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Physico-Mechanical Performance Evaluation of Large Pore Synthetic Meshes with Different Textile Structures for Hernia Repair Applications

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Abstract

This paper studied the relationship between the textile structure of warp knitted hernia repair meshes and their physico-mechanical properties to solve the problem of hernia patch application evaluation and clear the mechanism of hernia patch structure-performance for clinical application. Six different prototypes of large pore meshes were fabricated, including four kinds of meshes with different pore shapes: H (hexagonal), D (diamond), R (round) and P (pentagonal); and two kinds of meshes with inlays: HL (hexagonal with inlays) and DL (diamond with inlays), using the same medical grade polypropylene monofilament. All meshes were designed with the same walewise density and coursewise density. Then the influence of other structural parameters on the physico-mechanical properties of the meshes was analysed. The physico-mechanical properties of these meshes tested meet the requirements of hernia repair, except mesh DL, whose tear resistance strength (12.93 ± 2.44 N in the transverse direction) was not enough. Mesh R and P demonstrated less anisotropy, and they exhibited similar physico-mechanical properties. These four kinds of meshes without inlays demonstrated similar ball burst strength properties, but mesh HL and DL exhibited better ball burst strength than the others. All in all, uniform structures are expected to result in less anisotropy, and meshes with inlays, to some extent, possess higher mechanical properties. And the ratio of open loop number to closed loop number in a repetition of weave of fabric has marked effect on the physico-mechanical properties. Thus we can meet the demands of specific patients and particular repair sites by designing various meshes with appropriate textile structures.

Key words: *hernia repair, large-pore meshes, physico-mechanical properties, warp knitted meshes, pore shape, meshes with inlays.*

Introduction

More and more prosthetic patches have been used in hernia repair, especially textile based polypropylene meshes. But there is still not enough systematic study of textile based hernia repair meshes. Substantial evidence has shown that the post-operative complications of hernia repair using meshes including seroma, discomfort, and even chronic pain and recurrences are related to the textile structure and physico-mechanical properties of the meshes used [1-4].

Olivier Lefranc et al. [3] pointed out that mesh porosity, surface properties, biomechanics and stability are the key parameters for the success of hernia repair. And many researchers have shown that meshes with macroporosity above 1 mm displayed better repair performance, with fewer fibrous capsules as well as less shrinkage and discomfort [2, 5, 6]. The mechanical properties of commercially used meshes were investigated, including anisotropy, non-linearity and hysteresis [7, 8] in the uniaxial and biaxial directions of meshes with and without an adhesion barrier layer/coating, it was found that due to the different mesh types and their orientations, significant differences exist among them, with the mesh direction being very critical for the success of hernia repair. Moreover the properties of meshes should be matched with each patient perfectly. The stiffness and permanent deformation of Prolene mesh were also studied [9], which was mainly about the long term mesh performance, the anisotropy of meshes and their placement in surgery.

