Osteochondral Transplant Delivery System

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Abstract

Osteochondral allografting is an important procedure for the repair of articular cartilage defects. Trauma or overuse of articular cartilage can increase the risk for osteoarthritis and hinder recovery time after an injury [1]. Current techniques use impaction or press fitting to insert the bone. Forces from these techniques induce chondrocyte necrosis and apoptosis, which increase the risk of future complications in the patient [2]. There is a need for new allograft procedures that decrease the forces exerted on articular cartilage in order to increase chondrocyte viability. The final design is a novel method that consists of threading the insertion site and bone plug. A threaded recipient site and bone plug allows the plug to be screwed in by hand with very little compressive and torsional forces applied to the top chondral layer. However, no statistically significant difference was obtained between impaction and threading techniques in terms of cell viability. Further testing is required to differentiate these methods.

Background

Project Motivation

- Trauma, overuse or joint misalignment cause Articular Cartilage (AC) defects, which can lead to osteoarthritis [3] (Figure 1)
- AC is avascular & aneural – poor regenerative properties
- Osteochondral grafting – replace damaged bone/cartilage with a graft [4]
  - 30% failure rate
- Success associated with >70% chondrocyte viability one hour after procedure [5]

Figure 1: defect in the articular cartilage on the femoral condyle

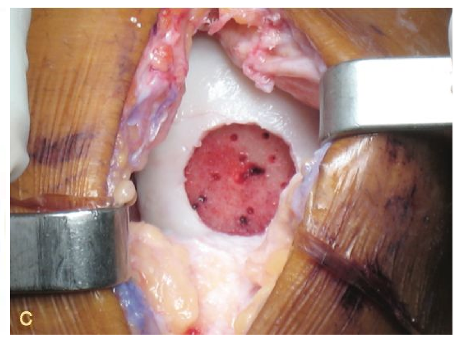

Figure 2: The recipient site fully prepped for graft insertion

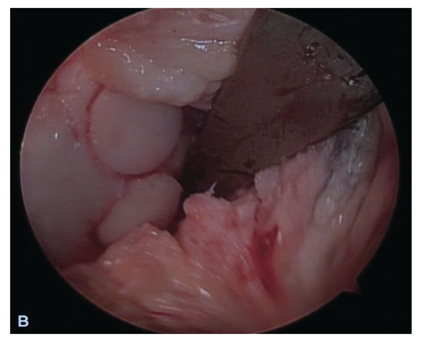

Figure 3: Graft after insertion

Current Delivery System (Figure 4)

- Cartilage defect drilled out from knee to create recipient site
- Graft harvested from donor tissue using measurements from recipient site
- Graft is inserted using a press-fit technique or impaction using a tamp [4]

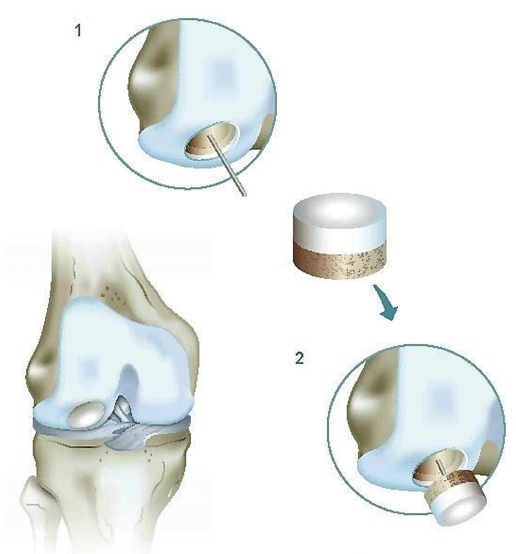

Figure 4: The basic steps of the osteochondral allograft procedure

Design Specifications

- Achieve more than 70% viability → decrease impaction forces during implantation
- Biocompatible and exhibit proper integration postoperatively
- Tools used in procedure should be capable of operating on bone
- Range of 5mm-20mm diameter and at least 10 mm depth for damage repair
- Materials should be sterilizable and comply with FDA regulations

