tissues and organs in terms of both form and function [6]. The current approaches to vascular regeneration include techniques like angioplasty and bypass procedures, in addition to applying intravascular devices such as stents, tissue-engineered vascular grafts, and non-biodegradable conduits [8]. Specific vascular forms and functionalities, however, are difficult to accomplish using traditional methods such as autologous implantation and allograft transplantation [9].

The development of techniques for vascular tissue regeneration has advanced significantly in tissue engineering in recent years. Rebuilding vascular scaffolds to direct the adherence, growth, and creation of new blood vessels is known as scaffold-based tissue engineering [10]. The intricate physiological architecture of human blood arteries, which are typified by their heterogeneous, porous, and permeable qualities, provide additional difficulties that are frequently unaddressed by conventional production techniques [11]. In response to these difficulties, 3D-printing technology has drawn a lot of interest due to its potential for creating intricate vascular scaffolds. It provides biocompatible and customizable hydrogel materials to help with the printing process, including gelatin and alginate-based hydrogels [12]. Further, advanced hydrogel-based materials have made a substantial contribution to vascular tissue engineering by offering a platform for the production of biocompatible scaffolds that closely resemble the extracellular matrix found in the body. This review aims to provide a thorough overview of the most recent developments in hydrogel design, including the use of cutting-edge biomaterials, creative manufacturing methods, and bioactive ingredients to produce next-generation vascular scaffolds.

2 Vascular tissue regeneration

Common treatments for damaged blood vessels involve using grafts made from materials like polytetrafluoroethylene (PTFE) or polyethylene terephthalate (PET). These grafts can be sourced from the patient's tissues (autografts), another person's tissues (allografts), or even animal tissues (xenografts) [13]. Although autologous grafts have several beneficial qualities, including a lengthy disintegration rate, good biocompatibility, and not being thrombogenic, accessibility is restricted since numerous recipients lack appropriate donation tissues. Synthetic grafts are applied for big-vessel implants with reduced resistance and blood circulation, resulting in minimal thrombogenicity and long-term consistency. However, if a vascular transplant is smaller than 6 mm, it can cause an immunological response and malfunction because of intimal hyperplasia, aneurysm, thrombosis, and blockage issues [14]. Hence, enhanced engineered tissue has been used as a cutting-edge method for the transplantation of vascular constructs [15].

Tissue engineering is described by the National Science Foundation (NSF) as the application of life science and engineering concepts and approaches to comprehend the fundamental relationships across the components and operations present in well-functioning and infected tissues in animals, to create artificial substitutes to preserve, enhance, or reestablish the functionality of tissues [16]. Remarkable advancements in constructed tissues are the result of innovative studies involving materials and cell-based treatments. The engineered tissue triad is made up of three primary elements: (1) scaffolds provide an environment and framework for cell growth and differentiation [17], (2) precursor cells or patients' stem cells for inducing and stimulating the intended tissue creation, as numerous studies have demonstrated the use of mesenchymal stromal cells, endothelial progenitor cells (EPCs), and bone marrow mononuclear cells (BMNC) in vascular tissue engineering [18]; (3) proliferation-stimulating compounds or biophysical enhancers have a significant impact on cellular activities. Biological, biochemical, and biophysical signals regulate pathways that influence cell adhesion, migration, differentiation, and survival [19]. Cytokine and proliferation cues can integrate with different signaling molecules and receptor production up and down, like in situ angiogenesis that is induced by VEGF and other growth stimulants [20]. After the graft is put in place, certain substances are released by specific tissues in the graft, or the patient's body produces them.

Medicinal vascular tissue engineering (VTE) targets to replicate the native vessels' functionality, including the elimination processes of byproducts of metabolism, oxygen, and nutrient exchange, and the elements of the ECM of the natural tissues, such as endothelial cells (ECs), smooth muscle cells (SMCs), bioactive molecules, stem cells, and other cell aggregates. Weinberg and Bell created the first manmade vessel in 1986 using a collagen scaffold supported by Dacron mesh and cultured bovine ECs, SMCs, and fibroblasts [21]. The significance of tissue-engineered implants utilizing human tissues was demonstrated as their transplant managed to maintain regular levels of blood pressure for a mere duration of between 3 and 6 weeks. Since then, research has been focusing on chemical alterations, biomaterials, and scaffolds that biodegrade [22].

Tissue engineering vascular grafts (TEVGs) aim to restore the function and structure of native vessels completely. It is a scaffold-free or scaffold-based approach. It involves applying self-assembled tissue cultures and a temporary scaffold that is modified, breaks down, and is subsequently substituted by neotissue, a newly created tissue with properties that are almost like those of native vasculature. The ideal degradable scaffolds should possess high porosity, be free of immune-stimulating substances, permit cellular adhesion, penetration, and growth, possess enough mechanical properties, and be able to withstand physiological stress