The Journal of Arthroplasty 32 (2017) 79–82

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Primary Arthroplasty

Tibial Tray Thickness Significantly Increases Medial Tibial Bone Resorption in Cobalt–Chromium Total Knee Arthroplasty Implants

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ARTICLE INFO

Article history:
Received 25 March 2016
Received in revised form
19 May 2016
Accepted 6 June 2016
Available online 22 June 2016

Keywords:
tibial base plate
stress shielding
cobalt–chromium
bone resorption
total knee arthroplasty

ABSTRACT

Background: Stress shielding is an uncommon complication associated with primary total knee arthroplasty. Patients are frequently identified radiographically with minimal clinical symptoms. Very few studies have evaluated risk factors for postoperative medial tibial bone loss. We hypothesized that thicker cobalt–chromium tibial trays are associated with increased bone loss.
Methods: We performed a retrospective review of 100 posterior stabilized, fixed-bearing total knee arthroplasty where 50 patients had a 4-mm-thick tibial tray (thick tray cohort) and 50 patients had a 2.7-mm-thick tibial tray (thin tray cohort). A clinical evaluation and a radiographic assessment of medial tibial bone loss were performed on both cohorts at a minimum of 2 years postoperatively.
Results: Mean medial tibial bone loss was significantly higher in the thick tray cohort (1.07 vs 0.16 mm; $P = .0001$). In addition, there were significantly more patients with medial tibial bone loss in the thick tray group compared with the thin tray group (44% vs 10%, $P = .0002$). Despite these differences, there were no statistically significant differences in range of motion, knee society score, complications, or revision surgeries performed.
Conclusion: A thicker cobalt–chromium tray was associated with significantly more medial tibial bone loss. Despite these radiographic findings, we found no discernable differences in clinical outcomes in our patient cohort. Further study and longer follow-up are needed to understand the effects and clinical significance of medial tibial bone loss.

Patient outcomes after total knee arthroplasty (TKA) continue to be excellent [1]. However, there have been increasing reports of stress shielding related to implant design in TKA [2-4]. Some of these studies have used dual energy x-ray absorptiometry (DEXA) scans to demonstrate stress shielding around the femoral [3] and tibial [5] components. We have noted that certain patients have demonstrated radiographic evidence of medial tibial bone resorption, which may be a result of stress shielding. We initially noted a case of medial tibial bone resorption after a patient underwent revision from an uncemented titanium tibial base plate to a cobalt–chromium tibial base plate and subsequently required reoperation for cement augmentation of the medial tibial metaphysis. It was speculated that the tibial base plate composition change from titanium (Ti) to cobalt–chromium (CoCr) resulted in substantial medial tibial bone loss.

Two unpublished studies helped to further define the patient population susceptible to medial tibial bone loss. Significant medial tibial bone loss was identified in a cohort of patients that had substantial preoperative varus deformities, were corrected to neutral, and had a cobalt–chromium tibial tray inserted at the time of primary TKA. This phenomenon was significantly less in similar patients implanted with an all-polyethylene tibial tray. Therefore, to determine if the composition of the tibial tray was responsible

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2016.06.007.

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http://dx.doi.org/10.1016/j.arth.2016.06.007
0883-5403/

for the bone loss, a second study was performed to compare patients with a severe varus deformity that were implanted with a cobalt–chrome, titanium, or all-polyethylene tibial component. The cobalt–chromium cohort had significantly more medial tibial bone loss than the other 2 cohorts. Therefore, we speculated that the tibial bone loss was related to stress shielding and that a more rigid implant, such as cobalt–chromium, caused more bone loss. Stress shielding results in a reduction in bone density secondary to a decrease in the amount of stress the area of bone commonly receives.

We hypothesized that not all CoCr tibial base plates would result in the same rate of medial tibial bone resorption. Construct rigidity with tibial base plates appears to be related not only to implant material (CoCr, titanium, etc.) but also to thickness of the material. Flexural rigidity of a plate increases by the cube of the thickness of the plate. Therefore, we decided to compare the impact on bone resorption of 2 cobalt–chromium tibial base plate designs with differing thickness. Secondary outcomes included a comparative analysis of patient clinical outcomes, revisions, and complications.