Recently some researchers have paid attention to mesh structures, especially their textile parameters [3, 10-12]. Jiang GM et al. [10] studied one kind of mesh with an atlas structure, and pointed out that a mesh with 18 to 20 courses per centimeter had the best mechanical properties. He also investigated the optimal heat-setting parameters of this kind of mesh. Zhu LM et al. [11] pointed out that large-pore meshes manufactured with monofilament had better properties. They also compared several kinds of textile structures: weft knitted, warp knitted, nonwoven and woven fabrics. It turns out that most textile mesh implants are warp knitted due to its stability when trimmed and keeping elasticity under load. However, there are insufficient systematic
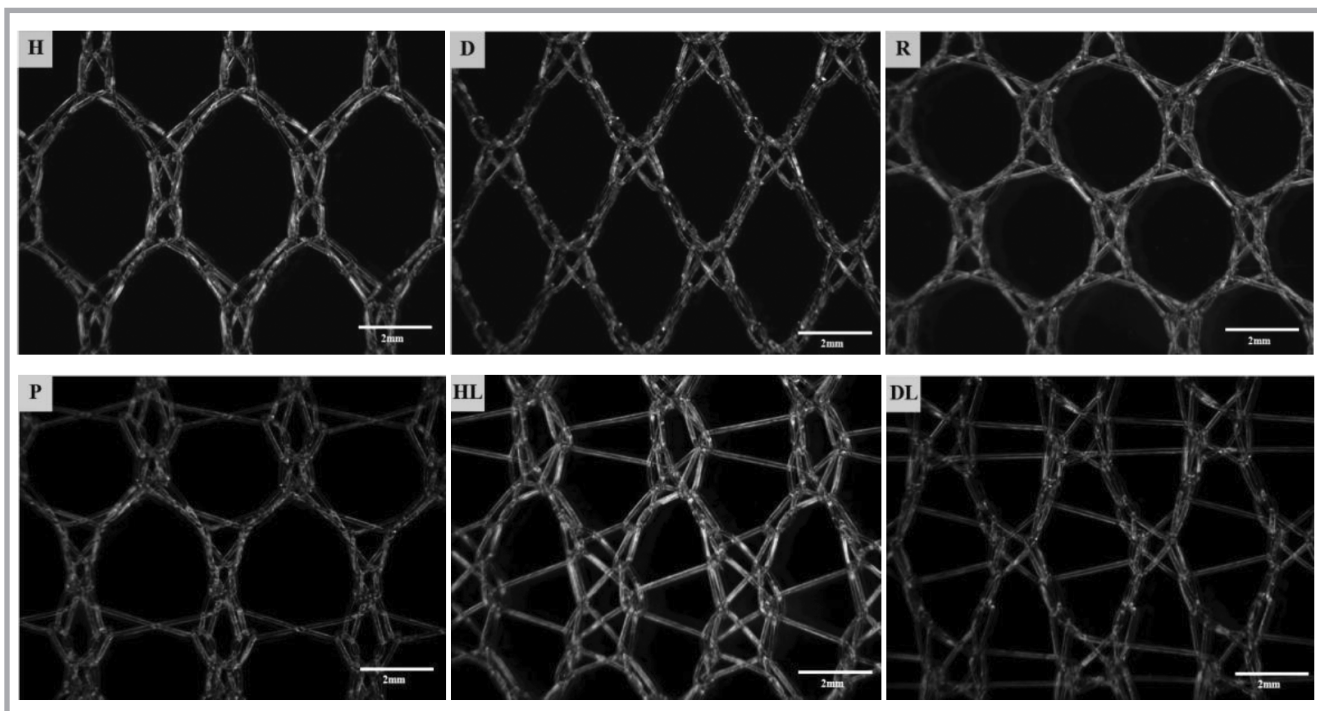
Figure 1. *Photos of each mesh investigated in this research: (H) hexagon, (D) diamond, (R) round, (P) pentagon, (HL) hexagon with laying in, (DL) diamond with laying in.* **Notes:** *Scale bar 2 mm.*
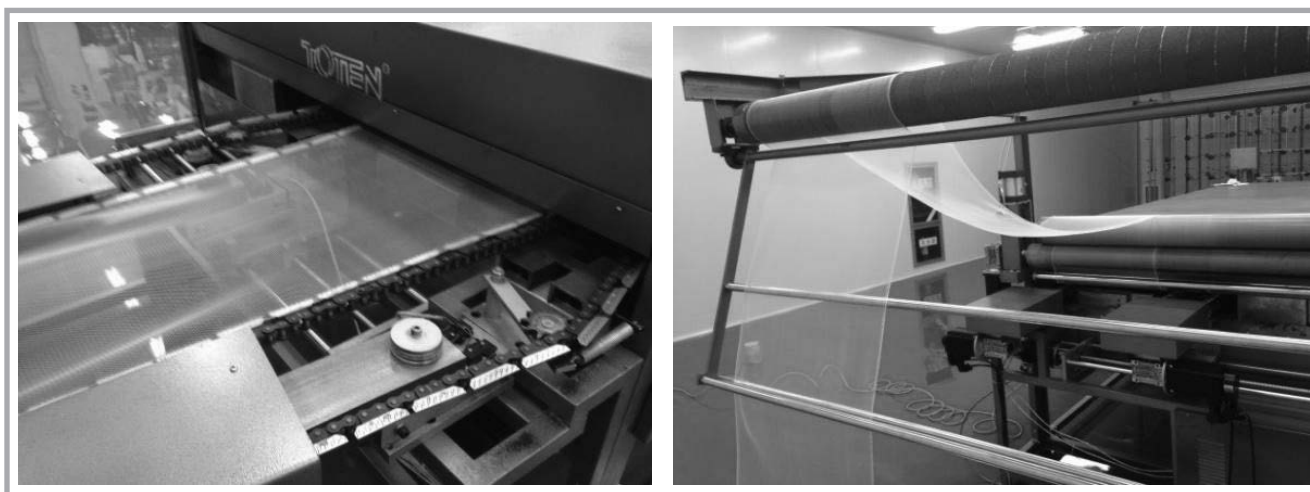
Figure 2. *Heating apparatus used in this study.*

studies on the relationship between their textile structure and performance.

Within the perspective of textile technology, raw materials, structural parameters and finishing techniques are key factors for the physico-mechanical properties and biological properties of meshes [13-15]. Mesh structure and physico-mechanical performance are very important during the application of a hernia patch, which is not only to meet the requirements of the application of tissue engineering, but also be suitable for a clinical doctor's convenience of operation. However, these basic problems of research on

the structure and physico-mechanical properties of a hernia patch have not yet been studied deeply. Scientific research has important academic significance and application value in exploring the relationship between the structure and performance of a hernia patch, and clear the mechanism of hernia patch structure-performance for clinical application evaluation. In this study, we aimed to explore the relationship between textile structural parameters of warp knitted macro porous meshes and their physico-mechanical properties. Especially meshes with large pores and different pore shape, with or without inlays, their physical charac-

terisation, uniaxial tensile strength, tear resistance, ball burst strength and suture retention strength were analysed.

■ Materials and method

Materials

Medical grade polypropylene monofilaments were supplied by the Shandong Xinhua Medical Device Co., LTD, China. According to the monofilament information they provided to us, PP monofilament was 0.1527 mm in diameter, and its linear density was 161 dtex. Its breaking strength was about 5.36 cN·dtex^{-1}, and its elongation at break was about 31%.

