Attune®
Knee System

Comparison of an Existing and New Total Knee Arthroplasty Implant Systems from the Same Manufacturer: A Prospective, Multicenter Study

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ABSTRACT

Aims

The goal of this study was to evaluate the outcomes of the P.F.C.™ SIGMA® Knee System that has been widely used for decades compared to the ATTUNE® Knee System, both manufactured by DePuy Synthes.

Methods and Patients

From October 2011-March 2015, 19 sites prospectively implanted 752 Subjects with the P.F.C. SIGMA Knee. Between November 2012 and May 2015, 23 sites (18 also enrolled P.F.C. SIGMA Knee), implanted 1130 Subjects with the ATTUNE Knee. Subjects were seen pre-operatively, less than 1-year, at 1-year, and at 2-years to collect patient reported outcome measures (PROMs), American Knee Society score (AKS), radiographs, and any complications. PROMs consisted of Knee Injury and Osteoarthritis Outcome Score (KOOS) (enables WOMAC scoring), Oxford Knee Score (OKS), Patient's Knee Implant Performance (PKIP) and EQ5D-3L, and a p-value threshold of 0.01 was used for PROMs comparisons. Responders were assessed at 2-years according to the Outcome Measures in Rheumatology-Osteoarthritis Research Society International (OMERACT-OARSI) using both WOMAC and KOOS outcomes. Kaplan-Meier (KM) implant survivorship (revision of any component for any reason) estimates were evaluated. Radiographs were evaluated by an independent radiographic reviewer.

Results

Mean (SD) follow-up was 2.2 (0.7) and 2.5 (0.8) years for the P.F.C. SIGMA Knee and ATTUNE Knee, respectively. The 2-year PROMs were compared between groups and demonstrated similar scores or scores in favor of the ATTUNE Knee compared to the P.F.C. SIGMA Knee. Mean outcomes for the ATTUNE Knee compared to the P.F.C. SIGMA Knee at 2-years were: KOOS (ADL: 89.0 vs. 86.8, p=0.005; Pain: 88.9 vs. 87.1, p=0.019; Symptoms: 84.1 vs. 82.2, p=0.017; Sport/Rec: 63.9 vs. 58.8, p=0.001, QOL: 77.0 vs. 73.5, p=0.003), PKIP (Overall: 76.5 vs. 73.5, p=0.003; Confidence: 8.4 vs. 8.1, p=0.004; Stability: 8.6 vs. 8.3, p=0.006; Satisfaction: 8.3 vs. 8.1, p=0.042; Modify Activities: 6.6 vs. 6.4, p=0.334), OKS (41.9 vs. 41.1, p=0.027), and EQ5D-3L (0.88 vs. 0.88, p=0.737).

The 2-year responder rates favored the ATTUNE Knee compared to the P.F.C. SIGMA Knee (using WOMAC: 93.9% vs. 90.6%, p=0.018; using KOOS: 94.2% vs. 91.5% p=0.042). The percent of Subjects with tibial or femoral radiolucencies (at bone-cement and/or the implant-cement) of 2mm or larger at 2-years was similar (p≥0.05) or favored the ATTUNE Knee. KM implant survivorship was similar between groups (log-rank p=0.9384).

Conclusions

The implant survivorship and radiographic assessments showed similar outcomes between the two groups. Several PROMs showed statistical significance favoring the ATTUNE Knee and the responder analysis demonstrated a slight increase in the percent of patients who achieved an optimal outcome.

INTRODUCTION

Total knee arthroplasty (TKA) has evolved into highly successful surgery, providing excellent implant survivorship,[1,2] pain relief[3] and improved quality of life[4,5] for the majority of patients who elect to have the surgery. However, up to 30%[5-10] of patients report dissatisfaction with the outcome of their surgery. New TKA implants and surgical processes are intended to improve performance, particularly from a patient perspective. Infrequently there is accompanying data to document relative performance of newly released

implants. The goal of this study was to evaluate clinical, patient reported, implant survivorship, adverse events and radiographic outcomes of an implant widely used for decades, P.F.C. SIGMA Knee, compared to a new implant introduced in 2011, the ATTUNE Knee System, both from DePuy Synthes. This white paper shares information that was recently presented at the Closed Meeting of the Knee Society[11] and expands upon a prior publication of interim data that focused on one year outcomes.[12]

