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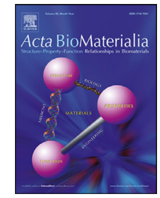

Review article

Application of textile technology in tissue engineering: A review

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A B S T R A C T

One of the key elements in tissue engineering is to design and fabricate scaffolds with tissue-like properties. Among various scaffold fabrication methods, textile technology has shown its unique advantages in mimicking human tissues' properties such as hierarchical, anisotropic, and strain-stiffening properties. As essential components in textile technology, textile patterns affect the porosity, architecture, and mechanical properties of textile-based scaffolds. However, the potential of various textile patterns has not been fully explored when fabricating textile-based scaffolds, and the effect of different textile patterns on scaffold properties has not been thoroughly investigated. This review summarizes textile technology development and highlights its application in tissue engineering to facilitate the broader application of textile technology, especially various textile patterns in tissue engineering. The potential of using different textile methods such as weaving, knitting, and braiding to mimic properties of human tissues is discussed, and the effect of process parameters in these methods on fabric properties is summarized. Finally, perspectives on future directions for explorations are presented.

Statement of Significance

Recently, biomedical engineers have applied textile technology to fabricate scaffolds for tissue engineering applications. Various textile methods, especially weaving, knitting, and braiding, enables engineers to customize the physical, mechanical, and biological properties of scaffolds. However, most textile-based scaffolds only use simple textile patterns, and the effect of different textile patterns on scaffold properties has not been thoroughly investigated. In this review, we cover for the first time the effect of process parameters in different textile methods on fabric properties, exploring the potential of using different textile methods to mimic properties of human tissues. Previous advances in textile technology are presented, and future directions for explorations are presented, hoping to facilitate new breakthroughs of textile-based tissue engineering.

1. Introduction

Many tissues in the human body do not possess the ability to regenerate, making damages to these tissues irreversible [1]. Using donated tissues is the primary method to repair these damages. However, the number of people on the waiting list for transplantation is growing due to the ever-increasing aging population and the shortage of organ donors. In the United States alone, more than 100,000 people are on the National Transplant Waiting List [2]. To address this critical medical demand, researchers in tissue engineering fields have proposed to fabricate artificial tissues that can be implanted into the human body as an alternative option. The artificial tissues require a 3-dimensional (3D) framework, or a scaffold, to provide structural integrity and a suitable microenvironment for cell growth.

One of the key elements in tissue engineering is to design and fabricate scaffolds with tissue-like properties. Various methods such as freeze-drying [3], 3-dimensional (3D) printing [4], self-assembling [5], and textile technology [6] have been used in fabricating scaffolds. Among them, textile technology, as the most ancient technique with a history of over 30,000 years [7], has shown its unique advantages in mimicking the hierarchical structure and the anisotropic and strain-stiffening properties of human tissues.

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Fibers with cells or bioactive cues can be assembled into textile-based scaffolds using different textile methods such as weaving, knitting, and braiding [6,8,9]. In addition, the textile-based scaffolds can be fabricated into various patterns to mimic the structures and properties of various tissues.

There are several excellent reviews of textile-based tissue engineering [6,10–13]. However, most of them mainly focused on the application of textile technology in different tissue engineering applications and did not systematically categorized process parameters during textile processes and summarized their effects on scaffold properties. Liberski et al. have systematically categorized process parameters in weaving, but not included knitting and braiding [13]. Jiao et al. made a comprehensive review about textile patterns and structure-property relations of textile-based scaffolds [14]. However, they mainly focused on structural factors that influence cell behaviors, the effect of process parameters on the physical and mechanical properties of textile-based scaffolds have not been systematically summarized. This review primarily focuses on the applications and potentials of various textile patterns in tissue engineering and summarizes the effect of process parameters on scaffold properties. The following subjects will be included:

- An overview of the development of three textile methods, i.e., weaving, knitting, and braiding
- A discussion of the advantages of textile-based scaffolds
- An overview of great advances in cell-laden fibers, smart textiles, and textile machines
- An overview of 2-dimensional (2D) and 3-dimensional (3D) woven patterns and their applications and potentials in tissue engineering
- An overview of basic and advanced knitted patterns and their applications and potentials in tissue engineering
- An overview of solid and hollow braided patterns and their applications and potentials in tissue engineering
- A discussion of the effects of critical process parameters in weaving, knitting, and braiding on fabric properties
- An overlook of future directions of textile technology for use in tissue engineering

2. Textile methods

A "textile", from the Latin adjective *textilis* meaning "woven", is a flexible material comprised of an interlacing network of fibers commonly used in cloth and baskets [10]. Now textile technology extends beyond weaving (e.g., knitting, braiding) and has been used in a range of applications, including biomedical devices [12], electronics [15], and aircraft [16]. Applying textile technology to tissue engineering has attracted great attention because various textile patterns and their corresponding properties have shown the potential to mimic the properties of different human tissues. This section will review the development of conventional textile methods and discuss the advantages of applying textile technology to tissue engineering.

2.1. Conventional textile methods

2.1.1. Weaving

Weaving is one of the most ancient textile techniques for creating cloth and baskets, dating back to over 30,000 years [7]. The weaving process can be accomplished with a handloom (Fig. 1a) or a power loom (Fig. 1b). Over the long history of weaving technology, the weaving process, including shedding, picking (filling), beating-up, take-up, and let-off (Fig. 1c), has been mostly unchanged [17]. By changing the shedding motion, various woven patterns such as plain, twill, and satin can be produced.

Traditional woven fabrics are 2-dimensional (2D) with limited applications outside the garments industry. The development of 3-dimensional (3D) weaving in the 1970s has expanded the use of woven textiles into other industries such as aircraft and automobiles. 3D woven fabrics can be fabricated using conventional weaving looms (Fig. 1d). However, the fabricated 3D woven fabrics have limited thickness, and the weaving process can be slow with low throughput [18]. Weaving thick and complex 3D structures requires specialized 3D weaving machines [19]. An example is the 3TEX weaving machine (Fig. 1e) with high throughput and can also fabricate 3D structures with complex cross-sections [18].

The application of woven fabrics, especially 3D woven fabrics, has been extended into biomedical and industrial areas. 3D fiber-reinforced composite weaving technology has been widely used in aircraft [20]. Weaving sensing fibers into electrochemical cloth has gained increasing interest in biomedical fields for monitoring health conditions [21].

2.1.2. Knitting

Knitting is the next major textile technique invented after weaving, dating back to the 5th century. Knitted fabrics feature interlacement of loops of yarn. Various knitted patterns developed in the history of knitting still attract great attention of researchers nowadays. A European Union-funded research project, Knitting in Early Modern Europe (KEME), focuses on knitted caps from the 15th to 17th centuries and aims to expand the knowledge of the origins and development of knitting [23].

Knitting can be categorized into weft and warp knitting. In weft knitting, the yarn travels horizontally (Fig. 2a), which can be performed on flat (Fig. 2b) and circular knitting machines (Fig. 2c). In warp knitting, the yarn travels vertically (Fig. 2d), which can be performed on Tricot (Fig. 2e) and Raschel machines (Fig. 2f).

The application of knitted fabrics has been extended into biomedical areas. Knitted fabrics can be used as medical dressings and have the advantages of good breathability and a great sense of comfort [24]. Knitting fabrics have also been used as implantable textiles, such as cardiac support devices and expandable metallic stents [24].

2.1.3. Braiding

Braiding can be traced back to 5000 years ago and was initially used in making ropes and hairstyling. Braided fabrics have cylindrical or flat structures intertwined by three or more yarns. In the long history of braiding, braided fabrics were predominately manufactured by hand. Braiding machines (Fig. 3a) that emerged during the industrial revolution can fabricate structures with complex cross-sections that cannot be made by hand [27].

The application of braided fabrics has been extended into biomedical and industrial areas. Braided sutures (Fig. 3b) and braided vascular stents have been widely used in clinics. Braided wires are often used as an electromagnetic shield because of their high mechanical strength and flexibility (Fig. 3c).

2.2. Textile technology in tissue engineering

2.2.1. Advantages of textile-based Scaffolds

In recent years, biomedical engineers have used textile technology and 3D printing to address the current limitations in tissue engineering [10]. 3D printing, including inkjet, extrusion, laser-assisted, and stereolithogarphy printing, is adaptive to a wide range of biomaterials and can fabricate tissues with patient-specific geometry [28,29]. Compared with 3D printing, textile technology has its unique advantages in mimicking the hierarchical structure, anisotropic property, and strain-stiffening property of human tissues.

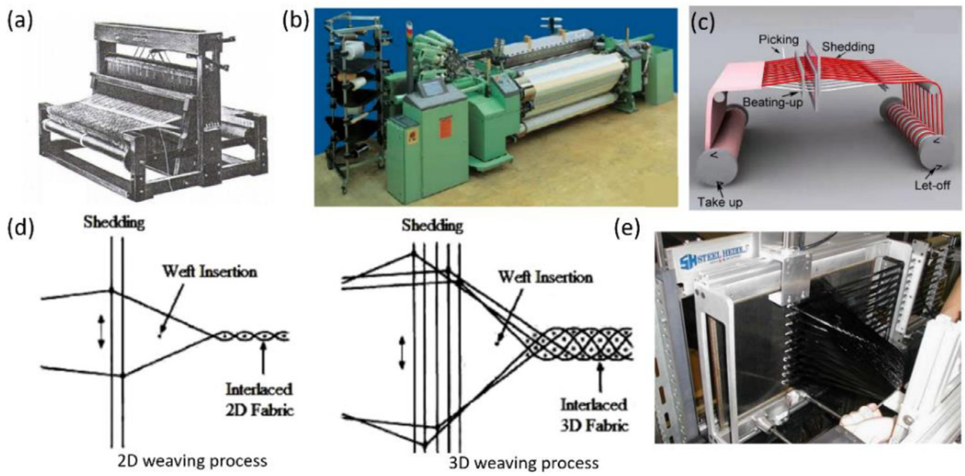

Fig. 1. Different types of weaving machines and techniques (a) A hand weaving loom. (b) A power weaving loom. (c) Basic loom motions in weaving. (a) - (c) reproduced with permission. Copyright 2018, Fiber2Apparel. (d) Comparison of the 2D weaving process and 3D weaving process. Reproduced with permission [22]. Copyright 2001, Taylor & Francis. (e) 3TEX weaving machine (Gardner Business Media, Inc.). Reproduced with permission [18].

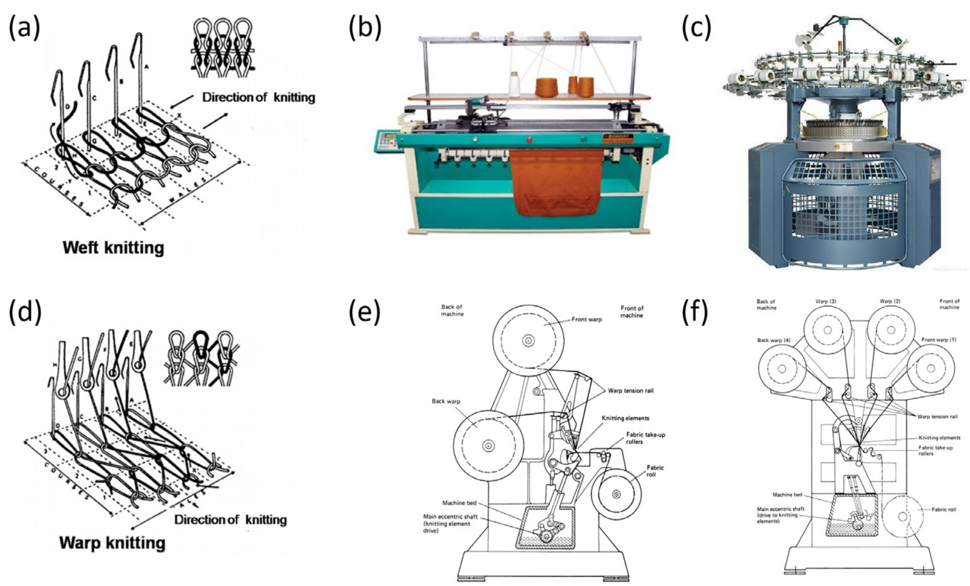

Fig. 2. Different types of knitting techniques and machines (a)Weft knitting. Reproduced with permission [25]. Copyright 2000, Elsevier. (b) Flat knitting machine. Reproduced with permission. Copyright 2019, Bharat Machinery Works. (c) Circular knitting machine. Reproduced with permission. Copyright 2020, Bharat Machinery Works. (d) Warp knitting. Reproduced with permission [25]. Copyright 2000, Elsevier. (e) Tricot knitting machine. Reproduced with permission [26]. Copyright 2001, Elsevier. (f) Raschel knitting machine. Reproduced with permission [26]. Copyright 2001, Elsevier.

Fibers made of natural materials (e.g. silk fibers (SF) [30–35], collagen [36,37], and alginate [38]) and synthetic materials (e.g. PCL [39–43], PGA [44], PLLA [45–48], PLGA [49,50], PLA [51–54], and PAN [55,56]), can both be assembled into textile-based scaffolds with different mechanical properties using different textile methods (Fig. 4).

These textile-based scaffolds have several advantages over scaffolds fabricated by other methods. Firstly, textile-based scaffolds can mimic the hierarchical structure of human tissues (Fig. 5a and 5b). The hierarchical element in the form of fibrous structures in textile-based scaffolds is different from that in the form of porous structures in 3D printed scaffolds and has advantages in mimicking fibrous structures present in the extracellular matrix of human tissues [57–59]. For example, textile yarns can be made into the fibers–singles–ply–cord structure strongly mimicking the collagen molecule–triple helix–collagen fibril–bone unit structure of bone tissues [60].

Secondly, textile-based scaffolds can mimic the anisotropic property of human tissues (Fig. 5c and 5d) [55]. Many human tissues, including the blood vessel, nerve, muscle, and heart wall, exhibit anisotropic mechanical behavior that could be mainly attributed to the variations in the distribution of collagen fibers in these tissues [61]. Knitted scaffolds have intrinsic anisotropic properties. Woven scaffolds can also have anisotropic properties by using different wefts and warps [42]. For 3D printed scaffolds, the mechanical anisotropy is often caused by the weak interlayer bonding and is represented by lower tensile strength and impact resistance in Z-direction [62,63].

Thirdly, textile-based scaffolds can mimic the strain-stiffening property of human tissues (Fig. 5e and 5f). Human tissues have a strain-stiffening property, which can be represented by a tri-phasic stress-strain curve (toe region, linear region, and yield region) (Fig. 5e) [64–67]. The toe region can prevent tissues from mechanical trauma, so it is a critical criterion when designing scaffolds.

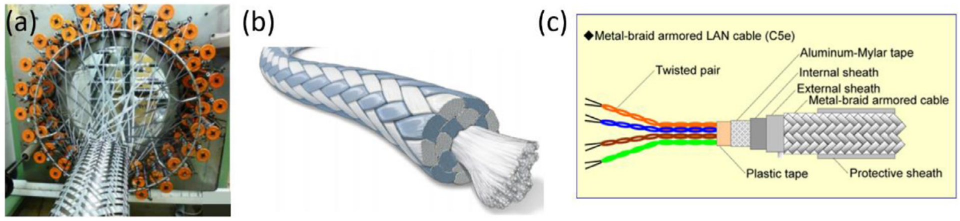

Fig. 3. (a) A braiding machine (Cobra Braiding Machinery Ltd). Reproduced with permission. (b) Structure of braided suture FireWire® (Arthrex, Inc.). Reproduced with permission. (c) Braided wires (Oki Electric Cable Co., Ltd). Reproduced with permission.

