Osteochondral Transplant Delivery System

TEAM: Rodrigo Umanzor, Eduardo Enríquez, Nick Zacharias, Billin Loi
CLIENT: Dr. Brian Walczak, DO, Department of Orthopedics and Rehabilitation – University of Wisconsin - Madison
ADVISOR: Professor Krishanu Saha, PhD, Department of Biomedical Engineering – University of Wisconsin - Madison

Abstract

Osteochondral grafts play an important role in the repair of articular cartilage defects. Articular cartilage defects arise from trauma and overuse of the joints which increases the risk for osteoarthritis and hinders injury recovery time [1]. Current surgical procedures for knee grafts use impaction or press fitting to insert the replacement tissue. Forces from these insertion techniques induce chondrocyte necrosis and later apoptosis, thus increasing the risk of complications and additional surgeries [2]. There is a need for a novel procedure that decreases the forces exerted on the articular cartilage and increases chondrocyte viability. This design is a novel technique consisting of threading the insertion site and bone plug and screwing them in manually, thereby reducing the compressive forces applied to the surface of the cartilage. However, testing showed no statistically significant difference between cell viability of impaction and threading insertion techniques. Furthermore, damage to cartilage during threading of the bone plug as well as complications with perfect mating does not allow us to recommend this novel procedure.

Background

Project Motivation

- Trauma, overuse or joint misalignment cause Articular Cartilage (AC) defects, which lead to osteoarthritis [3] (Figure 1)
- AC is avascular and 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

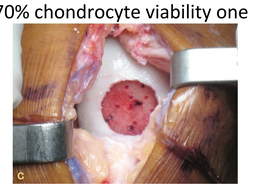


Figure 2: The recipient site fully prepped for graft insertion

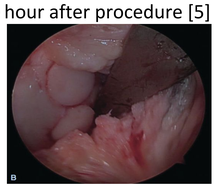


Figure 3: Graft after insertion

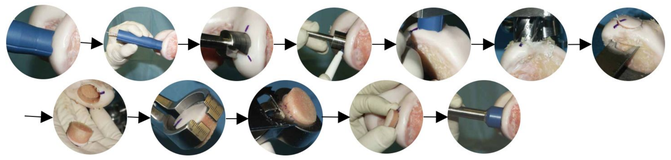


Figure 4: The steps of the clinical osteochondral allograft procedure

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]

Design Specifications

- Achieve more than 70% viability → increase in viability over impaction
- 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
- Sterilizable materials that comply with FDA regulations

Results

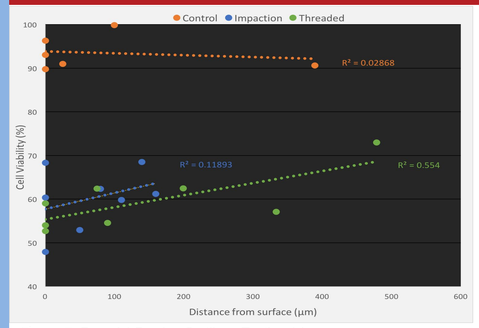


Figure 7: Round 1 Porcine Cartilage Testing 1-hr

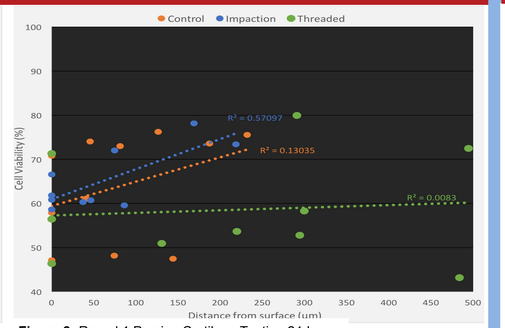


Figure 8: Round 1 Porcine Cartilage Testing 24-hr

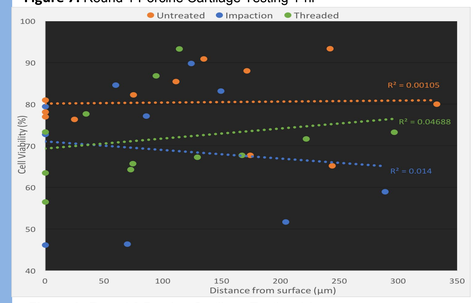


Figure 9: Round 2 Porcine Cartilage Testing 1-hr

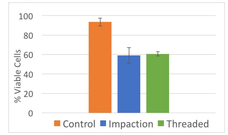


Figure 10: Round 1, 1-hr (total group)

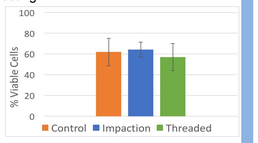


Figure 11: Round 1, 24-hr (total group)