MATERIALS AND METHODS

Study Design

This was a prospective, non-randomized multi-center clinical study of two total knee arthroplasty implant systems, the P.F.C. SIGMA Knee and the ATTUNE Knee System, both from DePuy Synthes Joint Reconstruction, Warsaw, IN. The ATTUNE Knee is similar to the P.F.C. SIGMA Knee design with some design modifications including: expanded size range, modified J-curve designed to improve anteroposterior kinematics, narrower and thinner anterior flange, proportional intracondylar box, finer increments of patellar thickness, an extended trochlear groove and 1 mm increments in polyethylene inserts. Approval was granted from each participating center's institutional review board or ethics committee and written informed consent was provided by all study Subjects prior to their enrollment. The ATTUNE Knee cohort was implanted with INTUITION™ Instruments. Both cohorts included all four TKA configurations (Cruciate Retaining Fixed Bearing– CR FB, Cruciate Retaining Rotating Platform- CR RP, Posterior Stabilized Fixed Bearing- PS FB, and Posterior Stabilized Rotating Platform- PS RP).

The study included two cohorts of Subjects (NCT01497730 and NCT01746524) in the US, United Kingdom, Australia and New Zealand. From October 2011-March 2015, 19 sites prospectively enrolled and implanted 752 Subjects with P.F.C. SIGMA Knee. Between November 2012 and May 2015, 23 sites (18 sites had enrolled P.F.C. SIGMA Knee), consecutively implanted 1130 Subjects with the ATTUNE Knee. The first 10 ATTUNE Knee learning curve cases that each surgeon implanted were included in this study and are reported separately.[13]

None of the investigators had a conflict of interest associated with the implants being studied. Study Investigators were trained on the ATTUNE Knee System prior to enrollment and most attended cadaveric based training. The majority of Investigators were assigned to implant one configuration, consistent with their standard of care, with several exceptions where surgeons also enrolled in an additional configuration to help the team complete enrollment. All surgeons followed their preferred surgical technique with respect to anterior/posterior referencing, femur first vs. tibia first, gap balancing vs measured resection, cement choice, cementing technique, and patella resurfacing.

Data Collection

Subjects were evaluated pre-operatively and post-operatively at regular intervals. The post-operative intervals were less than 1 year, 1 year, and 2 years after surgery. Data collection included a broad range of patient reported outcome measures (PROMs): Knee Injury and Osteoarthritis Outcome Score (KOOS)[14,15] (enables WOMAC scoring), Oxford Knee Score (OKS),[16] Patient's Knee Implant Performance (PKIP)[17,18] and EQ5D-3L[19]. The PROMs data was also analyzed using responder analysis. Responders were assessed at 2-years according to the Outcome Measures in Rheumatology-Osteoarthritis Research Society International (OMERACT-OARSI)[20,21] using both WOMAC and KOOS outcomes, where high responders were those who demonstrated at least a 50% and 20-point improvement on either Pain or Function score, and moderate responders were those who demonstrated at least a 20% and 10-point improvement in 2 of 3 scores: Pain, Function, or Quality of Life.

Radiographs were prospectively collected in the ATTUNE Knee cohort (1,118 provided pre-op radiographs; 907 provided minimum 2-year radiographs). For the P.F.C. SIGMA Knee cohort, all sites were asked to retrospectively provide their standard of care radiographs, but not all sites submitted them (497 provided pre-op radiographs; 308 provided minimum 2-year radiographs). Radiographic evaluation of both cohorts was performed by an independent core laboratory (Medical Metrics, Inc, Houston, TX) per the Knee Society recommendations[22] by fellowship trained musculoskeletal radiologists using a detailed radiographic analysis protocol. The bone-cement and the implant-cement interfaces were evaluated across zones consistent with Knee Society recommendations[22] based on implant geometry. Based on timing of observation, an index radiolucent line (RLL) was one that was observed on immediate post-operative radiographs and would be most likely the result of surgical process challenges such as poor cement interdigitation into sclerotic bone[23,24] since bone resorption would not be expected immediately after surgery. In this study index RLLs were defined as interface gaps and could be later classified as a RLL if the width increased at subsequent intervals. By zone, the width of each RLL was recorded in millimeters and progression over time was assessed. RLLs were tallied by Subject according to width: 0 to <1mm, ≥1mm to < 2mm, and ≥ 2mm. If a study Subject had a RLL in more than one zone, the knee was only counted once, for the widest RLL. Final data for this study were collected in August 2018.

