

Chapter 1

A Comprehensive Insights and Research Focus on Scaffolds for Meniscal Regeneration Using Additive Manufacturing

S. Sarveswaran

Sri Ramakrishna Engineering College, India

A. Kishore Kumar

Sri Ramakrishna Engineering College, India

A. Murugarajan

Sri Ramakrishna Engineering College, India

ABSTRACT

An essential component of a healthy knee joint is the meniscus. Complex fibro cartilaginous tissue called the meniscus is what keeps proper biomechanics in place. Meniscal injury is frequently associated with active lifestyles. In order to aid in the recovery of meniscal disorders, current meniscal tissue engineering and tissue regeneration research includes polymeric biomaterials, cell-based therapies, growth factors, and 3D printed hybrid scaffolds. Additive manufacturing, often known as three-dimensional (3D) printing, is able to create functional physical components with or without porosity by layer-by-layer deposition of the materials using 3D computer models. This chapter discusses the evolution of the computer-aided design (CAD) approach for creating meniscal scaffolds, as well as tips on how to optimise the internal architecture, cutting-edge materials, and manufacturing factors for the best biomimetic performance. The review study also covers the advantages and disadvantages of producing meniscal scaffolds using 3D printing technology.

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INTRODUCTION

Meniscus injuries are tragically rather prevalent despite the fact that they are generally acknowledged to be necessary for maintaining knee homeostasis. Proprioception, joint stability, force transmission, shock absorption, joint lubrication, and the preservation of the knee joint's homeostatic environment are all dependent on the meniscus. Meniscal tears can be managed surgically using a variety of techniques, such as suturing, partial or complete meniscectomy, implanting an artificial meniscus or an allogeneic meniscus, or placing a meniscal scaffold. This is due to the fact that meniscal function is lost after ripping, and this loss of function negatively affects the knee joint's health and biomechanics. Isolated meniscus tears are common in athletes and cause substantial time away from training, according to studies by Masini et al. (2015). Meniscus repair causes a greater loss than debridement. Meniscus injuries, which are typically brought on by physical trauma or ageing, have emerged as one of the most prevalent and challenging disorders affecting the knee joint, according to Walker and Erkiuan (1975). Because a torn meniscus causes persistent knee pain, a limited range of motion, and further decline that might end in knee osteoarthritis, it greatly reduces a patient's quality of life. Only the outside regions of the meniscus receive blood flow, which limits the meniscus's capacity to heal on its own. Some meniscus rips can be repaired surgically, however large or central lesions have few treatment choices. The clinical prognosis of meniscal allograft transplant, which involves replacing the damaged meniscus with a meniscus from a cadaver donor, is not adequate. Tissue rejection, a lack of functional recovery, and a constrained supply of materials are the key problems. Due to the enormous individual variations in meniscus geometry throughout the population, the meniscus geometry mismatch between the donor and the recipient considerably affects the efficiency of the replacement therapy. To overcome the limits of meniscus implantation and to maximise the restoration of meniscal function and joint integrity over time, implants with better biological potential and patient-specific size may be developed.

Meniscus Scaffolds

In regenerative medicine of the current scenario, scaffolds are most commonly used as a provisional template to promote the growth and remodelling of new tissue after implantation into a patient. Scaffolds for the meniscus regeneration from a mechanical perspective should have the following characteristics,

- (1) To function biomechanically to buffer implanted cells from damaging compressive/tensile forces.
- (2) To remain in place until adequate host tissue has regenerated at the defect site, without changing shape in any way.
- (3) Mechanical stimulation generation is the third step in the process of tissue regeneration.

The meniscal scaffolds should possess the following characteristics from a biological standpoint as

- (1) The proximity to living tissue requires that they be nontoxic and biocompatible. Also the ideal scaffold would be biocompatible.
- (2) Should have hydrophilicity and stiffness that promote cell attachment, differentiation, proliferation, cell-cell contact, and cell migration.
- (3) Be porous enough to allow cell media and growth factors to diffuse through the scaffold and reach the cells in all of its layers.

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