Comparison of complications between individually reconstructed breasts in Group 1 versus Group 2 revealed significantly increased rates of skin necrosis (3.0% versus 10.6%, $P = 0.018$) among Group 2 breasts. Rates of infection were also increased among Group 2 (10.4% versus 18.1%, $P = 0.098$), which approached significance. There was no difference in reconstructive failure, conversion to autologous reconstruction, seroma, wound dehiscence, hematoma, or fat necrosis between the two groups. Logistic regression further revealed greater ADM thickness to be a significant predictor of skin necrosis (OR 3.869, 95% CI 1.175–12.738).

CONCLUSIONS: To date, this study represents the largest analysis of the effect of ADM thickness on complications after TEBR and the first to show a significant difference in complications with bivariate analysis. Thicker ADMs were significantly correlated with increased rates of skin necrosis, though there may not likely be a direct causality in this relationship. The increased infection rate, though not significant, may be caused by the potential for the ADM to act as a nidus for infection as well as prolonged time of thicker ADM incorporation and neovascularization. Our results, similar to previous studies conducted on smaller patient samples, show that ADM thickness does indeed play a role in complication rates, and selection of ADM should be conducted carefully.

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Long Term Maintenance of Nipple Projection Using 3D-printed Poly-4-Hydroxybutyrate Bioabsorbable Scaffolds Augmented with Autologous Processed Costal Cartilage

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PURPOSE: Nipple reconstruction is a vital part of breast reconstruction after total mastectomy. However, nearly all local autologous tissue techniques suffer from scar contracture and loss of neo-nipple projection. Costal cartilage (CC) has been reported to maintain projection in nipple reconstruction, yet it has not been widely adopted due to the excessively firm resultant nipple. Herein we propose, using a 3D-printed bioabsorbable Poly-4-Hydroxybutyrate (3D-P4HB) scaffold loaded with processed CC, to promote ingrowth of tissue that mimics the biomechanical properties of native nipples and protect the regenerated tissue from contracture as it matures.

METHODS: 3D-P4HB scaffolds (diameter: 1.0 cm, height: 1.0 cm) were fabricated and sterilized. Patient-derived CC (discarded from DIEP procedures) was either minced (1 mm$^3$) or zested (<0.2 mm$^3$) in a sterile fashion to change its biomechanical qualities. Processed cartilage-filled 3D-P4HB scaffolds were subcutaneously implanted into nude rats using a CV flap technique. Additional groups consisted of empty 3D-P4HB scaffolds, and non-scaffolded (naked) processed cartilage. The constructs were explanted after 1, 3, and 6 months for gross, microstructural, histological, and biomechanical analysis. Four nipples per group/time point were analyzed.

RESULTS: All 3D-P4HB nipple reconstructions were well preserved in diameter and projection at 1, 3, and 6 months when compared with the non-scaffolded (naked) groups. A minor steady increase in tissue volume content was observed inside the scaffolds in both processed cartilage-filled 3D-P4HB groups overtime, due to cellular infiltration and tissue ingrowth through the pores and between cartilage pieces, although no significant differences were observed between groups ($P > 0.05$). However, the non-scaffolded (naked) group lost a significant amount of volume in the first 3 months (38% in minced and 26% in zested, $P < 0.05$), this smaller volume remained unchanged between 3 and 6 months. Biomechanical testing of elastic modulus indicated that the naked groups had minimal change in stiffness over 6 months within the range of 0.04–1 MPa due to the absence of scaffolds, but both processed cartilage-filled 3D-P4HB groups slightly increased in stiffness over 6 months within the range of 2–3 MPa. The newly formed spongy fibrovascular cartilaginous tissue (with viable chondrocytes within the lacunae) was noted in both processed cartilage-filled 3D-P4HB groups at 6 months. SEM images of 3D-P4HB scaffolds demonstrated degradation over time with widespread pitting on the outer surface of the scaffold walls. The inner wall of empty 3D-P4HB scaffolds had less surface erosion when compared with the cartilage-filled groups due
to less cell interaction with inner wall material. Molecular weight of the P4HB polymer decreased significantly in vivo but independently of sample configuration.

CONCLUSIONS: Using 3D-P4HB scaffolds filled with autologous processed CC, we have engineered nipples that maintain their projection and volume over time, while simultaneously allowing for the maturation of an internal structure of fibrovascular cartilaginous tissue that biomechanically mimics that of native nipples. Because P4HB devices for soft tissue reinforcement have previously been cleared by the FDA and possess a long track record of safety, we believe that this novel 3D-P4HB nipple reconstruction scaffold have a great potential for clinical translation.

Creating Neo-nipples with “Off the Shelf” Parts

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INTRODUCTION: Nipple reconstruction is critical to patient satisfaction post mastectomy and vital to the overall success of breast reconstruction. Autologous methods using local skip flaps for nipple reconstruction often suffer from contracture and significant loss of neo-nipple projection and volume. Our group has previously demonstrated improved long-term maintenance of nipple volume and projection using autologous, vital costal cartilage (CC) that has been softened by mechanical processing. Such donor tissue, however, is only be available for patients undergoing DIEP reconstruction, with obligatory removal of CC. In order to broaden the application of this methodology of nipple reconstruction to all types of breast reconstruction and allow for the use “off the shelf” tissues, we sought to determine if decellularized lamb CC within bioabsorbable PLA scaffolds encouraged tissue formation that would result in long-term maintenance of projection and volume of the engineered nipple.

METHODS: PLA scaffolds (diameter: 1.0 cm, height: 1.0 cm) were printed using a PRUSA 3D printer and sterilized. Lamb costal cartilage was minced (1 mm³) or zested (<0.2 mm³) and then decellularized. The quality of decellularization was assessed using DNA quantification and histological analysis. Decellularized cartilage was then packed into PLA scaffolds and implanted subcutaneously into immunocompetent Sprague Dawley rats using a CV flap technique. The constructs were explanted and evaluated at 1 month and 3 month timepoints.

RESULTS: All nipple reconstructions showed well-preserved diameter and projection due to persistence of the PLA scaffolds at 1 and 3 months. Mass and volume of the nipples were well preserved over the 1-month and 3-month timepoints. Compared with implantation mass, zested nipples show a 2% mass increase at 1 month and 5% mass decrease at 3 months. Minced nipples showed additional mass gain overtime, with neo-nipples showing an 18% increase at 1 month and 12% increase at 3 months. On explant, the volume of zested nipples showed similar preservation and augmentation. Compared with implantation volumes, zested nipple volume increased 17% at 1 month and 3% at 3 months. Minced nipples showed a similar volume retention pattern, increasing both 16% from implantation at 1 month and 4% at 3 months. Increased mass and volume can be attributed to fibrovascular tissue ingrowth and additional cartilage hydration. Histologic analysis demonstrated a mild inflammatory infiltrate 1 month after implantation, which had subsided by 3 months. Healthy fibrovascular tissue developed between the fragments of cartilage, which maintained their structure and collagenous matrix but proteoglycans were not detectable with Safranin O.

CONCLUSIONS: Using decellularized rib cartilage and bioabsorbable scaffolds, we have effectively engineered neo-nipples that maintain their projection and diameter through 3 months. Due to further cartilage hydration and fibrovascular tissue development, the nipples both maintained, and even increased in, mass and volume over time. The architecture of the internal decellularized cartilage was well preserved through the 3-month time point, showing minimal evidence of immune-mediated cellular degradation. This novel decellularized lamb cartilage neo-nipple provides a promising avenue for both immediate and lasting reconstruction, thus improving patient satisfaction post mastectomy and eliminating the morbidity associated with additional surgical intervention.