Preparation of prototype meshes

Six different prototype meshes (*Figure 1*) were fabricated on a raschel machine, RS4EL (Runyuan Medical Supplies Technology Co., LTD, Changzhou, Jiangsu, China), gauge E12 with an electronic guide bar control system. All of these meshes were knitted with the same walewise and coursewise density: 10 courses per centimeter, and 10 wales per centimeter.
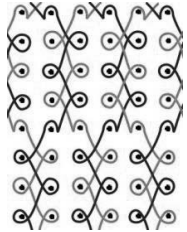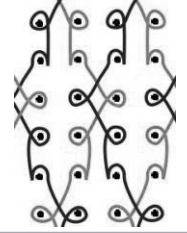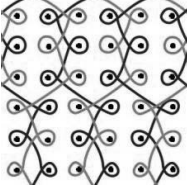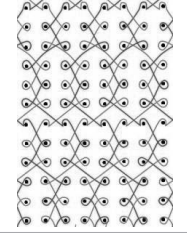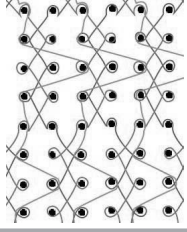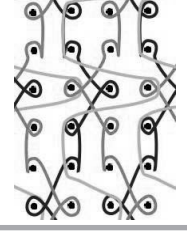
As shown in *Figure 1*, meshes H (hexagonal mesh), D (diamond mesh), R (round mesh) and P (pentagonal mesh) were fabricated on a warp knitted machine using two partly-threaded guide bars, while meshes HL (hexagonal with inlay mesh) and DL (diamond with inlay mesh) were made by adding a third partly-threaded inlay guide bar in the basal structure of mesh H and D, respectively. *Table 1* shows the parameters of the knitting process and knitting schemes of these six kinds of meshes. As we can see from *Table 1*, meshes H, D and P all possess both open and closed loops in their structures, while mesh R only has closed loops. The ratio of the open loop number to closed loop number in a repetition of weave of these four kinds of meshes was calculated. It turns out that mesh D possesses the highest ratio (1:2), followed by mesh H (1:3), while the ratio of the open to closed loop number of mesh P is 1:5. Due to the different distribution of open and closed loop underlap, they will display diverse characteristics.

The properties of meshes are not steady when off the loom, for instance, the density and flexural rigidity, and therefore they cannot be used in surgery immediately; thus heat-setting is necessary. In this research, six prototype meshes were heat-set at 130 °C for 10 minutes, according to our previous research [16]. The heat-setting machine used in this study was a TOOTEN small fabric stenter setting machine (Shanghai Tangyin Garment Machinery Factory). The meshes were fed in the machine after the temperature was steady, namely 130 ± 2 °C. After 10 minutes, the mesh was outputed on the other side and cooled down for the next process. *Figure 2* is the heating apparatus used in this study.

Physical characterisation testing

The weight per unit area of each mesh was described in grams per square meter (GSM) using a FA2004A electronic balance (BS124S, Germany). Each sample was cut to 100 mm × 100 mm, with 10 samples for each mesh (n = 10). Results were reported as the mean ± standard error of the mean (SEM).

The thickness of each mesh was measured using a YG141N digital fabric thickness tester (Nantong Hongda Experiment Instrument Co., LTD, China) in a standard atmosphere (20 ± 2 °C; 65 ± 2% humidity). Each mesh was tested 10 times at different points on the fabric and reported as mean ± SEM.

The images of six different prototype meshes were captured by a stereoscopic microscope (CH-2 NIKON, ECLIPSE E200, Japan) (*Figure 1*). Then Image J software was utilised to calculate the porosity of each mesh. And the pore size of each sample was measured via a vernier caliper.
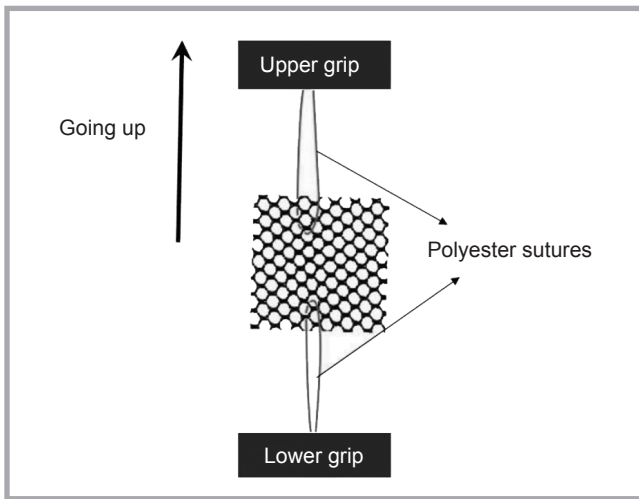
Table 1. *Parameters of the knitting process and knitting schemas.*