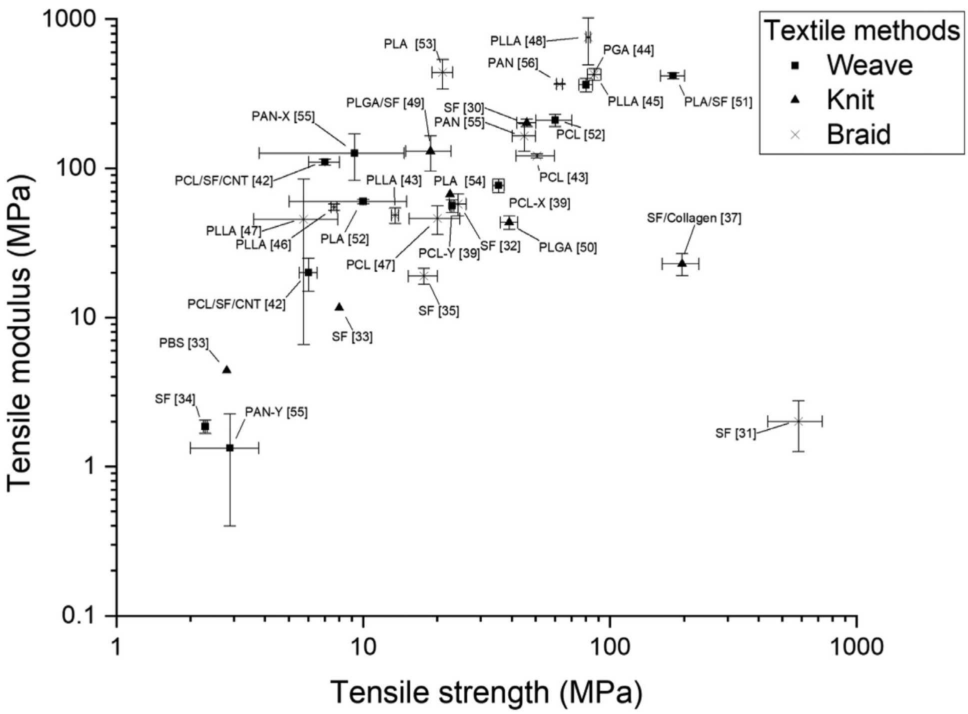

Fig. 4. Review of textile-based scaffolds' mechanical properties using different materials (-X and -Y: wale and weft directions of weaving scaffolds).

However, most synthetic biopolymers have a strain-softening property [68,69]. Theoretical studies have shown that human tissues' strain-stiffening property is associated with collagen and other fibrillar proteins' helical structure [70,71]. Textile-based scaffolds, featuring fiber corrugation structures, have the strain-stiffening property [211]. In addition, the toe region in their stress-strain curves can be modulated by changing parameters such as the number of braiding yarns [46], and yarns twisting level [48], to satisfy the requirements of different tissues. Using dual-material designs of embedding micro-structured reinforcement in a soft matrix, a 3D-printed scaffold can also have the strain-stiffening property [68]. However, its strain-stiffening property is highly dependent on how the different materials interface with each other which is decided by the properties of the materials involved and the printing conditions [72].

2.2.2. Cell-laden fibers for textile-based Scaffolds

Currently, most researchers use a top-down approach when fabricating textile-based scaffolds. Researchers assemble cell-free fibers into scaffolds and then seed cells on scaffolds to avoid damaging the cells during the textile process [8]. However, this approach makes researchers unable to control cell distribution in a 3D textile-based scaffold. The cells mostly rely on cell migration to occupy the inner parts of scaffolds, which is an inefficient process that is limited to a short travel distance. To address this limitation, researchers proposed a bottom-up approach by directly assembling cell-laden fibers into textile-based scaffolds.

Different designs of cell-laden fibers have been proposed for fabricating textile-based scaffolds. Cell-laden fibers can be fabricated by seeding cells [55,75] or coating cell-laden hydrogels on fibers (Fig. 6a) [76–78]. These types of cell-laden fibers have high mechanical strength. In addition, the surface morphology, porosity, cross-sectional shape, and material composition of fibers can be controlled to promote cell adhesion and regulate cell differentiation [78–80]. However, the exposed cells are vulnerable to harsh textile processes, and cell-laden hydrogel can be easily peeled off. Cell-laden fibers can also be fabricated by encapsulating cells in the core of fibers (Fig. 6b) [81–83]. This type of cell-laden fibers can protect encapsulated cells during textile processes. Hydrogels are often used as the outer shell to maintain the high viability of cells in the core. This type of encapsulated cell-laden fibers tends to have low mechanical strength and can only be used in simple textile patterns [84–86].

A promising design of cell-laden fibers is the multi-component heterogeneous cell-laden fibers [87]. Edward Kang et al. used a microfluidic platform consisting of digital, programmable flow control to fabricate fibers with tunable morphological, structural, and chemical features [88]. Different materials and cells and their dis-

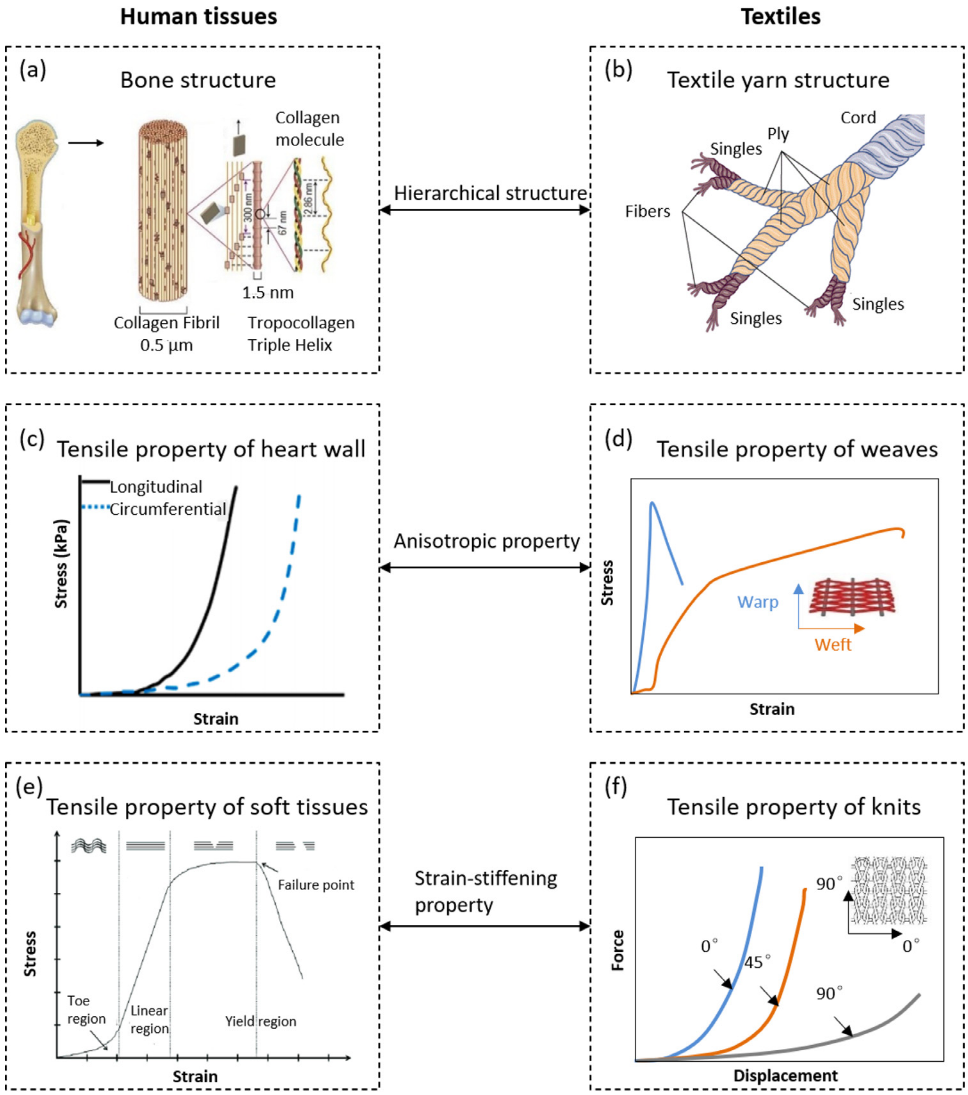

Fig. 5. Similar properties between human tissues and textile-based scaffolds. Hierarchical structure: (a) Bone structure. Reproduced with permission [60]. Copyright 2016, Elsevier. (b) Textile yarn structure. Reproduced with permission. Copyright 1994, Encyclopædia Britannica. Anisotropic property: (c) Tensile property of the heart wall. Reproduced with permission [73]. (d) Tensile property of weaves. Reproduced with permission [42]. Copyright 2017, American Chemical Society. Strain-stiffening property: (e) Textile property of soft tissues. Reproduced with permission [64]. Copyright 2011, InTech. (f) Tensile property of knits. Reproduced with permission [74].

tribution in fibers can be precisely controlled using this method, allowing greater accuracy in mimicking the heterogeneity of human tissues.

2.2.3. Smart textiles in biomedical engineering

Electronic components have been integrated into textile structures to impart smart functionalities such as sensing, monitoring, energy storage, and information processing [89]. To integrate electronic components into textiles, researchers have created conductive fibers by coating conductive materials on fiber surfaces [90], encapsulating conductive materials in fiber core [90,91], or embedding conductive materials in fiber matrix [92,212].

Smart textiles are being broadly developed in the field of sports and military defense [93,94]. Recently, they have been applied in biomedical engineering. Smart textiles are opening new scenarios in the field of diagnostics, pushing healthcare out of hospitals. For example, textile-based strain sensors have been used to monitor respiration [95–97] or other human motions [98–100], facilitating the diagnosis of respiratory diseases and rehabilitation after injury. Electrochemical textiles have been used to analyze sweat metabolites, enabling a more comprehensive analysis of health conditions of human body [21].

2.2.4. Textile machines for tissue engineering applications

The majority of existing textile-based scaffolds are fabricated manually [76], especially woven [38,42,101] and braided scaffolds [46,48]. This leads to low controllability and productivity when fabricating textile-based scaffolds. Efforts have been made to directly use or modify existing industrial textile machines to fabricate scaffolds [102–104]. These efforts have resulted in improved controllability and productivity of the fabrication process, but the variety of fabricated patterns is still limited to basic types. Developing advanced textile machines with computer-aided design (CAD) systems (Fig. 7a) [105] or deep learning-based pattern design software (Fig. 7b) [106] will benefit the design and fabrication of textile-based scaffolds.

With the increasing attention on the bottom-up approach in tissue engineering, researchers should focus on developing specialized textile machines for cell-laden fibers. Factors including the sanitary condition, temperature control, gentle manipulation, and

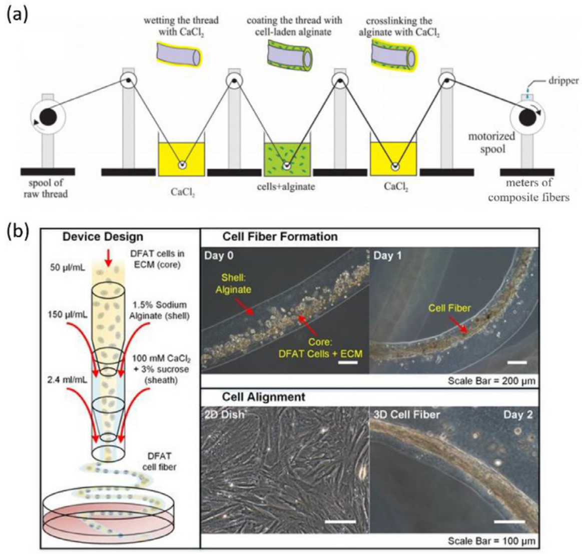

Fig. 6. (a) Schematic of an experimental setup to coat cell-laden hydrogel on a thread. Reproduced with permission [76]. Copyright 2014, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. (b) Schematic of the microfluidic device to encapsulate cells into the core of alginate fibers. Reproduced with permission [83]. Copyright 2015, Hsiao et al.

even the ability to operate in a bath need to be considered during the development process. Hiroaki Onoe et al. proposed a microfluidic handling tool for manipulating cell-laden fibers in a bath [85], providing insight into designing robust textile machines for tissue engineering applications.

3. Woven patterns and process parameters

3.1. Woven patterns

Weaving is a process in which two distinct yarn sets are interlaced at right angles. One of the yarn sets is warps, which run along the length of the woven fabric. Another yarn set is wefts, which pass through warps in the lateral direction (Fig. 8a). Some more intricate woven patterns, such as triaxial weave, use neither warps nor wefts. This section will review both 2-dimensional (2D) and 3-dimensional (3D) woven patterns.

3.1.1. 2D woven patterns

A basic woven pattern is a plain in which each weft passes over one warp and then under the following warp, with the trend reserved in the following row (Fig. 8a). The simplicity of the plain pattern does not hinder researchers from adjusting fabric properties. For example, by changing the weaving density of warps and wefts, researchers can control fabrics' strength, stability, and porosity [108]. These properties will then have an impact on the degradation rate and cell distribution of scaffolds. Researchers can also use different materials for warps and wefts to mimic the anisotropic property of bone [52] and cardiac tissues [102]. Heavyweight yarn is often used to create a raised rib in the fabric to mimic striated tissues such as cardiac muscles [109] and skeletal muscles [110].

Twill and satin patterns are two modifications of the plain pattern. In twill, a weft passes over and under multiple warps in an alternating sequence to create a diagonal pattern on the fabric surface (Fig. 8b). In satin, a warp floats over four or more wefts and then passes under one weft before repeating the process (Fig. 8c). Twill and satin fabrics have lower stability than plain fabrics. However, twill and satin fabrics have higher tear strength because the yarns can easily move and bunch together [111,112], which is similar to the high fracture resistance of human soft tissues [113]. Another important characteristic of satin fabrics is their asymmetry. Warps are predominantly on the satin face, while wefts occupy most spaces on the opposite side called the sateen face. The asymmetry can be very useful when wefts and warps differ in their cell affinity or mechanical properties and provide two sides of the fabric with distinctive properties [13].

Some novel patterns, such as the leno and triaxial woven patterns, have also gained growing importance in technical textiles. In leno, two warps twist and grip tightly around the weft (Fig. 8d). This twisted-yarn structure makes leno fabrics more stable than plain fabrics. In triaxial, three yarn sets are interlaced in three directions, 0° and ±60° (Fig. 8e). Another similar pattern is a tetra-axial pattern consisting of four sets of yarns inclined at 45° to each other. The intersections of triaxial and tetra-axial fabrics are locked to optimize their shear resistance and make them good candidates for constructing scaffolds for cardiac tissues [13].

Two-dimensional (2D) woven fabrics, especially plain fabrics, have been used as scaffolds in tissue engineering [34,38,42,52,101]. To improve the biocompatibility and thickness of 2D woven fabrics, hydrogels can be integrated with woven fabrics (Fig. 8f and 8g) to fabricate composite scaffolds [34,42,102]. However, such composite scaffolds tend to delaminate into layers and cannot be applied to tissues that experience multidirectional stresses. Using 3-dimensional (3D) weaving for scaffold fabrication can address some of these limitations.

3.1.2. 3D woven patterns

The most widely used 3D woven patterns are multilayer, angle interlock, and orthogonal patterns. The multilayer pattern consists

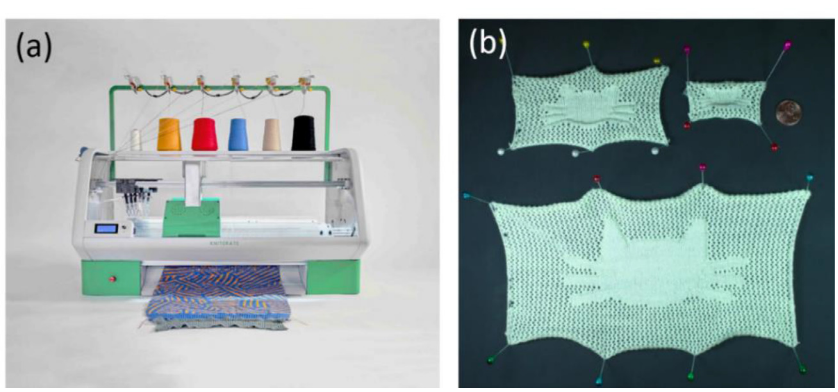

Fig. 7. (a) A computer-aided knitting machine (Kniterate). Reproduced with permission. (b) A knitted fabric made with the aid of AI-based knitting design software. Reproduced with permission [107]. Copyright 2019, ACM, Inc.

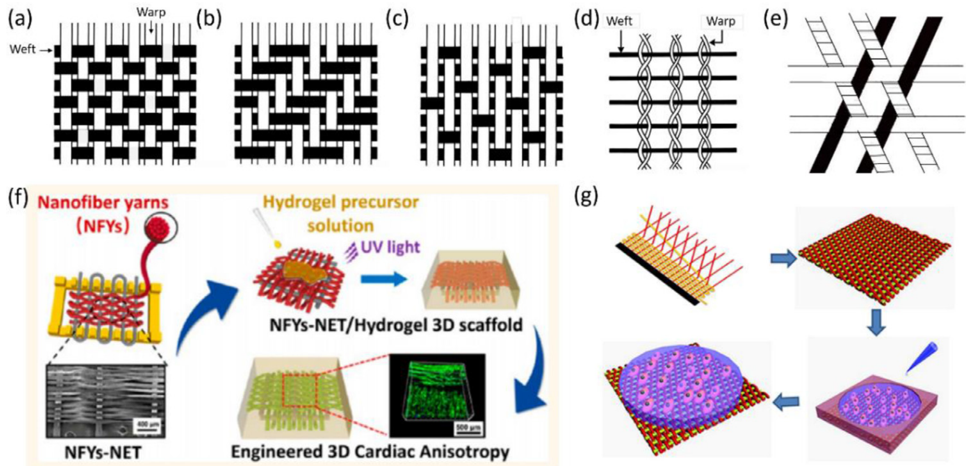

Fig. 8. The 2D woven patterns of (a) plain, (b) twill, (c) satin, (d) leno, and (e) triaxial weaving. (f) A composite scaffold fabricated by integrating hydrogel with woven fabrics for cardiac tissue engineering. Reproduced with permission [42]. Copyright 2017, American Chemical Society. (g) A composite scaffold fabricated by integrating cell-laden hydrogel with woven fabrics for heart valve engineering. Reproduced with permission [102]. Copyright 2017, Elsevier.