Analysis Methodology

Statistical summaries and analyses were conducted with all available data at respective time points for all enrolled Subjects. Data imputation methods were not utilized in cases of missing data. PROMs and AKS comparisons were conducted with a 2-sided independent samples t-test. Because of multiple comparisons of these many continuous outcomes, a p-value threshold of 0.01 for statistical significance was used for identifying differences which favored the ATTUNE Knee. The large sample sizes in this study (e.g. N>600 Subjects for the P.F.C. SIGMA Knee and N>900 Subjects for the ATTUNE Knee at 2-years), were sensitive to small effects; an effect size of 0.18 would have been detected with a 2-sided alpha of 0.01 and 80% power. Fisher's exact test was used to compare complication rates, responder rates, and the percent of Subjects with radiographic findings. Implant survivorship was estimated with Kaplan-Meier (KM) methodology and compared across cohorts with a log-rank p-value, where a revision was defined as the removal of any TKA component for any reason, and the implant was considered to be surviving if it had not been revised. For Subjects who were revised, the time to revision was the date of revision minus the date of primary TKA. The time to censoring for Subjects who were not revised was defined to be the time of the last clinical study visit, death, or study withdrawal minus the date of primary TKA.

RESULTS

Demographics

Demographics and follow-up summaries are presented in Table 1. Demographics were similar across cohorts, and representative of a typical primary TKA population. The mean duration of follow-up was slightly longer for ATTUNE Knee because many of the Subjects were at study centers who agreed to extend their follow-up by rolling over Subjects into an ongoing 15-year study (NCT01754363).

Table 1: Demographics and Follow-up

Variable		P.F.C. SIGMA Knee N=752	ATTUNE Knee N=1130
Age: mean (SD) (Range)		65.7 (8.16) (28-80)	65.2 (7.74) (34-85)
Gender: n (%) female		439 (58.4)	660 (58.4)
BMI [kg/m2]: mean (SD)		31.9 (6.35)	31.7 (5.81)
Primary Diagnosis: n (%) OA		737 (98.0%)	1124 (99.5%)
Configuration: n (%)	CR FB	186 (24.7%)	300 (26.5%)
	CR RP	202 (26.9%)	243 (21.5%)
	PS FB	154 (20.5%)	320 (28.3%)
	PS RP	210 (27.9%)	267 (23.6%)
Sample Size for PROMS and Radiographs* n PROMs; n radiographs	Pre-op	747; 497	1128; 1118
	1 Year	633; 387	966; 942
	2 Years	634; 308	922; 907
Duration of Follow-up [years]:** mean (SD)		2.2 (0.7)	2.5 (0.8)

*n for PROMs reflects subjects with KOOS-ADL; n for other PROMs varies; n for radiographs reflects subjects with radiographs on file; each view or evaluable may vary.
** Duration of follow-up was the time from index TKA to last PROMs or clinical follow-up, or revision.

Comparison of patient reported outcomes

Preoperatively, Subjects reported similar functional status across all PROMs and AKS. **Point estimates of mean outcomes for PROMs and AKS were all equal or better for the ATTUNE Knee compared to the P.F.C. SIGMA Knee at both 1 and 2-years**, with many p-values less than 0.01 (Table 2). Similarly, point estimates for nearly all change from baseline means were better for the ATTUNE Knee cohort compared to the P.F.C. SIGMA Knee cohort at both 1 and 2-years; all that had a p-value < 0.01 favored the ATTUNE Knee.

