INTRODUCTION

In post-traumatic osteoarthritis (PTOA), death and dysfunction of chondrocytes associated with acute cartilage injury presumably play an important role in triggering the pathomechanical cascade that eventually leads to whole-joint degeneration. To study details of the disease mechanisms, or to pilot treatment(s) to amend the disease process, a survival animal model in which OA predictably develops after mechanically-introduced acute cartilage injury is crucial. The cartilage injury must be introduced in the primary weight-bearing region. To create such acute cartilage injury in living rabbit knees, a novel impaction system has been developed. In an earlier study, it had been confirmed that this system is capable of creating full-thickness cartilage injury on the medial femoral condyle, where cartilage is thickest (Figure 1). The level of injury severity was regarded as "critical" in the sense that the full-thickness cartilage damage persisted for more than 8 weeks, being accompanied by degenerative changes on the opposing medial tibial surface [3]. In the present study, this impaction system was utilized to create graded cartilage injury in living rabbit knees. It was hypothesized that the magnitude of impaction insult would be controllable by modulating energy delivery.

METHODS

Sixty-nine New Zealand White rabbits were subjected to blunt impaction insult to the left knee, with institutional approval. By approaching through a posterior arthrotomy, the posterior aspect of the medial femoral condyle could be bluntly impacted using the novel impaction system (Figure 2). In this system, the rabbit was positioned prone, in order to impact cartilage in the primary weight-bearing region of the medial femoral condyle at 135 degrees of knee flexion (representative of the habitual physiologic knee position for rabbits in cage confinement). The leg fixation platform (Figure 3) held the distal femur in the V-shaped groove, which was designed to conform to the anterior bone contour of the femoral condyles, with the bone compacted toward the groove via a cannulated bone pusher [3]. This bone pusher was placed with guidance of a 1.25 mm K-wire, providing additional stability in the proximal-distal direction, without locally damaging the cartilage [3].

Figure 1: Cartilage histology of a rabbit knee (the medial femoral condyle) at 7 days after a 3.0 J impaction.

Figure 2: Drop-tower device for rabbit knee cartilage blunt impaction.

Figure 3: Custom leg-holding platform (A), V-shaped groove (B), and cannulated bone pusher (C) with denuded rabbit cadaver knee for visual clarity.
With the left thigh mounted on the leg fixation platform, a metal platen was placed on the medial femoral surface. This metal platen had a flat, oversized impaction face (diameter 7 mm) so that edge loading effects were alleviated, and that the distribution of impaction force across the contact area was relatively uniform. An impaction force pulse was delivered by a drop mass (1.55 kg). The magnitude of the energy delivery was 2.0 J (drop height 13.2 cm) for 45 animals, 3.0 J (19.7 cm) for 20 animals, and 4.0 J (26.2 cm) for 4 animals. The impaction magnitude was measured using an accelerometer mounted in the drop mass. Using the acceleration signal (sampled at 30 kHz), the history of compressive force during each impaction was determined. The impulse was verified by integrating the force curve. With pressure sensitive film (Fujifilm Co., Tokyo, Japan), the measured contact area between the metal platen and cartilage during impaction was used to estimate the peak contact stress, using rabbit cadaveric knees.

Data were statistically compared between impaction magnitudes using the single factor ANOVA test with a significance level set at \( p < 0.05 \).

**RESULTS AND DISCUSSION**

The data indicated that peak contact forces of 819 ± 98, 1037 ± 99, and 1313 ± 46 N, and impulses of 2.9 ± 0.1, 3.4 ± 0.1, and 3.9 ± 0.1 N-sec (Figure 4) were achieved, with energy delivery levels of 2.0, 3.0, and 4.0 J, respectively. The data also indicated a time-to-peak contact force of 2.2 ± 0.5 msec, across all energy delivery levels. None of the 69 animals tested exhibited a fracture complication. The cadaver validation experiment data indicated the peak contact stresses were approximately 70 or 100 MPa for 2.0 or 3.0 J impactions, respectively.

The peak contact force and impulse results demonstrate that the impaction magnitude was well discriminated between the 2.0, 3.0, and 4.0 J deliveries. Therefore, the novel impaction system can effectively control the severity of impaction by adjusting the level of energy delivery. The peak contact force developed was equivalent to or higher than that in previous studies [1,2], which had a peak contact force of approximately 800 N with a much higher energy delivery (23 J), using a pendulum-based system. Also, the time-to-peak force was especially short when compared to the 18 ± 2 msec in the previous studies [1,2]. A possible explanation for these differences is the rigidity of leg fixation achieved by the custom platform. Despite these differences, however, the peak contact stresses for both impaction systems were similar [1,2].

**CONCLUSIONS**

These data suggest that this impaction system is effective for modeling graded acute cartilage injury in living rabbit knees, facilitating translational research to improve orthopaedic treatment for PTOA.

**REFERENCES**


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