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Dear Hun Jin Jeong:

Congratulations! On behalf of the ORS Scientific Program Committee we are happy to inform you that your abstract has been chosen to be presented as a **POSTER** presentation at the ORS 2022 Annual Meeting in Tampa, Florida, February 4-8. Details regarding your presentation are noted below:

POSTER SESSION #: PS1-005
POSTER CATEGORY: Biomaterials - Scaffolds
POSTER #: 0418
POSTER TITLE: Novel Dragging 3D Printing For Vascular Tissue Engineering In Musculoskeletal Regeneration
AUTHORS: Hun Jin Jeong; Hyoryung Nam; Jae-Seok Kim; SungKeon Cho; Hyun-Ha Park; Young-Sam Cho; Chang Lee; Jinah Jang; Seung-Jae Lee

IMPORTANT NEXT STEPS
Register for the Meeting
Register to attend in person the ORS 2022 Annual Meeting at https://www.ors.org/2022-am-reg/.

Book your Hotel Accommodations
The ORS works hard to ensure that we offer you the best hotel rates in Tampa, at properties that are a short walking distance to the convention center and provide you with the comforts of home. Book your room today at https://www.ors.org/2022-hotels-travel/.

POSTER SESSION INFORMATION
Poster Session 1 (PS1): Posters displayed Saturday and Sunday
You are expected to be at your poster during the designated times noted below:
If your POSTER # is EVEN you will present on Saturday, February 5, 10:15 AM - 11:15 AM
If your POSTER # is ODD you will present on Sunday, February 6, 10:15 AM - 11:15 AM
A Poster Reception will be held on Saturday, February 5, 5:30 PM - 7:00 PM

Poster Session 2 (PS2): Posters displayed Monday and Tuesday
You are expected to be at your poster during the designated times noted below:
If your POSTER # is EVEN you will present on Monday, February 7, 10:15 AM - 11:15 AM
If your POSTER # is ODD you will present on Tuesday, February 8 9:00 AM - 10:00 AM
A poster reception will be held on Monday, February 7, 5:30 PM - 7:00 PM

POSTER FORMAT: Poster size is 45" x 45" (Maximum)
Poster must reflect the material summarized in your submitted abstract. For all posters

we suggest that you embed a QR code that can be used for those visiting your poster to hear your personal presentation, and to include your email for any questions your colleagues may have about your work. Information for poster presenters - including poster set-up, removal, etc. is available on the 2022 Annual Meeting website at https://www.ors.org/2022-poster-presenter-speaker-moderator-info.

POSTER PRINTING SERVICE
ORS will offer a Poster Printing Service through a third-party vendor. Poster presenters (Presenting authors) will receive an email in December with information on the poster printing service. Poster presenters wanting to take advantage of this service will be able to pick up their poster upon arrival to the Tampa Convention Center.

If you have any questions, please contact us at orsabstracts@ors.org or 847-823-5770.

We look forward to seeing you in Tampa!

Sincerely,

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Poster No. 412
Prodrug Bmp-7 Alleviates Fibrosis In Bleomycin-induced Localized Scleroderma Animal Model
Cheol-Hee Jeong; Hyun Sil Kim; Yoon Hae Kwak

Poster No. 413
Biocompatible Mechanically-optimized Bioadhesive For Tendon-to Bone Repair
Fei Fang; Roscoe Linstadt; Kollbe Ahn; Guy Genin; Stavros Thomopoulos

Poster No. 414
Tensile Strength Of A Novel Superficial Suture Pattern Compared To Traditional Suture Patterns In A Cadaveric Human Skin Model
Francisco Rodriguez Fontan; Nicole Look; Todd Baldini; Bennie Lindeque

PS1-005
Biomaterials - Scaffolds

Poster No. 415
Characterization Of A Bmp-2bpa Nanofiber—Demineralized Bone Matrix (dbm) Composite Scaffold For Structural Integrity And Osteoinductivity
Nicholas Lanzetta; Andrew Furman; Alexander Linton; Elianna Fred; Charlotte Chen; Nick Sather; Mark McClendon; Wellington Hsu; Samuel Stupp; Erin Hsu

Poster No. 416
Adhesion Prevention In Tendon Repair With Intact Fish Skin Grafts: A Case Series
Ruby N. Huynh; Michael J. Lacqua; Evelyn Quintin; Gunnar Johannsson

Poster No. 417
A Library Of Janus Base Nano-matrices For Tissue Engineering
Anne Yau; Libo Zhou; Yupeng Chen; Wuxia Zhang

