INTRODUCTION:
Hallux rigidus is a common degenerative osteoarthritic process affecting the first metatarsophalangeal (MTP) joint. It is characterised by progressive loss of MTP joint range of motion (ROM) and notable dorsal or periarticular osteophyte formation [1]. Whilst conservative management is common, these measures are often ineffective at preventing longterm deformation progression [2].

Total arthroplasty of the first MTP joint aims to relieve pain and increase ROM. It has had variable success in the past [1,3]. A variety of different types of implant materials and designs have been used and tested clinically in an attempt to develop the ideal implant. Clinical studies reporting these outcomes are usually based on subjective assessments made by the patient as well as clinical tests [3]. Although these studies provide invaluable information regarding the longer term clinical outcomes of the implant and procedure, they provide information regarding one type of implant only. Using these study reports to directly compare competing designs can be difficult due to patient variability and the subjective nature of the study.

The aim of this study was to use a cadaveric model to investigate the effect of four different metatarsal head geometries on the hallux joint kinematics and articulating surface contact properties. The intact (native) joint kinematics and contact properties were also investigated and compared. The hypothesis was that alteration in ergonomics of the implant to a more anatomical shape would improve joint ROM, whilst maintaining joint congruency.

METHODS:
Five fresh frozen cadaveric lower limbs (66±22 years of age, 5 males, 1 female) were supplied by ScienceCare (USA). Each limb was gripped in a vise about the calf such that the foot was free to articulate. The ankle joint was stabilized and two K-wire pins were aligned with the sagittal plane and driven through the metatarsal and proximal phalanx bones of the hallux used to monitor joint kinematics. The K-wire movement was monitored with a high resolution digital camera (JAI, CB-200GE). A pressure transducer (Tekscan, I-Scan 6900 electronic pressure sensor), positioned within the MTP joint, was used to measure the contact force, pressure and area across the articulating joint surfaces. K-wire motion and contact properties were determined both before and after surgery.

Standardised dorsiflexion loads were applied to the great toe by looping a wire around the proximal-distal hallux joint and pulling on the wire loop with a 50N load for 5 seconds and then releasing. The metatarsal and proximal phalanges K-wire pin angles were measured from the digital images with the toe in neutral (0N) and fully dorsiflexed positions (+50N) to determine the range of motion (ROM). During each joint load cycle the articulating joint contact data was continuously monitored (sampling rate 10Hz) and the contact force, area and pressure data determined at the peak of the fourth cycle.

Surgery consisted of the first metatarsal and proximal phalanx being prepared for implantation using standard TOEFIT-PLUS™ (Smith and Nephew Orthopaedics AG, Rotkreuz, Switzerland) surgical instrumentation and approach. A standard TOEFIT-PLUS™ proximal component (provided by Smith & Nephew Surgical, Australia) was placed in the phalanx while the modular metatarsal base component was exchanged with three other heads (Eccentric TOEFIT-PLUS™, Swiss and Grooved designs). The Swiss and Grooved anatomical designs are

RESULTS:
In terms of joint ROM, all implanted joints tended towards a higher absolute flexion angle than the intact joint. The Grooved implant demonstrated the highest absolute flexion angle followed by the Swiss, Standard and Eccentric (Figure 2). These results treat each test as an individual outcome. However, comparing the ROM of each implant as a ratio of the ‘Standard’ TOEFIT-PLUS™ implant ROM within each joint, the Grooved joint demonstrated a significantly greater flexion angle (+40%) than the Standard joint (p<0.05). While the Swiss joint ROM was also higher than the Standard this was not significant. Eccentric ROM was similar to Standard.

Figure 1: The Standard Toefit-Plus (a) and Grooved implant (b) in top and dorsal view

All implanted joints demonstrated a significantly lower contact area (+50%) than the intact joint when a 50N flexion load was applied to the toe. There was no significant difference in contact area within the implanted joints under loaded conditions (Figure 3).

Figure 2: Absolute dorsiflexion range of motion (change in joint angle from unloaded (0N) to loaded (50N) dorsiflexion load applied to hallux)

Figure 3: Mean contact area at 50N dorsiflexion load

All the implanted joints demonstrated a trend towards higher contact pressure than the intact joint, however only the Eccentric was significantly greater (p=0.033). There was no significant difference in contact pressure across implanted groups, p>0.05.

DISCUSSION:
The first MTP joint is a complex condyloid joint [4]. Healthy motion involves rolling, sliding and compression [5]. The bearing surface of the total implant should ideally be designed with this biomechanics in mind, since this design will not only dictate the contact areas and pressures but also the allowable range of motion.

The TOEFIT-PLUS™ implant is a two component design. The bearing surface geometry is important as it should be designed so that ideally it follows the migrating axis of the intact joint [5].

The design rationale for the anatomic bearing designs was to accommodate the sesamoid bones, situated on the plantar surface of the metatarsal head. The grooved design allows the flexor mechanism to passively stretch more easily as the toe moves to dorsiflexion on the heel raise part of the gait cycle. In plantarflexion, the sesamoids lie near the head-neck junction. With dorsiflexion of the hallux, they are drawn distally to the distal end of the head and tilt dorsally [6]. The anatomic designs allow for a smoother, more congruent motion along the sesamoids, reducing impingement and hence increasing ROM, as is seen in the results of this study.

The TOEFIT-PLUS™ implant has shown to restore joint ROM, particularly using the anatomical designs. Joint contact properties did not vary between designs suggesting that the anatomical designs would function, at the minimum, equally as well as the current TOEFIT-PLUS™ arthroplasty.

REFERENCES: