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Comparison of four chondral repair techniques in the hip joint: a biomechanical study using a physiological human cadaveric model

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SUMMARY

Objective: The objective of this study was to assess the biomechanical stability of three types of chondral flap repair techniques as well as a hydrogel scaffold implantation on the acetabular articular surface using a physiological human cadaveric model.

Methods: Chondral flaps were created in the antero-superior zone of the acetabulum in a series of human cadaveric hip joints. The chondral flap was repaired by fibrin glue, cyanoacrylate, suture technique and an agarose hydrogel scaffold sealed with fibrin glue using six hips in each case. After each repair, the specimens were mounted in a validated jig and tested for 1500 gait cycles. In order to determine the stability of the repair, specimens were evaluated arthroscopically at specific intervals.

Results: The fibrin glue and cyanoacrylate techniques were technically the easiest to perform arthroscopically, all flaps repaired with fibrin were detached at 50 cycles while those repaired with cyanoacrylate lasted for an average of 635 cycles. On the other hand, both the suture repair and scaffold implantation techniques were more technically challenging but were both stable till the endpoint of 1500 cycles.

Conclusion: Fibrin glue on its own does not provide sufficient fixation to repair chondral flaps on the acetabular surface. Cyanoacrylate repairs universally failed midway through the testing protocol employed here, raising doubts as to the effectiveness of that technique. The suture and hydrogel scaffold technique were the most reliable for chondral repair at any given cycle. The results of this biomechanical study demonstrate the relative effectiveness of chondral repair and fixation techniques.

Introduction

Focal chondral injuries are often a result of sports injuries or trauma, and are a common cause of joint pain and disability[1]. Due to its avascular nature, articular cartilage has very limited capacity for repair[2]. Injuries of the articular cartilage that do not penetrate the subchondral bone (partial thickness) do not heal and usually progress to the degeneration of the articular surface[2]. Since the knee is the most commonly affected joint[3], accounting for approximately 75% of all chondral lesions[4]; a lot of empirical work has focused on cartilage repair in the knee. In fact, cartilage repair techniques are one of the most cited topics in arthroscopic orthopaedic surgery and second most cited topic in orthopaedics[5]. Cartilage lesions are common in the hip joint due to either traumatic or atraumatic pathologies[6]. A direct association between acetabular labral injuries and chondral lesions of the femoral head and acetabulum has been reported by various authors[7,8].

There is growing interest in arthroscopic treatment of chondral lesion in the hip joint, since they are a frequent cause of pain and functional limitation. With increased availability of hip arthroscopy over the past years[9], repair techniques commonly applied to the knee are being transferred to the hip joint[10–13]. The most common treatment of chondral lesion in the hip joint is arthroscopic debridement and microfractures[14]. Recently new techniques of

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chondral repair have emerged, such as arthroscopic chondral flap repair with suture anchors[13] or fibrin glue[12,15]; while chondral defects are being repaired with scaffolds[10] or collagen membranes[16]. These techniques are based on previous studies carried out in the knee[17–19]. In addition these techniques of chondral repair may reduce the progression of chondral lesion into end stage osteoarthritis.

Currently the three main techniques used for chondral repair in the hip joint are fibrin glue[15], suture anchors[13], and a scaffold implant such as autologous chondrocyte transplantation (ACT)[10]. Mechanical properties of scaffolds are usually evaluated by doing compression tests to characterise elasticity, durability and stability under load[20]. Various authors have carried biomechanical studies to assess the stability of implanted scaffolds in cadaveric knees using continuous passive motion (CPM)[19,21]. While tissue engineered constructs are attaining popularity in treating defects in the knee, to our knowledge, these scaffolds have not been biomechanically tested in a physiological cadaveric hip model.

The objective of this study is to compare the biomechanical stability of three different chondral flap repairs and scaffold implantation on the acetabular articular surface of the hip joint using a physiological cadaveric model.

Materials & methods

Specimen preparation

The present study was carried out on six fresh frozen human cadavers. The specimens were handled under the recommendations and guidelines of the Human Tissue Act (2008). Ethical approval of the study was granted by the Mater Misericordiae University Hospital Research Ethics and University College Dublin Human Research Ethics Committee – Sciences. The hips were initially screened radiographically and arthroscopically for gross arthritis, dysplasia and femoro-acetabular impingement. None of the specimens showed any of the above conditions. There were two male and two female donors, whose ages ranged from 40 to 49 years with an average of 45 years. The donors had an average weight of 53 kg (40–65.8 kg) and an average height of 172 cm (150–180 cm). The specimens were stored at −40°C (−40°F) and thawed at room temperature for preparation of the lesion, repair and testing. All specimens were dissected of skin and muscles, leaving an intact hip joint. Testing was carried out in specific sequence starting with the fibrin glue repair first followed by the cyanoacrylate repair, suture repair and leaving the scaffold repair technique as the final test. All specimens were carefully examined arthroscopically after every experiment to ensure that the chondral flap was viable for further experimentation.