Mesh code	Chain notation	Warp feed, mm/rack	Knitting schemas
H	GB1: 2-3/2-1/2-3/2-1/1-0/1-2/1-0/1-2//	GB1: 2300	
	GB2: 1-0/1-2/1-0/1-2/2-3/2-1/2-3/2-1//	GB2: 2350	
D	GB1: 1-0/1-2/2-1/2-3/2-1/1-2//	GB1: 2250	
	GB2: 2-3/2-1/1-2/1-0/1-2/2-1//	GB2: 2190	
R	GB1: 1-0/1-2/2-1/2-3/2-1/1-2//	GB1: 2585	
	GB2: 2-3/2-1/2-3/1-0/1-2/1-0//	GB2: 2530	
P	GB1: 1-0/1-2/1-0/2-3/2-1/2-3/4-5/4-3/4-5/3-2/3-4/3-2//	GB1: 2585	
	GB2: 4-5/4-3/4-5/3-2/3-4/3-2/1-0/1-2/1-0/2-3/2-1/2-3//	GB2: 2490	
HL	GB1: 2-3/2-1/2-3/2-1/1-0/1-2/1-0/1-2//	GB1: 2700	
	GB2: 1-0/1-2/1-0/1-2/2-3/2-1/2-3/2-1//	GB2: 2700	
	GB3: 0-0/2-2/0-0/1-1/0-0/3-3/0-0/1-1//	GB3: 1150	
DL	GB1: 1-0/1-2/2-1/2-3/2-1/1-2//	GB1: 2438	
	GB2: 2-3/2-1/1-2/1-0/1-2/2-1//	GB2: 2480	
	GB3: 2-2/0-0/0-0/3-3/0-0/0-0//	GB3: 1600	

Figure 3. *Schematic illustration of suture retention strength testing.*
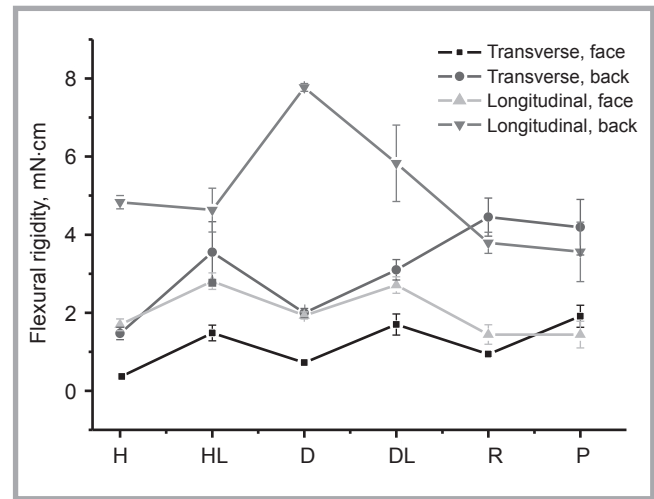

Figure 4. *Flexural rigidity of each mesh for their technical face and technical back in the longitudinal and transverse directions.*

In this research, the longitudinal direction is the orientation parallel to the leg of the warp knitted loop, and the transverse direction is the orientation perpendicular to the longitudinal direction.

The measurement of flexural rigidity of each prototype mesh was based on the national standard GB/T18318-2001 (Textiles-Determination of bending length of fabric), utilising the equipment of a LLY-01B electronic stiffness tester (Laizhou Electronic Instrument Co., LTD, China). Compared with ISO 9073-7:1995, this criterion applies to many more kinds of fabrics. In this research, the inclined plane flexural rigidity testing method was used to evaluate the flexural rigidity of each mesh in the longitudinal and transverse directions, as well as the technical face and technical back of each mesh. The slope angle was 41.5°, and the size of each sample was 25 mm × 250 mm, with 10 samples for each situation. Each sample was cut parallel or perpendicular to the stitch direction of the knitted fabric structure. Results were reported as mean ± SEM.

Uniaxial tensile testing

Uniaxial tensile testing was based on the national standard of GB/T 3923.1-1997 (Textiles – Tensile properties of fabrics – Part 1: Determination of breaking force and elongation at breaking force – Strip method), using a HD 026N+ electronic fabric strength tester (Nantong Hongda Experiment Instrument Co., LTD, China). Compared with ISO/DIS 13934.1-94, this standard also applies to knitted fabric, nonwoven fabric, coated fabric, among others. The clamping length was 200 mm, the stretching speed 100 mm/min, and the pre-tension was 2N. The size of each sample was 50 mm × 250 mm, cut parallel or perpendicular to the stitch direction of the knitted fabric structure. Results were reported as mean ± SEM.

Tear resistance testing

Tear resistance testing was based on the criterion of GB/T 3917.3-2009 (Textiles – Tear properties of fabrics – Part 3: Determination of tear force of trapezoid-shaped test specimens) with reference to ISO 9073-4: 1997, Textiles – Test methods for nonwovens – Part 4: Determination of tear resistance using the trapezoidal tearing method to measure the tear resistance strength of each direction of the samples. The apparatus used was a HD 026N+ electronic fabric strength tester (Nantong Hongda Experi-

ment Instrument Co., LTD, China), with a clamping length of 25mm. This test was performed at a rate of 100 mm/min, with an initial load of 1N until the sample tore in half. Each sample was cut parallel or perpendicular to the stitch direction of the knitted fabric structure. Tear strength was recorded as mean ± SEM.