Table 2: PROMS and AKS Outcomes, including Change from Pre-operative Baseline (CFB)

			Pre-Op			1 year			2 years		
	Outcome	Scale	P.F.C. SIGMA Knee Mean (SD)	ATTUNE Knee Mean (SD)	p-value*	P.F.C. SIGMA Knee Mean (SD) CFB Mean (SD)	ATTUNE Knee Mean (SD) CFB Mean (SD)	p-value*	P.F.C. SIGMA Knee Mean (SD) CFB Mean (SD)	ATTUNE Knee Mean (SD) CFB Mean (SD)	p-value*
KOOS	Activities of Daily Living	0-100	49.2 (18.64)	48.9 (17.91)	0.8099	84.8 (15.61) 34.9 (19.87)	87.7 (14.23) 38.1 (19.32)	0.0001 0.0012	86.8 (15.23) 36.8 (20.49)	89.0 (14.58) 39.3 (19.56)	0.0051 0.0169
	Pain	0-100	45.7 (16.81)	44.0 (16.40)	0.0264	84.4 (16.61) 38.2 (20.36)	86.8 (15.19) 42.3 (19.79)	0.0030 <0.0001	87.1 (15.80) 40.6 (20.59)	88.9 (15.05) 44.4 (19.70)	0.0186 0.0002
	Symptoms	0-100	48.1 (18.91)	46.5 (18.25)	0.0574	78.4 (16.75) 30.2 (22.24)	80.5 (15.34) 33.4 (21.76)	0.0092 0.0035	82.2 (15.35) 33.6 (21.95)	84.1 (14.80) 37.3 (21.34)	0.0168 0.0011
	Sport & Recreation	0-100	18.1 (20.41)	17.2 (19.63)	0.3820	53.7 (30.52) 35.1 (31.22)	59.7 (28.85) 41.6 (29.96)	<0.0001 <0.0001	58.8 (29.87) 40.8 (31.79)	63.9 (29.08) 46.2 (29.75)	0.0010 0.0008
	Quality of Life	0-100	24.2 (17.62)	23.9 (17.35)	0.7105	69.5 (23.01) 44.6 (25.83)	73.2 (22.22) 48.8 (25.80)	0.0010 0.0014	73.5 (23.00) 48.7 (26.64)	77.0 (22.54) 52.4 (25.19)	0.0032 0.0045
	OKS	0-48	22.7 (8.07)	22.5 (7.90)	0.5898	40.1 (7.31) 17.0 (8.78	41.3 (6.65) 18.4 (8.67)	0.0011 0.0021	41.1 (6.82) 18.0 (8.94)	41.9 (6.86) 19.0 (8.71)	0.0273 0.0241
PKIP	Overall	0-100	27.1 (14.90)	28.5 (13.27)	0.0512	71.2 (18.82) 43.8 (21.74)	73.9 (18.43) 45.1 (21.56)	0.0033 0.2225	73.5 (19.37) 46.1 (22.59)	76.5 (19.24) 47.3 (21.59)	0.0030 0.3263
	Confidence	0-10	3.6 (2.02)	3.7 (1.94)	0.2015	7.9 (1.89) 4.3 (2.44)	8.2 (1.84) 4.4 (2.35)	0.0014 0.2060	8.1 (1.94) 4.4 (2.49)	8.4 (1.90) 4.5 (2.38)	0.0037 0.5460
	Stability	0-10	3.4 (2.10)	3.4 (2.02)	0.4273	8.2 (1.96) 4.8 (2.46)	8.5 (1.88) 5.0 (2.42)	0.0092 0.1708	8.3 (2.01) 4.9 (2.48)	8.6 (1.94) 5.0 (2.40)	0.0061 0.3048
	Satisfaction	0-10	2.1 (1.64)	2.1 (1.55)	0.3290	7.9 (2.05) 5.8 (2.50)	8.1 (2.07) 6.0 (2.51)	0.0374 0.3140	8.1 (1.98) 6.0 (2.49)	8.3 (2.05) 6.1 (2.47)	0.0415 0.3826
	Modifying Activities	0-10	3.6 (2.83)	4.0 (2.85)	0.0174	6.2 (3.31) 2.6 (4.30)	6.4 (3.42) 2.4 (4.45)	0.4370 0.4604	6.4 (3.33) 2.8 (4.22)	6.6 (3.46) 2.6 (4.57)	0.3336 0.4544
	EQ 5D	-1 - 1	0.64 (0.193)	0.63 (0.187)	0.5994	0.87 (0.147) 0.22 (0.208)	0.88 (0.137) 0.24 (0.195)	0.0646 0.1247	0.88 (0.139) 0.24 (0.210)	0.88 (0.153) 0.23 (0.203)	0.7366 0.8765

