Summary of Safety and Effectiveness

I. GENERAL INFORMATION

Device Generic Name:	Total Hip System, Ceramic Articulation
Device Trade Name:	Duraloc® Option Ceramic Hip System
Applicant's Name and Address:	DePuy Orthopaedics, Inc. 700 Orthopaedic Drive Warsaw, IN 46580
Premarket Approval (PMA) Number:	P040023
Date of Panel Recommendation:	None
Date of Notice of Approval to the Applicant:	May 3, 2005

The approval of DePuy's Duraloc® Option Ceramic Hip System is being granted in part due to a licensing agreement with CeramTec who owns the rights to the PMA for the TRANSCEND Ceramic Hip System (P010001) and also distributes the ceramic components used in both the Duraloc® Option and TRANSCEND Systems. The Duraloc® Option Hip System uses identical ceramic inserts and nearly identical ceramic heads as the TRANSCEND System and uses DePuy's own acetabular shells (manufactured to mate with the ceramic inserts) and a subset of DePuy's femoral stems. A component comparison and preclinical test results were used to demonstrate that the Duraloc® Option performs similarly to the TRANSCEND device. Therefore, the clinical data referenced from the PMA for the TRANSCEND System has been used to predict the clinical outcome of the Duraloc® Option System.

II. INDICATIONS FOR USE

The Duraloc® Option Ceramic Hip System is indicated for non-cemented use in primary total hip arthroplasty in skeletally mature patients with non-inflammatory degenerative joint disease (NIDJD) such as osteoarthritis, avascular necrosis, congenital hip dysplasia, and post-traumatic arthritis.

III. CONTRAINDICATIONS

- overt or latent infection in or around the hip joint;
- skeletally immature patients;
- loss of musculature, neuromuscular compromise or vascular deficiency in the affected limb, rendering the procedure unjustifiable; and
- poor bone quality, such as osteoporosis, where in the surgeon's opinion, there is inadequate bone to support the implant(s).

IV. WARNINGS and PRECAUTIONS

The warnings and precautions can be found in the Duraloc® Option Ceramic Hip System's physician labeling.

V. DEVICE DESCRIPTION

The Duraloc® Option Ceramic Hip System consists of a modular ceramic insert that secures to a Duraloc® Option Acetabular Shell via a taper locking mechanism and a ceramic femoral head that is attached to a femoral stem to complete the total hip prosthesis. Both the insert and the femoral head are manufactured from Biolox® forte.

The Duraloc® Option ceramic acetabular insert is available in 28mm and 32mm inner diameters. Liners with a 28mm inner diameter are offered in outer diameters of 46mm, 48/50mm, 52mm, 54/56mm, 58/60mm, and 62/64/66mm. Liners with a 32mm inner diameter are offered in outer diameters of 52mm, 54/56mm, 58/60mm, and 62/64/66mm. The insert is manufactured by CeramTec from high purity, dense aluminum oxide (99.7%) conforming to ISO 6474[1].

The insert is secured into a Porocoat® porous-coated titanium alloy Ti-6Al-4V (ASTM F620[2]) Duraloc® Option acetabular shell by means of an 18° included angle taper which locks into a corresponding taper in the acetabular shell. The coating consists of multiple layers of commercially pure titanium beads, which are sintered to the exterior portion of the shell. The shells are for cementless use only.

The acetabular shells have two or three bone fixation screw holes, dependent upon shell size, and an apical threaded hole. The shells are offered in 11 sizes, from 46mm to 66mm, in 2mm increments. If required, 6.5mm cancellous bone screws, in lengths from 15mm to 70mm, and an apex hole eliminator may be used in conjunction with the shell.

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[1]ISO 6474 – "Implants for Surgery – Ceramic materials based on high purity alumina"
[2]ASTM F620 – "Standard Specification for Alpha Plus Beta Titanium Alloy Forgings for Surgical Implants"

The ceramic femoral heads have diameters of 28mm and 32mm, 12/14 or 11/13 tapers, and offsets of +0 to +9mm. The heads are manufactured by CeramTec of the same material as the inserts: high purity, dense aluminum oxide (99.7%) conforming to ISO 6474. The heads are assembled to Ti-6Al-4V femoral stems, with 12/14 or 11/13 tapers.

The S-ROM® and Summit™ femoral stems are manufactured from titanium alloy Ti-6AL-4V (ASTM F-620) and are designed to assemble to the ceramic femoral head components described above. The femoral components also feature porous coatings of commercially pure titanium beads. The femoral stem components are for cementless use only.

VI. ALTERNATIVE PRACTICES AND PROCEDURES

Depending on individual circumstances, alternative procedures may include the use of other commercially available total hip replacement implants, non-surgical treatment such as reduced activity and/or pain medication; or other surgical treatments that do not involve the use of an implant, such as hip joint fusion. Other bearing surface alternatives used in total hip replacement include: ceramic on polyethylene, metal on metal, and metal on polyethylene bearing articulations.