Ball burst testing

Ball burst testing was based on the national standard of GB/T 19976-2005 (Textiles – Determination of Bursting Strength – Steel Ball Method), using a HD 026N+ electronic fabric strength tester (Nantong Hongda Experiment Instrument Co., LTD, China). The main technical contents of this standard are formulated by reference to ISO 3303:1990 "Rubber-or Plastic-coated Fabric-Determination of Bursting Strength" and EN 12332-1:1998 "Rubber-or Plastic-coated Fabric-Determination of Bursting Strength – Part 1: Steel Ball Method", with a clamping length of 400mm and bursting speed of 100 mm/min. Each sample was cut into a round shape with a diameter of 60 mm. The diameter of the stainless steel ball utilised to burst through the mesh was 20 mm. The results were reported as mean ± SEM.

Suture retention strength testing

Figure 3 shows a schematic illustration of suture retention testing. The apparatus utilised in this study was a YG (B) 026H-500 multifunctional medical textiles strength tester (Wenzhou Darong Textile Instrument Co., LTD, China), with two high strength polyester sutures passing through the mesh, one about 4 mm to

Table 2. *Mesh thickness, GSM and porosity of meshes investigated in this study.*

Mesh type	Thickness, mm	GSM, g/m²	Porosity, %
H	0.576±0.003	40.26±0.69	75.90±2.70
HL	0.655±0.009	53.47±0.31	63.38±1.12
D	0.571±0.014	42.47±1.28	76.53±3.02
DL	0.577±0.013	53.25±1.00	65.7±2.73
R	0.559±0.005	46.78±0.75	73.21±1.09
P	0.545±0.017	46.16±1.35	73.21±1.09
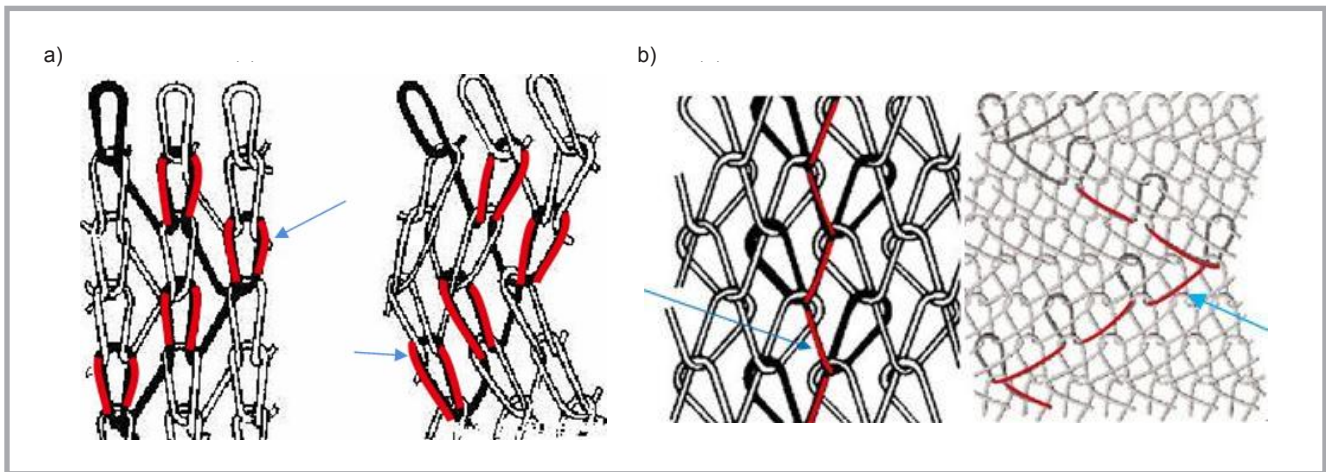
Figure 5. *Structure samples of warp knitted fabric: a) technical face with open loops and closed loops; the arrow indicates loop legs., b) technical back, all closed loops; the arrow indicates the underlap.*

the upper edge of the mesh, and the other one about 4 mm to the lower edge of the mesh. Then the suture on the upper edge of the mesh went up with a speed of 100 mm/min until the suture pulled through the mesh. Each sample was cut parallel or perpendicular to the stitch direction of the knitted fabric structure. The size of each sample was 50 mm × 50 mm. Both the longitudinal direction and transverse direction of the meshes were tested and recorded as mean ± SEM.

Statistical analysis

A one-way analysis of variance (ANOVA) was performed using Minitab software (version 17), followed by Tukey's post-test. A Pearson correlation test was performed to examine whether the physical characterisation (thickness, GSM, or porosity) of the meshes correlated to the physico-mechanical properties. Correlations were defined as strong (r = 0.7 – 1.0), mild (r = 0.4 – 0.7), or weak (r = 0.2 – 0.4). The statistical significance was set at the p < 0.05 level, and all results were reported as the mean ± standard error of the mean.

Results and discussion

Physical characterisation testing

The mesh thickness, GSM and porosity are presented in *Table 2*. Mesh R and mesh P presented almost the same thickness, GSM and porosity. Similarly meshes HL and DL also had nearly the same physical characterisation. As we can see, meshes HL and DL exhibited very high GSM, both above 53 g/m², and very low porosity.

