Introduction
Malalignment and ligament imbalance in total knee arthroplasty (TKA) produce unequal loads on the medial and lateral tibial plateaus increasing wear of the components [1,3]. A computer assisted gap equalization (CAGE) technique was developed using a knee balancing device (Stryker Xcelerate knee balancing, Stryker Howmedica Osteonics, Allendale, NJ). It was adapted with load cells and computer software enabling it to quantitatively measure soft tissue tension and angular alignment of the flexion and extension gaps. This computer assisted technique of knee balancing was compared to the conventional measured resection technique.

Methods
Eight pairs of fresh-frozen cadaveric knees (average = 77 years old, 5 male, 3 female) were randomized into two groups: control (measured resection technique) and CAGE. TKAs were performed using the posterior stabilized Scorpio knee system (Stryker Osteonics-Howmedica). For the control group, bone was resected using the measured resection technique and femoral rotation was determined using the epicondylar axis. Soft tissue balancing was performed qualitatively. In the contralateral specimens (CAGE group), the gap resection technique enhanced with the CAGE device was used. Distal femoral and proximal tibial resections were performed first. With the knee in extension, soft tissues were tensioned to 170 – 200 N and balanced quantitatively using CAGE. The knee was then brought to 90° of flexion, soft tissues were tensioned with CAGE to the same force as used in extension and the posterior femur was resected parallel to the tibial cut. Residual bone and soft tissue balancing was performed to create equally sized flexion and extension gaps under equal soft tissue tension. Final implants were cemented and a polyethylene tibial load transducer [2] that measured medial and lateral compartment loads was inserted. Patellae were not resurfaced.

Outcome assessment consisted of two parts: 1) Pre-component insertion balance: CAGE was used as an instrument to measure gap angular alignment and load symmetry in both groups once final balancing was complete, 2) Post-component insertion balance: the tibial load transducer measured medial and lateral compartment forces under applied muscular loads (150 N quadriceps, 60 N hamstrings) at five flexion angles (0°, 30°, 45°, 60° and 90°) using a knee simulator.

Results
Pre-component insertion extension gap angular assessment resulted in 1.9° ± 0.9° of malalignment in the control group and 1.3° ± 1.0° in the CAGE group. Although there was a trend towards improved alignment in the CAGE group, the difference was not significant (p = 0.27, paired t-test). Assessment of femoral rotation in flexion resulted in 2.0° ± 2.2° of malrotation in the control group and 0.4° ± 0.7° in the CAGE group. There was a trend towards improved femoral rotation in the CAGE group, but a significant difference (p = 0.07, paired t-test) was not demonstrated.

Pre-component insertion assessment of gap soft tissue tension symmetry in the control group resulted in 184 ± 36 N in extension and 107 ± 58 N in flexion. The difference was significant (p = 0.02, paired t-test). In the CAGE group, tension in extension was 146 ± 64 N and in flexion was 175 ± 71 N and this difference was not significant (p = 0.3, paired t-test) suggesting that gap tension was better balanced than in the control group.

Post-component insertion medial and lateral compartment loads at five flexion angles for the two groups are illustrated in Figure 1. Two-way repeated measures ANOVA showed no significant difference in compartment load balance between the two groups at any flexion angle. The average lateral loads were higher than medial loads at all angles of flexion and this difference was significant at 0° (p = 0.02) and 30° (p = 0.03) of flexion for both groups. The medial and lateral loads at 0° of flexion were significantly (p < 0.001) higher in both groups compared to the other angles of flexion.

Discussion
CAGE showed a trend towards improved gap angular alignment and a significant improvement in gap load balance prior to component insertion. This was due to the ability of CAGE to provide quantitative feedback of residual gap angulation and soft tissue tension imbalance. As well, CAGE more accurately guided the posterior femoral resection with the soft tissues under tension resulting in a rectangular flexion gap. Although the amount of soft tissue tension that should be applied when balancing the knee is unknown, a distraction force of 170 – 200 N was chosen since pilot studies showed this force to be within the linear region of the ligament distraction/tension curve and well-past the toe-in (or ligament recruitment) low-load stage.

The improvement using CAGE in gap balance pre-component insertion did not translate into improved joint balance post-component insertion. A similar result has been shown clinically [4]. An uneven cement mantle and component design may account for a slight change in angular alignment. Rotational alignment of the tibial component may also change the final balance. The lateral loads were higher in both groups which may be due to consistent internal malrotation of the tibial component. Improved methods of determining tibial rotation or a rotating tibial bearing may achieve better results. The loads in extension were higher in both groups compared to the other angles perhaps because the posterior soft tissues tighten as they become draped over the posterior condyles in full extension. Ideally, this should be taken into account when the gap loads are balanced prior to final component cementing.

The application of this computer assisted gap equalization device improves knee balance pre-component insertion. Final knee balance remains unchanged. Further work is needed to translate the improved surgical accuracy into improved balance following component insertion.

References