VII. MARKETING HISTORY

Since 2000, the Duraloc® Option has been sold in the following countries (in alphabetical order): the Australia, Austria, France, Germany, Italy, New Zealand, Sweden, Switzerland, and the United Kingdom. The ceramic femoral heads have also been sold and implanted in the United States and Japan, but not as part of a ceramic on ceramic hip system. The device has not been removed from the market due to any reason related to the safety or effectiveness.

VIII. POTENTIAL ADVERSE EFFECTS OF THE DEVICE ON HEALTH

The Duraloc® Option Ceramic Hip System is similar to the previously approved TRANSCEND Ceramic Hip System (P010001). DePuy references the clinical data from P010001, under a licensing agreement, as clinical support for the Duraloc® Option System. The clinical data are relevant because the ceramic acetabular inserts of the Duraloc® Option System are identical to a subset of the ceramic acetabular inserts of the TRANSCEND System (P010001) and the ceramic femoral heads of the Duraloc® Option System are nearly identical to a subset of the ceramic femoral heads of the TRANSCEND System (same articulating surface). A system comparison between the Duraloc® Option and the TRANSCEND was performed to demonstrate that the systems perform similarly enough on the bench that the clinical data referenced can be used to predict the clinical outcomes for the Duraloc® Option system.

Please see Table 3 in the Summary of Clinical Studies section for a tabulation of reported adverse events that occurred in the referenced study (P010001).

Potential Complications Associated with Any Total Hip Arthroplasty

1. Excessive wear of the ceramic components secondary to damage of mating wear surfaces or debris particles;
2. Although rare, metal sensitivity reactions in patients following joint replacement have been reported;
3. Implantation of foreign material in tissues can result in histological reactions involving macrophages and fibroblasts;
4. Possible detachment of the porous coating, which could lead to increased debris particles;
5. Pain;
6. Femoral or acetabular perforation, or bone fracture while seating the device;
7. Damage to blood vessels resulting in hematoma;
8. Temporary or permanent nerve damage resulting in pain or numbness of the affected limb;
9. Undesirable shortening or lengthening of the limb;
10. Traumatic arthrosis of the hip from intraoperative positioning of the extremity;
11. Cardiovascular disorders including venous thrombosis, pulmonary embolism, or myocardial infarction;
12. Temporary or permanent neuropathies;
13. Delayed wound healing;
14. Infection;
15. Migration, loosening, subluxation, or dislocation of the prosthesis;
16. Periarticular calcification or ossification, with or without impediment to joint mobility;
17. Inadequate range of motion due to improper selection or positioning of components, by femoral impingement, and periarticular calcification; and
18. Death.

Potential Complications Associated with the Duraloc® Option Ceramic Hip System

1. Wear of the ceramic acetabular components has been reported following total hip replacement. Higher rates of wear may be initiated by particles of cement, metal, or other debris that can cause abrasion of the articulating surfaces. Higher rates of wear may shorten the useful life of the prosthesis, and lead to early revision surgery to replace the worn prosthetic components.
2. While rare, fatigue fracture of the prosthetic component can occur as a result of trauma, strenuous activity, improper alignment, or duration of service.
3. Component dissociation.
4. Breakage or chipping of the femoral head or acetabular insert.

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IX. SUMMARY OF PRECLINICAL STUDIES

The results of the preclinical testing listed below demonstrate that the Duraloc® Option Ceramic Hip System performs similarly on the bench to the CeramTec TRANSCEND Ceramic Hip System (P010001). The Duraloc® Option System uses identical ceramic inserts and nearly identical ceramic heads as the TRANSCEND System and uses DePuy's own acetabular shells and a subset of DePuy's femoral stems. The comparability of the Duraloc® Option System and the TRANSCEND System was demonstrated through a side-by-side component comparison and a comparison of preclinical test results.

Preclinical studies conducted by CeramTec included microbiological, toxicological, immunological and biocompatibility studies. The ceramic material conforms to ASTM F603[3] and ISO 6474.

DePuy conducted several nonclinical laboratory studies in support of the design of the Duraloc Option Ceramic Hip System, as discussed below.

Ceramic Femoral Head Testing

The purpose of this battery of testing was to evaluate the performance of the ceramic femoral heads paired with the DePuy femoral stem tapers. Ceramic femoral heads of "worst-case" geometry (as defined below) for each outer diameter/taper configuration were tested for static burst strength, fatigue strength, post-fatigue burst strength and axial pull-off strength.

Static Burst

Static burst testing was conducted to determine the compressive load to failure of the worst-case ceramic femoral head. Testing was performed for 28mm +5 heads on 12/14 Ti-6Al-4V tapers, 32mm +9 heads on 12/14 Ti-6Al-4V tapers, and for 32mm +6 heads on 11/13 Ti-6Al-4V tapers. The stated femoral head configurations were considered worst-case scenarios because of two parameters. First, the wall thickness (the amount of ceramic material between the taper bore and the outer diameter of the head) is at a minimum with the smallest diameter heads for a given taper family (i.e. 12/14 and 11/13). Second, the +5, +9 and +6 offset options provide the least amount of contact surface area between the metal taper and the ceramic head for each respective femoral head outer diameter. This results in a more concentrated load (higher stress) between the contact surfaces of the femoral head and stem tapers. Smaller offset heads, which provide a greater contact surface area with the metal taper, will result in a less concentrated load (lower stress). The 12/14 taper was tested in both the 28mm and 32mm outer diameter because the offset options are different for each diameter. The 12/14 Ti-6Al-4V taper is found on the Summit Stems. The 11/13 Ti-6Al-4V taper is found on the S-ROM stems.