* Note: p-values < 0.01 are shown in bold
** The Original AKS is not considered a PROM, but is included in this table. The 2011 AKS was collected for ATTUNE, along with the original AKS pain score to allow for original AKS scoring of ATTUNE. Core-lab radiographic assessment of tibiofemoral alignment was used for both P.F.C. SIGMA and ATTUNE.

The comparison of 2-year OMERACT-OARSI responder rates (moderate or high combined) and high responder rates favored ATTUNE Knee with p-values < 0.05 (Table 3).

Table 3. OMERACT-OARSI responder analysis at 2 years

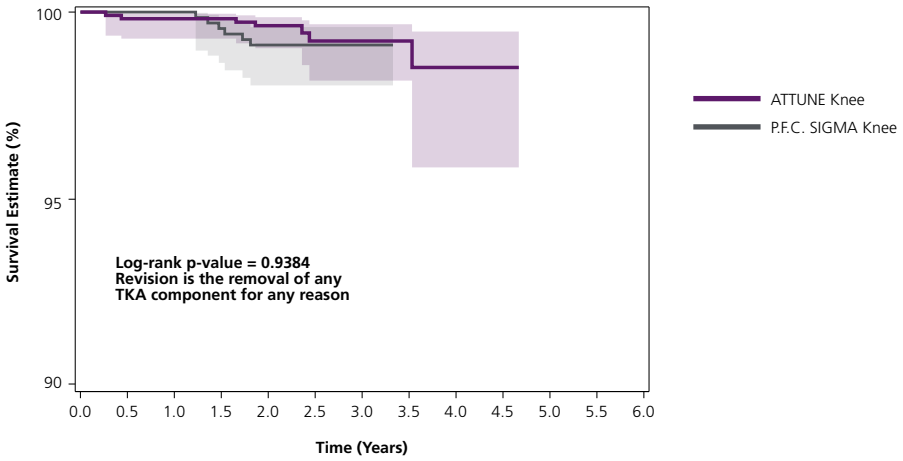
Criteria		P.F.C. SIGMA Knee	ATTUNE Knee	p-value
WOMAC	High Responder	76.3% (476/624)	81.2% (736/906)	0.0210
	Moderate or High Responder	90.6% (572/631)	93.9% (866/922)	0.0177
KOOS	High Responder	76.7% (487/635)	82.8% (770/930)	0.0035
	Moderate or High Responder	91.5% (579/633)	94.2% (877/931)	0.0420

Note: Sample sizes vary by criteria because of subjects with missing endpoints (WOMAC or KOOS sub scores)

Comparison of Kaplan Meier Implant Survivorship

A total of 11 P.F.C. SIGMA Knee and 19 ATTUNE Knee Subjects underwent revision of any component for any reason, and KM implant survivorship results for this definition are presented in Table 4; the log-rank p-value comparing survivorship was 0.9384.

Table 4. KM Implant Survivorship (revision of any component for any reason)



	1 Year KM Survivorship (95% CI) N with Later Follow-up (Cumulative Revised)	2 Year KM Survivorship (95% CI) N with Later Follow-up (Cumulative Revised)	3 Year KM Survivorship (95% CI) N with Later Follow-up (Cumulative Revised)	4 Year KM Survivorship (95% CI) N with Later Follow-up (Cumulative Revised)
P.F.C. SIGMA Knee (N=752)	99.7% (98.9, 99.9) N = 706 (2 Revised)	98.5% (97.3, 99.2) N = 548 (10 Revised)	98.3% (97.0, 99.1) N = 70 (11 Revised)	NA
ATTUNE Knee (N=1130)	99.3% (98.6, 99.6) N = 1099 (8 Revised)	98.7% (97.9, 99.2) N = 924 (14 Revised)	98.1% (96.8, 98.9) N = 258 (17 Revised)	96.3% (92.4, 98.2) N = 80 (19 Revised)

The reason and timing of each revision is provided in Table 5. A total of 11/752 P.F.C. SIGMA Knees (1.5%) and 19/1130 ATTUNE Knees (1.7%) were revised for any reason. Amongst these revision, 6 P.F.C. SIGMA Knees (0.8%) and 7 ATTUNE Knees (0.6%) involved the removal of metal TKA components (tibial or femoral) as highlighted in Table 5.

Table 5. Reasons for revision, timing, and components removed (highlighted cells indicate removal of metal components). F=Femoral, T= Tibial, I=Insert, P=Patella

P.F.C. SIGMA Knee (N=752) 11 Revisions			ATTUNE Knee (N=1130) 19 Revisions		
Revision Reason	**Time [Years] at Revision**	**Components removed***	**Revision Reason**	**Time [Years] at Revision**	**Components removed***
Infection	0.5	F, T, I, P	Bone fracture	0.3	F, T, I, P
	1.1	I		1.2	P
	1.5	F, T, I, P	Crepitus	0.9	I
	2.0	I	Infection	0.0	I
Instability	1.2	F, I		0.6	P
Loosening	1.7	F, T, I, P		1.7	F, T, I, P
Pain	0.6	I		2.4	F, T, I, P
	1.0	F, T, I, P		2.4	F, T, I
	1.7	P		2.6	I
	1.8	I	Loosening	1.9	F, T, I
	1.8	F, T, I, P	Pain	1.6	I
				1.8	I
				3.5	F, T, I
			Stiffness	0.4	I
				0.4	I
				0.4	F, T, I
				0.9	I
				1.2	I
				3.9	I

Comparison of Radiographic results

Radiographic outcomes are presented in Table 6. At the implant/cement interface, the first postoperative radiographs demonstrated similar rates of interface gaps. At the bone/cement interface, the immediate postoperative radiographs demonstrated statistically lower rates of interface gaps for all components in the ATTUNE Knee. For the P.F.C. SIGMA Knee cohort, interface gaps were observed at both the femoral and tibial bone/cement interfaces in 8% of the knees, whilst for the ATTUNE Knees they were observed near the femoral component in 1.6% of the TKAs and near the tibial base in 3.4% of the TKAs. At later intervals, the width of the majority of RLLs were in the ≥1mm to <2mm category with a very low incidence of RLL ≥2mm in either cohort at either the implant/cement or the bone/cement interfaces. Additionally, wider RLLs (≥ 2mm) and those that were also progressive were rare in both groups.

Table 6. Radiographic outcomes – including post-op interface gaps and radiolucencies at Implant/Cement and Bone/Cement interfaces