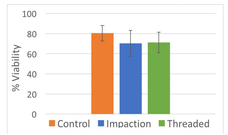


Figure 12: Round 2, 1-hr

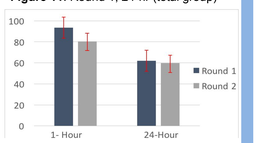
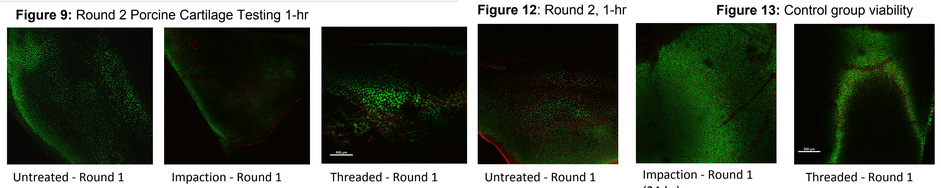
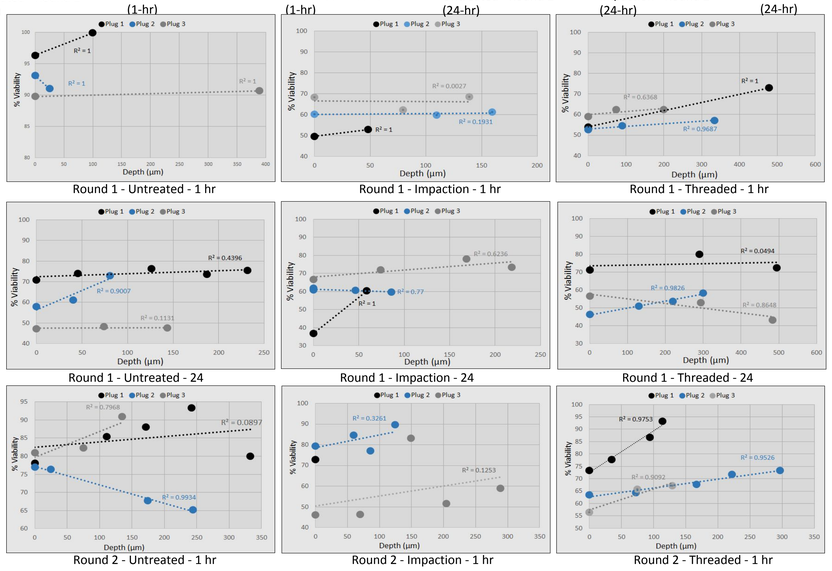


Figure 13: Control group viability





Methods

Testing Materials

- Fresh Landrace X Porcine limbs
- D-PBS (1X)
- MEM-C media
- 2 µM Calcein AM/4 µM Ethidium homodimer-1
- 2 Surgical Scalpels
- 3 Microscope Slides
- 11/32 drill bit
- 7/16-14 tap and die

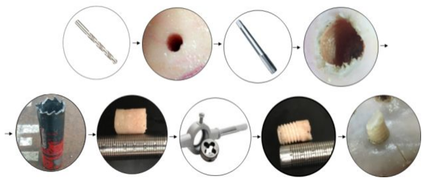


Figure 5: Schematic of the procedure associated with the final design

Testing Methods

- 3 replicates: impaction, threaded, and control conditions
- Remove cartilage and section into halves
- Culture one half for one hour and the other for 24-hour time point
- Wash with 5 mL PBS and section with scalpel
- Stain with Calcein AM/Ethidium homodimer-1 and incubate for 20min
- Wash with 5 mL PBS
- Image under FITC and TRITC channels on confocal microscope (Nikon A1RS)
- Count cells in Imagej with background and particulate exclusion

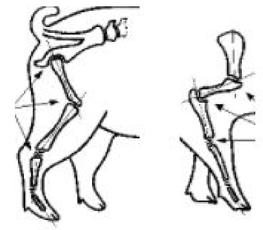


Figure 6: Porcine Skeleton of Hindleg and Foreleg

Discussion

- No statistically significant increase in viability.
  - Round 1 - p value: 0.3869
  - Round 2 - p value: 0.4577
- Plug extraction proved damaging to cartilage
- Uncommon shear forces during threaded insertion
- Difficulty in perfect mating of threaded surfaces
- Grafts are susceptible to fracture during threading
- Must thread cartilage surface
- Variable trends in the relation of cell viability with depth

Figure 14: Threading of a graft

Conclusions & Future Work

Conclusions

- Cannot recommend threading as an alternative technique for knee graft procedures
- Threaded procedure may introduce further surgical complications

Future Work

- Eliminate need to thread cartilage
- Investigate torsional stress placed on cartilage
- Refine procedure for consistent thread mating

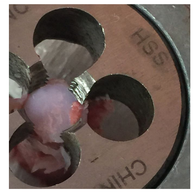


Figure 15: Threading at the cartilaginous surface

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References

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