[3] ASTM F603 – "Standard Specification for High-Purity Dense Aluminum Oxide for Medical Application"

The acceptance criterion was defined as an average burst strength greater than 46kN with no single ball head below 20kN. This acceptance criterion is as defined in "The Guidance Document for the Preparation of Pre-Market Notifications for Ceramic Ball Hip Systems", dated January 10, 1995 that is available at http://www.fda.gov/cdrh/ode/355.pdf.

The results of the static burst test are provided in the table below.

	Avg. Burst Strength (Std. Dev.)	Acceptance Criterion for Avg. Burst Strength	Minimum Value for a Single Head	Acceptance Criterion for Minimum Value	Pass/Fail
12/14 Ti taper 28mm +5 offset	68.5kN (11.7kN)	> 46 kN	43.1kN	> 20 kN	PASS
12/14 Ti taper 32mm +9 offset	61.0kN (6.2kN)		54.9kN		PASS
11/13 Ti taper 32mm +6 offset	83.9kN (21.4kN)		48.1kN		PASS

All femoral head components tested in static burst met the acceptance criteria as defined in the above mentioned guidance document.

Fatigue/Post-fatigue Burst

Fatigue and subsequent post-fatigue burst testing was conducted on the worst-case components previously described in "Static Burst" to evaluate the strength of the component following cyclic compressive loading.

The acceptance criteria required the ceramic femoral head component to pass ten (10) million cycles of cyclic loading at 14kN with no macroscopically visible component failure and have no post-fatigue burst strength below 20kN. This acceptance criteria is as defined in "The Guidance Document for the Preparation of Pre-Market Notifications for Ceramic Ball Hip Systems", dated January 10, 1995 that is available at http://www.fda.gov/cdrh/ode/355.pdf.

The results of the fatigue testing demonstrated that all femoral heads passed 10 million cycles of fatigue with no component failures. The post-fatigue burst results are provided in the table below.

	Avg. Burst Strength (Std. Dev.)	Minimum Value for Single Head	Acceptance Criterion for Minimum Value	Pass/Fail
12/14 Ti taper 28mm +5 offset	63.0kN (2.6kN)	60.7kN	Min > 20 kN	PASS
12/14 Ti taper 32mm +9 offset	69.0kN (2.4kN)	67.3kN		PASS
11/13 Ti taper 32mm +6 offset	74.2kN (11.5kN)	64.4kN		PASS

All femoral head components tested in fatigue and post-fatigue burst met the acceptance criteria as defined in the above mentioned guidance document.

Axial Pull-Off

Axial pull-off testing was conducted on the worst-case components previously described in "Static Burst" to evaluate the strength of the taper locking mechanism between the ceramic femoral head and metal femoral stem taper.

The results of the axial pull-off testing are provided in the table below.

	Avg. Pull-off Strength (Std. Dev.)	Acceptance Criterion as Defined by CeramTec	Pass/Fail
12/14 Ti taper 28mm +5 offset	1430N (170N)	> 250N	PASS
12/14 Ti taper 32mm +9 offset	1500N (190N)		PASS
11/13 Ti taper 32mm +6 offset	920N (260N)		PASS

All femoral head components tested in axial pull-off met the acceptance criteria as defined in the CeramTec Qualification Program for Ceramic Ball Heads.

Ceramic Liner Testing

The purpose of this testing was to evaluate the performance of the Duraloc® Option ceramic liners in Duraloc® Option shells. Inserts of "worst-case" geometry (as defined below) were tested for burst strength, fatigue strength, post-fatigue burst strength, push-out force, rotational stability and lever-out force. In addition to the mechanical testing, wear testing, impact load testing and a range of motion analysis were also performed.

Static Burst

The purpose of this test was to determine the minimum static fracture load for the smallest ceramic insert (worst-case). The ceramic insert size 28/37G was determined to be the worst-case for testing because it has the thinnest cross sectional area (to resist static compressive loads) within the range of available sizes.

The acceptance criterion was defined as an average burst strength greater than 46kN with no single sample below 25kN. This acceptance criterion was established based on "The Guidance Document for the Preparation of Pre-Market Notifications for Ceramic Ball Hip Systems", dated January 10, 1995 that is available at http://www.fda.gov/cdrh/ode/355.pdf. The minimum burst value requirement as stated in the Guidance Document was increased to 25kN for ceramic liners to provide an additional factor of safety.