Final Design

Procedure

1. Obtain donor condyle and materials
2. Drill out damaged section on recipient
3. Tap recipient hole
4. Bore the corresponding sized plug from the donor condyle using harvester
5. Use saw to cut perpendicular to plug, removing undesired bone
6. Remove harvester and plug from the donor condyle
7. Push the plug out of the harvester by knob on core extruder
8. Place the plug in a vice and use a die to cut mating threads
9. Hand-tighten the plug into the recipient site until cartilage is flush

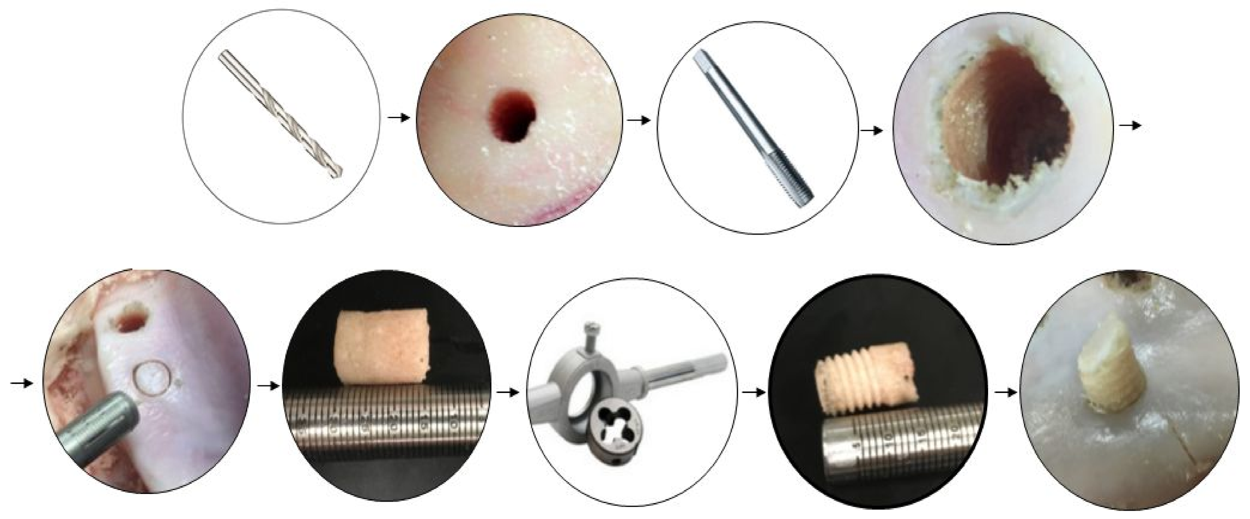

Figure 5: Schematic of the procedure associated with the final design

Figure 6: Recipient sites drilled into cow femoral head

Figure 7: Threaded allograft plug

Materials

- All non biological materials must be sterilized
- Sized drill bit
- Sized tap and die
- Surgical saw
- Donor condyle
- Vice
- Saw
- Mallet
- Osteochondral autograft transfer system (REF AR - 1S81 - 10S)
- Specialized reamer

