position, pain?

Operative technique

All implants were placed without cement. The superior approach was used for all procedures, with patients in the side-lying position. The incision starts at the posterior corner of the greater trochanter and extends proximally 8 cm in parallel with the gluteus maximus fibers. The pericapsular fat is identified, and the piriformis and conjoined tendons are tenotomized. With the posterior capsule completely exposed, the capsulotomy begins distally on the femoral neck and then extends to the superior acetabular margin. The hip is dislocated posteriorly, and the femoral head is removed after an osteotomy across the neck [9]. No traction tables were used, and gentleness of surgical technique was emphasized. Immediate postoperative weight bearing was encouraged. Procedures after 2005 were performed with the assistance of preoperative computer templating. Intraoperative radiographs were taken for all procedures. A few procedures were performed using intraoperative computed tomographic (O-arm) scanning, surgical navigation, or the robotic arm, but this was discontinued after 2011 because it added time and expense to the procedure without evidence of clinical benefit.

Implants used

The acetabular implant consists of a two-piece, porous-coated acetabular component that offers the opportunity for screw fixation (Fig. 1; FDA 510K-963101). The polyethylene is GUR 1020 (Ticona, Industrial Park Hoechst, Frankfurt am Main, Germany) cross-linked with 7.5 mrad with gamma irradiation, remelted at 155 °F, and sterilized with ethylene oxide (MediTECH-Quadrant, Fort Wayne, IN). The polyethylene thickness is 4 mm (Fig. 2). This acetabular component is approximately 10 mm larger than

Fig. 1 This photograph shows a porous-coated titanium acetabular shell. The *gold color* is from titanium nitride (ceramic) coating (color figure online)

Fig. 2 This is a photograph of a 4-mm-thick cross-linked polyethylene acetabular liner with secure locking tabs and an impingement-free inferior cutout

the width of the femoral neck. The acetabular component is typically used for hip resurfacing and has a larger internal diameter (40–52 mm) than a typical THR (28–36 mm) acetabular component.

The thin cross-linked polyethylene must be supported fully by the metal rim that is a few degrees less than a full hemisphere to maximize the impingement-free range of motion. Increased side walls in the critical anterior and posterior portions of the acetabular component enhance fixation, and most prostheses are placed without screws. The acetabular polyethylene bearings are seated into a $TiAl_6V_4$ shell. The shells are hemispherical except for inferior extensions and an anatomic inferior cutout. This shell geometry was first described in 1973 to reduce impingement and psoas tendon irritation [28, 29]. The shells have up to five fixation holes and are porous-coated on the outer surface with sintered commercial pure titanium beads to give an average pore size of 350 μM and a volume porosity of 30%. They are 2 mm thick and with a 1-mm porous coating. Acetabular components that are any thinner can deform and defeat a locking mechanism. A thinner implant will need to be one piece, which would reduce fixation options in difficult primary or revision situations. The shells provide a locking mechanism for the polymer bearings that consist of recessed grooves with flexible locking tabs and three anti-rotational key ways. The bearings are placed into the locking mechanism on a snap-fit basis.

The femoral component is ceramic-coated bipolar (Fig. 3). The inner femoral head can be either ceramic or ceramic-coated metal and can be placed on any compatible femoral stem design (Fig. 4). The titanium nitride ceramic surface layer coating is 8 μM that is deposited using a physical vapor deposition process (Ionbond, Rockaway, NJ). The surface roughness of the femoral components was <3 μM. The most common femoral components used in this study were wedge-shaped proximal loading implants. There are important nuances in selecting the bipolar bearing. The outside spherical surface is eccentric to the inner surface that allows the construct to be "self-centering," which is critical to providing progressive resistance to wear. Most bipolar prostheses are designed to work against a patient's own acetabulum and may have negative eccentricity. They still work reasonably well, but for a high-demand hip replacement, positive eccentricity is needed [33].

Results

Of the 160 patients reviewed in this study, 149 patients self-rated their THR and answered all four questions at the 2-year postoperative visit (11 patients did not complete all questions of the evaluation). Ninety-eight percent were satisfied with their pain relief, 90% were satisfied with their sports participation, 99% had no hip-related limitation in their sexual participation, and 97% were satisfied overall. Two patients had incomplete pain relief, and two had unmet functional needs that precluded a good or excellent rating. Two patients reported they had pain with high flexion and external rotation during sexual activity, yet both remained sexually active. Five patients did not achieve their desired range of motion. Four of these five were examined under anesthesia, and no joint separation or sign of impingement was found. There were no dislocations.