The mean static axial compressive fracture load for the Duraloc Option ceramic insert was 62.68kN (minimum 56.3kN). This result exceeds the acceptance criteria by a factor of 1.4. Furthermore, the mean static fracture load is 27.3 times greater than the hip stem compressive fatigue load recommended by ISO 7206-8[4].

Fatigue/Post-fatigue Burst

The purpose of this test was to determine the static fracture load for the smallest ceramic insert (worst-case) after cyclic fatigue testing. The ceramic insert size 28/37G was determined to be the worst-case for testing because it has the thinnest cross sectional area (to resist static compressive loads) within the range of available sizes.

The acceptance criteria required the ceramic liner samples to pass 10 million cycles at 14kN with no macroscopically visible component failure and have no post-fatigue burst strength below 25kN. This criterion was established by CeramTec based on "The Guidance Document for the Preparation of Pre-Market Notifications for Ceramic Ball Hip Systems", dated January 10, 1995 that is available at http://www.fda.gov/cdrh/ode/355.pdf. The minimum burst value requirement as stated in the Guidance Document was increased to 25kN for ceramic liners to provide an additional factor of safety.

The results of the fatigue testing demonstrated that all ceramic liners passed 10 million cycles of fatigue without component failures. The mean post-fatigue axial compressive fracture load was recorded as 60.3kN (minimum 55.2kN). This result exceeds the acceptance criteria by a factor of 2.2 and is 26.2 times greater than the hip stem compressive fatigue load recommended by ISO 7206-8.

Push-out

The purpose of this test was to evaluate the integrity of the metal shell/ceramic liner taper connection. The ceramic insert size 28/37G was determined to be the worst-case for testing because it has the least amount of surface area for engagement of the insert and shell tapers.

The acceptance criterion required an average push-out value greater than 200N. This acceptance criterion was established based on the average push-out value

[4] ISO 7206-8: 1995(E). Implant for surgery- Partial and total hip joint prostheses. *"Endurance Performance of Stemmed Femoral Components with Application of Torsion."*

(200N) reported by Greenwald[5] et al. The publication presents results obtained by testing approved and marketed modular acetabular components.

The average push-out value for the ceramic liner samples tested was 9300N. Compared to the Greenwald testing, the push-out strength of the Duraloc Option ceramic liners is 46.5 times greater than the push-out strength of approved and marketed modular acetabular components.

Torsional Test

The purpose of this test was to determine the torsional force required to dissociate the taper-fit between the ceramic insert and the metal acetabular shell. The ceramic insert size 28/37G was determined to be the worst-case for testing because it has the least amount of surface area for engagement of the insert and shell tapers.

The acceptance criterion was defined as an average torsional force greater than 4N*m (400N*cm). This acceptance criterion was established based on the fact that the torque due to friction at the ball-liner interface is approximately 2.4N*m and the locking mechanism of the liner in the shell should exceed this by a factor of safety. The defined acceptance criterion exceeds the 2.4N*m acceptance criterion by a safety factor of 1.7.

The average torque measured for the ceramic liner in the Duraloc Option shell was 67N*m (6700N*cm). This result exceeds the 4N*m acceptance criterion by a factor of 16.75.

Lever-out Test

The purpose of this test was to evaluate the integrity of the metal shell/ceramic liner taper connection. The ceramic insert size 28/37G was determined to be the worst-case for testing because it has the least amount of surface area for engagement of the insert and shell tapers.

The acceptance criteria was defined as an average lever-out force greater than 3000N*cm (30N*m). This acceptance criterion was established based on published data by Tradonsky[6], et al. which defines a range of lever-out values (4.9 – 77.3 N*m) for clinically available products. All components tested by Tradonsky were manufactured from ultra high molecular weight polyethylene (UHMWPE) with metal shells and various metal retaining rings or UHMWPE flanges used as locking mechanisms.

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[5] Greenwald, A. Seth, S. Tradonsky, P. D. Postak, A.I. Froimson. "Performance Characteristics of Two Piece Acetabular Cups." AAOS 1991, 10M0591.

[6] Tradonsky, S., P.D. Pstak, A.I. Froimson, A.S. Greenwald. "A Comparison of the Dissociation Strength of Modular Acetabular Components." Clinical Orthopaedics and Related Research 1993; 296: 154-60.

The recorded lever-out value for the ceramic liner in the Duraloc Option shell was 10,741N*cm (107.4N*m). The test protocol specifies that the force be increased on the lever arm until the ceramic liner detaches, or up to a maximum force of 95N*m. In two of the five samples tested, the insert disassociated from the acetabular shell. In the other three samples, the maximum 95N*m force was exceeded and the insert did not detach from the acetabular shell. In conclusion, the lever-out values demonstrated by the ceramic liner in the Duraloc Option shell exceed the highest reported lever-out value (77.3N*m) reported by Tradonsky, et al., by a factor of 1.4.