Structural parameters play a vital role in the properties of meshes. The pore size of the meshes has the greatest significant impact on the wound healing process [17, 18]. According to Cobb W et al. [5] and Gonzalez R et al. [19], porosity is a critical factor to control fibrosis, and the mesh pore size must be around or larger than 1-1.5 mm. If the pore size is too small, there is a risk of bacterial penetration without gaining access to the immune competent cells. Besides meshes with a large pore size show lower granuloma formation and less foreign-body reaction than the small pore size meshes [20]. These six kinds of meshes all possess a large pore size of more than 3 mm, which will be enough for the immune competent cells to get through. But with different textile structures, they exhibit various mechanical properties.

Deeken et al. [7] researched nine commercially used meshes for inguinal hernia repair and made a classification of meshes. According to their study, all the six prototype meshes in this research had a very large area of interstices (greater than 2,000 μm, *Figure 1*), and belonged to the "Thin" group in thickness. While meshes HL and DL presented thicker and heavier characterisation and lower porosity mainly due to their additional third inlays, which appeared in the middle of the mesh pore. They belonged to the "Medium-weight" (50-90 g/m²) group in GSM, and the other four prototype meshes to the "Light-weight" (35-50 g/m²) group. But compared with the clinically available uncoated polypropylene hernia meshes: BardMesh (Davol, Inc), PROLENE (Ethicon, Inc), and ProLite (AtriumMedical Corp), the six kinds of

meshes fabricated herein are all lighter than them, and their GSM are of the same level as for ProLite Ultra (Atrium Medical Corp)(density = 50.11 ± 0.5 g/m²) [7]. While the thickness of ProLite (0.47 ± 0.008 mm) and ProLite Ultra (0.39 ± 0.028 mm) is thinner than that of the six meshes manufactured herein, that of BardMesh is thicker (0.73 ± 0.006 mm). The six kinds of meshes have almost the same thickness as PROLENE (0.53 ± 0.007 mm) [7].

Flexural rigidity reflects the soft degree of fabric, and it can, to some extent, represent the sense of the foreign-body reaction of hernia repair mesh implanted in a patient's body. As shown in *Figure 4*, each prototype mesh exhibited greater flexural rigidity of the technical back than the technical face in the same direction. Fabric take-up is always rolling the cloth from the technical face to the technical back during the knitting process, which causes the technical face to bend more easily than the technical back.

All of these meshes exhibited greater flexural rigidity of the same technical surface in the longitudinal direction than in the transverse direction. The needle loop is located between the loop legs and underlap, and hence will affect the bending rigidity of both the technical face and technical back. The difference that occurred may be due to the arrangement direction of the loop legs and underlap. There are only loop legs on the technical face, as shown in *Figure 5.a*, and the legs are mostly aligned in the longitudinal direction; thus the longitudinal direction's flexural rigidity is larger than for the transverse direction, except for mesh-
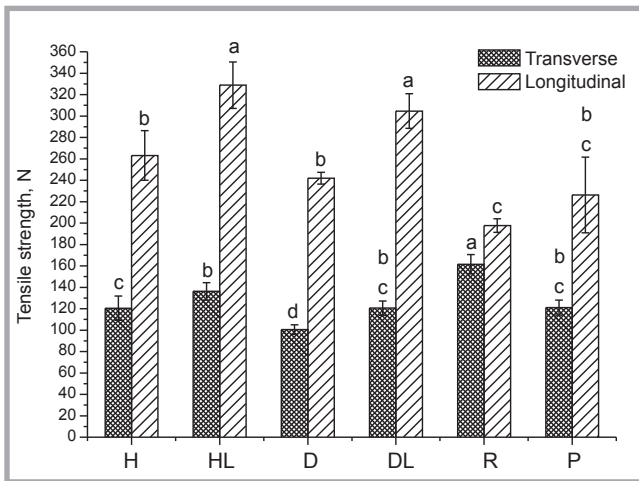
Figure 6. *Uniaxial tensile testing (units = N) depicted as mean ± SEM. For each direction, different letters, if any, represent statistically significant differences.*
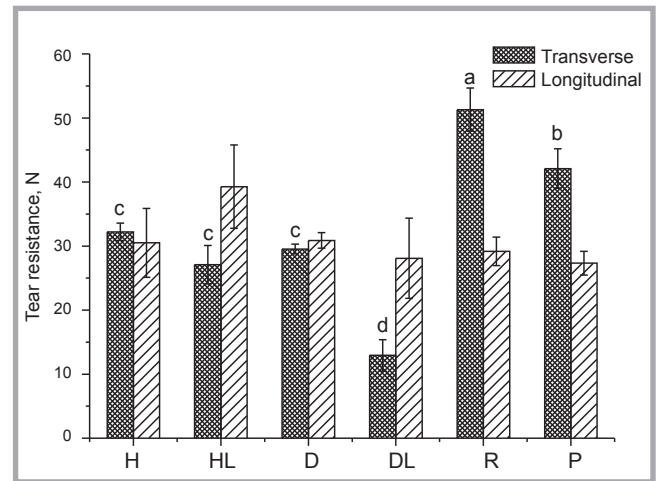
Figure 7. *Tear resistance of each mesh in the longitudinal and transverse directions in mean ± SEM. Different letters, if any, represent statistically significant differences.*

es R and P, which was almost the same in the perpendicular directions. While on the technical back, as shown in *Figure 5.b*, the underlap arrangement of the structure with only closed loops is more uniform than that with both open loops and closed loops. Therefore we can infer that the fewer open loops a fabric has, the higher its transverse flexural rigidity will be. The ratio of the open loop number to closed loop number of meshes R and P is smaller than for meshes H and D, hence their transverse flexural rigidity is larger than for meshes R and P. Meanwhile the gap between the longitudinal and transverse flexural rigidity of meshes R and P is narrowed.

The flexural rigidity of mesh HL and mesh DL in the technical face and back as well as in the longitudinal and transverse directions was not significantly different, meaning that meshes DL and HL had the same softness in the same technical face or direction as for meshes R and P. While mesh D exhibited extremely high flexural rigidity of the technical back in the longitudinal direction, which meant mesh D possessed a hard handfeel along the longitudinal direction in the technical back. Mesh H exhibited the lowest flexural rigidity of the technical face and technical back in the longitudinal and transverse

directions, and as a result it had a softer handfeel than the others. Therefore it is necessary to distinguish the technical back or face and the longitudinal or transverse direction when cutting the meshes.

Uniaxial tensile testing

The strength of each mesh varied widely (*Figure 6*), but they all exhibited greater longitudinal strength than transverse strength. The longitudinal direction is parallel to the leg of the warp knitted loop. When pulled in the longitudinal direction, it is the leg of the loop and cross points of the sinker loop and needle loop that mainly bear the load. On the contrary, it is the sinker loop, needle loop, underlap and their cross points that bear the load when stretched in the transverse direction. As stated above, legs in the longitudinal direction are more uniform, and thus the strength of this direction is larger. Meshes DL and HL exhibited excellent tensile properties of the perpendicular axes, significantly higher than for meshes H and D, respectively. For meshes H, D, R and P, the transverse tensile strength was markedly different. Due to the relatively uniform underlap of mesh R, with no open loops in its structure, it showed significantly higher transverse strength than the other three kinds of meshes. While the longitudinal tensile

strength of meshes H, D, and P did not have that much difference, mesh R displayed significantly lower longitudinal strength than the other meshes. Nevertheless mesh R was the least anisotropic mesh, without a marked difference in the two perpendicular directions, as a result of a nearly consistent number of monofilaments and stretch conditions. As for mesh with and without additional inlays (meshes H & HL and meshes D & DL), the third inlays added cross points among the monofilaments, as a result of which increasing the frictional force when stretched; consequently the tensile strength of mesh HL and mesh DL were larger than for meshes H and D. Tensile strength is closely associated with fabric density and the structure of fabrics; the more cross points there are, the larger tensile strength is.

Tear resistance testing

The tear resistance strength of the longitudinal direction of the six prototype meshes in this study had no significant differences (*Figure 7*), all about 30 N, which was enough for hernia repair ($\geq 20N$) [7]. However, in the transverse direction, meshes R and P exhibited much greater tear resistance than the other prototype meshes, 51.3 ± 3.37 N and 42.09 ± 3.09 N, respectively. While mesh

Table 3. *Pearson correlations.*

Physical character	Ball burst strength	Uniaxial tensile strength		Tear resistance		Suture retention strength	
		transverse	longitudinal	transverse	longitudinal	transverse	longitudinal
Thickness	0.729	0.115	0.702	-0.363	0.389	0.270	0.228
GSM	0.609	0.324	0.550	-0.411	0.167	0.218	0.653
Porosity	-0.686	-0.189	-0.720	0.493	-0.223	-0.265	-0.630
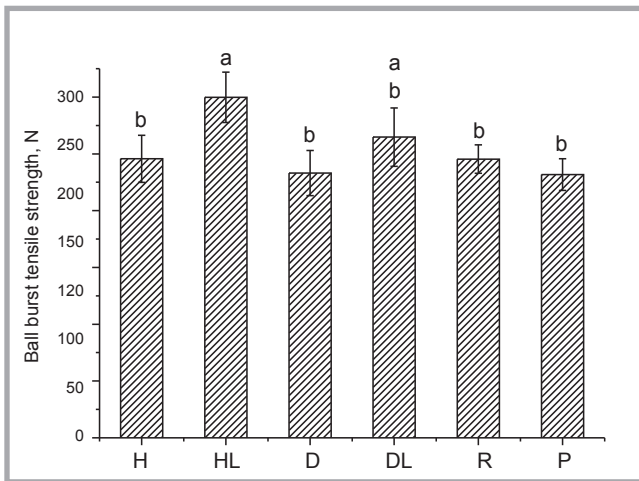
Figure 8. *Ball burst tensile strength (units = N) depicted as mean ± SEM. Different letters, if any, represent statistically significant differences.*
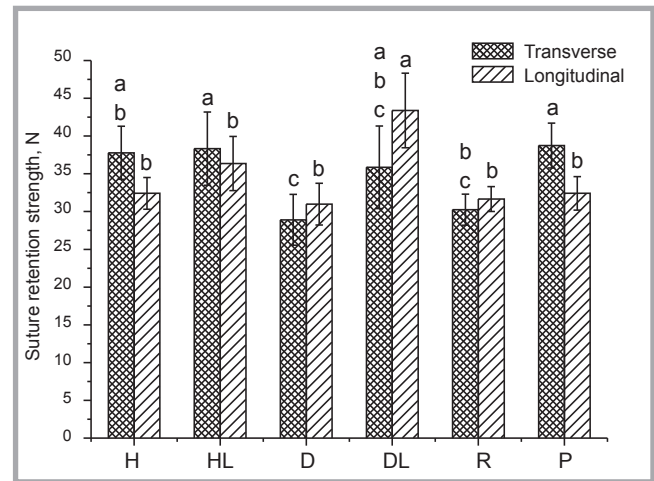
Figure 9. *Suture retention of each mesh in the longitudinal and transverse directions in mean ± SEM. Different letters, if any, represent statistically significant differences.*