Materials and Methods

Following IRB approval, we performed a retrospective review using the joint registry at our institution. We identified all patients that underwent a posterior stabilized, fixed-bearing TKA from 2009 to 2013 with minimum radiographic follow-up of 2 years and then selected those with a preoperative radiographic varus deformity (mechanical axis $<0^\circ$) who underwent implantation using either a 4-mm-thick CoCr tibial base plate (DePuy Attune TKA, Warsaw, IN) or with a 2.7-mm-thick CoCr tibial base plate (Stryker Triathlon TKA, Kalamazoo, MI). Varus alignment increases the stresses of the medial tibia, and therefore if the knee is corrected to neutral alignment, may produce more stress shielding that a preoperative valgus alignment. All patients underwent a similar preparation of the tibia including cement gun pressurization of the tibial cement mantle and use of Stryker Simplex cement in most patients (Kalamazoo, MI).

Patient Demographics

We selected 50 consecutive patients from both implant cohorts. The average age, number of females, preoperative hip–knee angle, postoperative kip knee angle, and follow-up were similar between the 2 groups, though body mass index (BMI) was higher in the thick tray cohort (Table 1).

Radiographic Assessment

All radiographs were reviewed by all authors. Preoperative full-length Anteroposterior (AP) radiographs of the hip to ankle were initially reviewed to determine if the patient had a preoperative varus deformity. All valgus knees were excluded at this time. Next, immediate postoperative AP knee radiographs were reviewed to ensure that the tibial implant was not initially placed with overhang. Overhang was defined as the most medial portion of the tibial base plate having no medial tibial bone immediately inferior to it. An AP radiograph was obtained with the leg internally rotated approximately 3°-5° and the beam angles approximately 3°-5° caudal. Precision of the AP radiograph was confirmed if the posterior femoral condyles were not visible and the fibular head overlapped the tibia by 45%-55%. Finally, the most recent AP knee radiograph was evaluated to determine the amount of medial tibial bone loss. Medial tibial bone loss was defined as the distance from the medial edge of the inferior tibial base plate to the edge of the medial tibial plateau (Fig. 1A and B).

Table 1
Patient Demographic Data.

Variable	Thick Tray Cohort	Thin Tray Cohort	*P* Value
Age (y)	67.8 (±9)	65.5 (±10)	.23
Female sex	26	28	.84
BMI (kg/m^2)	31.7 (±7)	28.0 (±6)	.01
Preop hip–knee angle	4.04 (±2.7)	4.52 (±2.5)	.36
Postop hip–knee angle	−3.48 (±1.3)	−3.70 (±1.3)	.40
Follow-up (y)	2.58 (±0.5)	2.70 (±0.8)	.36

BMI, body mass index.

Clinical Outcomes

Preoperatively, patients had a full-length standing radiograph. All patients were evaluated clinically and radiographically at distinct time intervals including: preoperatively and then at 3 months, 1 year, 2 years, and 5 years postoperatively. At each follow-up appointment, patients had an AP, lateral and merchant knee radiograph performed. Knee society scores (KSS) were calculated preoperatively and at each follow-up appointment. Complications, revision, and reoperations were recorded continuously by our joint registry.

Statistical Analysis

A statistical analysis was performed using Student *t* tests for continuous data and Fisher exact tests for categorical data to compare preoperative demographics. To assess the risk of medial tibial bone loss, odds ratios were calculated using 2-tailed Fisher exact tests. Differences were considered to be significant for $P < .05$.

Results

Radiographic Comparison

Patients in the thick tray cohort had a 7.1 times increased risk of medial tibial bone loss when compared with patients in the thin tray cohort ($P = .0002$). In addition, the average bone loss of the entire cohort of thick tray patients was significantly greater than that of the thin tray cohort ($P = .0001$; Table 2).

Clinical Comparison

Preoperative KSS were lower in the thick tray group, but KSS and range of motion were similar between groups at final follow-up (Table 3).

Revision and Reoperation Comparison

We noted 1 revision surgery in each cohort. The thick tray cohort had 1 patient that underwent a 2-stage revision for a deep infection. The thin tray cohort had 1 patient that underwent revision to a constrained implant for a lateral collateral ligament injury. The overall complication rates between the 2 cohorts were not statistically significantly different (Table 4).

Discussion

Stress shielding is a well-known phenomenon in primary TKA [2,5-9]. Many of the current studies evaluate femoral and tibial stress shielding using DEXA scans or quantitative computed tomography [10]. We have identified medial tibial bone resorption in patients with a preoperative varus deformity that have been corrected to neutral alignment. Cobalt-chromium–cemented tibial trays have already been associated with significantly increased