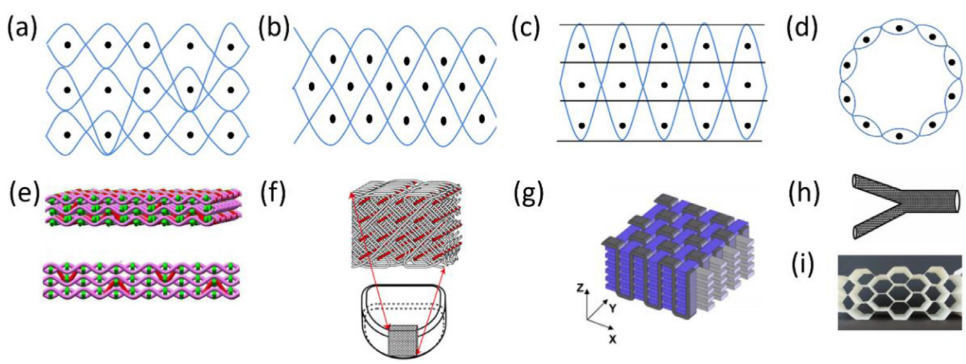

Fig. 9. The 3D woven patterns of (a) multilayer, (b) angle interlock, (c) orthogonal, and (d) tubular weave. (e) A bone scaffold with multilayer woven patterns. Reproduced with permission [51]. Copyright 2016, Elsevier. (f) An intervertebral disk scaffold with angle interlock woven patterns. Reproduced with permission [116]. Copyright 2010, Elsevier. (g) A cartilage scaffold with orthogonal woven patterns. Reproduced with permission [126]. Copyright 2010, Elsevier. (h) A tubular weave with bifurcated structures. Reproduced with permission [127]. Copyright 2013, The Textile Institute. (i) A tubular weave with honeycomb shapes. Reproduced with permission. Copyright 2020, 3D Weaving.

of multiple layers, each of which has its own sets of warps and wefts (Fig. 9a). Different layers are connected by self-stitching existing yarns or external sets of yarns. The angle interlock pattern consists of layers of straight wefts and a set of crimping warps (Fig. 9b) that either run through-thickness or run from one layer to the adjacent layer of wefts. The orthogonal pattern consists of three sets of yarns perpendicular to each other (X, Y, Z yarns, Fig. 9c). The Z yarns interconnect all individual warps and wefts to solidify the fabric. The angle interlock pattern enhances delamination resistance [114], and the orthogonal pattern has high through-thickness elastic and strength properties [115].

3D woven patterns have been used in tissue engineering. Weili Shao et al. used the multilayer pattern to fabricate a bone scaffold with its Young's modulus and tensile strength 2- and 4-fold higher than those of nonwoven scaffolds (Fig. 9e) [51]. Yasuo Shikinami et al. used the angle interlock pattern to fabricate an intervertebral disk scaffold exhibiting biomimetic 'J-shaped' stress-strain behavior (Fig. 9f) [116]. Franklin T. Moutos et al. used the orthogonal pattern to fabricate bone scaffolds (Fig. 9g) [39,40,44] and demonstrated that the 3D structure could promote higher production of the mineralized bone matrix than 2D substrates [117,118].

Another type of 3D woven pattern is the tubular weave characterized by hollow spaces (Fig. 9d). The hollow spaces can be customized in shapes such as circular and honeycomb shapes. The tubular weave with a circular shape has been used as vascular scaffolds [119–122], and bifurcated structures made of tubular weave with circular shapes can mimic vascular systems in the human body (Fig. 9h) [123]. The tubular weave with a honeycomb shape (Fig. 9i) can be used in cardiac tissue engineering as scaffolds with honeycomb structures have been shown to promote heart cell alignment and mimic mechanical properties closely resembling human myocardium [124].

3D woven fabrics are durable and ideal for scaffolds that require long-term load-bearing because they are flexible enough to move with the body's natural motions without delamination [125]. Different densities of yarns can be used in 3D woven fabrics to enhance controlled porosity and create special reinforcement zones [44]. Hydrogel or cell-hydrogel mixture can be integrated with 3D woven scaffolds to improve their biocompatibility [40,44].

3.2. Process parameters

Understanding the effect of process parameters on fabric properties is crucial to improve the controllability of weaving. This section will discuss the effect of two process parameters in weaving, yarn twist level and weaving density, on fabric properties (Table 1).

3.2.1. Yarn twist level

As the building block of textile fabrics, yarn properties can significantly affect fabric properties. An important factor is the twist level of the yarn, defined as the number of twists per unit length.

Table 1
Effects of various process parameters on the properties of woven fabrics.

	Yarn twist level	Weaving density (PPI)
Air permeability	↗↘	↘
Stiffness	↘	↗
Tear strength	N/A	↘
Tensile strength	↗↘	↗
Modulus	↘	↗

Parham Soltani et al. showed that the yarn twist level could affect fabric air permeability within a certain threshold [128]. In their study, fabric air permeability increased as the yarn twist level increased. However, when the twist level exceeds 780 twists per meter (tpm), fabric air permeability decreased slightly as the twist level increased. Increasing the yarn twist level will increase yarn compactness and the void fraction of the fabric, leading to increased air permeability. As the yarn twist level went beyond a certain threshold, yarn will start to have fiber breakage with increased yarn hairiness resulting in a partial reduction of fabric air permeability.

The yarn twist level also affects the mechanical properties of fabrics. Baets et al. found that the fabric stiffness decreased from 63 GPa to 43 GPa with the introduction of 19° twisted yarns compared to the fabric made with twistless yarns [129]. A critical yarn twist level also exists for tensile strength. Ma et al. found that as the yarn twist level increased, fabric tensile strength first increased and then decreased after a critical twist level (90 tpm) was reached [130].

As one of the essential process parameters in weaving, the yarn twist level can significantly influence the performance of woven scaffolds. Optimizing twist level can enhance the intrinsic solidity of yarns and improve the weaving process. However, a higher-than optimal-twist level can probably increase the internal stress of yarns and negatively affect the mechanical properties of scaffolds [131]. Thus, an optimum yarn twist level should be determined when fabricating woven scaffolds.

3.2.2. Weaving density

The fabric density is defined as the number of yarns in a square inch. For woven fabrics, there are two types of density: warp density and weft density. Warp density is usually quantified as ends per inch (EPI), i.e., the number of wraps per inch, and weft density as picks per inch (PPI), i.e., the number of wefts per inch. Since EPI is usually fixed by the type of weaving loom used, PPI is the parameter altered during the weaving process to customize the properties of woven fabrics.

Changing the weaving density (PPI) can affect the morphologies of woven fabrics. Increasing the weaving density will decrease the air permeability as the structure becomes tighter [132,133]. Manipulating air permeability using this method allows the optimization of the nutrient exchange performance of woven scaffolds in tissue engineering applications.

Weaving density also affects the mechanical properties of woven fabrics. Increasing weaving density can increase the fabric stiffness. Gadah et al. showed that increasing weaving density from 61 to 80 PPI led to increased fabric stiffness by 30%, 58%, and 48% for plain, satin, and twill patterns, respectively [132]. Ching-Wen Lou et al. revealed that increased weaving density led to decreased tear strength and increased tensile strength and modulus [133–135].

Various 2D and 3D woven patterns provide great potential to customize the properties of woven scaffolds for different tissue engineering applications. However, the versatility of woven patterns has not been fully explored, and the effect of process parameters on woven scaffold properties has not been systematically investigated. Future studies should explore more textile patterns in scaffold fabrication and understand the correlations and interactions between these patterns and scaffold properties.

4. Knitted patterns and process parameters

4.1. Knitted patterns

Knitting is a process in which yarns are drawn through a previous loop to form interconnected loops. Rows running across the width of knitted fabrics are called courses, and columns running along the length of knitted fabrics are called wales (Fig. 10a). Unlike woven fabrics, knitted fabrics can be stretched, making them suitable for soft tissue engineering. Furthermore, the high porosity of knitted fabrics provides a favorable environment for nutrient exchange and cell proliferation. This section will review both basic and advanced knitted patterns.

4.1.1. Basic knitted patterns

Basic knitted patterns include knit and purl loops (Fig. 10b), which mirror each other. Purl loops are knit loops flipped over viewed from the other side. Fabrics in which one side is all knit loops, and the other side is all purl loops, such as stockinette stitch, tend to curl, while those in which knit and purl loops are arranged symmetrically, such as ribbing, garter, and seed stitches, tend to lie flat (Fig. 10b) [136]. These stitches can be used to fabricate scaffolds for tissues with curved structures such as heart valves (cusp, annulus, and sinus) [137].

Derivatives of the basic knitted patterns are float and tuck stitches. A float stitch is produced when a needle holding its old loop fails to receive the new yarn that passes, forming a float loop (Fig. 10c). Float stitches reduce the fabric width, as the stitches will draw wales closer together compared to knit stitches, reducing width-wise elasticity and improving fabric stability. A tuck stitch is produced when a needle receives the new loop but not intermeshed through the old loop (Fig. 10d). Tuck stitches reduce fabric length, as they rob yarn from adjacent loops, reducing length-wise elasticity and improving fabric stability. Using float and tuck stitches will enable the fabrication of knitted fabrics with different porosity and mechanical properties (Fig. 10e) [24].

Knitted fabrics have been used in tissue engineering because of their excellent elasticity and great variety [33,55,138–141]. However, the large pore size of knitted fabrics is unsuitable for cell seeding. To improve cell attachment and proliferation on knitted fabrics, researchers have integrated cell sheets [142,143], collagen [103,144–147], silk sponges [148,149], chitosan [150], or electrospun fibers [30,104,151] into fabrics to fabricate composite scaffolds (Fig. 10f, 10g, and 10h) with good mechanical properties and biological properties. However, current studies on this type of composite scaffolds have only employed basic knitted patterns. Using more advanced knitted patterns will greatly broaden the applicability and fulfill the potential of knitted fabrics in tissue engineering.

4.1.2. Advanced knitted patterns

An innovative aspect of knitting is its capability of coding, as different yarns or patterns can be knitted in a single fabric. For example, jacquard knitting can create a fabric consisting of several types of yarns (Fig. 11a) with the potential to precisely control cell growth on knitted fabrics. Another example is seamless knitting, combining different knitted patterns into a fabric (Fig. 11b). It can be used to fabricate scaffolds for connective tissues with two sections of different properties. However, seamless knitting requires advanced manual skill and experience, limiting its controllability and productivity [153].

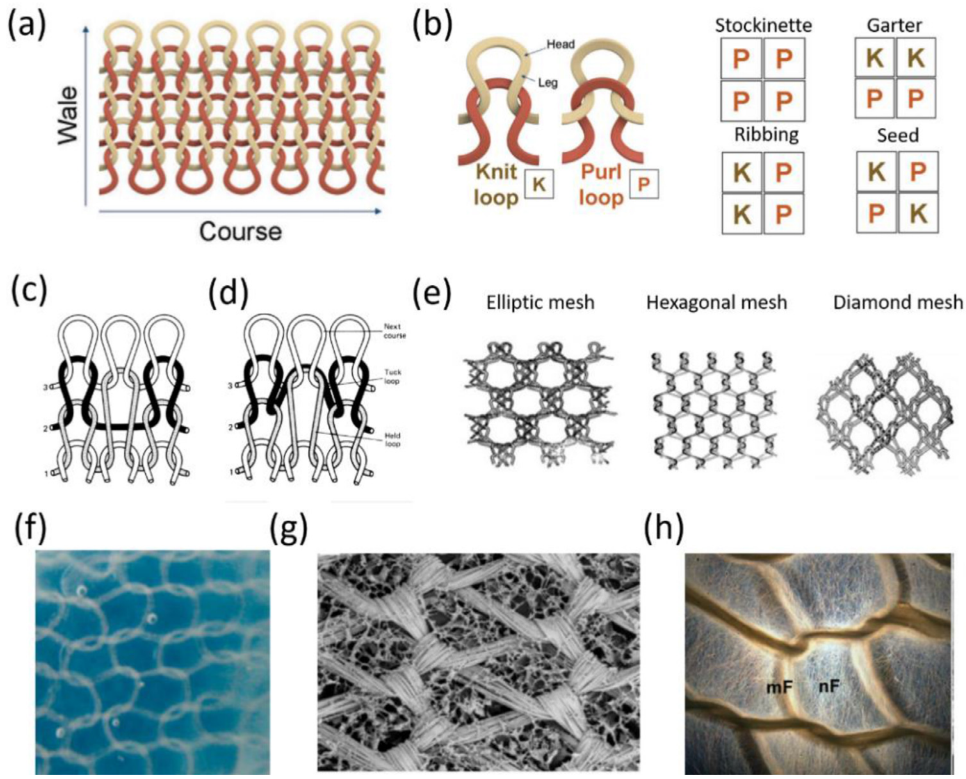

Fig. 10. (a) A knitted fabric with the top side of knit loops. Reproduced with permission [136]. Copyright 2017, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. (b) Basic knit patterns. Reproduced with permission [136]. Copyright 2017, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. (c) Float stitches. Reproduced with permission [152]. Copyright 2000, Woodhead Publishing Ltd. (d) Tuck stitches. Reproduced with permission [152]. Copyright 2000, Woodhead Publishing Ltd. (e) Some examples of knitted patterns. Reproduced with permission [24]. (f) A composite scaffold by integrating cell sheets and knitted fabrics for ligament tissue engineering. Reproduced with permission [142]. Copyright 2005, Wiley Periodicals, Inc. (g) A composite scaffold by integrating collagen sponge and knitted fabrics for skin tissue engineering. Reproduced with permission [144]. Copyright 2000, The Royal Society of Chemistry. (h) A composite scaffold by coating electrospun nanofibers (nF) on knitted microfiber (mF) for connective tissue engineering. Reproduced with permission [104]. Copyright 2010, Wiley Periodicals, Inc.

3D knitted fabrics have shown their advantages in tissue engineering. Tubular knitting (Fig. 11c) has been widely used to fabricate scaffolds for tissues such as urethras [154], muscles [155], bones [54,156], hearts [157], nerves [158], and vessels [159,160]. 3D knitted fabrics can also be fabricated by joining 2D sections. These sections are cut into desired shapes and outlines, and then assembled into a 3D fabric (Fig. 11d) [161].

Knitted fabrics with a negative Poisson ratio or Auxetic properties have also increased importance in tissue engineering. When stretched, a scaffold having a negative Poisson ratio becomes thicker perpendicular to the applied force. Knitted fabrics with rotational rectangle structures [162], re-entrant hexagon structures [162], or compacted V structures (Fig. 11e) [163] have auxetic properties. Such fabrics, having high energy absorption and fracture resistance, can be used to repair load-bearing tissues [164]. They can also be used to repair tissues with auxetic properties such as arteries [165], tendons [166], and annulus fibrosus of the intervertebral disk [167]. In addition, they can be used to load drugs (Fig. 11f) or growth factors, which can be released under extension.

4.2. Process parameters

Although different knitted patterns have different properties, there are some common parameters affecting fabric properties. This section will discuss two process parameters, knitting density and number of yarn plies, and their effects in knitting, knitting density, and the number of yarn plies, on fabric properties (Table 2).

Table 2
Effects of process parameters on properties of knitted fabrics.

	Knitting density		Number of yarn plies
Pore size	↘	↘	
Tensile stress	Vertical	↘↗	↗
	Horizontal	↗↘	
Stiffness	↘	↘	
Tear strength	↗	↗	
Bursting stress	↗	↗	

4.2.1. Knitting density

Knitting density measures the closeness of the intermeshing loops and is defined as the number of stitches per unit area or the number of courses/wales per length.

The relationship between knitting density and tensile stress is not monotonic. The tensile stress of knitted fabrics includes vertical stress and horizontal stress. The stress in the wale direction is always higher than that in the course direction because the knitted fabric is connected by loops along the wale direction but connected by overlaps along the course direction, with the stress of connected loops greater than connected overlaps. Wanli Xu et al. found the vertical stress decreased initially and then increased while the horizontal stress increased initially and slightly decreased with an increase in knitting density [169].