Wear Testing:
A simulator wear test was completed to evaluate the wear performance of the 28mm BIOLOX® *forte* alumina ceramic articulation (heads and liners) that are a part of the Duraloc® Option Ceramic Hip System. The 28mm bearing combination was chosen as the worst-case scenario since wear decreases with increasing femoral head size for hard-on-hard bearings.

The total wear rate for Duraloc Option 28mm ceramic bearing couple is reported at 0.08mm^3/million cycles averaged over a 5 million cycle test. This is consistent with alumina-alumina wear rates reported in literature and summarized in the DePuy test report.

Impact Load Testing
The purpose of this test was to evaluate the performance characteristics of the Duraloc Option ceramic femoral head and liner during cyclic loading with micro-separation and establish the load at which failure of the component(s) occurs. Separation of the ceramic head from the ceramic liner was accomplished to simulate potential micro-separation during gait in-vivo. A value of 0.5 mm separation was chosen for the testing conditions to allow for optimal control of the test and to provide for the impact loading. The tests were run under load control to allow accurate control of the peak applied load during the impact after micro-separation.

Loads were determined based on a reasonable worst-case estimate for a physiological load and impact rate. The load was defined as 4kN and an impact rate of 32 kN/sec (7,200 lbs/sec) based on 5 times body weight for an 80 kg (180 lb.) patient under average gait conditions (roughly 0.125 sec. to peak load upon heel strike-based on a Paul curve). Given this, tests were run with maximum loads of 8kN (10 x body weight (BW)), 14kN (17.5 x BW), and 20kN (25 x BW). All samples tested under these loads survived 1 million cycles of fatigue without component failure. Failures were achieved at loads higher than 22kN and 88kN/sec impact rates.

The results demonstrate that under an impact loading situation the Duraloc Option alumina/alumina ceramic on ceramic specimens require extreme loads and impact

rates to achieve failures. These loads and impact rates are well beyond the physiological ranges.

Range of Motion

The range of motion provided by the Duraloc Option alumina head/insert combinations was evaluated by moving the implants through a maximum range of motion (ROM) via computer simulation (CAD).

The CAD range of motion was evaluated using the worst-case combination (least amount of ROM) of Duraloc Option system components. Range of motion was measured in the anterior/posterior (A/P) and medial/lateral (M/L) planes. The worst case scenarios and resulting range of motion are provided in the table below.

	Worst Case- Summit (12/14)	Worst Case- SROM (11/13)
Acetabular Shell	46mm Shell	52 Shell
Ceramic Insert	28mm ID x 46mm OD	32mm ID x 52mm OD
Ceramic Femoral Head	28mm +1.5	32mm +0
Femoral Stem	Summit, size 10	SROM, size 30 STD
ROM A/P	130.8°	131.3°
ROM M/L	123.7°	121.9°

X. SUMMARY OF CLINICAL STUDIES

As previously stated, the Duraloc® Option Ceramic Hip System is similar to the previously approved TRANSCEND Ceramic Hip System (P010001). DePuy references the clinical data from P010001, under a licensing agreement, as clinical support for the safety and effectiveness of the Duraloc® Option System. The clinical data are relevant because the ceramic acetabular inserts of the Duraloc® Option System are identical to a subset of the ceramic acetabular inserts of the TRANSCEND system (P010001) and the ceramic femoral heads of the Duraloc® Option System are nearly identical to the ceramic femoral heads of the previously approved system (same articulating surface). The Duraloc® Option System uses DePuy's own acetabular shells (designed to mate with the ceramic inserts) and a subset of DePuy's femoral stems. The two systems were shown to perform similarly on the bench.

A. Published Literature

Published literature of early results of the referenced ceramic hip system discuss significant improvement in average Harris Hip scores and SF-12 scores. No fractures of the ceramic components were reported in these articles[7,8].

[7]Garino, Jonathan P., M.D. "Modern Ceramic-on-Ceramic Total Hip Systems in the United States." *Clinical Orthopaedics and Related Research 2000;* 379:41-47.

[8]Murphy, Stephen B., M.D., and Wael K. Barsoum, M.D. "Ceramic-Ceramic Bearings in Total Hip Arthroplasty: Preliminary Clinical Results." *The Orthopaedic Journal at Harvard Medical School 2001;* 3:92-94.

B. Pivotal Clinical Study

The study was a prospective, multi-center, non-masked clinical trial of 959 procedures in 848 patients, comparing the referenced ceramic hip system to a historical control group.

Although the primary efficacy endpoint in the clinical study was the survivorship of the referenced ceramic hip system (as assessed at the two year postoperative interval), for the purpose of the clinical study, the primary efficacy endpoints included Harris Hip Score and radiographic assessments at 2 years as well. In addition, patient satisfaction was assessed by the SF-12 at two years.

Complication rates were the primary safety endpoint.