Fig. 3 This photograph shows a double-assembly femoral bearing. The outer bearing is ceramic-coated titanium with a self-centering inner bearing. Any suitable femoral head can be attached to a femoral stem of choice

Fig. 4 This photograph shows a completed double-assembly (tripolar) hip prosthesis

The mean follow-up period was 11 years (range 6–19 years), and the mean UCLA activity score goal was 8.5. No patients were excluded because of activity goal. The mean postoperative UCLA score for primary procedures was 8.8 (range 7–10), and 80% of patients had a UCLA activity score of ≥8. There were significant improvements in range of motion, sexual frequency, Harris Hip Score, WOMAC, SF-12, and UCLA scores 2 years following surgery ($P < .001$; Tables 2, 3).

Preoperatively, 54% of men and 86% of women were limited in their sexual activity. Pain and limitations in position were the reasons stated for sexual limitations by patients preoperatively. Before their THR, 36% of patients were concerned about experiencing a dislocation and 39% were concerned about limiting their position. Postoperatively, 99% of patients were not limited in any way and only 2% had any residual concerns; 19% reported an increase in sexual frequency.

Seventy-four percent of patients said they were healed and had better function than prior to surgery within 6 weeks (range 3–21 weeks). The most common patient-reported time to full recovery was 6 months (range 3–9 months). The physical therapist found increasing strength and range of motion for up to 24 months postoperatively (range 5–24 months).

Table 2 Results of scoring assessments

Instrument	Preoperative Mean (range)	Postoperative Mean (range)	*P* value
Harris Hip	51 (21–81)	96 (52–100)	<0.0001
WOMAC	52 (30–68)	5 (0–16)	<0.0001
SF-12			
Mental	44 (22–61)	54 (24–64)	<0.005
Physical	36 (22–48)	54 (26–64)	<0.0001
UCLA	4 (2–7)	8.8 (6–10)	<00001

Table 3 Range of motion results

Motion	Preoperative Mean (range)	Postoperative Mean (range)	*P* value
Flexion	98 (70–130)	126 (110–140)	<.0001
Internal rotation	4 (−10 to 20)	35 (15–60)	<.0001
External rotation	20 (0–35)	40 (25–50)	<.001

Seventy percent of recent patients were discharged the same day as their surgery and 95% in less than 48 h (range 3–72 h). The mean time to walking with no external support was 9 days (range 0–16 days). The mean time to return to employment was 15 days (range 1–31 days).

Twenty-seven patients died during the follow-up period of causes unrelated to the surgery. Twelve patients were lost to follow-up during the 19-year study period, but only one was lost and one died within the first 2 years of follow-up.

Radiographic results

The mean acetabular inclination angle was 39° (range 29°–49°). The mean anteversion was 16° (range 9°–26°). The mean femoral head size for women was 44 mm (range 40–47 mm) and for men was 49 mm (range 44–52 mm). The mean reduction in femoral head size from the preoperative native femoral head size to the femoral implant was 1.5 mm. The mean thickness of the medial acetabular wall was 9 mm. The limb length was increased a mean of 3 mm (range −3 to +9 mm).

Complications

There was one instance of a failed acetabular osseointegration requiring revision, one periprosthetic fracture, one femoral nerve injury, and two instances of femoral loosening. Four implants were retrieved during these revision procedures. Two implants were removed for infection, and two were removed postmortem. There were no bearing surface failures or signs of impending failure. The eight polyethylene retrieval specimens obtained at revision or postmortem at periods of 3, 5, 7, 8, 9, 9, 10, and 11 years post-resurfacing showed a mean acetabular bearing wear rate of 0.05 mm/year (range 0.03–0.07). The inner bearing had a wear rate of 0.07 mm/year (range 0.05–0.09). There was no internal or rim cracking, scratching, burnishing, or delamination, and the original machining marks were visible on seven of the eight liners. Two liners showed signs of polyethylene creep into the screw holes.

Activities

Patients who underwent primary THR stated they participated in a variety of physically demanding activities postoperatively, as listed in Table 4.

Discussion

The goals of providing a full range of motion, complete stability, and low wear were met in these high-demand patients. The mean postoperative UCLA scores exceeded the patients' preoperative goal. The second goal was to match their durability needs. There were no bearing surface failures, and the retrievals showed a low rate of wear. The third goal of complete hip stability was also achieved, as there were no dislocations or complaints of instability.