DL possessed very low transverse tear resistance, namely 12.93 ± 2.44 N, and was not appropriate for hernia repair (at least for larger than 20N) [7]. In fact, as shown in *Figure 1*, the textile structure of mesh DL was not as tight as the others. As a result, there were not sufficient monofilaments bearing the load when torn. Meshes H, HL and D exhibited nearly the same tear resistance in the two orthogonal directions.

We can find that the transverse tensile strength and tear resistance strength show a contrast to the ratio of open loops and closed loop number of meshes H, D, P and R. Namely mesh R displays the highest strength and mesh D the lowest in these two aspects, and meshes P and H are moderate. We can infer that the ratio of open loops to closed loops in the textile structure do have a significant effect on its physico-mechanical properties.

Ball burst testing

The ball burst strength (*Figure 8*) of mesh HL was significantly higher than for meshes H, D, R and P, but had no significant differences from mesh DL, mainly due to its third additional inlay. And mesh DL had no significant differences from meshes H, D, R and P.

The ball used in this study to test its burst strength was about 2 cm in diameter. Mesh HL exhibited a high ball burst tensile strength, about 300 N on average. But the ball burst strength of mesh DL was moderate, about 265 N; the other four kinds of meshes were about 240 N on average. When the ball pushes up, the mesh bears forces from multiple direc-

tions, and it tears from the weakest point. Knitted fabrics usually have good ball burst strength due to their higher elongation and better isotropic than woven fabrics. This test shows us that the ball burst strength can be improved by adding inlays to the structure. Besides fabrics with thicker yarn or higher density also have better ball burst strength.

Suture retention strength testing

Six kinds of mesh represented nearly the same suture retention strength in the longitudinal direction, except mesh DL, which was significantly higher than the other meshes, about 44 N on average (*Figure 9*). While in the transverse direction, there were significant differences among the six kinds of meshes. The pentagon shaped mesh (P) and hexagon shaped mesh with inlay monofilament (HL) had significantly great suture retention strength, namely 38.75 ± 2.97 N and 38.33 ± 4.85 N, respectively. And the diamond shaped mesh (D) exhibited the lowest suture retention strength in the transverse direction, namely 28.9 ± 3.37 N. Others were moderate and meshes HL, D and R represented less anisotropy. The six kinds of meshes all possessed suture retention strengths much larger than the 20 N that hernia repair requires in the two directions [7], and hence they all meet hernia repair demands in suture retention strength.

Pearson correlation testing

A pearson correlation test showed that, as shown in *Table 3*, there was a strong relation between mesh thickness and mesh ball burst strength (p < 0.001) as well as between mesh thickness and ten-

sile strength in the longitudinal direction (p < 0.001), while mesh thickness was weakly related to the other physico-mechanical properties (p < 0.001). Compared with thickness, mesh porosity had a weak correlation with the ball burst strength of the mesh (p < 0.001) and tear resistance in the transverse direction (p = 0.006) and with the suture retention strength in the longitudinal direction (p < 0.001). It also had a strong relation with the tensile strength in the longitudinal direction (p < 0.001). While a mild correlation was found between GSM and the ball burst strength (p < 0.001), GSM and tensile strength in the longitudinal direction (p < 0.001), and GSM and suture retention strength in the longitudinal direction (p < 0.001). And it seems that the tear resistance in both directions had a weak or even no pearson correlation with these three physical parameters, which may be related to the diameter of the monofilaments or the mesh textile structures.

■ Conclusions

This study fabricated and characterised the physico-mechanical properties of six kinds of macro porous warp knitted meshes, four a with different pore shape and two with inlays. The performances of these meshes tested meet the requirements of hernia repair, except mesh DL, whose tear resistance strength (12.93 ± 2.44 N in the transverse direction) was not sufficient. Overall uniform textile structures are expected to result in less anisotropy, and meshes with inlays, to some extent, possess higher mechanical properties. Moreover a change in the

filament diameter accompanies changes in flexual rigidity and other performances. Thus the filament diameter is also an important technical parameter to determine when knitting meshes. In addition to the monofilament diameter, the ratio of the open loop number to the closed loop number in a weave repetition is also a critical factor to consider when designing mesh textile structures. Additional studies considering their in vivo properties may further tell us the relationship between textile structures and their performances.

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