Study Design

The study was a prospective, multi-center, historical control, clinical trial. The historical control group was later selected as the population of patients implanted with a metal on polyethylene hip consisting of non-inflammatory degenerative joint disease cases. Study patients consisted of individuals over 21 years of age presenting for total hip arthroplasty due to osteoarthritis, congenital hip dysplasia, traumatic arthritis and avascular necrosis. A total of 329 procedures have been performed with the referenced ceramic hip system in the original clinical population (Original Clinical Population). An additional 630 procedures were implanted under Continued Access. The total number (Original Clinical Population and Continued Access) meeting the inclusion/exclusion criteria as required by the protocol is 959 procedures in 848 patients. Over a two-year period, 211 hip prostheses (179 patients) with metal femoral stems and plastic cups were implanted in the control group.

Pivotal Clinical Patient Assessment

Each patient was evaluated at the immediate and 6, 12, and 24-month post-operative intervals, unless otherwise indicated by complications. At each follow-up visit, a Harris Hip Score and SF-12 was administered as well as obtaining AP and lateral radiographs. Radiographs were reviewed by the implanting surgeon. There were no pre-specified success/failure criteria in the clinical study.

Demographics

For the study population, there were a total of 965 procedures performed in 854 patients at 12 sites by 19 surgeons. Six of these patients did not meet study inclusion criteria (one procedure enrolled as a replacement for a previously implanted total hip replacement (THR) and five procedures performed in patients with rheumatoid arthritis). These six procedures are excluded from this analysis. Therefore, the primary analysis sample included 959 procedures for first hip replacements performed in 848 patients.

The patient accounting and Baseline Demographics are summarized in Tables 1 and 2. Note that there were 9 deaths, none of which were related to the study or to the device.

Table 1: Patient Accounting

Evaluation Interval	Original Clinical Patient Population (n=329)			Continued Access Population (n=630)		
	TFU	EFU	AFU(%)	TFU	EFU	AFU(%)
Pre-Op	329	329	100% (n=329)	630	630	100% (n=630)
6 months	329	323	93% (n=300)	602	602	71% (n=430)
12 months	329	321	91% (n=293)	443	442	53% (n=233)
24 months	329	321	94% (n=302)	151	150	0% (n=0)

TFU=Theoretical Follow-Up; EFU=Expected Follow-Up (Theoretical Follow-Up minus deaths and removals without replacement); AFU=Actual Follow-Up

Table 2: Baseline and Demographics

Values	Total Study Procedures (n=959)	Historical Control Group (n=211)
Mean Age in years	51.4 years (range 20-80)	62.7 years (range 22-87)
Gender	595 (62%) Males 364 (38%) Females	112 (53%) Males 99 (47%) Females
Mean Body Mass Index (kg/m^2)	28.8 (range 17.7-65.8)	27.1 (range 22.8-40.9)
Diagnosis: Osteoarthritis Avascular Necrosis Traumatic Arthritis Congenital Hip Dysplasia	 692 (72.2%) 189 (19.7%) 36 (3.8%) 42 (4.4%)	 180 (85.3%) 31 (14.7%) 0 0
Mean Baseline Total HHS (range 1-100)	45.1 (range 8.3-95.9)	42.7 (range 11-79)
Mean Baseline Pain HHS (range 0-44)	12.9 (range 0-44)	13.2 (range 0-30)
Mean Baseline Harris ROM°(range 0-5)	3.8 (range –3.1-4.88)	4.1 (range not available)

Safety and Effectiveness Data

Safety Results

The adverse events related to total hip replacement surgery reported in the pivotal clinical study of 959 procedures in 848 patients are listed in Table 3.

Table 3: Reported Adverse Events

Event	Clinical Study (n=959)		Historical Control Group (n=211)	
Systemic	**Freq.**	**% of Pop.**	**Freq.**	**% of Pop.**
Deaths	9	0.9%	0	0%
Pulmonary Embolism	2	0.2%	2	0.9%
Deep Vein Thrombosis	4	0.4%	0	0%
Local	**Freq.**	**% of Pop.**	**Freq.**	**% of Pop.**
Revisions/Removals[1]	11	1.1%	8	3.8%
Breakage/Fracture of Component[2]	See Note	See Note	2	0.9%
Dislocation (single) of Component[3]	8	0.8%	3	1.4%
Dislocation (recurrent) of Component[4]	2	0.2%	0	0%
Femoral Fracture	18	1.9%	9	4.3%
Hematoma	2	0.2%	0	0%
Heterotopic Ossification	1	0.1%	1	0.5%
Infection: Deep, Early < 1 year	2	0.2%	0	0%
Infection: Deep, Late > 1 year	1	0.1%	0	0%
Infection: Superficial	7	0.7%	0	0%
Loosening of Component	3	0.3%	2	0.9%
Migration of Component	2	0.2%	0	0%
Persistent Foot Drop	2	0.2%	0	0%
Pain	10	1.0%	0	0%
Perforation of Femur During Reaming	2	0.2%	0	0%
Wear of Component	1	0.1%	0	0%
Subsidence of Component	3	0.3%	2	0.9%
Soft Tissue Trauma	0	0%	0	0%
Wound Problems	2	0.2%	0	0%
Other Local Complication[5]	10	1.0%	0	0%
Local – Hip	**Freq.**	**% of Pop.**	**Freq.**	**% of Pop.**
Trochanteric Bursitis	16	1.7%	1	0.5%
Trochanteric Non-union	0	0%	0	0%
Trochanteric Avulsion	4	0.4%	0	0%

Notes:

[1]See details in Table 4.