Sexual activity is an important part of life for older adults and is positively associated with overall health

Table 4 Patient activities post-THR (more than one activity possible)

Activity	Number of patients
Teaching yoga	12
Teaching pilates	6
Martial arts	10
Teaching paddle board	2
Bungee jumping	2
Surfing	8
Extreme skiing	9
Acrobatics	2
Circus performer	2
Flight jumpers for fire fighting	2
Orthopedic surgeons	6
Other physicians	7
Professional cycling	4
Professional ballet	4
Teaching gymnastics	2
Professional swimming diver	3
Other professional sports (soccer, tennis, golf)	6
Iron man competitor	8
Rodeo performer	3
Firefighter	14

among middle-aged and older adults [34, 35]. Only 1% of patients in this study were limited postoperatively in their sexual activity compared with 34–47% of patients with ongoing limitations following conventional THR. In the present study, 19% of patients had a marked increase in the frequency of their sexual activity compared to 4.5–27% in other studies. Freedom to assume all positions for sexual activity is a benefit, as 36% of our patients preoperatively and 39% of patients after conventional THR are concerned about hip dislocation. Most women prefer positions other than those recommended by a survey of the American Association of Hip and Knee Surgeons [18]. Therefore, the ability to assume any desired degree of abduction and external rotation is considered an advantage [16, 18–20, 22, 23].

There are limitations in this study. All procedures were performed by a highly experienced surgeon. A close match to the patient's native femoral head size is important in achieving a full range of motion. Thus, only one femoral component and one acetabular component are correct for each patient. Also, the position of each component is critical to the success of the procedure. Other centers may not achieve the results of this study, as the operation is very demanding and extensive surgeon experience along with precise surgical technique is necessary. It is possible that with even longer-term follow-up the flaws of cross-linked polyethylene will become apparent but the follow-up period in this study is as long as that of most other studies.

Hip stability is a complex issue, and several studies have shown that most hip prostheses are not placed ideally [14, 15]. The femoral head size is typically reduced to 28–36 mm in conventional THR [2, 29, 36]. The reduction in femoral head size has been a concession to engineering and manufacturing considerations. Charnley [1] originally used a 41.5-mm femoral head for THR to gain the greatest range of motion and stability. He later reduced the size to 22.5 mm because of concern about polyethylene wear and frictional torque on the acetabular fixation [1].

The first tripolar prostheses that were used were to treat femoral neck fracture following hip resurfacing or for recurrent hip instability. They sometimes failed over time due to polyethylene wear and prosthetic loosening [7, 36]. Captured or constrained tripolar prostheses fail mechanically [12]. Dual-mobility prostheses have been very successful as a solution for hip instability, and it is possible they will perform as well as this tripolar assembly. There are occasional intraprosthetic wear-related dislocations, but with improving polyethylene these are rare [5].

For patients with lower activity demands, a conventional THR without individualized component selection or ideal placement can result in a successful outcome. Also, patients can become very skilled at accommodating flaws in their hip as they adjust to their arthritic hip over time.

Postoperatively, 50% of patients with conventional cementless THR are limited in their activity [37] and 70% of surgeons recommend limitations following THR [22]. The reasons for the self- or surgeon-imposed limitations are pain, a limp, and concerns about wear and hip stability in certain positions [11, 14, 15, 22].

Patients interested in pursuing adventure sports are different than the typical THR patient. They are younger, more flexible, and in need of greater range of motion. Most conventional THR prostheses offer 100° of flexion and approximately 30° of internal and external rotation [21, 36, 37]. The patients in this study achieved a mean flexion of 126° with a mean internal and external rotation of 45°. Patients in this study were advised that it was not necessary to restrict their activities in any way. They achieved the range of motion and activity participation that their natural flexibility and agility allowed.

As the quality of polyethylene has improved [30], the focus in implant manufacturing has turned to the other parts of the bearing couple [29]. Cobalt chromium has been used since 1938, and it works well [38]. A variety of ceramic materials has been used. Titanium can be used if it is protected by a ceramic coating. Titanium nitride coatings are common for industrial applications and are finding an increasing role in hip, shoulder, and knee implants. Wear simulator studies with up to 48 million cycles using a 47-mm femoral head size support the use of titanium nitride coatings for THR and hip resurfacing [31]. Metal sensitivity can occur with cobalt chromium, but it has not been reported with titanium-nitride-coated implants [39, 40].

The ideal hip prosthesis will allow complete and full function with the promise of durability. The patient sets the goal rather than the surgeon, thus allowing the surgeon to focus on providing confidence and removing barriers to full recovery rather than managing expectations and setting limits. Improved techniques, planning, design, and implant manufacturing methods are now able to match patient needs. This tripolar hip replacement prosthesis is a valid choice for a patient who participates in adventure sports and athletic activities.

Compliance with ethical standards

Conflict of interest J.W.P. certifies that he has no commercial associations (consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest with this article.

Ethical approval The author certifies that he has institutional approval for this study and the investigation was conducted in conformity with ethical principles of research and that informed consent was obtained.

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