Figure 8: Threaded graft following insertion into the recipient site

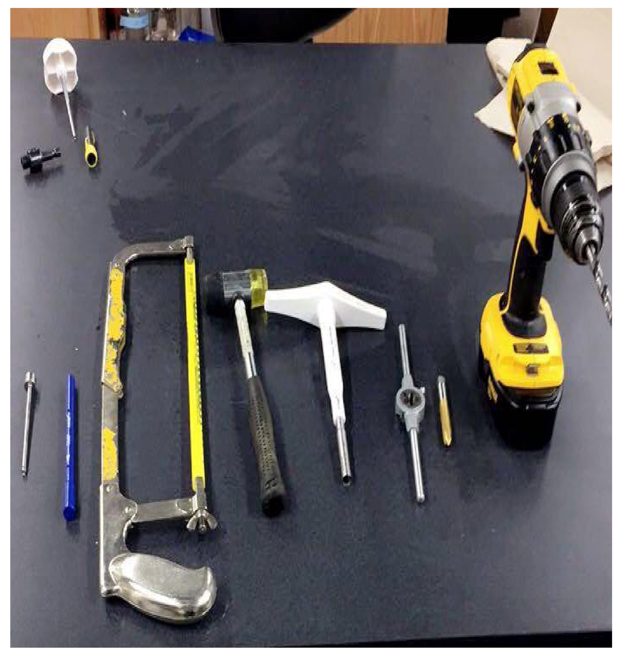

Figure 9: From left to right: graft driver, tamp/sizer, hand saw, mallet, harvester, die, tap, cordless drill and bit

Testing

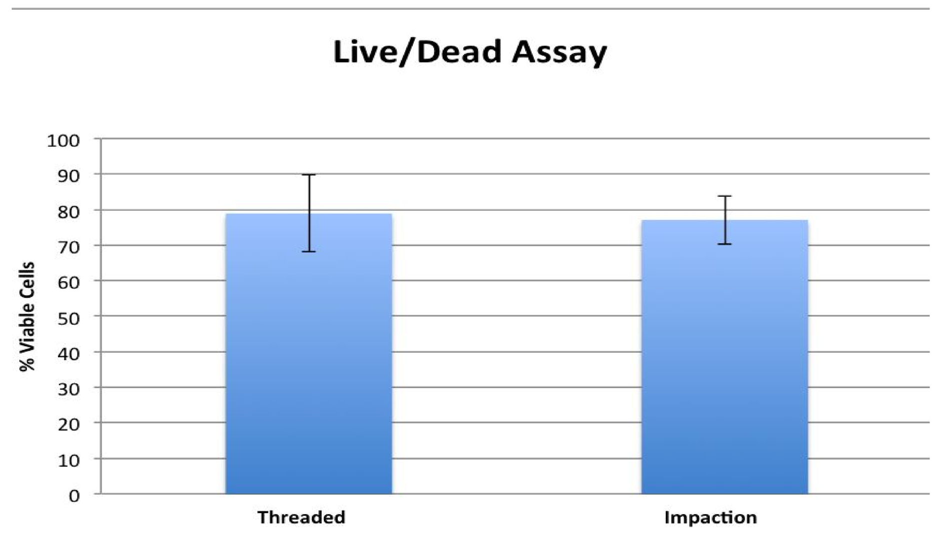

Figure 10: After one hour in live/dead solution, threaded grafts had about 78% cell viability and impacted grafts had about 77% viability

Plug	Viability of Threaded Plugs	Viability of Impacted Plugs
1	59.56 %	63.50 %
2	96.73 %	83.43 %
3	80.54 %	84.41 %
Average	78.94 %	77.11 %
Standard Deviation	18. 64 %	11.80 %
Standard Error	10.76 %	6. 81 %

Table 1: Comparison of threaded and impacted grafts with three replicates for each condition