[2]Clinical Study: Frequency of chipping of ceramic acetabular liner during placement requiring intraoperative revision was 0.5% (5/959 cases). The frequency of this adverse event reported for the Duraloc Option devices commercially distributed from May 2005 to November 2005 is estimated to be 2.8%.

Historical Control Group: Broken metal peg of acetabular cup

[3]2 were revised for this reason

[4]1 was revised for this reason.

[5]Consisted of: 3 cases of irritation/inflammation; 2 cases where patients fell; 1 case of component mismatch; 1 case of liner malposition; 1 case where the acetabular shell seated too deeply in the reamed cavity; 1 case of hip flexor weakness; and 1 case where the anterior abductor pulled off.

Revisions and Removals

Eleven devices out of the 959 primary procedures in the trial have been revised or removed. Table 4 summarizes the clinical information pertaining to these cases.

Table 4: Summary of Revisions and Removals

Procedures	Age/Gender	Diagnosis	Duration of Implantation	Reason for Revision/ Removal
Revision of acetabular component with bone graft and cage implantation	50/F	AVN	84 days	Migration of acetabular component
Revision of femoral head with a longer neck	29/F	Congenital Hip Dysplasia	1 day	Dislocation
Replaced acetabular component to larger size (32mm) and replaced femoral head to 35mm	43/M	Severe osteoarthritis with mild hip dysplasia	1 day	Dislocation
Replacement of acetabular component, liner, and femoral head. Repair of abductor mechanism.	62/M	Osteoarthritis	38 days	Persistent dislocation following closed reduction; trochanteric fracture with avulsion of abductors
Revision followed by removal and girdlestone procedure	51/M	Traumatic arthritis	210 days	Deep infection and stitch abscess
Replacement of acetabular liner	36/F	Congenital hip dysplasia	3 days	Acetabular liner disassociated from shell
Replacement of acetabular liner and femoral head	41/M	Osteoarthritis	14 days	Increasing pain, suspected infection
Replacement of acetabular liner and femoral head	58/M	Avascular Necrosis	953 days	Excessive wear due to impingement on acetabular cup rim
Replacement of femoral head from 32mm to 28mm	50/M	Osteoarthritis	1 day	Liner/head size mismatch noted on postoperative film
Replacement of (uncemented) femoral stem to cemented stem	56/M	Osteoarthritis	657 days	Pain and progressive subsidence due to undersized (uncemented) femoral stem
Replacement of femoral stem and head	56/F	Osteoarthritis	786 days	Femoral component loosening

Efficacy results

Table 5, below, shows the mean and range of Harris Hip Scores for each study cohort preoperatively and two years postoperatively.

Table 5: Efficacy Results - HHS

Primary Efficacy Assessment	Original Patient Population (n=329)[1]	Continued Access Population (n=630)[2]	Historical Control Group (n=211)
Preoperative mean HHS (range)	44.8 (13-89)	45.2 (8-96)	42.7 (11-79)
2 year postop mean HHS (range)	94.8 (34-100)	88.1 (17-100)	92.7 (39-100)
% Excellent/Good Results (HHS 80-100 points) at 2 years postop	92.2%	76.9%	88.2%

Notes:

[1] Original clinical population includes the first 329 procedures enrolled in the clinical study. This includes replacement and removals prior to 24 months (n=9), deaths prior to 24 months (n=7), and cases in which only a partial Harris Hip Score at 24 months or later was available (n=4)

[2] The *Continued Access* sample (N=630) includes procedures performed after the original clinical population without Month 24+ outcomes. Therefore, outcomes reported were defined on the basis of Last Observation Carried Forward (LOCF) and represent the latest clinical results available for that procedure.

Any Radiographic Lucency

Radiolucencies were recorded at each follow-up visit based on if they involved the entire Gruen zone (7 AP femoral zones, 7 lateral femoral zones, 3 AP acetabular zones, and 3 Lateral acetabular zones). Table 6 summarizes these results.

Table 6: Any Radiolucency

Lucency	Original Study Population (n=329)	Historical Control Group (n=211)
Femoral	18 (5.5%)	66 (31.3%)
Acetabular	9 (2.8%)	56 (26.5%)
Overall	22 (6.8%)	77 (36.5%)

In addition, any subsidence was reported for the original study population for 0.9% of the femoral stems and 0.3% pf the acetabular cups. In the historical control group there were two instances of femoral stem subsidence (1.0%).

Implant Survivorship

Implant survivorship was the pre-specified primary endpoint in the pivotal clinical study of the referenced ceramic hip system. Kaplan-Meier cumulative survivorship is shown in Tables 7 and 8 for the referenced ceramic hip system and the historical control group over time.

The cumulative Kaplan-Meier survivorship values for the femoral or acetabular component are shown in Tables 7 and 8 based on the longest duration of follow-up available in each study cohort.