Chondral defect preparation

An anterior arthrotomy to accesses the hip joint was used to create chondral lesion, repair and allowed observation during testing. The hip specimen was put under traction and the articular surface was examined arthroscopically to confirm the absence of arthritis greater than a grade 2 Outerbridge score[22]. The labrum was screened for any defects which may affect the natural hip seal and ultimately the stability of the repair. Initially a 1 cm^2 chondral flap was created in geographical zone 2[23], classified as a grade 4 in the modified Outerbridge by McCarthy *et al.*[24]. The location of the chondral lesion was chosen following retrospective data from our institution and previous studies which showed that cartilage lesions during hip arthroscopy are mostly identified in geographical zone 2, which is the antero-superior region of the acetabulum[25].

Chondral flap repair

The chondral flap created was repaired using three different techniques, fibrin glue, suture anchor and cyanoacrylate.

a. Tisseel™ (Baxter AG) was used for the fibrin glue technique. Fibrin glue was prepared using Fibrinotherm™ (Baxter AG) heating system and mixing device as per manufacturer's instructions. The fibrin glue was then applied behind the chondral flap and the cartilage flap was compressed for 10 min until the fibrin clot has set. The joint was cleared from any excess fibrin glue and the cadaveric model was then transferred to the biomechanical lab for testing.
b. In the suture anchor technique, the chondral flap was repair using 2.9 Osteoraptor™ (Smith & Nephew Ltd) anchor loaded with 2–3 PDS™ II(Ethicon Inc.) size 2/0. Osteoraptor™ anchors are bio-absorbable anchors incorporating hydroxyapatite, while PDS™ II is a monofilament synthetic absorbable suture. PDS II is able to support tissue up to 6 weeks[26] at which time its strength is reduced by 40%. The anchor was positioned in the perilabral sulcus above the chondral flap. The suture was passed from the perilabral sulcus into the pocket behind the chondral flap through the medial part of the labrum at its attachment to the acetabular rim (a technique preferred by the senior author KJM) rather than over the labrum, to maintain the sealing effect of the labrum as much as possible. The suture was then passed through the chondral flap and back into the post-chondral space, through the labrum to end up in the perilabral sulcus. The method was repeated for the remaining sutures. The chondral flap was then stabilised with a series of knots in the perilabral sulcus. Stability was checked by probing the chondral flap after which the specimen was transferred to the biomechanical lab for testing.
c. N-butyl-2-cyanoacrylate (Glubran® 2, GEM S.r.l) was used in the cyanoacrylate (superglue) technique. Glubran® 2, GEM S.r.l is the only cyanoacrylate currently approved for internal use in the European Union[27,28]. The post-chondral space created was initially dried and 0.2 ml of cyanoacrylate was injected using a syringe. Polymerization of N-Butyle-2-cyanoacrylate is complete at 3 s and pressure on the chondral flap was applied for 5 s. After 10 min the joint was washed to remove any excess glue and the flap was probed to assess stability. The model was then transferred to the biomechanical lab for testing.
d. The chondral flap was completely debrided and a 1 cm^2 chondral defect was created. A 4% agarose hydrogel (type VII, Sigma–Aldrich) was fashioned to match the shape of the defect as much as possible. The shape matched hydrogel was implanted in the defect and the scaffold chondral interface was sealed with fibrin glue (Tisseel™ Baxter AG). The scaffold was allowed to set for 10 min after which the joint was irrigated with saline and the cadaveric model was transferred to the biomechanical lab for testing.

Mechanical loading

The mechanical tests were carried out in the biomechanical lab. An Instron® multi axial 8870 series fatigue testing system with a 10 kN cell was used combined with a single axis hydraulic powered second arm with a 1 kN cell in a customised configuration (Fig. 1). A custom made clamp was used to hold the hemi-pelvis in the Instron®. The hemi-pelvis was positioned in a lateral decubitus position while the Instron® was used to simulate the three main vectors (X, Y, Z) acting on the hip joint in order to simulate a walking cycle in the cadaveric model.

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