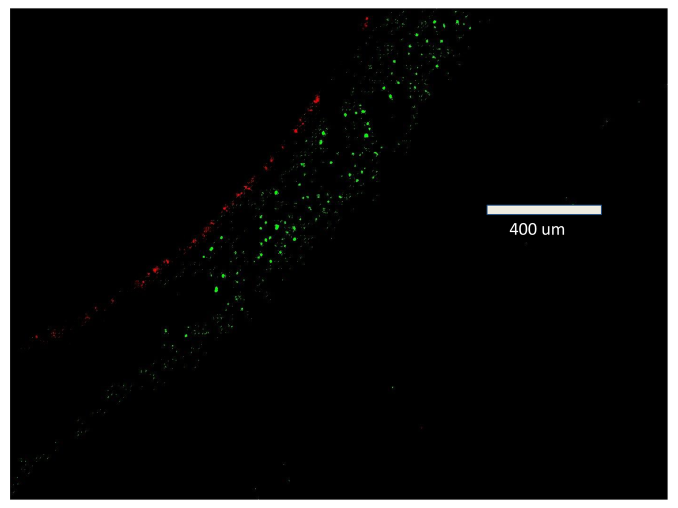

Figure 11: Threaded graft sample at 4x

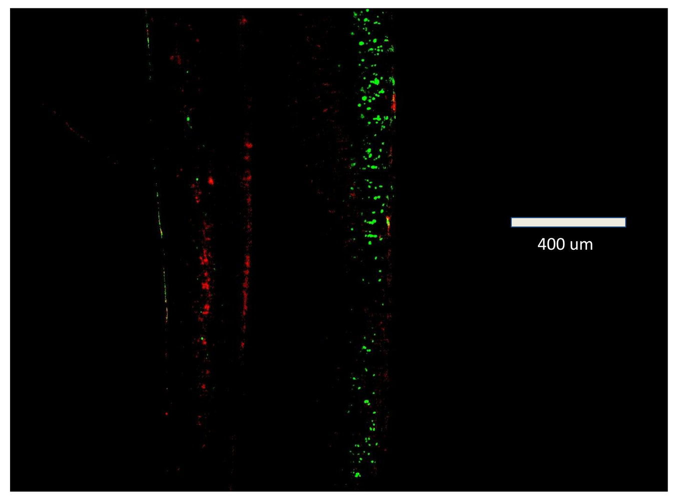

Figure 12: Impacted graft sample at 4x

- FITC (live)
- TRITC (dead)

Testing Materials

- Femoral head of cow knee
- 1 L PBS (1X)
- MEM-C media
- 10 mL - 2 µM Calcein AM/4 µM Ethidium homodimer-1
- 2 Surgical Scalpels
- 3 Microscope Slides
- Q-sized drill bit
- 10mm by 1.5 mm tap and die

Testing Methods

- 3 replicates each for impaction, threaded, and control conditions
- Culture for one hour after obtaining cartilage sections
- Stain with Calcein AM/Ethidium homodimer-1
- Image under FITC and TRITC channels on fluorescence microscope

Conclusions

- The delivery system reduces the compressive forces necessary for graft insertion
- Data regarding the difference in chondrocyte viability between the threaded and impaction conditions were not statistically significant

  Threaded grafting technique shows promise in improving chondrocyte viability under a surgical setting

  This method could be applicable to other grafting techniques using bone tissue

Future Work

Optimization

- *In vitro* testing utilizing sterile environments and improved tools
- Confocal Imaging for more accurate representation of cell viability
- Testing of multiple layers of cartilage
- *In vivo* testing in animal models

Implementation

- Higher quality tools
  - variable tap and die sizes
  - unique vice to prevent damage
  - surgical grade tools
- Multiple time points for live/dead analysis

Figure 10: Oscillating saw used in osteochondral allograft procedures

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References

1. Flanigan DC, et al. Prevalence of Chondral Defects in Athletes' Knees: A Systematic Review, *Med. Sci. Sports Exerc.* 2010; 42(10):1795-1801
2. Boris H, et al. Effect of Impact on Chondrocyte Viability During Insertion of Human Osteochondral Grafts, *J Bone Joint Surg Am.* 2006; 88(9):1934-1943
3. Memon, AR & JF Quinlan. Surgical Treatment of Articular Cartilage Defects in the Knee: Are We Winning? *Adv Orthop.* 2012; 2012: 528423
4. Sgaglione NA, et al. AANA Advanced Arthroscopic Surgical Techniques, *SLACK Inc.* 2016 (pp.243-255)
5. Cook JL, et al. Importance of Donor Chondrocyte Viability for Osteochondral Allografts, *Am J Sports Med.* 2016; 44(5):1260-1268