Immediate Post-op Finding		**P.F.C. SIGMA Knee**	**ATTUNE Knee**	**P-Value**
Implant/Cement Interface Gap	Femoral	6/341 (1.8%)	28/1056 (2.7%)	0.4236
	Tibial	9/341 (2.6%)	15/1056 (1.4%)	0.1499
Bone/Cement Interface Gap	Femoral	26/341 (7.6%)	17/1056 (1.6%)	< 0.0001
	Tibial	27/341 (7.9%)	36/1056 (3.4%)	0.0013
1 Year Finding		**P.F.C. SIGMA Knee**	**ATTUNE Knee**	**P-Value**
Implant/Cement RLL ≥ 2mm	Femoral	2/381 (0.5%)	1/936 (0.1%)	0.2025
	Tibial	0/392 (0%)	0/944 (0%)	NA
Implant/Cement RLL ≥ 2mm and Progressive	*Femoral*	*0/381 (0%)*	*1/936 (0.1%)*	*1.00*
	Tibial	*0/392 (0%)*	*0/944 (0%)*	*NA*
Bone/Cement RLL ≥ 2mm	Femoral	6/381 (1.6%)	0/935 (0%)	0.0006
	Tibial	4/393 (1.0%)	1/943 (0.1%)	0.0284
Bone/Cement RLL ≥ 2mm and Progressive	*Femoral*	*0/381 (0%)*	*0/935 (0%)*	*NA*
	Tibial	*0/393 (0%)*	*1/943 (0.1%)*	*1.00*
2 Year Finding		**P.F.C. SIGMA Knee**	**ATTUNE Knee**	**P-Value**
Implant/Cement RLL ≥ 2mm	Femoral	1/292 (0.3%)	1/906 (0.1%)	0.4282
	Tibial	1/297 (0.3%)	1/914 (0.1%)	0.4305
Implant/Cement RLL ≥ 2mm and Progressive	*Femoral*	*0/292 (0%)*	*1/906 (0.1%)*	*1.00*
	Tibial	*0/297 (0%)*	*0/914 (0%)*	*NA*
Bone/Cement RLL ≥ 2mm	Femoral	6/292 (2.1%)	0/906 (0%)	0.0002
	Tibial	2/297 (0.7%)	3/912 (0.3%)	0.6016
Bone/Cement RLL ≥ 2mm and Progressive	*Femoral*	*2/292 (0.7%)*	*0/906 (0%)*	*0.0593*
	Tibial	*0/297 (0%)*	*3/912 (0.3%)*	*1.00*

DISCUSSION

It is well documented that total knee arthroplasty can reduce pain and improve function, but a significant percent of patients are incompletely satisfied. Newer implants are designed to improve these suboptimal outcomes. This study was designed to carefully document a wide array of outcomes, with a focus on PROMswith the ATTUNE Knee, using the P.F.C. SIGMA Knee implant as a control.

Post-operatively, Subjects in both cohorts reported statistically significant improvements in PROMs compared to pre-operative baseline. At both one and two years post-operative, PROMs favored the ATTUNE Knee compared to the P.F.C. SIGMA Knee. These differences in the 1- and 2-year means for each cohort were modest in magnitude, which is expected as TKAs in general have been shown to have a positive effect on patients' quality of life[25]. The magnitude of these differences warrants additional studies to characterize the clinical importance against broader populations over the lifetime. Health economic literature focused on cost-effectiveness modelling evidence shows that even small improvements in PROMs can significantly raise cost-effectiveness favorability when translated into gains in Quality Adjusted Life Years provided the improvement is sustained over long periods of time.[26] Additionally, the OMERACT-OARSI[20,21] responder analysis

further enhanced the interpretation of study Subjects who had substantial improvements vs. pre-operative baseline. Approximately 3% to 6% more of the ATTUNE Knee Subjects were responders compared to P.F.C. SIGMA Knees, inclusive of both responder criteria.

The three year KM implant survivorship rates (revision defined as removal of any component for any reason) demonstrated no statistically significant difference (log rank, p=0.9384) between cohorts and were similar to 3 year estimates for the ATTUNE Knee and the class of TKAs from national joint registries[1,27,28] and similar to the 97.50% implant survivorship estimate from the Michigan Arthroplasty registry[29] and the recent Kaiser Registry presentation.[30] The reasons for revisions in the two cohorts in this study were similar at this time point. There were slightly more revisions for stiffness in the ATTUNE Knee compared to the P.F.C. SIGMA Knee and these 6 cases were across 5 different study sites, with no apparent pattern when the motion data of the two cohorts were examined. Additionally, a comparison of range of motion outcomes demonstrate either no statistically significant difference in mean passive flexion at 1 or 2 years postoperatively, and or a higher improvement in flexion compared to preoperative baseline for ATTUNE Knees (compared to the P.F.C. SIGMA Knee) at both 1 and 2 years ($p<0.05$). Knee extension showed improvements from an average of approximately 4.5 degrees flexion contracture pre-operatively to less than 1 degree at 1 and 2 years in both cohorts. Further, the aseptic loosening rate in both cohorts was low and similar, which complements two RSA studies that showed no difference in maximum total point motion (MTPM) compared to the P.F.C. SIGMA Knee in one study,[31] and MTPM consistent with published criteria in the second study.[32]

This is the first study to review a sizable quantity of ATTUNE Knee radiographs and compare them with a clinically successful product. The results from the independent radiographic reviewer's assessment of the metal-cement and the bone-cement interfaces out to two years demonstrated that the ATTUNE Knee has similar results compared to P.F.C. SIGMA Knee.

