Investigating the Effect of Magnetic Nanoparticles on Collagen Alignment

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INTRODUCTION

The extracellular matrix (ECM) is a protein-rich network in cells, mostly made of collagen type 1. In cancer, collagen alignment is increased, contributing to stiffer ECM and consequently increasing cell migration and tumor progression. Magnetic nanoparticles (MNPs) show a promising way of replicating and studying the cancer microenvironment in vitro. In this study, we aim to visualize how magnetic nanoparticles influence collagen alignment. We use SeraSil-Mag Silica Coated Superparamagnetic beads to serve as magnetic nanoparticles and magnetic bars to induce alignment of collagen. A confocal reflectance microscopy (CRM) is used to view the alignment and is quantified with CurveAlign and MATLAB. Developing this model will lead to further study of drug resistance in cancer

BACKGROUND

Collagen is a primary component of tumor microenvironment and plays a key role in cancer fibrosis. Often regulated through mutated genes and transcription factors. Collagen influences tumor cell behaviors through receptors and signaling pathways. In the case of cancer, collagen becomes more aligned, decreasing the migration of T cells and limiting their entry into the tumor mass. To mimic native collagen fibers in cancer microenvironment, researchers have explored the use of magnetic nanoparticles. This approach was first used in 1983; however, many other studies have been hindered due to the need for powerful Tesla order magnets. Although the use of high magnetic fields generates more aligned collagen fibers, there is a need for specialized equipment and strenuous safety measures. Therefore, a better alternative is a low-safety and cost-effective way to align collagen effectively.

EXPERIMNETAL DESIGN

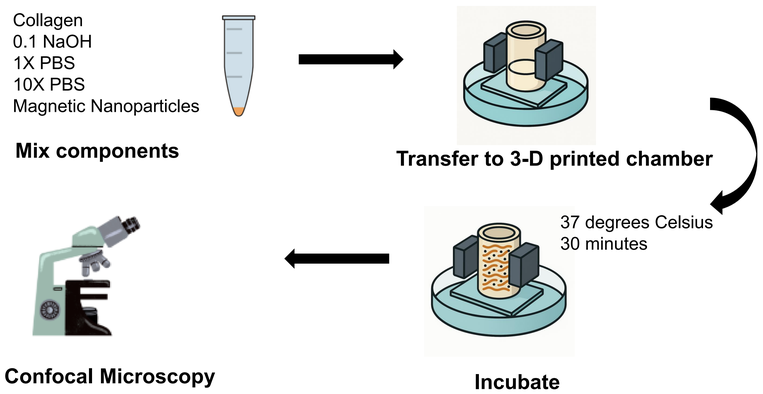

Figure 1 **| Experimental Overview**

1. To prepare hydrogels, mix the components in order
    1. 1X PBS
    2. Collagen hydrogel
    3. 10X PBS
    4. 0.1 NaOH
    5. Magnetic nanoparticles
2. Vortex after each step
3. Pipette the desired volume into the 3-D printed mold and attach the magnets to the side of the mold
4. Incubate at 37 degrees Celsius for 30 minutes
5. After incubating the image using confocal reflectance microscopy

RESULTS

CurveAlign GUI

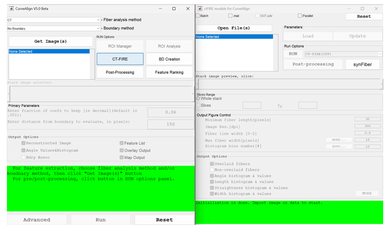

Figure 2 **| CurveAlign Graphic User Interface**

Figure 2 shows CurveAlign, a graphical user Interface used along with MATLAB to quantify collagen fiber. The software uses two methods: CT-FIRE and curvelet fiber representation CFR. In this study, CT-FIRE is used.

Collagen fiber Alignment Output

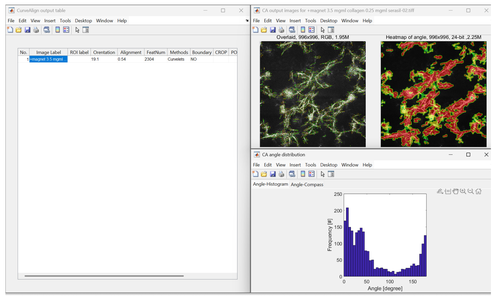

Figure 3 **| Collagen fiber alignment output from CurveAlign.**

Figure 3 shows a sample output from CurveAlign. The output involves the degree of orientation, the coefficient of alignment. The histogram shows the relative angles of fibers with the range of 0 to 180 degrees; at the top right is a heat map to show areas that are aligned.

Magnetized vs. Non-Magnetized Collagen

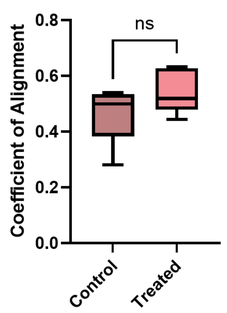

Figure 4 **| Alignment Coefficient of Magnetized vs Non-Magnetized Collagen Gels**

The box plot compares magnetized and non-magnetized collagen fiber alignment. The y-axis represents the coefficients of alignment, and the x-axis shows the control group (non-magnetized collagen) and the treated group (magnetized collagen fiber). The results of the box plot suggest that there is no significant difference between the coefficients of alignment between the magnetized and non-magnetized collagen

FUTURE DIRECTIONS

- Comparison between the coefficient of alignment between the treated and control samples shows no significant difference
    - Further parameters, such as exposure time, can be modified
- Some studies suggest that nanoparticles of different shapes affect drug uptake.
    - Spherical shapes are often used because of their high specific surface area, but other shapes, like filomicelles, have a higher drug loading capacity
- Next steps include studying different shapes of NPs and their uptake in aligned and non-aligned collagen

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[5] Figure 1 made with openAI