For knitted scaffolds used for vascular or cardiac tissues, bursting stress is a key factor in resisting these tissues' internal pressure. Bursting stress increases linearly with an increase in knitting density because of the decreased loop length [169,170].

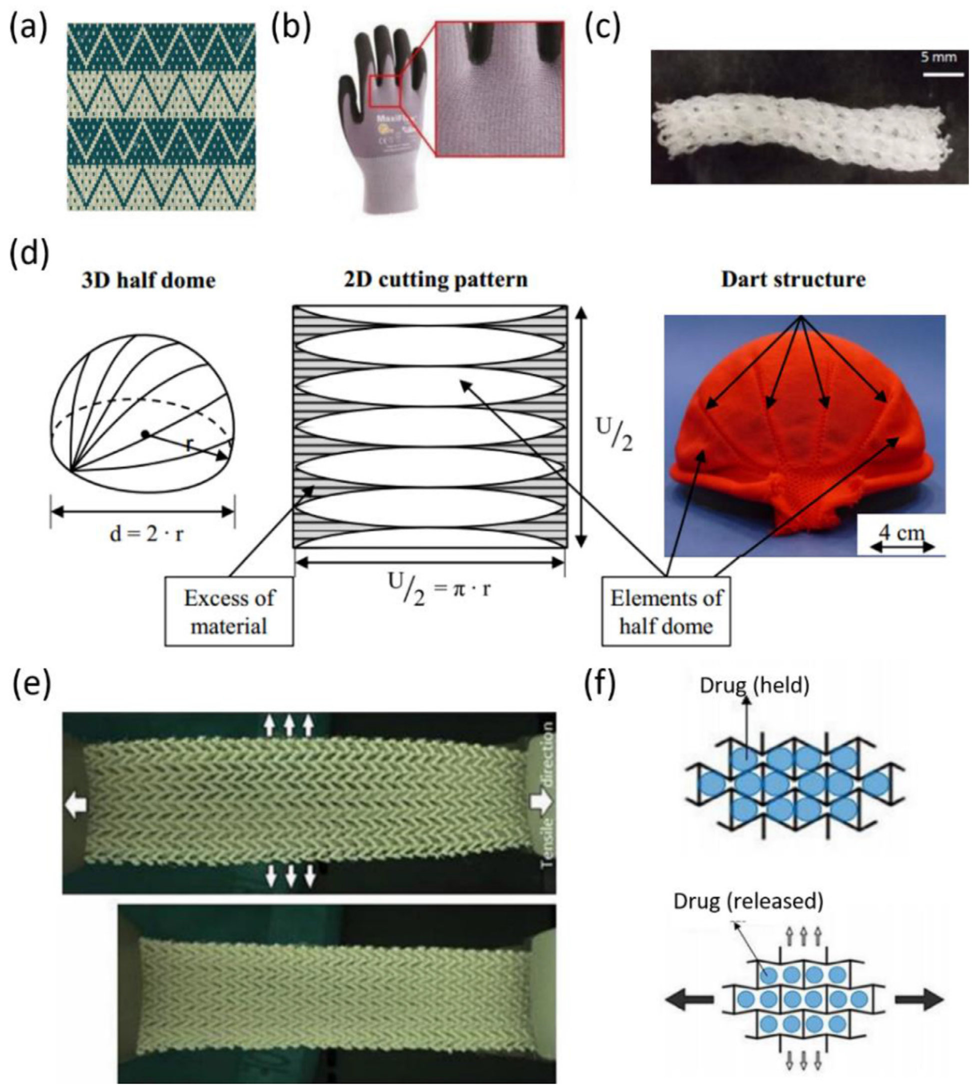

Fig. 11. (a) A jacquard knitted fabric. (b) Seamless knitted gloves. (c) A tubular knitted scaffold for anterior cruciate ligament reinforcement. Reproduced with permission [54]. Copyright 2016, Wiley Periodicals, Inc. (d) Cutting design for joining 2D fabrics into 3D knitted fabrics. Reproduced with permission [161]. Copyright 2017, IOP Publishing. (e) Auxetic knitted fabrics with compacted V structures. Reproduced with permission [163]. Copyright 2014, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. (f) Principle of using auxetic fabrics to load drugs. Reproduced with permission [168]. Copyright 2017, The Textile Institute.

4.2.2. Number of yarn plies

Similar to woven fabrics, yarn properties in knitted fabrics also affect fabric properties. The number of yarn plies is one of such important properties that affect the fabric properties. Multiple fibers wrap around each other to form a ply, and then multiple plies wrap around each other to form a yarn. Plies hold fibers together, and the friction between fibers keeps them from pulling apart. Single-ply yarns, which are "not plied yarns", feature low tear strength since there is not enough friction to hold the fiber in place. For the same type of fibers, increasing the number of plies increases the yarn's tensile stress. Mehmet et al. found that increasing the number of yarn plies from 2 to 3 increased the thickness and stitch density of the knitted fabric, leading to an increase in bursting stress [114].

Knitted fabrics, which feature high flexibility and elasticity, have shown advantages in tissue engineering. Although various knitted patterns are available, the ideal knitted pattern for each tissue engineering application is yet to be determined. Systematic studies should be conducted to establish the relationship between knitted patterns and scaffold properties.

5. Braided patterns and process parameters

5.1. Braided patterns

Braiding is made by intertwining yarns in a diagonal direction. Unlike weaving, which usually intertwined two sets of yarns at right angles, braiding uses three or more yarns intertwined at acute angles (usually 10° to 80°). Braided fabrics can be made into a solid or hollow structure, with a wide range of biomedical applications such as surgical sutures and vascular scaffolds.

5.1.1. Solid braided patterns

The most commonly used braided pattern has a flat, solid, three-yarn structure. The solid braided pattern has been widely used in tissue engineering due to easy fabrication and stable structure (Fig. 12a) [32,43,53,171]. Mechanical properties of scaffolds made from braided fabrics can also be adjusted by changing the number of yarns. John G. Barber et al. showed that 4- and 5-yarn braided scaffolds had higher Young's modulus, yield stress, and ultimate stress than 3-yarn braided scaffolds did (Fig. 12b) [46].

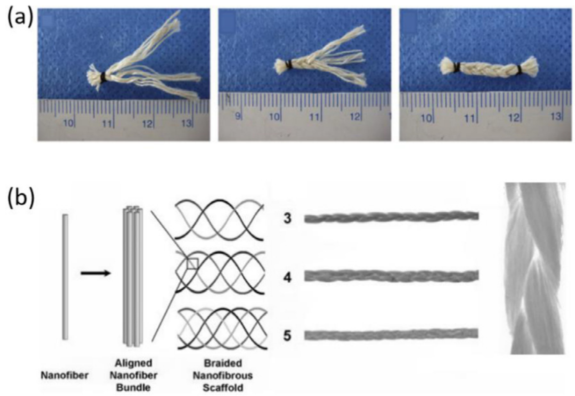

Fig. 12. (a) Process of braiding a silk scaffold. Reproduced with permission [171]. Copyright 2009, Elsevier. (b) Illustration of the hierarchical structure of braided scaffolds. Individual nanofibers were collected as an aligned nanofiber bundle, and then 3-, 4-, or 5-nanofiber bundles (from top to bottom) were braided into scaffolds. Reproduced with permission [46]. Copyright 2013, Mary Ann Liebert, Inc.

Braided scaffolds are good at mimicking intertwined collagen fibers and the corresponding tri-phasic mechanical properties (toe region, linear region, and yield region) [46]. Tri-phasic mechanical property is commonly observed in many human tissues, and the toe region is essential to protect tissues from mechanical trauma. Braided scaffolds have the tri-phasic mechanical property because of the similarities between braided structures and intertwined collagen fibers. In addition, by using twisted yarns or hydrogel-coated yarns [45,48], researchers can adjust the length of the toe region of braided scaffolds to mimic different tissues.

5.1.2. Hollow braided patterns

Hollow braided patterns are preferred over solid braided patterns in tissue engineering because hollow structures can provide ample space for cell growth and new tissue regeneration [56]. Hollow braided scaffolds have been used to repair nerves [56,172], vessels [173,174], and urethra [175,176]. However, the insufficient radial compressive properties of hollow braided scaffolds often limit their applications in repairing a long-distance defect of tissues. To address this limitation, Biqiao Wang et al. used a tube-in-tube design that sufficiently improved the structure's compressive properties for nerve tissue engineering (Fig. 13a and 13b) [177].

Hollow braided patterns have been widely used in vascular tissue engineering because they have sufficient flexibility and can be easily compressed in a delivery system (Fig. 13c) [178,179]. Compared with other methods to fabricate vascular scaffolds, such as laser cutting, braiding is a cost-effective method since no material is lost in the manufacturing process, which is of special interest when high-priced materials like drug-eluting materials are used [180]. Braided fabrics can also be used as one layer of vascular scaffolds to mimic the nonlinear mechanical behavior of the vascular system and integrated with hydrogels or electrospun fibers to form a multilayer structure (Fig. 13d) [35,181].

5.2. Process parameters

Properties of braided scaffolds can be tailored to match the properties of target tissues using appropriate braiding parameters. This section will discuss the effect of three process parameters in braiding, braiding angle, yarn diameter, and the number of braiding layers (Fig. 14a) on fabric properties (Table 3).

5.2.1. Braiding angle

Braiding angle, the most important parameter in braiding, is defined as the angle between braided yarns and the longitudinal direction. Changing the braiding angle will change the number of stitches per inch (SPI) and affect braided fabrics' morphologies and mechanical properties. Increasing the braiding angle decreases the fabric pore size [182,183], which can modulate cell growth on braided scaffolds [184,185]. Braiding angle can be changed during the braiding process to create a scaffold with different pore sizes (Fig. 14b) for connective tissue engineering applications [182,186,187].

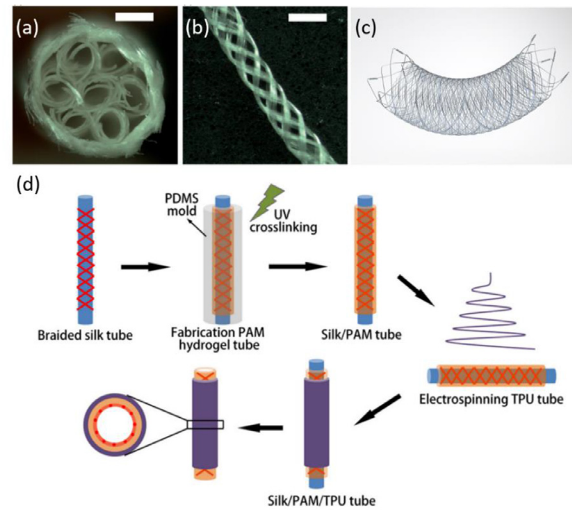

Fig. 13. A nerve scaffold with tube-in-tube structure: (a) Cross-sectional view of the tube-in-tube nerve scaffold (scale bar: 1 mm). Reproduced with permission [177]. Copyright 2015, SAGE Publications. (b) View inside the micro-tube (scale bar: 1 mm). Reproduced with permission [177]. Copyright 2015, SAGE Publications. (c) A braided vascular scaffold (FRED, TERUMO). (d) Schematic of the fabrication procedure for a vascular scaffold with a braided fabric as the inner layer. Reproduced with permission [35]. Copyright 2019, Elsevier.

Table 3
Effects of process parameters on properties of braided fabrics.

	Braiding angle	Yarn diameter	Braiding layers
Pore size	↘	↗	↘
Toe region	↗	–	↘
Modulus	↘	↗	
Yield load	↗	↗	↗

Changing the braiding angle can also affect the mechanical properties of braided scaffolds. As the braiding angle increases, yarns move further away from the longitudinal axis (the loading axis), requiring stronger force to be aligned to the longitudinal direction and increasing the length of the toe region [48,188]. As the braiding angle decreases, more yarns are closely aligned to the longitudinal direction, resulting in a stiffer scaffold with a higher modulus [43,189].

5.2.2. Yarn diameter

Yarn diameter, another important parameter in braiding, can be easily changed by changing the number of fibers used in a yarn [32]. Increasing the yarn diameter significantly increases the pore size, modulus, and yield load of braided scaffolds [188]. However, the toe region is not significantly affected by changing the yarn diameter [188].

Yarns with different diameters can be used in braided fabric to achieve unique properties. One pioneering work in this field is the helical auxetic yarn (HAY) (Fig. 14c) [190]. A HAY structure is formed by winding a stiffer and thinner yarn around an elastic and thicker yarn. Under tensile loading, the stiffer yarn became

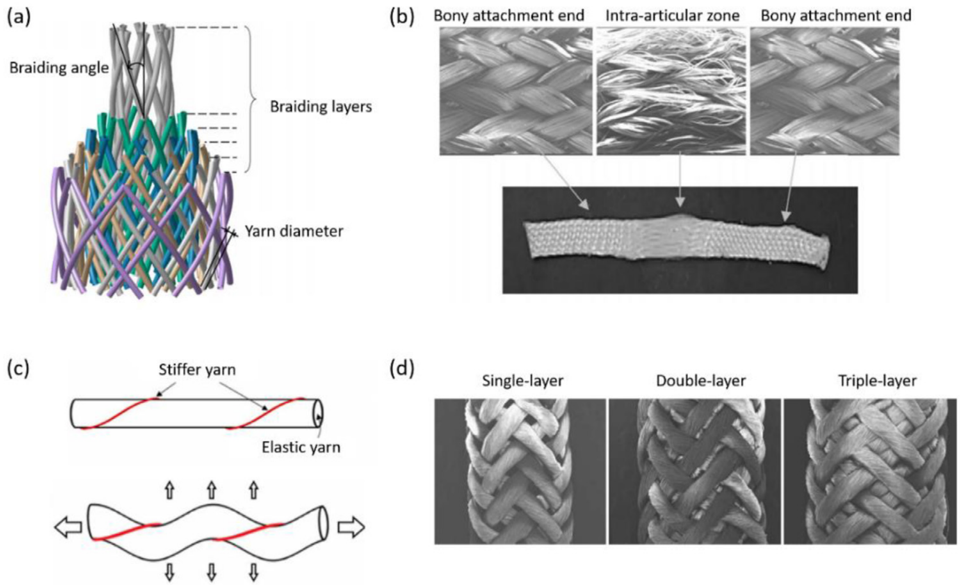

Fig. 14. (a) Schematic of three major braiding parameters. Reproduced with permission [188]. Copyright 2012, Elsevier. (b) A 3D braided ligament scaffold with different braiding angles. Reproduced with permission [182]. Copyright 2005, Elsevier. (c) Schematic of the helical auxetic yarn (HAY). Reproduced with permission [190]. Copyright 2018, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. (d) SEM images of circular braided nerve scaffolds with different layers. Reproduced with permission [191]. Copyright 2009, Springer.

Table 4
Mechanical properties of human tissues.

Tissues	Tensile strength (MPa)	Tensile modulus (MPa)
Tendon	9–55 [194]	300–1200 [195,196]
Anterior cruciate ligament	13–37 [197]	49–163 [197]
Cartilage	15–35 [198,199]	5–26 [200,201]
Bone	Cancellous bone: 116–177 [202]Cortical bone: 0.92–6 [203]	Cancellous bone: 15,000–23,000 [202]Cortical bone: 160–806 [203]
Vessel	0.03–4 [204–206]	0.1–130 [204–206]
Skin	10–40 [207]	15–240 [207,208]
Heart	1–2 [209]	0.05–17 [210]

straightened and displaced the elastic yarn into a crimped form, expanding the structure in the lateral direction. HAY has great potential in mimicking tissues with auxetic properties such as arteries [165], tendons [166], and annulus fibrosus of the intervertebral disk [167].

5.2.3. *Number of braiding layers*

The number of braiding layers, an important parameter in 3D braiding, affects braided scaffolds' physical properties. By increasing braiding layers, more stable scaffolds with a smaller pore size can be fabricated (Fig. 14d) to modulate cell growth on these scaffolds [191–193].

In circular braiding, increasing the number of layers increases will increase the diameter of the braided fabric, leading to an increase in the braiding angle. However, too much increase in the number of braiding layers will be detrimental to the toe region and pore size of braided scaffolds [188].

Braided fabrics with solid and hollow patterns have been widely used in tissue engineering, especially for replacing connective tissues, vessels, and nerves, due to their structural stability, high axial strength, and adjustable properties. However, braided fabrics are not well-suited for applications in complex tissues such as cardiac tissues due to their limited geometry. Compared with weaving and knitting, braiding has fewer patterns but more yarn sets. Thus, using functional yarns such as HAY or electrically conductive yarns in braiding holds the key to increase variability and functionality of braided fabrics.

6. Conclusion and future directions

Textile technology has shown great advantages in fabricating scaffolds for tissue engineering applications. The versatility of textile patterns provides the potential to mimic the diverse properties of various tissues. However, most textile-based scaffolds only use simple textile patterns such as plain weaving, weft knitting, and three-yarn braiding without exploring and utilizing more advanced textile patterns. Moreover, most textile-based scaffolds have mechanical properties that do not match well with their target tissues. Currently, there have been no proposed textile-based scaffolds with similar mechanical properties as the heart and cortical bone (Fig. 15). More textile patterns and their mechanical properties need to be explored for tissue engineering to find the textile-based scaffolds that match the mechanical properties of their target tissues.

Designing and fabricating textile patterns with high efficiency will also require great advances in textile machines. The majority of existing textile-based scaffolds are currently fabricated manually, greatly limiting the scale-up and scale-out of textile-based scaffolds. Developing advanced textile machines will benefit the design and fabrication of textile-based scaffolds. In addition, developing textile machines that can assemble cell-laden fibers will allow greater accuracy in mimicking the heterogeneity of human tissues.

Another potential direction for textile-based scaffolds is developing 4D textile-based scaffolds responsive to external stimuli by incorporating growth factors, drugs, monitoring devices, or smart

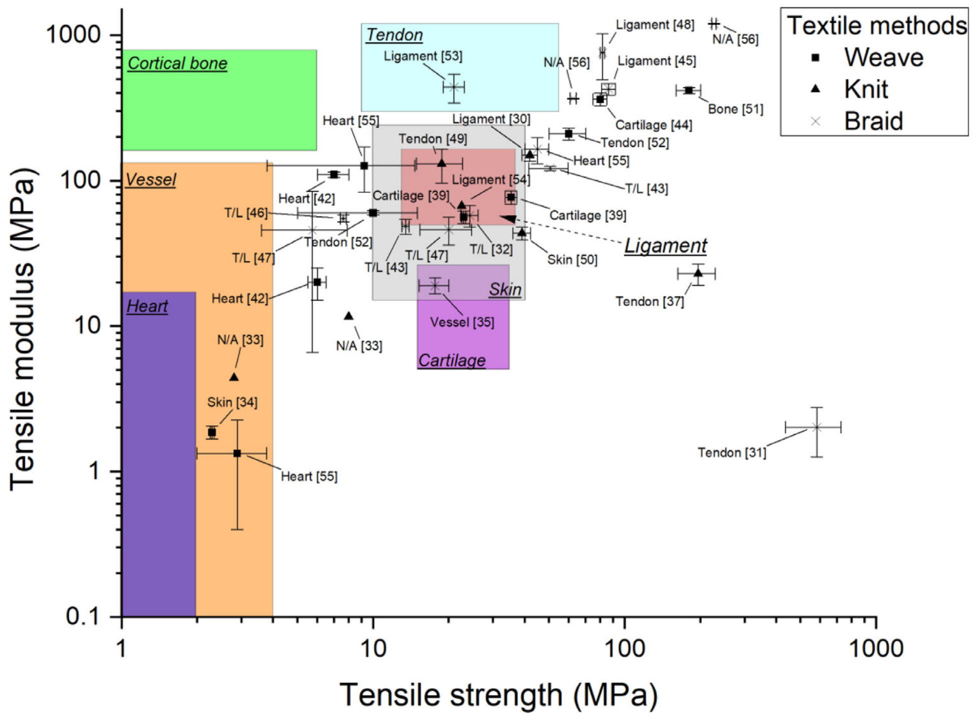

Fig. 15. Review of mechanical properties of textile-based scaffolds for different target tissues (T/L: Tendon/Ligament, colored areas are mechanical property ranges of human tissues (Table 4)).

materials into the scaffolds [2,23]. With the recent advancement in organoids and organ-on-a-chip research, 4D textile-based scaffolds can provide a suitable platform for organ development and drug discovery researches.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] S. Sabetkish, A.M. Kajbafzadeh, N. Sabetkish, R. Khorramirouz, A. Akbarzadeh, S.L. Seyedian, P. Pasalar, S. Orangian, R.S. Hossein Beigi, Z. Aryan, H. Akbari, S.M. Tavangar, Whole-organ tissue engineering: decellularization and recellularization of three-dimensional matrix liver scaffolds, J. Biomed. Mater. Res. - Part A. 103 (2015) 1498–1508, doi:10.1002/jbm.a.35291.

[2] Organ Procurement and Transplantation Network, in: Definitions, Qeios, 2020. https://doi.org/10.32388/ypyitc.

[3] C.M. Brougham, T.J. Levingstone, N. Shen, G.M. Cooney, S. Jockenhoevel, T.C. Flanagan, F.J. O'Brien, Freeze-Drying as a Novel Biofabrication Method for Achieving a Controlled Microarchitecture within Large, Complex Natural Biomaterial Scaffolds, Adv. Healthc. Mater. 6 (2017) 1700598, doi:10.1002/adhm.201700598.

[4] H. Liu, A. Ahlinder, M.A. Yassin, A. Finne-Wistrand, T.C. Gasser, Computational and experimental characterization of 3D-printed PCL structures toward the design of soft biological tissue scaffolds, Mater. Des. 188 (2020) 108488, doi:10.1016/j.matdes.2020.108488.

[5] J.K. Lee, J.M. Link, J.C.Y. Hu, K.A. Athanasiou, The self-assembling process and applications in tissue engineering, cold spring harb, Perspect. Med. 7 (2017) a025668, doi:10.1101/cshperspect.a025668.

[6] M. Akbari, A. Tamayol, S. Bagherifard, L. Serex, P. Mostafalu, N. Faramarzi, M.H. Mohammadi, A. Khademhosseini, Textile technologies and tissue engineering: a path toward organ weaving, Adv. Healthc. Mater. 5 (2016) 751–766, doi:10.1002/adhm.201500517.

[7] K. Grömer, The Art of Prehistoric Textile Making. : The development of Craft Traditions and Clothing in Central Europe, 2016, doi:10.26530/oapen_604250.

[8] A. Tamayol, M. Akbari, N. Annabi, A. Paul, A. Khademhosseini, D. Juncker, Fiber-based tissue engineering: progress, challenges, and opportunities, Biotechnol. Adv. 31 (2013) 669–687, doi:10.1016/j.biotechadv.2012.11.007.

[9] S.H. Rao, B. Harini, R.P.K. Shadamarshan, K. Balagangadharan, N. Selvamurugan, Natural and synthetic polymers/bioceramics/bioactive compounds-mediated cell signalling in bone tissue engineering, Int. J. Biol. Macromol. 110 (2018) 88–96, doi:10.1016/j.ijbiomac.2017.09.029.

[10] R.D. Pedde, B. Mirani, A. Navaei, T. Styan, S. Wong, M. Mehrali, A. Thakur, N.K. Mohtaram, A. Bayati, A. Dolatshahi-Pirouz, M. Nikkhah, S.M. Willerth, M. Akbari, Emerging biofabrication strategies for engineering complex tissue constructs, Adv. Mater. 29 (2017) 1606061, doi:10.1002/adma.201606061.

[11] A. Tamayol, M. Akbari, N. Annabi, A. Paul, A. Khademhosseini, D. Juncker, Fiber-based tissue engineering: progress, challenges, and opportunities, Biotechnol. Adv. 31 (2013) 669–687, doi:10.1016/j.biotechadv.2012.11.007.

[12] A. Fallahi, A. Khademhosseini, A. Tamayol, Textile processes for engineering tissues with biomimetic architectures and properties, Trends Biotechnol 34 (2016) 683–685, doi:10.1016/j.tibtech.2016.07.001.

[13] A. Liberski, N. Ayad, D. Wojciechowska, R. Kot, D.M.P. Vo, D. Aibibu, G. Hoffmann, C. Cherif, K. Grobelny-Mayer, M. Snycerski, H. Goldmann, Weaving for heart valve tissue engineering, Biotechnol. Adv. 35 (2017) 633–656, doi:10.1016/j.biotechadv.2017.07.012.

[14] Y. Jiao, C. Li, L. Liu, F. Wang, X. Liu, J. Mao, L. Wang, Construction and application of textile-based tissue engineering scaffolds: a review, Biomater. Sci. 8 (2020) 3574–3600, doi:10.1039/d0bm00157k.

[15] J. Lee, B. Llerena Zambrano, J. Woo, K. Yoon, T. Lee, Recent advances in 1D stretchable electrodes and devices for textile and wearable electronics: materials, fabrications, and applications, Adv. Mater. 32 (2020) 1902532, doi:10.1002/adma.201902532.

[16] A. Saboktakin, 3D textile preforms and composites for aircraft strcutures: a review, Int. J. Aviat. Aeronaut. Aerosp. 6 (2019), doi:10.15394/ijaaa.2019.1299.

[17] X. Gong, X. Chen, Y. Zhou, Advanced weaving technologies for high-performance fabrics, in: high-performance appar, Mater. Dev. Appl. (2017) 75–112, doi:10.1016/B978-0-08-100904-8.00004-3.

[18] M.H. Mohamed, A.E. Bogdanovich, Comparative analysis of different 3D weaving processes, machines and products, ICCM Int. Conf. Compos. Mater, 2009.

[19] MohamedMethod of Forming Variable Cross-Sectional Shaped Three-Dimensional Fabrics, 1992 United States Pat.

[20] O.A. Golra, J. Tariq, N. Ehsan, E. Mirza, Strategy for introducing 3D fiber reinforced composites weaving technology, Procedia Technol. 1 (2012) 211–216, doi:10.1016/j.protcy.2012.02.046.

[21] L. Wang, L. Wang, Y. Zhang, J. Pan, S. Li, X. Sun, B. Zhang, H. Peng, Weaving sensing fibers into electrochemical fabric for real-time health monitoring, Adv. Funct. Mater. (2018) 28, doi:10.1002/adfm.201804456.

[22] N. Khokar, 3D-Weaving: theory and Practice, J. Text. Inst. 92 (2001) 193–207, doi:10.1080/00405000108659570.

[23] Knitting Early Modern Europe: materials, Manufacture and Meaning, (n.d.). https://cordis.europa.eu/project/id/656748.

[24] X. Zhang, P. Ma, Application of knitting structure textiles in medical areas, Autex Res. J. 18 (2018) 181–191, doi:10.1515/aut-2017-0019.

[25] K.H. Leong, S. Ramakrishna, Z.M. Huang, G.A. Bibo, Potential of knitting for engineering composites - a review, Compos. Part A Appl. Sci. Manuf. 31 (2000) 197–220, doi:10.1016/S1359-835X(99)00067-6.

[26] D.J. Spencer, Classes of warp knitting machines, Knitt. Technol. (2001) 298–312, doi:10.1533/9781855737556.298.
[27] S.S. Roy, P. Potluri, Braiding: from cordage to composites, 3Rd Text. Res. Conf. (2016) 12–15 http://trc.clothinginstitute.org/.
[28] I.T. Ozbolat, Roadmap to organ printing, in: 3D Bioprinting, 2017, pp. 243–269, doi:10.1016/b978-0-12-803010-3.00008-1.
[29] W. Sun, B. Starly, A.C. Daly, J.A. Burdick, J. Groll, G. Skeldon, W. Shu, Y. Sakai, M. Shinohara, M. Nishikawa, J. Jang, D.W. Cho, M. Nie, S. Takeuchi, S. Ostrovidov, A. Khademhosseini, R.D. Kamm, V. Mironov, L. Moroni, I.T. Ozbolat, The bioprinting roadmap, Biofabrication (2020) 12, doi:10.1088/1758-5090/ab5158.
[30] C. Vaquette, C. Kahn, C. Frochot, C. Nouvel, J.L. Six, N. De Isla, L.H. Luo, J. Cooper-White, R. Rahouadj, X. Wang, Aligned poly(L-lactic-co-e-caprolactone) electrospun microfibers and knitted structure: a novel composite scaffold for ligament tissue engineering, J. Biomed. Mater. Res. - Part A. 94 (2010) 1270–1282, doi:10.1002/jbm.a.32801.
[31] K. Hennecke, J. Redeker, J.W. Kuhbier, S. Strauss, C. Allmeling, C. Kasper, K. Reimers, P.M. Vogt, Bundles of spider silk, braided into sutures, resist basic cyclic tests: potential use for flexor tendon repair, PLoS ONE 8 (2013), doi:10.1371/journal.pone.0061100.
[32] A. Pagán, S.D. Aznar-Cervantes, J. Pérez-Rigueiro, L. Meseguer-Olmo, J.L. Cenis, Potential use of silkworm gut fiber braids as scaffolds for tendon and ligament tissue engineering, J. Biomed. Mater. Res. - Part B Appl. Biomater. 107 (2019) 2209–2215, doi:10.1002/jbm.b.34300.
[33] L.R. Almeida, A.R. Martins, E.M. Fernandes, M.B. Oliveira, V.M. Correlo, I. Pashkuleva, A.P. Marques, A.S. Ribeiro, N.F. Durães, C.J. Silva, G. Bonifácio, R.A. Sousa, A.L. Oliveira, R.L. Reis, New biotextiles for tissue engineering: development, characterization and in vitro cellular viability, Acta Biomater. 9 (2013) 8167–8181, doi:10.1016/j.actbio.2013.05.019.
[34] F. Han, S. Liu, X. Liu, Y. Pei, S. Bai, H. Zhao, Q. Lu, F. Ma, D.L. Kaplan, H. Zhu, Woven silk fabric-reinforced silk nanofibrous scaffolds for regenerating load-bearing soft tissues, Acta Biomater. 10 (2014) 921–930, doi:10.1016/j.actbio.2013.09.026.
[35] H.Y. Mi, Y. Jiang, X. Jing, E. Enriquez, H. Li, Q. Li, L.S. Turng, Fabrication of triple-layered vascular grafts composed of silk fibers, polyacrylamide hydrogel, and polyurethane nanofibers with biomimetic mechanical properties, Mater. Sci. Eng. C. 98 (2019) 241–249, doi:10.1016/j.msec.2018.12.126.
[36] M. Younesi, A. Islam, V. Kishore, J.M. Anderson, O. Akkus, Tenogenic induction of human MSCs by anisotropically aligned collagen biotextiles, Adv. Funct. Mater (2014) 5762–5770, doi:10.1002/adfm.201400828.
[37] L. Tang, Y. Yang, Y. Li, G. Yang, T. Luo, Y. Xu, W. Zhang, Knitted silk mesh-like scaffold incorporated with sponge-like regenerated silk fibroin/collagen I and seeded with mesenchymal stem cells for repairing Achilles tendon in rabbits, Acta Bioeng. Biomech. 20 (2018) 77–87, doi:10.5277/ABB-01128-2018-01.
[38] B. Aghaei-Ghareh-Bolagh, S.M. Mithieux, M.A. Hiob, Y. Wang, A. Chong, A.S. Weiss, Fabricated tropoelastin-silk yarns and woven textiles for diverse tissue engineering applications, Acta Biomater. 91 (2019) 112–122, doi:10.1016/j.actbio.2019.04.029.
[39] F.T. Moutos, F. Guilak, Functional properties of cell-seeded three-dimensionally woven poly(ε-Caprolactone) scaffolds for cartilage tissue engineering, Tissue Eng. - Part A. 16 (2010) 1291–1301, doi:10.1089/ten.tea.2009.0480.
[40] I.C. Liao, F.T. Moutos, B.T. Estes, X. Zhao, F. Guilak, Composite three-dimensional woven scaffolds with interpenetrating network hydrogels to create functional synthetic articular cartilage, Adv. Funct. Mater. 23 (2013) 5833–5839, doi:10.1002/adfm.201300483.
[41] M. van Lieshout, G. Peters, M. Rutten, F. Baaijens, A. Knitted, Fibrin-covered polycaprolactone Scaffold for tissue engineering of the aortic valve, Tissue Eng (2006) 060317120837002 0, doi:10.1089/ten.2006.12.ft-48.
[42] Y. Wu, L. Wang, B. Guo, P.X. Ma, Interwoven aligned conductive nanofiber yarn/hydrogel composite scaffolds for engineered 3D cardiac anisotropy, ACS Nano. 11 (2017) 5646–5659, doi:10.1021/acsnano.7b01062.
[43] S.K. Czaplewski, T.L. Tsai, S.E. Duenwald-Kuehl, R. Vanderby, W.J. Li, Tenogenic differentiation of human induced pluripotent stem cell-derived mesenchymal stem cells dictated by properties of braided submicron fibrous scaffolds, Biomaterials 35 (2014) 6907–6917, doi:10.1016/j.biomaterials.2014.05.006.
[44] F.T. Moutos, L.E. Freed, F. Guilak, A biomimetic three-dimensional woven composite scaffold for functional tissue engineering of cartilage, Nat. Mater. 6 (2007) 162–167, doi:10.1038/nmat1822.
[45] S. Madhavarapu, R. Rao, S. Libring, E. Fleisher, Y. Yankannah, J.W. Freeman, Design and characterization of three-dimensional twist-braid scaffolds for anterior cruciate ligament regeneration, Technology (Singap World Sci) 05 (2017) 98–106, doi:10.1142/s2339547817500066.
[46] J.G. Barber, A.M. Handorf, T.J. Allee, W.J. Li, Braided nanofibrous scaffold for tendon and ligament tissue engineering, Tissue Eng. - Part A. 19 (2013) 1265–1274, doi:10.1089/ten.tea.2010.0538.
[47] B.B. Rothrauff, B.B. Lauro, G. Yang, R.E. Debski, V. Musahl, R.S. Tuan, Braided and stacked electrospun nanofibrous scaffolds for tendon and ligament tissue engineering, Tissue Eng. - Part A. 23 (2017) 378–389, doi:10.1089/ten.tea.2016.0319.
[48] J.W. Freeman, M.D. Woods, C.T. Laurencin, Tissue engineering of the anterior cruciate ligament using a braid-twist scaffold design, J. Biomech. 40 (2007) 2029–2036, doi:10.1016/j.jbiomech.2006.09.025.
[49] W. Zhang, Y. Yang, K. Zhang, Y. Li, G. Fang, Weft-knitted silk-poly(lactide-co-glycolide) mesh scaffold combined with collagen matrix and seeded with mesenchymal stem cells for rabbit Achilles tendon repair, Connect. Tissue Res. 56 (2015) 25–34, doi:10.3109/03008207.2014.976309.
[50] E. McKenna, T.J. Klein, M.R. Doran, K. Futrega, Integration of an ultra-strong poly(lactic-co-glycolic acid) (PLGA) knitted mesh into a thermally induced phase separation (TIPS) PLGA porous structure to yield a thin biphasic scaffold suitable for dermal tissue engineering, Biofabrication 12 (2020) 015015, doi:10.1088/1758-5090/ab4053.
[51] W. Shao, J. He, Q. Han, F. Sang, Q. Wang, L. Chen, S. Cui, B. Ding, A biomimetic multilayer nanofiber fabric fabricated by electrospinning and textile technology from polylactic acid and Tussah silk fibroin as a scaffold for bone tissue engineering, Mater. Sci. Eng. C. 67 (2016) 599–610, doi:10.1016/j.msec.2016.05.081.
[52] S. Wu, Y. Wang, P.N. Streubel, B. Duan, Living nanofiber yarn-based woven biotextiles for tendon tissue engineering using cell tri-culture and mechanical stimulation, Acta Biomater 62 (2017) 102–115, doi:10.1016/j.actbio.2017.08.043.
[53] A. Leroy, B. Nottelet, C. Bony, C. Pinese, B. Charlot, X. Garric, D. Noël, J. Coudane, PLA-poloxamer/poloxamine copolymers for ligament tissue engineering: sound macromolecular design for degradable scaffolds and MSC differentiation, Biomater. Sci. 3 (2015) 617–626, doi:10.1039/c4bm00433g.
[54] C. Pinese, A. Leroy, B. Nottelet, C. Gagnieu, J. Coudane, X. Garric, Rolled knitted scaffolds based on PLA-pluronic copolymers for anterior cruciate ligament reinforcement: a step by step conception, J. Biomed. Mater. Res. - Part B Appl. Biomater. 105 (2017) 735–743, doi:10.1002/jbm.b.33604.
[55] S. Wu, B. Duan, P. Liu, C. Zhang, X. Qin, J.T. Butcher, Fabrication of aligned nanofiber polymer yarn networks for anisotropic soft tissue scaffolds, ACS Appl. Mater. Interfaces. 8 (2016) 16950–16960, doi:10.1021/acsami.6b05199.
[56] Q. Quan, C. Xiao, H. Liu, Q. Huang, W. Zhao, X. Hu, G. Huan, Preparation and characterization of braided tube reinforced polyacrylonitrile hollow fiber membranes, J. Appl. Polym. Sci. 132 (2015) 41795, doi:10.1002/app.41795.
[57] S. Miao, W. Zhu, N.J. Castro, J. Leng, L.G. Zhang, Four-dimensional printing hierarchy scaffolds with highly biocompatible smart polymers for tissue engineering applications, Tissue Eng. - Part C Methods. 22 (2016) 952–963, doi:10.1089/ten.tec.2015.0542.
[58] S.A. Abbah, L.M. Delgado, A. Azeem, K. Fuller, N. Shologu, M. Keeney, M.J. Biggs, A. Pandit, D.I. Zeugolis, Harnessing hierarchical nano- and micro-fabrication technologies for musculoskeletal tissue engineering, Adv. Healthc. Mater. 4 (2015) 2488–2499, doi:10.1002/adhm.201500004.
[59] A. Béduer, N. Piacentini, L. Aeberli, A. Da Silva, C.A. Verheyen, F. Bonini, A. Rochat, A. Filippova, L. Serex, P. Renaud, T. Braschler, Additive manufacturing of hierarchical injectable scaffolds for tissue engineering, Acta Biomater 76 (2018) 71–79, doi:10.1016/j.actbio.2018.05.056.
[60] X. Wang, S. Xu, S. Zhou, W. Xu, M. Leary, P. Choong, M. Qian, M. Brandt, Y.M. Xie, Topological design and additive manufacturing of porous metals for bone scaffolds and orthopaedic implants: a review, Biomaterials 83 (2016) 127–141, doi:10.1016/j.biomaterials.2016.01.012.
[61] A. Chanda, C. Callaway, Tissue anisotropy modeling using soft composite materials, Appl. Bionics Biomech. 2018 (2018), doi:10.1155/2018/4838157.
[62] A.R. Torrado, C.M. Shemelya, J.D. English, Y. Lin, R.B. Wicker, D.A. Roberson, Characterizing the effect of additives to ABS on the mechanical property anisotropy of specimens fabricated by material extrusion 3D printing, Addit. Manuf. 6 (2015) 16–29, doi:10.1016/j.addma.2015.02.001.
[63] O.S. Es-Said, J. Foyos, R. Noorani, M. Mendelson, R. Marloth, B.A. Pregger, Effect of layer orientation on mechanical properties of rapid prototyped samples, Mater. Manuf. Process. 15 (2000) 107–122, doi:10.1080/10426910008912976.
[64] R. K., S. Saarakkal, Biomechanics and Modeling of Skeletal Soft Tissues, Theor. Biomech. (2011), doi:10.5772/19975.
[65] S. Motte, L.J. Kaufman, Strain stiffening in collagen i networks, Biopolymers 99 (2013) 35–46, doi:10.1002/bip.22133.
[66] J.H.C. Wang, Q. Guo, B. Li, Tendon biomechanics and mechanobiology - a minireview of basic concepts and recent advancements, J. Hand Ther. 25 (2012) 133–141, doi:10.1016/j.jht.2011.07.004.
[67] M. Jaspers, M. Dennison, M.F.J. Mabesoone, F.C. MacKintosh, A.E. Rowan, P.H.J. Kouwer, Ultra-responsive soft matter from strain-stiffening hydrogels, Nat. Commun. 5 (2014) 5808, doi:10.1038/ncomms6808.
[68] K. Wang, C. Wu, Z. Qian, C. Zhang, B. Wang, M.A. Vannan, Dual-material 3D printed metamaterials with tunable mechanical properties for patient-specific tissue-mimicking phantoms, Addit. Manuf. 12 (2016) 31–37, doi:10.1016/j.addma.2016.06.006.
[69] M. Jaspers, S.L. Vaessen, P. Van Schayik, D. Voerman, A.E. Rowan, P.H.J. Kouwer, Nonlinear mechanics of hybrid polymer networks that mimic the complex mechanical environment of cells, Nat. Commun. 8 (2017) 15478, doi:10.1038/ncomms15478.
[70] I.K. Piechocka, R.G. Bacabac, M. Potters, F.C. Mackintosh, G.H. Koenderink, Structural hierarchy governs fibrin gel mechanics, Biophys. J. 98 (2010) 2281–2289, doi:10.1016/j.bpj.2010.01.040.
[71] C. Wu, J. Huang, B. Chu, J. Deng, Z. Zhang, S. Tang, X. Wang, Z. Wang, Y. Wang, Dynamic and hierarchically structured networks with tissue-like mechanical behavior, ACS Nano 13 (2019) 10727–10736, doi:10.1021/acsnano.9b05436.
[72] L.R. Lopes, A.F. Silva, O.S. Carneiro, Multi-material 3D printing: the relevance of materials affinity on the boundary interface performance, Addit. Manuf. 23 (2018) 45–52, doi:10.1016/j.addma.2018.06.027.
[73] W. Liu, Z. Wang, Current understanding of the biomechanics of ventricular tissues in heart failure, Bioengineering 7 (2020), doi:10.3390/bioengineering7010002.

[74] O. Kononova, A. Krasnikovs, K. Dzelzitis, G. Kharkova, A. Vagel, M. Eiduks, Silmuskootud puuvillakangast komposiitide mehaaniliste omaduste modelleerimine ja võrdlemine katsetulemustega, Est. J. Eng. 17 (2011) 39–50, doi:10.3176/eng.2011.1.05.
[75] L. Wang, Y. Wu, B. Guo, P.X. Ma, Nanofiber yarn/hydrogel core-shell scaffolds mimicking native skeletal muscle tissue for guiding 3d myoblast alignment, elongation, and differentiation, ACS Nano 9 (2015) 9167–9179, doi:10.1021/acsnano.5b03644.
[76] M. Akbari, A. Tamayol, V. Laforte, N. Annabi, A.H. Najafabadi, A. Khademhosseini, D. Juncker, Composite living fibers for creating tissue constructs using textile techniques, Adv. Funct. Mater. 24 (2014) 4060–4067, doi:10.1002/adfm.201303655.
[77] R. Costa-Almeida, R.M.A. Domingues, A. Fallahi, H. Avci, I.K. Yazdi, M. Akbari, R.L. Reis, A. Tamayol, M.E. Gomes, A. Khademhosseini, Cell-laden composite suture threads for repairing damaged tendons, J. Tissue Eng. Regen. Med. 12 (2018) 1039–1048, doi:10.1002/term.2605.
[78] A. Fallahi, I.K. Yazdi, L. Serex, E. Lesha, N. Faramarzi, F. Tarlan, H. Avci, R. Costa-Almeida, F. Sharifi, C. Rinoldi, M.E. Gomes, S.R. Shin, A. Khademhosseini, M. Akbari, A. Tamayol, Customizable composite fibers for engineering skeletal muscle models, ACS Biomater. Sci. Eng. 6 (2020) 1112–1123, doi:10.1021/acsbiomaterials.9b00992.
[79] C. Jiang, K. Wang, X. Jiang, C. Zhang, B. Wang, Quantitative investigation of the process parameters of electrohydrodynamic direct-writing and their effects on fiber surface roughness and cell adhesion, Polymers (Basel) 12 (2020) 1–12, doi:10.3390/polym12112475.
[80] B. Mirani, E. Pagan, S. Shojaei, S.M.H. Dabiri, H. Savoji, M. Mehrali, M. Sam, J. Alsaif, R.B. Bhiladvala, A. Dolatshahi-Pirouz, M. Radisic, M. Akbari, Facile method for fabrication of meter-long multifunctional hydrogel fibers with controllable biophysical and biochemical features, ACS Appl. Mater. Interfaces. 12 (2020) 9080–9089, doi:10.1021/acsami.9b23063.
[81] H. Liu, Y. Wang, Y. Yu, W. Chen, L. Jiang, J. Qin, Simple fabrication of inner chitosan-coated alginate hollow microfiber with higher stability, J. Biomed. Mater. Res. - Part B Appl. Biomater. 107 (2019) 2527–2536, doi:10.1002/jbm.b.34343.
[82] A.R. Kang, J.S. Park, J. Ju, G.S. Jeong, S.H. Lee, Cell encapsulation via microtechnologies, Biomaterials 35 (2014) 2651–2663, doi:10.1016/j.biomaterials.2013.12.073.
[83] A.Y. Hsiao, T. Okitsu, H. Onoe, M. Kiyosawa, H. Teramae, S. Iwanaga, T. Kazama, T. Matsumoto, S. Takeuchi, Smooth muscle-like tissue constructs with circumferentially oriented cells formed by the cell fiber technology, PLoS ONE 10 (2015) 0119010, doi:10.1371/journal.pone.0119010.
[84] Y. Zuo, X. He, Y. Yang, D. Wei, J. Sun, M. Zhong, R. Xie, H. Fan, X. Zhang, Microfluidic-based generation of functional microfibers for biomimetic complex tissue construction, Acta Biomater 38 (2016) 153–162, doi:10.1016/j.actbio.2016.04.036.
[85] H. Onoe, T. Okitsu, A. Itou, M. Kato-Negishi, R. Gojo, D. Kiriya, K. Sato, S. Miura, S. Iwanaga, K. Kuribayashi-Shigetomi, Y.T. Matsunaga, Y. Shimoyama, S. Takeuchi, Metre-long cell-laden microfibres exhibit tissue morphologies and functions, Nat. Mater. 12 (2013) 584–590, doi:10.1038/nmat3606.
[86] H. Onoe, R. Gojo, Y. Tsuda, D. Kiriya, M. Kato-Negishi, S. Takeuchi, Cell fibers: construction of centimeter-scale 3D tissues by weaving, 14th Int. Conf. Miniaturized Syst. Chem. Life Sci. 2010, MicroTAS 2010. 1 (2010) 629–631.
[87] K. Yao, W. Li, K. Li, Q. Wu, Y. Gu, L. Zhao, Y. Zhang, X. Gao, Simple Fabrication of Multicomponent Heterogeneous Fibers for Cell Co-Culture via Microfluidic Spinning, Macromol. Biosci. 20 (2020) 1900395, doi:10.1002/mabi.201900395.
[88] E. Kang, G.S. Jeong, Y.Y. Choi, K.H. Lee, A. Khademhosseini, S.H. Lee, Digitally tunable physicochemical coding of material composition and topography in continuous microfibres, Nat. Mater. 10 (2011) 877–883, doi:10.1038/nmat3108.
[89] S. Rajendran, Advanced Textiles For Wound Care, 2009, doi:10.1533/9781845696306.
[90] J. Eom, R. Jaisutti, H. Lee, W. Lee, J.S. Heo, J.Y. Lee, S.K. Park, Y.H. Kim, Highly sensitive textile strain sensors and wireless user-interface devices using all-polymeric conducting fibers, ACS Appl. Mater. Interfaces. 9 (2017) 10190–10197, doi:10.1021/acsami.7b01771.
[91] Z. Yin, M. Jian, C. Wang, K. Xia, Z. Liu, Q. Wang, M. Zhang, X. Liang, H. Wang, X. Liang, Y. Long, X. Yu, Y. Zhang, Splash-resistant and light-weight silk-sheathed wires for textile electronics, Nano Lett. 18 (2018) 7085–7091, doi:10.1021/acs.nanolett.8b03085.
[92] S. Lee, S. Shin, S. Lee, J. Seo, J. Lee, S. Son, H.J. Cho, H. Algadi, S. Al-Sayari, D.E. Kim, T. Lee, Ag nanowire reinforced highly stretchable conductive fibers for wearable electronics, Adv. Funct. Mater. 25 (2015) 3114–3121, doi:10.1002/adfm.201500628.
[93] R.G. Revaiah, T.M. Kotresh, B. Kandasubramanian, Technical textiles for military applications, J. Text. Inst. 111 (2020) 273–308, doi:10.1080/00405000.2019.1627987.
[94] R. Shishoo, Textiles For Sportswear, 2015, doi:10.1016/C2013-0-16491-4.
[95] L. Yu, Y. Feng, L. Yao, R.H. Soon, J.C. Yeo, C.T. Lim, Dual-core capacitive microfiber sensor for smart textile applications, ACS Appl. Mater. Interfaces. 11 (2019) 33347–33355, doi:10.1021/acsami.9b10937.
[96] X. You, J. He, N. Nan, X. Sun, K. Qi, Y. Zhou, W. Shao, F. Liu, S. Cui, Stretchable capacitive fabric electronic skin woven by electrospun nanofiber coated yarns for detecting tactile and multimodal mechanical stimuli, J. Mater. Chem. C. 6 (2018) 12981–12991, doi:10.1039/C8TC03631D.
[97] C. Massaroni, C. Venanzi, A.P. Silvatti, D.Lo Presti, P. Saccomandi, D. Formica, F. Giurazza, M.A. Caponero, E. Schena, Smart textile for respiratory monitoring and thoraco-abdominal motion pattern evaluation, J. Biophotonics. 11 (2018), doi:10.1002/jbio.201700263.
[98] S. Seyedin, J.M. Razal, P.C. Innis, A. Jeiranikhameneh, S. Beirne, G.G. Wallace, Knitted strain sensor textiles of highly conductive all-polymeric fibers, ACS Appl. Mater. Interfaces. 7 (2015) 21150–21158, doi:10.1021/acsami.5b04892.
[99] M. Zhu, M. Lou, I. Abdalla, J. Yu, Z. Li, B. Ding, Highly shape adaptive fiber based electronic skin for sensitive joint motion monitoring and tactile sensing, Nano Energy 69 (2020), doi:10.1016/j.nanoen.2019.104429.
[100] M. Zohair, K. Moyer, J. Eaves-Rathert, C. Meng, J. Waugh, C.L. Pint, Continuous energy harvesting and motion sensing from flexible electrochemical nanogenerators: toward smart and multifunctional textiles, ACS Nano. 14 (2020) 2308–2315, doi:10.1021/acsnano.9b09445.
[101] M.S. Khil, S.R. Bhattarai, H.Y. Kim, S.Z. Kim, K.H. Lee, Novel fabricated matrix via electrospinning for tissue engineering, J. Biomed. Mater. Res. - Part B Appl. Biomater. 72 (2005) 117–124, doi:10.1002/jbm.b.30122.
[102] S. Wu, B. Duan, X. Qin, J.T. Butcher, Living nano-micro fibrous woven fabric/hydrogel composite scaffolds for heart valve engineering, Acta Biomater 51 (2017) 89–100, doi:10.1016/j.actbio.2017.01.051.
[103] X. Chen, Y.Y. Qi, L.L. Wang, Z. Yin, G.L. Yin, X.H. Zou, H.W. Ouyang, Ligament regeneration using a knitted silk scaffold combined with collagen matrix, Biomaterials 29 (2008) 3683–3692, doi:10.1016/j.biomaterials.2008.05.017.
[104] S. Sahoo, S. Lok Toh, J.C. Hong Goh, PLGA nanofiber-coated silk microfibrous scaffold for connective tissue engineering, J. Biomed. Mater. Res. - Part B Appl. Biomater. 95 (2010) 19–28, doi:10.1002/jbm.b.31678.
[105] E. Mbise, T. Dias, W. Hurley, Design and manufacture of heated textiles, Electron. Text. Smart Fabr. Wearable Technol. (2015) 117–132, doi:10.1016/B978-0-08-100201-8.00007-2.
[106] A. Kaspar, T.H. Oh, L. Makatura, P. Kellnhofer, W. Matusik, Neural inverse knitting: from images to manufacturing instructions, 36th Int. Conf. Mach. Learn. ICML 2019 (2019) 5709–5723.
[107] A. Kaspar, L. Makatura, W. Matusik, Knitting skeletons: a computer-aided design tool for shaping and patterning of knitted garments, in: UIST 2019 - Proc. 32nd Annu. ACM Symp. User Interface Softw. Technol., 2019, pp. 53–65, doi:10.1145/3332165.3347879.
[108] X. Sun, L. Tong, M.D.K. Wood, Y.W. Mai, Effect of stitch distribution on mode I delamination toughness of laminated DCB specimens, Compos. Sci. Technol. 64 (2004) 967–981, doi:10.1016/j.compscitech.2003.07.004.
[109] N.J. Severs, The cardiac muscle cell, BioEssays 22 (2000) 188–199 :2<188::AID–BIES10>3.0.CO;2-T, doi:10.1002/(SICI)1521-1878(200002)22.
[110] R.L. Lieber, Skeletal muscle structure, function, and plasticity, Skelet. Muscle Struct. Funct. Plast. (2011) 1–304, doi:10.1016/s0031-9406(05)60189-7.
[111] A.A. Almetwally, M.M. Mourad, Effects of spandex drawing ratio and weave structure on the physical properties of cotton/spandex woven fabrics, J. Text. Inst. 105 (2014) 235–245, doi:10.1080/00405000.2013.835092.
[112] I. Jahan, Effect of fabric structure on the mechanical properties of woven fabrics, Adv. Res. Text. Eng. 2 (2017) 1018, doi:10.26420/advrestexteng.2017.1018.
[113] K. Bircher, M. Zündel, M. Pensalfini, A.E. Ehret, E. Mazza, Tear resistance of soft collagenous tissues, Nat. Commun. 10 (2019) 792, doi:10.1038/s41467-019-08723-y.
[114] P. Gurkan, 3D Woven Fabrics, in: Woven Fabr., 2012. https://doi.org/10.5772/37492.
[115] R. Umer, H. Alhussein, J. Zhou, W.J. Cantwell, The mechanical properties of 3D woven composites, J. Compos. Mater. 51 (2017) 1703–1716, doi:10.1177/0021998316681187.
[116] Y. Shikinami, Y. Kawabe, K. Yasukawa, K. Tsuta, Y. Kotani, K. Abumi, A biomimetic artificial intervertebral disc system composed of a cubic three-dimensional fabric, Spine J. 10 (2010) 141–152, doi:10.1016/j.spinee.2009.10.008.
[117] M. Persson, P.P. Lehenkari, L. Berglin, S. Turunen, M.A.J. Finnilä, J. Risteli, M. Skrifvars, J. Tuukkanen, Osteogenic Differentiation of Human Mesenchymal Stem cells in a 3D Woven Scaffold, Sci. Rep. 8 (2018) 10457, doi:10.1038/s41598-018-28699-x.
[118] K.A. Glass, J.M. Link, J.M. Brunger, F.T. Moutos, C.A. Gersbach, F. Guilak, Tissue-engineered cartilage with inducible and tunable immunomodulatory properties, Biomaterials 35 (2014) 5921–5931, doi:10.1016/j.biomaterials.2014.03.073.
[119] C. Singh, C. Wong, X. Wang, Medical textiles as vascular implants and their success to mimic natural arteries, J. Funct. Biomater. 6 (2015) 500–525, doi:10.3390/jfb6030500.
[120] M. Takeuchi, T. Kuratani, S. Miyagawa, Y. Shirakawa, K. Shimamura, K. Kin, T. Yoshida, Y. Arai, T. Hoashi, N. Teramoto, K. Hirakawa, N. Kawaguchi, Y. Sawa, Tissue-engineered stent-graft integrates with aortic wall by recruiting host tissue into graft scaffold, J. Thorac. Cardiovasc. Surg. 148 (2014) 1719–1725, doi:10.1016/j.jtcvs.2014.04.003.
[121] X. Yang, L. Wang, G. Guan, M.W. King, Y. Li, L. Peng, Y. Guan, X. Hu, Preparation and evaluation of bicomponent and homogeneous polyester silk small diameter arterial prostheses, J. Biomater. Appl. 28 (2014) 676–687, doi:10.1177/0885328212472216.
[122] S. Enomoto, M. Sumi, K. Kajimoto, Y. Nakazawa, R. Takahashi, C. Takabayashi, T. Asakura, M. Sata, Long-term patency of small-diameter vascular graft made from fibroin, a silk-based biodegradable material, J. Vasc. Surg. 51 (2010) 155–164, doi:10.1016/j.jvs.2009.09.005.
[123] Z. Liu, G. Li, Z. Zheng, Y. Li, Y. Han, D.L. Kaplan, X. Wang, Silk fibroin-based woven endovascular prosthesis with heparin surface modification, J. Mater. Sci. Mater. Med. 29 (2018) 46, doi:10.1007/s10856-018-6055-3.

[124] G.C. Engelmayr, M. Cheng, C.J. Bettinger, J.T. Borenstein, R. Langer, L.E. Freed, Accordion-like honeycombs for tissue engineering of cardiac anisotropy, Nat. Mater. 7 (2008) 1003–1010, doi:10.1038/nmat2316.
[125] M. Kellomäki, K. Laine, V. Ellä, T. Annala, Biomed. Text, Bioabsorbable fabrics for musculoskeletal scaffolds, Orthop. Surg. Appl. Fundam. Appl. Tissue Eng. (2015) 67–90, doi:10.1016/B978-1-78242-017-0.00004-0.
[126] P.K. Valonen, F.T. Moutos, A. Kusanagi, M.G. Moretti, B.O. Diekman, J.F. Welter, A.I. Caplan, F. Guilak, L.E. Freed, In vitro generation of mechanically functional cartilage grafts based on adult human stem cells and 3D-woven poly(ε-caprolactone) scaffolds, Biomaterials 31 (2010) 2193–2200, doi:10.1016/j.biomaterials.2009.11.092.
[127] G. Li, Y. Liu, P. Lan, Y. Li, Y. Li, A prospective bifurcated biomedical stent with seamless woven structure, J. Text. Inst. 104 (2013) 1017–1023, doi:10.1080/00405000.2013.767429.
[128] P. Soltani, M. Zarrebini, Acoustic performance of woven fabrics in relation to structural parameters and air permeability, J. Text. Inst. 104 (2013) 1011–1016, doi:10.1080/00405000.2013.771427.
[129] J. Baets, D. Plastria, J. Ivens, I. Verpoest, Determination of the optimal flax fibre preparation for use in unidirectional flax-epoxy composites, J. Reinf. Plast. Compos. 33 (2014) 493–502, doi:10.1177/0731684413518620.
[130] H. Ma, Y. Li, D. Wang, Investigations of fiber twist on the mechanical properties of sisal fiber yarns and their composites, J. Reinf. Plast. Compos. 33 (2014) 687–696, doi:10.1177/0731684413520187.
[131] F. Omrani, P. Wang, D. Soulat, M. Ferreira, Mechanical properties of flax-fibre-reinforced preforms and composites: influence of the type of yarns on multi-scale characterisations, Compos. Part A Appl. Sci. Manuf. 93 (2017) 72–81, doi:10.1016/j.compositesa.2016.11.013.
[132] G.A. Abou Nassif, Effect of weave structure and weft density on the physical and mechanical properties of micro polyester woven fabrics, Life Sci. J. 9 (2012) 1326–1331.
[133] C.W. Lou, C.W. Lin, C.H. Lei, H.C. Chen, Y.M. Li, J.H. Lin, Weaving technology and mechanical properties of extended-PTFE fabrics, J. Mater. Process. Technol. 192–193 (2007) 319–322, doi:10.1016/j.jmatprotec.2007.04.064.
[134] K.M. Eng, M. Mariatti, N.R. Wagiman, K.S. Beh, Effect of different woven linear densities on the properties of polymer composites, J. Reinf. Plast. Compos. 25 (2006) 1375–1383, doi:10.1177/0731684406065081.
[135] S.J.K.M. ovardhana Rao Chilukoti, M.K.S. Pushyami Akula, D. Rout, Study on Effect of Picks per Inch on Fabric Properties, Int. J. Text. Eng. Process. 1 (2015) 73–77.
[136] M.W. Han, S.H. Ahn, Blooming Knit Flowers: loop-Linked Soft Morphing Structures for Soft Robotics, Adv. Mater. (2017) 29, doi:10.1002/adma.201606580.
[137] A. Liberski, N. Ayad, D. Wojciechowska, D. Zielińska, M.H. Struszczyk, N. Latif, M. Yacoub, Knitting for heart valve tissue engineering, Glob. Cardiol. Sci. Pract. 2016 (2016), doi:10.21542/gcsp.2016.31.
[138] I. Calejo, R. Costa-Almeida, R.L. Reis, M.E. Gomes, A Textile Platform Using Continuous Aligned and Textured Composite Microfibers to Engineer Tendon-to-Bone Interface Gradient Scaffolds, Adv. Healthc. Mater. 8 (2019), doi:10.1002/adhm.201900200.
[139] J. Boublik, H. Park, M. Radisic, E. Tognana, F. Chen, M. Pei, G. Vunjak-Novakovic, L.E. Freed, Mechanical properties and remodeling of hybrid cardiac constructs made from heart cells, fibrin, and biodegradable, elastomeric knitted fabric, Tissue Eng. 11 (2005) 1122–1132, doi:10.1089/ten.2005.11.1122.
[140] J. Sogorkova, V. Zapotocky, M. Cepa, V. Stepankova, H. Vagnerova, J. Batova, M. Pospisilova, J. Betak, K. Nesporova, M. Hermannova, D. Daro, G. Duffy, V. Velebny, Optimization of cell growth on palmitoyl-hyaluronan knitted scaffolds developed for tissue engineering applications, J. Biomed. Mater. Res. - Part A. 106 (2018) 1488–1499, doi:10.1002/jbm.a.36353.
[141] M.C. Lin, J.H. Lin, C.Y. Huang, Y.S. Chen, Tissue engineering stent model with long fiber-reinforced thermoplastic technique, J. Mater. Sci. Mater. Med. 31 (2020), doi:10.1007/s10856-020-06411-8.
[142] H.W. Ouyang, S.L. Toh, J. Goh, T.E. Tay, K. Moe, Assembly of bone marrow stromal cell sheets with knitted poly (L-lactide) scaffold for engineering ligament analogs, J. Biomed. Mater. Res. - Part B Appl. Biomater. 75 (2005) 264–271, doi:10.1002/jbm.b.30281.
[143] K.W. Ng, D.W. Hutmacher, Reduced contraction of skin equivalent engineered using cell sheets cultured in 3D matrices, Biomaterials 27 (2006) 4591–4598, doi:10.1016/j.biomaterials.2006.04.020.
[144] G. Chen, T. Ushida, T. Tateishi, A hybrid network of synthetic polymer mesh and collagen sponge, Chem. Commun. (2000) 1505–1506, doi:10.1039/b003508o.
[145] F. Pu, N.P. Rhodes, Y. Bayon, J.A. Hunt, In vitro cellular response to oxidized collagen–PLLA hybrid scaffolds designed for the repair of muscular tissue defects and complex incisional hernias, J. Tissue Eng. Regen. Med. 10 (2016) E454–E466, doi:10.1002/term.1837.
[146] G. Chen, T. Sato, H. Ohgushi, T. Ushida, T. Tateishi, J. Tanaka, Culturing of skin fibroblasts in a thin PLGA-collagen hybrid mesh, Biomaterials 26 (2005) 2559–2566, doi:10.1016/j.biomaterials.2004.07.034.
[147] W. Dai, N. Kawazoe, X. Lin, J. Dong, G. Chen, The influence of structural design of PLGA/collagen hybrid scaffolds in cartilage tissue engineering, Biomaterials 31 (2010) 2141–2152, doi:10.1016/j.biomaterials.2009.11.070.
[148] H. Fan, H. Liu, S.L. Toh, J.C.H. Goh, Anterior cruciate ligament regeneration using mesenchymal stem cells and silk scaffold in large animal model, Biomaterials 30 (2009) 4967–4977, doi:10.1016/j.biomaterials.2009.05.048.
[149] H. Fan, H. Liu, E.J.W. Wong, S.L. Toh, J.C.H. Goh, In vivo study of anterior cruciate ligament regeneration using mesenchymal stem cells and silk scaffold, Biomaterials 29 (2008) 3324–3337, doi:10.1016/j.biomaterials.2008.04.012.
[150] X. Wang, Q. Li, X. Hu, L. Ma, C. You, Y. Zheng, H. Sun, C. Han, C. Gao, Fabrication and characterization of poly(l-lactide-co-glycolide) knitted mesh-reinforced collagen-chitosan hybrid scaffolds for dermal tissue engineering, J. Mech. Behav. Biomed. Mater. 8 (2012) 204–215, doi:10.1016/j.jmbbm.2012.01.001.
[151] S. Sahoo, J.G. Cho-Hong, T. Siew-Lok, Development of hybrid polymer scaffolds for potential applications in ligament and tendon tissue engineering, Biomed. Mater. 2 (2007) 169–173, doi:10.1088/1748-6041/2/3/001.
[152] S.C. Anand, Technical Fabric Structures - 2. Knitted Fabrics, in: Handb. Tech. Text. Second Ed. (2016) 107–162, doi:10.1016/B978-1-78242-458-1.00005-4.
[153] The Textile Institute and Woodhead Publishing, Text. Fash. (2015) p. ii, doi:10.1016/b978-1-84569-931-4.09001-2.
[154] I. Kanatani, A. Kanematsu, Y. Inatsugu, M. Imamura, H. Negoro, N. Ito, S. Yamamoto, Y. Tabata, Y. Ikada, O. Ogawa, Fabrication of an optimal urethral graft using collagen-sponge tubes reinforced with copoly(L-lactide/ε-caprolactone) fabric, Tissue Eng 13 (2007) 2933–2940, doi:10.1089/ten.2007.0052.
[155] J. Foroughi, G.M. Spinks, S. Aziz, A. Mirabedini, A. Jeiranikhameneh, G.G. Wallace, M.E. Kozlov, R.H. Baughman, Knitted carbon-nanotube-sheath/spandex-core elastomeric yarns for artificial muscles and strain sensing, ACS Nano 10 (2016) 9129–9135, doi:10.1021/acsnano.6b04125.
[156] D. Deng, W. Wang, B. Wang, P. Zhang, G. Zhou, W.J. Zhang, Y. Cao, W. Liu, Repair of Achilles tendon defect with autologous ASCs engineered tendon in a rabbit model, Biomaterials 35 (2014) 8801–8809, doi:10.1016/j.biomaterials.2014.06.058.
[157] D. Sodhani, S. Reese, R. Moreira, S. Jockenhoevel, P. Mela, S.E. Stapleton, Multi-scale modelling of textile reinforced artificial tubular aortic heart valves, Meccanica 52 (2017) 677–693, doi:10.1007/s11012-016-0479-y.
[158] A. Wang, Q. Ao, W. Cao, M. Yu, Q. He, L. Kong, L. Zhang, Y. Gong, X. Zhang, Porous chitosan tubular scaffolds with knitted outer wall and controllable inner structure for nerve tissue engineering, J. Biomed. Mater. Res. - Part A. 79 (2006) 36–46, doi:10.1002/jbm.a.30683.
[159] T. Yagi, M. Sato, Y. Nakazawa, K. Tanaka, M. Sata, K. Itoh, Y. Takagi, T. Asakura, Preparation of double-raschel knitted silk vascular grafts and evaluation of short-term function in a rat abdominal aorta, J. Artif. Organs. 14 (2011) 89–99, doi:10.1007/s10047-011-0554-z.
[160] B. Tschoeke, T.C. Flanagan, S. Koch, M.S. Harwoko, T. Deichmann, V. Ellå, J.S. Sachweh, M. Kellomåki, T. Gries, T. Schmitz-Rode, S. Jockenhoevel, Tissue-engineered small-caliber vascular graft based on a novel biodegradable composite fibrin-polylactide scaffold, Tissue Eng. - Part A. 15 (2009) 1909–1918, doi:10.1089/ten.tea.2008.0499.
[161] K. Simonis, Y.S. Gloy, T. Gries, 3D knitting using large circular knitting machines, IOP Conf. Ser. Mater. Sci. Eng. (2017) 092004, doi:10.1088/1757-899X/254/9/092004.
[162] H. Hu, Z. Wang, S. Liu, Development of auxetic fabrics using flat knitting technology, Text. Res. J. 81 (2011) 1493–1502, doi:10.1177/0040517511404594.
[163] Z. Wang, H. Hu, 3D auxetic warp-knitted spacer fabrics, Phys. Status Solidi Basic Res. 251 (2014) 281–288, doi:10.1002/pssb.201384239.
[164] Y.J. Park, J.K. Kim, The effect of negative Poisson's ratio polyurethane scaffolds for articular cartilage tissue engineering applications, Adv. Mater. Sci. Eng. (2013) 2013, doi:10.1155/2013/853289.
[165] L.H. Timmins, Q. Wu, A.T. Yeh, J.E. Moore, S.E. Greenwald, Structural inhomogeneity and fiber orientation in the inner arterial media, Am. J. Physiol. - Hear. Circ. Physiol. 298 (2010) H1537–H1545, doi:10.1152/ajpheart.00891.2009.
[166] R. Gatt, M.Vella Wood, A. Gatt, F. Zarb, C. Formosa, K.M. Azzopardi, A. Casha, T.P. Agius, P. Schembri-Wismayer, L. Attard, N. Chockalingam, J.N. Grima, Negative Poisson's ratios in tendons: an unexpected mechanical response, Acta Biomater. 24 (2015) 201–208, doi:10.1016/j.actbio.2015.06.018.
[167] A. Derrouiche, F. Zaïri, F. Zaïri, A chemo-mechanical model for osmo-inelastic effects in the annulus fibrosus, Biomech. Model. Mechanobiol. 18 (2019) 1773–1790, doi:10.1007/s10237-019-01176-8.
[168] P. Ma, Y. Chang, A. Boakye, G. Jiang, Review on the knitted structures with auxetic effect, J. Text. Inst. 108 (2017) 947–961, doi:10.1080/00405000.2016.1204901.
[169] W. Xu, P. Ma, G. Jiang, A. Wan, Mechanical properties of polypropylene warp-knitted hernia repair mesh with different pull densities, Polymers (Basel) 10 (2018) 1322, doi:10.3390/polym10121322.
[170] C.D. Kane, U.J. Patil, P. Sudhakar, Studies on the Influence of Knit Structure and Stitch Length on Ring and Compact Yarn Single Jersey Fabric Properties, Text. Res. J. 77 (2007) 572–582, doi:10.1177/0040517507078023.
[171] Q. Fang, D. Chen, Z. Yang, M. Li, In vitro and in vivo research on using Antheraea pernyi silk fibroin as tissue engineering tendon scaffolds, Mater. Sci. Eng. C. 29 (2009) 1527–1534, doi:10.1016/j.msec.2008.12.007.
[172] J.D. Yuan, W.B. Nie, Q. Fu, X.F. Lian, T.S. Hou, Z.Q. Tan, Novel three-dimensional nerve tissue engineering scaffolds and its biocompatibility with Schwann cells, Chinese J. Traumatol. - English Ed. 12 (2009) 133–137, doi:10.3760/CMA.J.ISSN.1008-1275.2009.03.002.
[173] H.Y. Mi, X. Jing, E. Yu, J. McNulty, X.F. Peng, L.S. Turng, Fabrication of triple-layered vascular scaffolds by combining electrospinning, braiding, and thermally induced phase separation, Mater. Lett. 161 (2015) 305–308, doi:10.1016/j.matlet.2015.08.119.
[174] X. Ding, T. Zou, X. Gong, C. Ren, H. Kang, P. Xu, H. Liu, Y. Fan, Trilayered sulfated silk fibroin vascular grafts enhanced with braided silk tube, J. Bioact. Compat. Polym. 31 (2016) 613–623, doi:10.1177/0883911516643107.

