A Novel Electrospun Polydioxanone Patch for the Biological Enhancement of Rotator Cuff Repairs

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INTRODUCTION:
Rotator cuff tendon pathology accounts for 30-70% of all shoulder pain [1]. Surgical re-attachment of the tendon to the bone with a non-absorbable suture is a common option. However, the failure rate of these repairs is very high, estimated at up to 75%. A number of studies have shown that in late disease stages the tendon itself is extremely degenerate, with reduced cellularity and poor matrix organization [2]. A recent direction of research is improving the biological environment by adding biological factors such as platelet rich plasma (PRP) and stem cells [3]. However, the articular capsule of the glenohumeral joint and the subacromial bursa are both large potential spaces, and injecting PRP or stem cells into either of these locations post-operatively does not ensure localization of the beneficial factors. We have thus sought to develop a biocompatible, degradable patch, in order to create a confinement area around the repair area in order to help guide injection and retain factors such as PRP and cells for the critical healing period following rotator cuff repair. The material used for the patch was polydioxanone (PDO). PDO sutures have been shown to be biocompatible with tendon derived cells but had relatively poor cell adhesion due to smooth surface (Hakimi, 2011, in print). Thus, in order to improve cell attachment, PDO was electrospun into a microfibrous patch. This study is a proof of concept for the use of this novel patch to enhance tendon regeneration.

METHODS:
Patch production
Patches were electrospun using 7% w/v PDS dissolved in hexafluoro-fluoro-2-propanol (HFP). A voltage of 13.5kV was applied between a nozzle and a ground electrode 26 cm above the substrate. The electrospun fiber diameter was ranging from 0.1 to 1µm, with the electrospun material density of 1.124g/cm³. For control, a dura mater commercial patch Ethisorb (DuraPatch, DePuy) was used. This implant comprises of a fleece of Vicryl (Polyglactin 910) and a polydioxanone foil.

Primary tendon-derived cells
Rotator cuff tissue was collected from patients with full thickness supraspinatus tears undergoing surgical repairs. The tissue samples were resected from the edge of the tendon tear intraoperatively and transferred into a sterile tube containing DMEM F12 (Lonza, UK). Human tendon derived cells were obtained by explanting these tissues as previously described [4]. Approval for the study was obtained from the local Research Ethics Committee.

Cell assays
Cell growth was monitored by detecting the consumption of alamarBlue (AbD Serotec, UK). To visualize cell spreading on the patch, cells were fixed in 10% formalin (Fisher Scientific), permeabilized and stained using DAPI (4',6-diamidino-2-phenylindole, Molecular Probes) and Rhodamine-Phalloidin (Invitrogen). Images were captured on a fluorescence microscope (eclipse TE300, Nikon).

Patch Detection by ultrasound
The patch was attached to a sample of sheep infraspinatus tendon and embedded within a gelatin-based phantom model in order to simulate the in-vivo imaging environment. The patch was imaged using a GE Healthcare Logiq E9 with 13MHz linear array probe. Guided injection of dye into the patch was performed.

RESULTS:
Our results indicated that cells attached, spread and survived on the patch for up to 21 days (Figure 1). Cells infiltrated the patch, forming cell-cell connections on the 3D matrix.

DISCUSSION:
In the study presented above, we used a well-established biocompatible material (polydioxanone) to develop a novel patch for creating a confinement zone above rotator cuff repairs, in order to retain PRP, cells or other supplementary factors in proximity to the healing tendon. We successfully showed that the patch is highly compatible with tendon-derived cells grown in vitro, detectable by ultrasound as well as efficient in absorbing and retaining cells. Future studies will establish safety and efficacy of the patch in vivo.

SIGNIFICANCE:
We have presented a proof of concept and preliminary compatibility data, demonstrating the suitability of electrospun PDO for rotator cuff repairs. This has the potential to enhance the efficacy of current PRP injection procedures and facilitate stem-cell implantation during and as a follow up after rotator cuff repair, as well as fill a similar function in other orthopaedic surgical procedures.

REFERENCES: