Characterization of a Novel Reinforced Implant for Tendon and Ligament Healing

Andrew J Carter PhD[1], Vedran Lovric PhD[2], Per Morberg MD[2], Jeff Ott BS[3], Justin Bendigo MS[3], Jacob Komenda MS[3], Mark Aronson PhD[4], Kevin Rocco MS[3], Steven Arnoczky DVM[5], William R Walsh PhD[1]

[1]Accent Biomedical, Stow, MA, [2]Prince of Wales Hospital, Sydney, Australia [3]Biorez, New Haven, CT [4]University of Virginia, Charlottesville, VA [5]Michigan State University, East Lansing, MI

Disclosures: Andrew J Carter (3B–Biorez), Vedran Lovric (N), Per Morberg (N), Jeff Ott (3A–Biorez), Justin Bendigo (3A–Biorez), Jacob Komenda
(3A–Biorez), Mark Aronson (3B–Biorez), Kevin Rocco (3A–Biorez), Steven Arnoczky (4–Biorez), William R Walsh (4–Biorez)

Introduction

Prolonged recovery following rotator cuff tendon repair or anterior cruciate ligament reconstruction remains a challenge for both the patient and surgeon. The ability to optimize the healing process and potentially shorten rehabilitation time would constitute a significant advancement. A novel, reinforced implant has been des-igned to participate in the healing process through tissue ingrowth and remodeling to improve tendon and ligament repair and re- construction. This study characterized time-zero properties (strength, pore structure) and degradation kinetics. The in vivo response and its ability to support rapid host cell ingrowth and tissue maturation was evaluated in a sheep patella tendon defect and subcu-taneous models.

Methods

The reinforced implant (BioBrace®, CONMED) is a highly-porous collagen matrix, reinforced with bioresorbable PLLA microfila-ments, to provide an open 3-D biologic implant with strength **(Fig. 1A,B)**. Mercury Porosimetry (MIP): The pore structure of the BioBrace® was characterized via scanning elec-tron microscopy (SEM) and mercury porosimetry. Mercury intrusion volu-me was recorded as a function of pore diameter for 2.5cm long segments of 5mm wide BioBrace® implants; log differential was calculated to remove noise from the data. In vitro degra-dation testing: PLLA fibers were sub-merged in phosphate-buffered saline

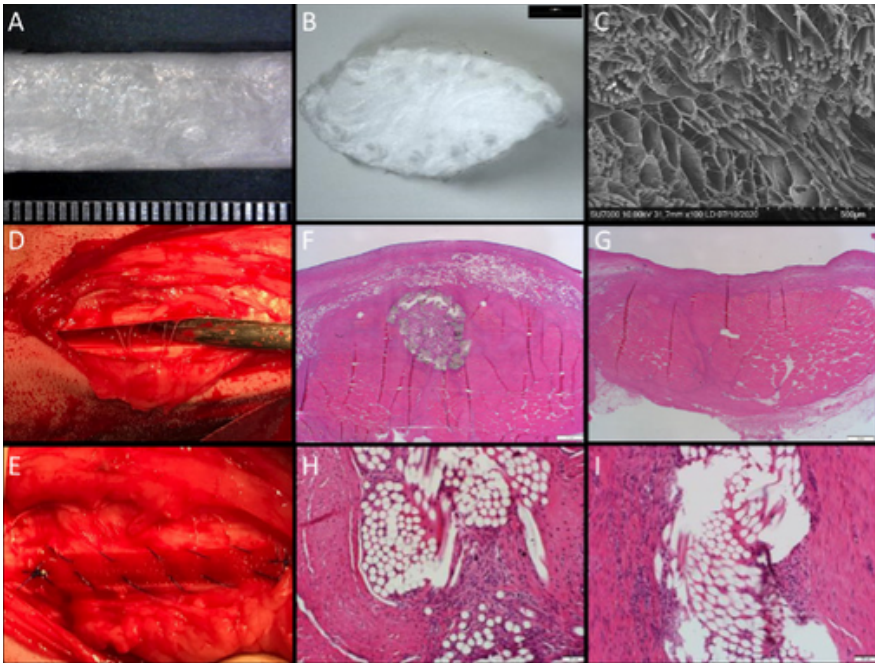

Figure 1. *Macroscopic surface (**A**), cross-section (**B**), and SEM (**C**) images of the implant. Middle third patellar tendon empty defect (**D**). BioBrace® sutured in defect (**E**). H&E histology of the BioBrace® (**F**) and empty defect (**G**) at 3 weeks. H&E histology of the BioBrace® at 12 weeks in cross-section (**H**) and longitudinal section (**I**).*

(PBS) at a 30:1 solution-to-polymer mass ratio and maintained at 37C ± 2C and pH 7.4 ± 0.2. Tensile testing (per ASTM D2256) was carried out on n=12 samples per timepoint at a strain rate of 2%/second. Molecular weight (MW) was measured on one sample per time point via Gel Permeation Chromatogra-phy (GPC). 5mm-wide BioBrace® implants underwent tensile testing (n=6) at a strain rate of 2%/second. In vivo response: The central third of the patella tendon was excised and the BioBrace® secured with interrupted sutures (**Fig. 1D**), or the defect was left empty (**Fig. 1E**) following ethics approval. Paraffin histology was performed at 3 and 12 weeks to evaluate the local cell and tissue responses.

Results

SEM of the BioBrace® cross section revealed a porous, interconnected matrix with polymer filaments measuring 15µm in diameter (**Fig. 1C**). Mercury poro-

simetry data revealed a porosity of 80%, cumulative pore volume of 4.2 cm3/gm, and a peak pore diameter of 19.7µm (**Fig. 2-top**). The in vitro degradation profile of tenacity (ultimate tensile strength/weight of the material) and molecular weight of the PLLA fiber demonstrate near complete loss after 130 and 156 weeks, respectively (**Fig. 2-bottom**). The correlation coefficient between tenacity loss and molecular weight loss was R=0.983. Ultimate tensile strength of the BioBrace® was 141.0N ± 4.5N, and stiffness was 14.5N/mm ± 0.5N/mm. The BioBrace® supported rapid cellular ingrowth and extracellular matrix production in both the subcutaneous and patellar tendon locations at 3 weeks (**Fig. 1F**) while the empty defect collapsed on itself with some new fibrous tissue noted (**Fig. 1G**). At 12 weeks tissue remodeled in the patella tendon and subcutaneous sites (**Fig. 1H,I**). Scattered multinucleated cells were noted adjacent to some of the PLLA fibers at both 3 (not shown) and 12 weeks (**Fig. 1H,I**). There is also increased tissue production, maturation, and alignment with no evidence of an adverse inflammatory response.

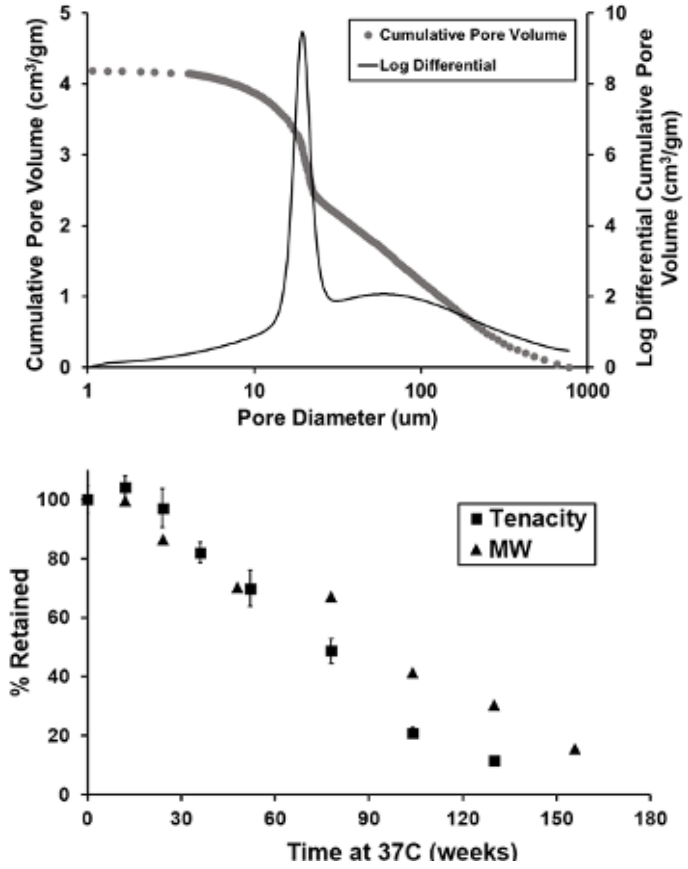

Figure 2. *Top: Cumulative pore volume and log differential as a function of pore diameter in the BioBrace®. Bottom: In vitro degradation of PLLA fiber fraction of BioBrace® over time as measured by retained molecular weight (MW) and remaining tenacity (tensile strength/weight).*

Discussion

This preclinical assessment demonstrates the reinforced implant architecture has a high degree of porosity that is adequate in size and volume to support bulk cellular infiltration. PLLA fibers used in the BioBrace® have a reproducible degradation curve that correlates with the reduction of its tensile strength over time. Previous studies (data on file) have shown that the degradation profile of the PLLA fibers is directly related to that of the BioBrace® construct. When placed in an in vivo environment, the BioBrace® supports a rapid ingrowth and maturation of new tissue. Comparison of the cellular response across BioBrace® sites revealed similar responses. In a clinical setting, the initial strength of the BioBrace® and the resultant host tissue ingrowth may serve to opti- mize the balance between the local biomechanical and biological heal- ing environment. Further studies are warranted and underway.

Significance/Clinical Relevance

The ability of a reinforced implant to rapidly induce the formation of host generated regularly oriented connective tissue within in a tendon defect may represent a novel approach to the repair/ reconstruction of severely damage tendons or ligaments.

This abstract or variations thereof was presented at the following conferences: Carter et al. ORS 2021 (Podium)
Rocco et al. Military Health System Research Symposium 2020 (Accepted, Poster)