The strengths of this study include: prospective data collection with large sample sizes; consecutive enrollment; multi-center data coming from experienced surgeons/ clinical researchers who included all consecutive knees starting with their first ATTUNE Knee implanted. Additional strengths include the use of multiple validated PROMs to better understand the patient's perspective; utilization of knee-specific PROMs that included more advanced activities such as KOOS Sports & Recreation and a newer PROM (PKIP) that included questions related to underlying reasons associated with functional outcomes, such as confidence and stability when performing activities. An independent radiographic core lab reviewed both cohorts of radiographs using the identical protocol and 12 sites in the ATTUNE Knee cohort have elected to continue follow-up to 15 years thus providing opportunity to follow this original cohort long term. Approximately half of the Subjects in both cohorts come from the United States, which currently does not have product-level reporting in their registry;[33] thus, this study provides a broader view of the available implant survivorship information for this new product beyond what is currently available in published registry reports.[1,2,27]

The weaknesses of this study included non-randomized enrollment, which was balanced by the fact that several of the same sites were used in both cohorts to minimize biases associated with institutional practices. There was incomplete radiographic review of the P.F.C. SIGMA Knees; however, since the collection was a pragmatic sample of those sites that were able to contribute, concerns regarding potential bias were minimized. Lastly this study was funded by the manufacturer of the implant being studied, and most of the investigators are consultants with that manufacturer and we believe that the emphasis on patient outcomes negates this potential conflict of interest.

While improvements that are demonstrated with the ATTUNE Knee in this study are subtle, the ATTUNE Knee System has resulted in PROMs that are moving in a positive direction. With many examples of implant "improvements" in the orthopedic industry leading to poorer performance, this data shows that collaboration between clinicians and industry to improve outcomes in TKA can produce positive results. The early PROMs and radiographic outcomes of the ATTUNE Knee has produced positive and encouraging results with significant improvement in the majority of PROMs whilst maintaining the low level of radiolucency of the Existing TKR, which suggests satisfactory long-term implant survival.

The authors recommend that new implants that are introduced undergo similar levels of scrutiny. longer-term follow-up is ongoing for a many of the study sites who have chosen to join the ongoing 15-year study (NCT01754363).

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Table KT6 Cumulative Percent Revision of Primary Total Knee Replacement by Primary Diagnosis

Primary Diagnosis	N Revised	N Total	1 Yr	3 Yrs	5 Yrs	10 Yrs	15 Yrs	17 Yrs
Osteoarthritis	22205	588190	1.0 (1.0, 1.1)	2.7 (2.7, 2.7)	3.6 (3.5, 3.6)	5.3 (5.3, 5.4)	7.5 (7.3, 7.6)	8.4 (8.1, 8.7)
Rheumatoid Arthritis	309	8019	1.0 (0.8, 1.2)	2.2 (1.9, 2.6)	2.9 (2.5, 3.3)	5.1 (4.5, 5.7)	7.0 (6.1, 8.0)	7.2 (6.2, 8.4)
Other Inflammatory Arthritis	133	2993	1.5 (1.1, 2.0)	3.0 (2.4, 3.8)	4.2 (3.4, 5.1)	6.2 (5.2, 7.5)	9.1 (7.1, 11.7)	
Osteonecrosis	99	1928	1.1 (0.7, 1.8)	3.7 (2.9, 4.7)	5.3 (4.3, 6.6)	7.1 (5.7, 8.7)	8.2 (6.5, 10.3)	
Other (5)	134	1319	2.8 (2.0, 3.9)	8.1 (6.5, 10.0)	11.2 (9.2, 13.5)	18.0 (14.8, 21.8)		
TOTAL	**22880**	**602449**						

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