Poster No. 418
Novel Dragging 3D Printing For Vascular Tissue Engineering In Musculoskeletal Regeneration
Hun Jin Jeong; Hyoryung Nam; Jae-Seok Kim; SungKeon Cho; Hyun-Ha Park; Young-Sam Cho; Chang Lee; Jinah Jang; Seung-Jae Lee

Poster No. 419
In Vitro And In Vivo Characterization Of A Decellularized And Lyophilized Placental Membrane For Potential Orthopedic Applications
Fanwei Meng; Britini Ork; Jennifer Morse; Davorka Softic; Xiaofei Qin

Poster No. 420
A Nanoporous 3D-printed Scaffold For Human Ligament Tissue Engineering Applications
Jean-Gabriel Lacombe; Megan Cooke; Hyeree Park; Suliman Mohammed Alshammari; Rahul Gawri; Showan Nazhat; Paul Martineau; Derek Rosenzweig

Novel dragging 3D printing for vascular tissue engineering in musculoskeletal regeneration

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Disclosures: Hun Jin Jeong (N), Hyoryung Nam (N), Jae-Seok Kim (N), SungKeon Cho (N), Chang H. Lee (N), Jinah Jang (N), Seung-Jae Lee (N)

INTRODUCTION: Tissue engineering has been extensively investigated to produce functional tissue substitutes for musculoskeletal regeneration. Recently, 3D printing technique has emerged as a versatile tool to fabricate custom-designed 3D scaffolds with desired microarchitecture for musculoskeletal regeneration. However, the outstanding challenges in musculoskeletal tissue engineering include vascularization through engineered tissues in large-volume. Given the pivotal roles of blood vessels in regeneration of musculoskeletal system, this study aims to develop a novel, efficient 3D printing technique for engineering bi-layered, small diameter blood vessels. We devised dragging printing technology that enables fabrication of micro-thin tubular vessels with homogenously distributed micro-pores on the lumen walls, leading to self-assembly of endothelial and smooth muscle bi-layers through cell migration directed by oxygen concentration gradient. Our data show promising outcome in engineering of small blood vessels as self-assembled with endothelial and smooth muscle cells, which can be readily integrated with various 3D printed scaffolds for musculoskeletal tissue engineering. **METHODS:** The tubular structure was fabricated by our novel dragging 3D printing technique as a thin-porous layer without any extra-material/device using medical grade polycaprolactone (mPCL, Resomer C209, Evonik, Germany; MW 73K; 0.8-1.0 dl/g in 0.1% chloroform) (**Fig. 1A & B**). Briefly, mPCL pellets were melted in a stainless-steel print head (SS10, U-Jin Tech., Korea) at 85 ℃, the print bed was kept at 35℃, and the ambient temperature was maintained at 15-18℃ during the printing. The mPCL was printed at the equal pneumatic pressure of 600 ± 10 kPa via 100-μm size precision nozzles (SHN-0.1N, Musashi, Japan). As per our well-established methods, we applied custom-designed G-codes to adjust various printing parameters, including printing column arc, length, discrete feeding speed, and timely application of fan, to create a patterned micro-porosity specifically designated location of vascular lumen (**Fig. 1A**). Then we printed 2% collagen-based bioink loaded with 4:1 ratio of human umbilical vein endothelial cells (HUVECs) and human aortic smooth muscle cells (SMCs) with 30 ± 10 kPa pressure and 26-G nozzles (PN-26G-13, U-Jin Tech, Korea) into the space between the inner and outer layer of scaffolds. Upon printing of the cell-laden bio-ink, it underwent gelation by 30 min incubation at 37℃. To investigate the effect of oxygen concentration gradient on cell migration, group 1, induced oxygen concentration gradient, had a tubular structure cultivated into the static environment (**Fig. 1C**), whereas group 2, non-oxygen concentration gradient, had the tubular structure divided into two equal parts to induce a similar condition at the inner and outer layer by exposing the inner layer (**Fig. 1D**). After 7 and 14 days, migration and localization of HUVECs and SMCs were evaluated using immunofluorescence for their markers, VE-Cadherin and α-SMA, respectively. **RESULTS:** Our dragging 3D printing with pre-determined printing parameters successfully fabricated sealed, vessel-like tubular structures with small portion of micro-pores allowing cell migration (**Fig. 1A-C**). By 7 days after printing cell-laden bioink, confocal microscopy showed that the SMCs migrated to both the inner and outer layers regardless of the oxygen concentration gradient (**Fig. 1E**). In contrast, HUVECs were concentrated in the pores, wherein they migrated to the inner layer with a low oxygen concentration gradient (**Fig. 1E**). After 14 days, the SMCs were predominantly moved to the outer layer forming an outer wall (**Fig. 2A**). Similarly, most of the HUVECs were retained in the inner layer as connected together forming an endothelial layer, reminiscent of inner wall of blood vessels (**Fig. 2B**). Our engineered blood vessels by dragging 3D printing were further matured *in* vitro (3days) that showed promising functional properties in term of mechanical properties, blood flow, and platelet adhesion (data not shown). **DISCUSSION:** In reconstructing large volumes of musculoskeletal tissues, the presence of blood vessels is considered essential for effective tissue regeneration. Our findings may represent an efficient approach to incorporate small blood vessels in 3D-printed scaffolds for large-scale tissue engineering. Given the advantages of 3D printing technique, the size, shape, and thickness of the blood vessels can be readily designed and established as incorporated in various types of scaffolds. In addition, we have demonstrated the potential of our dragging printing technique to create patterned micro-pores through the vessel walls. These pores successfully established oxygen concentration gradient between the inside and outside of tubular structure, which in turn induced selected migration of HUVEC and SMCs building endothelial and smooth muscle layers, reminiscent of native blood vessels. As being free of printing layered printing of multiple cell types, this approach is suitable for forming small vascular structure with complete bi-layer of endothelium and smooth muscle. In conclusion, our dragging 3D printing technique combined with cell bioprinting and oxygen gradient method may serve as an efficient approach to implement functional blood vessels through large, tissue engineered musculoskeletal tissue constructs.

