3D Bioprinting for Cartilage

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***Abstract*—Even though artificial cartilage is one of the hardest tissues to recreate, it is also one of the first tissues to be successful engineered. From creating scaffolds for artificial cartilage to building the cartilage by laser bioprinting or inkjet bioprinting, it has now been done and leads to great hope for the future with regenerative medicine and direct drug therapy.**

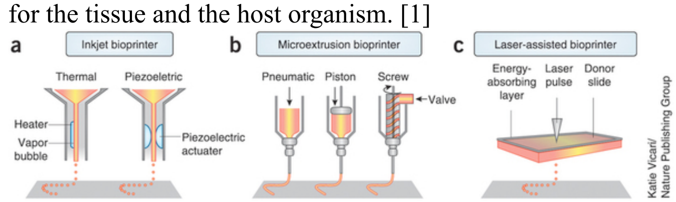
I. Introduction

TISSUE engineering has evolved from culturing cells in a cell bank and have them grow in correct environment of tissue culture to being able to bioprint tissue. Cartilage is a connective tissue that is flexible but supportive and strong at the same time because of the chondroblasts turn into chondrocytes and form a matrix of: collagen fibers, elastic fibers and proteoglycan. Cartilage is avascular, therefor it cannot regenerate itself as well as other connective tissues since there are no blood vessels to deliver the nutrients needed for repair. Today the most common treatments for cartilage repair are complex and intrusive and will not even fully repair the cartilage to become healthy tissue that will last. In the end someone may have to have cartilage repair surgery multiple times during their lifetime because it just does not last. [1] Articular cartilage covers the ends of the bones acting like a cushion between synovial joints. [2] Close to a million cases of serious injuries to articular cartilage, occur annually. [3] "While articular cartilage had been predicted to be one of the first tissues to be successfully engineered, it proved to be challenging to reproduce the complex architecture and biomechanical properties of the native tissue." [2] The artificial cartilage has to physically be able to withstand compression forces and be flexible but also remain as the same complex formation of the original articular cartilage; chemically it has to be able to grow into and connect with any original tissue that is left, also it has to be able to guide tissue formation. [2] These were the challenges the engineers had to overcome but came out with creating scaffolds for cartilage and 3D bioprinting with bioink.

II. Methods

One method for creating artificial cartilage is by designing a three dimensional polymer scaffold that would guide the tissue as it cultures and grows. Growing the scaffold in-vitro, using mesenchymal stem cells, found in bone marrow. Different chemical cues can be used to guide the cells during culturing to grow and form in the correct form and to be able to act as if it is the original cartilage, chemically and physically. [2]

Another method is by bioprinting the cartilage. The bioprinter has to be precise with no chance of placement error, print compatible biomaterials, have a cell source, and maturate the cells. When you use bioprinting the sizes of the tissues have to be under 400 micrometers because others it reaches the limit on oxygen diffusion. Another effect with bioprinting is that the cells may be damaged or altered because of the stress and heat from printing with a small nozzle head that is necessary for the high printing resolution. All you have to do is evaluate the cells for safety before you transfer them into a body. [1] There are five options for different types of bioprinters: extrusion, laser, inkjet, thermal inkjet, and piezoelectric inkjet. Extrusion is a form of contact printing, using temperature control polymerized materials for scaffolds, but it is not ideal because it has a high cell casualty rate. Laser printing has a higher cell rate and a high printing resolution but it may over dry which leads to failing in adopting back to surrounding cartilage and bones. Resulting with a low printing efficiency and higher cost for the equipment. Inkjet printing is non-contact, uses tiny bioink drops, and a combination of thermal, piezoelectric, and electromagnetism. Thermal inkjet printing uses heat to create small air bubbles that ended collapsing and creating pressure pulses which then ejects the ink out of the nozzle. The sizes of the drops affect the temperature of the printing, the frequency of the pulses and the viscosity of the ink. Instead of heat like the thermal inkjet in piezoelectric inkjet printers, polycrystalline piezoelectric ceramic is in the nozzles which causes the pressure to eject the ink drops. Using water-based bioinks allows the printers to freely place cells depending on the settings for concentration and pattern, and it is safest way for the tissue and the host organism. [1]



[4]

III. Discussion

In conclusion, inkjet bioprinting is the way to go for repairing and recreating cartilage because it can directly repair the cartilage and integrates with original cartilage of different sizes and thickness, with no additional damages. Out of the inkjet options, thermal inkjet printing because it can print both soft and hard tissues and is the most accurate with minimal side effects. The future for bioprinting will lead to optimizing scaffolds and for the use of targeted drug therapy and gene transfection.

References

[1] Gao, G., & Cui, X. (2015). Three-dimensional bioprinting in tissue engineering and regenerative medicine. *Biotechnology Letters,* 1-9. doi:10.1007/s10529-015-1975-1

[2] Camarero-Espinosa, S., Rothen-Rutishauser, B., Weder, C., & Foster, E. (2015). Directed cell growth in multi-zonal scaffolds for cartilage tissue engineering. *Biomaterials,* 42-52. doi:10.1016/j.biomaterials.2015.09.033

[3] What is Tissue Engineering. (n.d.). Retrieved October 17, 2015, from http://www.rpi.edu/dept/chem-eng/Biotech-Environ/Projects00/tissue/What is Tissue Engineering.htm

[4] Murphy, S., & Atala, A. (2014). 3D bioprinting of tissues and organs. *Nat Biotechnol Nature Biotechnology,* 773-785. doi:10.1038/nbt.2958