Table 7: Referenced Ceramic Hip System Implant Survivorship

Interval	Number Entering Interval	Number Withdrawn	Number Revised in Interval	Cumulative Survival	Standard Error
12 months	528	69	8	0.9909	0.0041
24 months	279	78	1	0.9876	0.0066
36 months	1	0	0	0.9308	0.0562

Table 8: Historical Control Group Implant Survivorship

Interval	Number Entering Interval	Number Withdrawn	Number Revised in Interval	Cumulative Survival	Standard Error
12 months	234	8	3	0.9870	0.0074
24 months	223	70	1	0.9817	0.0090
36 months	152	103	1	0.9719	0.0131
48 months	48	34	3	0.8779	0.0481
60 months	11	11	0	0.8779	0.0481

Patient Success Criteria

Table 9 describes the proportion of patients meeting individual clinical success criteria at 2 years postoperatively.

Table 9: Patient Success Criteria at 2 Years

Patient Success Criteria	Original Patient Population (n=329)[1]	Historical Control Group (n=211)
Absence of Revision (%)	96.7% (n=318)	98.1% (n=207)
Total HHS ≥ 70	96.8% (n=318)	95.3% (n=201)
No Complete Radiolucencies[2]	99.7% (n=328)	88.5% (n=184)

Notes:

[1] The *Original Patient Population* sample includes procedures in the *Complete Endpoint* (n=309) sample plus procedures with revisions, replacements, or removals prior to Month 24 (N=9); who died prior to Month 24 (N=7); or who had only a partial Harris Hip Score assessment at Month 24 or later (N=4). This sample was constructed in order to facilitate an analysis of efficacy and safety endpoints for hips that were at-risk for a complication and that 'completed the study'. For *Complete Follow-up* procedures (N=329), the Month 24+ endpoint was defined as the Month 24 value and if not available, values after Month 24 were used. Original clinical study population includes the first 329 procedures enrolled in the clinical study. This includes replacements and removals prior to 24 months (n=9), deaths prior to 24 months (n=7), and cases in which only a partial Harris Hip Score at 24 months or later was available (n=4)

[2] Absence of complete radiolucency was determined by radiographic evaluation for four views: acetabular AP view (3 regions), acetabular lateral view (3 regions), femoral stem AP view (7 regions), and femoral stem lateral view (7 regions). Complete radiolucency in a view was defined to be present if there was any radiolucency present in all zones comprising that view. Absence of complete radiolucency was defined to be present if none of these four views had complete radiolucency.

XI. CONCLUSIONS DRAWN FROM THE STUDIES

The preclinical and referenced clinical data provide reasonable assurance that the Duraloc® Option Ceramic Hip System is safe and effective for total hip

replacement in patients with osteo/degenerative arthritis, avascular necrosis, and related diagnoses. A system comparison analysis between the Duraloc® Option and the TRANSCEND (P010001) was performed to demonstrate that the systems perform similarly enough on the bench that the clinical data referenced above can be used to predict the clinical outcomes for the Duraloc® Option device.

XII. PANEL RECOMMENDATIONS

In accordance with the provisions of section 515(c)(2) of the act as amended by the Safe Medical Devices Act of 1990, this PMA application was not referred to the Orthopedic Devices Panel, an FDA advisory committee, for review and recommendation because the information in the PMA substantially duplicates information previously reviewed by this panel.

XIII. CDRH DECISION

The applicant has adequately submitted all answers to the FDA's questions and comments for their PMA application. The preclinical data and similarities in device design to the previously approved ceramic hip system (P010001) provide reasonable assurance that the Duraloc® Option Ceramic Hip System is safe and effective when used as directed for total hip arthroplasty patients requiring total hip arthroplasty due to non-inflammatory degenerative joint disease (NIDJD) such as osteoarthritis, avascular necrosis, congenital hip dysplasia, and post-traumatic arthritis.

In addition, the applicant has agreed to conduct a post-approval study to evaluate the longer-term safety and effectiveness of the Duraloc® device. The study will be two phased, consisting of a clinical follow-up phase and a clinical outcomes phase. Two hundred and fifty (250) subjects will be longitudinally followed for a total of 10 years following their primary total hip replacement surgery. During the first (medium term: 0-5 year) phase, clinical, radiographic, and subject self-assessment information will be collected for each subject through five years. For the sixth through the tenth postoperative years, subjects will be asked to return an outcomes questionnaire designed to determine the status of their hip replacement as the second (long-term: 6-10 years) study phase.

The applicant's manufacturing facilities were inspected and determined to be in compliance with the Quality System Regulation (21 CFR Part 820).

FDA issued an approval letter to the applicant on May 3, 2005.

XIV. APPROVAL SPECIFICATIONS

Directions for Use: See the Device Labeling

Hazards to Health from Use of the Device: See Indications, Contraindications, Warnings, Precautions and Adverse Events in the label

Post-Approval Requirements and Restrictions: See Approval Order