SIGNIFICANCE: This study has significant implication in vascularization of large-volume tissue engineered construct, as implemented by novel dragging printing technique and self-assembled endothelial and smooth muscle layers directed by oxygen concentration gradient.

IMAGES AND TABLES:

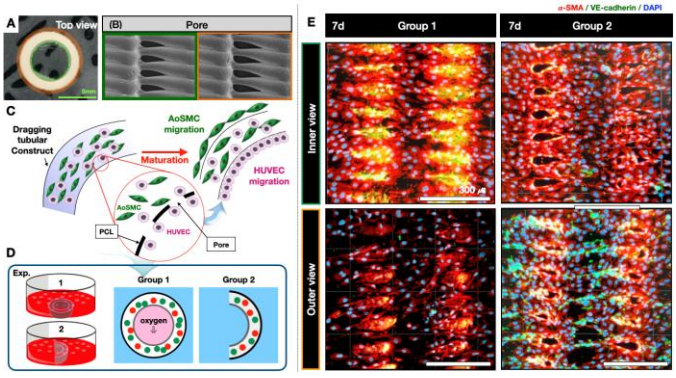

Fig. 1. (A) Tubular construct using Dragging 3D printing technique and (B) pore formation on the thin layer (C) Concept and (D) experimental design of the investigation of the effect of oxygen concentration gradient on the behavior of the cell in a static culture. IF shows migration of HUVEC and SMCs regulated by oxygen concentration gradient (E).

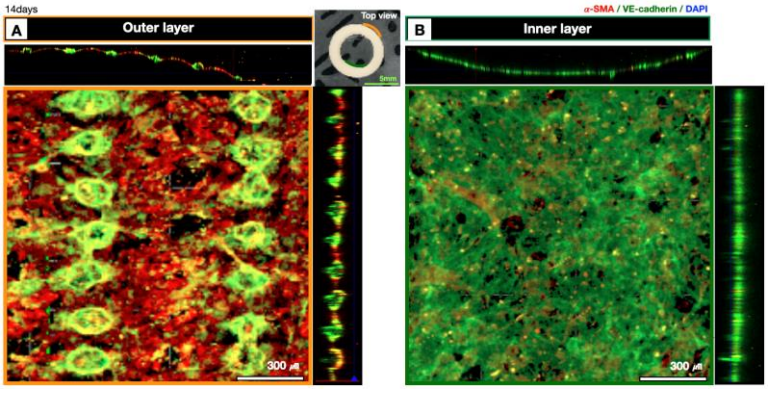

Fig. 2. Confocal images of the tubular construct containing human umbilical vein endothelial cells (HUVEC) and human aortic smooth muscle cell (SMC) in the ratio 4:1. (A) Left image shows the migration of the SMC to inner layer and (B) right image shows the migration of the SMC to outer layer on the oxygen concentration gradient condition (day 14).