[175] Z.J. Shen, N.L. Chen, Preparation technics of polyglycolic acid braiding urethral scaffold, J. Clin. Rehabil. Tissue Eng. Res. 14 (2010) 2111–2113, doi:10.3969/j.issn.1673-8225.2010.12.006.
[176] I. Kanatani, A. Kanematsu, Y. Inatsugu, M. Imamura, H. Negoro, N. Ito, S. Yamamoto, Y. Tabata, Y. Ikada, O. Ogawa, Fabrication of an optimal urethral graft using collagen-sponge tubes reinforced with copoly(L-lactide/ε-caprolactone) fabric, Tissue Eng. 13 (2007) 2933–2940, doi:10.1089/ten.2007.0052.
[177] B. Wang, P. Zhang, W. Song, L. Zhao, C. he, Design and properties of a new braided poly lactic-co-glycolic acid catheter for peripheral nerve regeneration, Text. Res. J. 85 (2015) 51–61, doi:10.1177/0040517514542144.
[178] W.Z. Zhou, Z.Q. Yang, S. Liu, C.G. Zhou, J.G. Xia, L.B. Zhao, H.Bin Shi, A newly designed stent for management of malignant distal duodenal stenosis, Cardiovasc. Intervent. Radiol. 38 (2015) 177–181, doi:10.1007/s00270-014-0899-9.
[179] P. Zamiri, Y. Kuang, U. Sharma, T.F. Ng, R.H. Busold, A.P. Rago, L.A. Core, M. Palasis, The biocompatibility of rapidly degrading polymeric stents in porcine carotid arteries, Biomaterials 31 (2010) 7847–7855, doi:10.1016/j.biomaterials.2010.06.057.
[180] D. Aibibu, M. Hild, C. Cherif, An overview of braiding structure in medical textile, Adv. Braid. Technol. (2016) 171–190, doi:10.1016/b978-0-08-100407-4.00006-5.
[181] M. Zamani, M. Khafaji, M. Naji, M. Vossoughi, I. Alemzadeh, N. Haghighipour, A biomimetic heparinized composite silk-based vascular scaffold with sustained antithrombogenicity, Sci. Rep. 7 (2017) 41795, doi:10.1038/s41598-017-04510-1.
[182] J.A. Cooper, H.H. Lu, F.K. Ko, J.W. Freeman, C.T. Laurencin, Fiber-based tissue-engineered scaffold for ligament replacement: design considerations and in vitro evaluation, Biomaterials 26 (2005) 1523–1532, doi:10.1016/j.biomaterials.2004.05.014.
[183] M.E. Hoque, H.Q. Mao, S. Ramakrishna, Hybrid braided 3-D scaffold for bioartificial liver assist devices, J. Biomater. Sci. Polym. Ed. 18 (2007) 45–58, doi:10.1163/156856207779146088.
[184] M. Spector, M.J. Michno, W.H. Smarook, G.T. Kwiatkowski, A high-modulus polymer for porous orthopedic implants: biomechanical compatibility of porous implants, J. Biomed. Mater. Res. 12 (1978) 665–677, doi:10.1002/jbm.820120508.
[185] C. Wright, Handbook of biomaterials evaluation: scientific, technical, and clinical testing of implant materials, J. Vasc. Surg. 6 (1987) A1, doi:10.1016/s0741-5214(87)70041-x.
[186] X. Gao, A. Siddique, B. Sun, B. Gu, Effect of braiding angle on dynamic mechanical properties of 3-D braided rectangular composites under multiple impact compressions, J. Compos. Mater. 53 (2019) 1827–1846, doi:10.1177/0021998318812926.
[187] C.T. Laurencin, J.W. Freeman, Ligament tissue engineering: an evolutionary materials science approach, Biomaterials 26 (2005) 7530–7536, doi:10.1016/j.biomaterials.2005.05.073.
[188] C.P. Laurent, D. Durville, D. Mainard, J.F. Ganghoffer, R. Rahouadj, A multilayer braided scaffold for Anterior Cruciate Ligament: mechanical modeling at the fiber scale, J. Mech. Behav. Biomed. Mater. 12 (2012) 184–196, doi:10.1016/j.jmbbm.2012.03.005.
[189] B. Dauda, S.O. Oyadiji, P. Potluri, Characterising mechanical properties of braided and woven textile composite beams, Appl. Compos. Mater. 16 (2009) 15–31, doi:10.1007/s10443-008-9073-3.
[190] N. Jiang, H. Hu, Auxetic Yarn Made with Circular Braiding Technology, Phys. Status Solidi Basic Res. 256 (2019) 1800168, doi:10.1002/pssb.201800168.
[191] M.C. Lu, Y.T. Huang, J.H. Lin, C.H. Yao, C.W. Lou, C.C. Tsai, Y.S. Chen, Evaluation of a multi-layer microbraided polylactic acid fiber-reinforced conduit for peripheral nerve regeneration, J. Mater. Sci. Mater. Med. 20 (2009) 1175–1180, doi:10.1007/s10856-008-3646-4.
[192] H. Ahn, K.J. Kim, S.Y. Park, J.E. Huh, H.J. Kim, W.R. Yu, 3D braid scaffolds for regeneration of articular cartilage, J. Mech. Behav. Biomed. Mater. 34 (2014) 37–46, doi:10.1016/j.jmbbm.2014.01.004.
[193] X. Liu, A. Baldit, E. de Brosses, F. Velard, G. Cauchois, Y. Chen, X. Wang, N. de Isla, C. Laurent, Characterization of bone marrow and Wharton's jelly mesenchymal stromal cells response on multilayer braided silk and silk/PLCL scaffolds for ligament tissue engineering, Polymers (Basel) 12 (2020), doi:10.3390/POLYM12092163.
[194] P.L. Blanton, N.L. Biggs, Ultimate tensile strength of fetal and adult human tendons, J. Biomech. 3 (1970) 181–184, doi:10.1016/0021-9290(70)90005-9.
[195] M. Beldjilali-Labro, A.G. Garcia, F. Farhat, F. Bedoui, J.F. Grosset, M. Dufresne, C. Legallais, Biomaterials in tendon and skeletal muscle tissue engineering: current trends and challenges, Materials (Basel) 11 (2018) 116, doi:10.3390/ma11071116.
[196] T.D. O'Brien, N.D. Reeves, V. Baltzopoulos, D.A. Jones, C.N. Maganaris, Mechanical properties of the patellar tendon in adults and children, J. Biomech. 43 (2010) 1190–1195, doi:10.1016/j.jbiomech.2009.11.028.
[197] N. Chandrashekar, H. Mansouri, J. Slauterbeck, J. Hashemi, Sex-based differences in the tensile properties of the human anterior cruciate ligament, J. Biomech. 39 (2006) 2943–2950, doi:10.1016/j.jbiomech.2005.10.031.
[198] G.E. Kempson, M.A. Tuke, J.T. Dingle, A.J. Barrett, P.H. Horsefield, The effects of proteolytic enzymes on the mechanical properties of adult human articular cartilage, BBA - Gen. Subj. 428 (1976) 741–760, doi:10.1016/0304-4165(76)90205-1.
[199] D.L. Bader, G.E. Kempson, A.J. Barrett, W. Webb, The effects of leucocyte elastase on the mechanical properties of adult human articular cartilage in tension, BBA - Gen. Subj. 677 (1981) 103–108, doi:10.1016/0304-4165(81)90150-1.
[200] D.M. Elliott, F. Guilak, T.P. Vail, J.Y. Wang, L.A. Setton, Tensile properties of articular cartilage are altered by meniscectomy in a canine model of osteoarthritis, J. Orthop. Res. 17 (1999) 503–508, doi:10.1002/jor.1100170407.
[201] S. Akizuki, V.C. Mow, F. Müller, J.C. Pita, D.S. Howell, D.H. Manicourt, Tensile properties of human knee joint cartilage: I. Influence of ionic conditions, weight bearing, and fibrillation on the tensile modulus, J. Orthop. Res. 4 (1986) 379–392, doi:10.1002/jor.1100040401.
[202] R. Vincentelli, M. Grigoroy, The effect of Haversian remodeling on the tensile properties of human cortical bone, J. Biomech. 18 (1985) 201–207, doi:10.1016/0021-9290(85)90205-2.
[203] L. Røhl, E. Larsen, F. Linde, A. Odgaard, J. Jørgensen, Tensile and compressive properties of cancellous bone, J. Biomech. 24 (1991) 1143–1149, doi:10.1016/0021-9290(91)90006-9.
[204] W. Li, Biomechanical property and modelling of venous wall, Prog. Biophys. Mol. Biol. 133 (2018) 56–75, doi:10.1016/j.pbiomolbio.2017.11.004.
[205] C.M. Suh, S.H. Kim, K.L. Monson, W. Goldsmith, Tensile characteristics and behavior of blood vessels from human brain in uniaxial tensile test, KSME Int. J. 17 (2003) 1016–1025, doi:10.1007/BF02982986.
[206] F. Montini-Ballarin, D. Calvo, P.C. Caracciolo, F. Rojo, P.M. Frontini, G.A. Abraham, G.V. Guinea, Mechanical behavior of bilayered small-diameter nanofibrous structures as biomimetic vascular grafts, J. Mech. Behav. Biomed. Mater. 60 (2016) 220–233, doi:10.1016/j.jmbbm.2016.01.025.
[207] M. Ottenio, D. Tran, A. Ní Annaidh, M.D. Gilchrist, K. Bruyère, Strain rate and anisotropy effects on the tensile failure characteristics of human skin, J. Mech. Behav. Biomed. Mater. 41 (2015) 241–250, doi:10.1016/j.jmbbm.2014.10.006.
[208] K. Ma, T. Yong, K.C. Chan, S. Ramakrishna, Collagen-blended biodegradable polymer nanofibers: potential substrates for wound healing in skin tissue engineering, in: Proc. 5th IASTED Int. Conf. Biomed. Eng. BioMED 2007, 2007, pp. 262–266.
[209] J. Walraevens, B. Willaert, G. De Win, A. Ranftl, J. De Schutter, J. Vander Sloten, Correlation between compression, tensile and tearing tests on healthy and calcified aortic tissues, Med. Eng. Phys. 30 (2008) 1098–1104, doi:10.1016/j.medengphy.2008.01.006.
[210] T. Pham, F. Sulejmani, E. Shin, D. Wang, W. Sun, Quantification and comparison of the mechanical properties of four human cardiac valves, Acta Biomater. 54 (2017) 345–355, doi:10.1016/j.actbio.2017.03.026.
[211] Chen Jiang, Kan Wang, Yi Liu, Chuck Zhang, Ben Wang, Textile-based sandwich scaffold using wet electrospun yarns for skin tissue engineering, journal of the mechanical behavior of biomedical materials 119 (104499) (2021), doi:10.1016/j.jmbbm.2021.104499.
[212] Chen Jiang, Kan Wang, Yi Liu, Chuck Zhang, Ben Wang, Using Wet Electrospun PCL/Gelatin/CNT Yarns to Fabricate Textile-Based Scaffolds for Vascular Tissue Engineering, ACS Biomaterials Science & Engineering (2021), doi:10.1021/acsbiomaterials.1c00097.