Clinical Anatomy 32:961–969 (2019)

ORIGINAL COMMUNICATION

The Fascial Connections of the Pectineal Ligament

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In clinical settings, the pectineal ligament forms a basic landmark for surgical approaches. However, to date, the detailed fascial topography of this ligament is not well understood. The aim of this study was to describe the morphology of the pectineal ligament including its fascial connections to surrounding structures. The spatial–topographical relations of 10 fresh and embalmed specimens were dissected, stained, slice plastinated, and analyzed macroscopically, and in three cases histological approaches were also used. The pectineal ligament is attached ventrally and superiorly to the pectineus muscle, connected to the inguinal ligament by the lacunar ligament and to the tendinous origin of rectus abdominis muscle and the iliopubic tract. It forms a site of origin for the internal obturator muscle, and throughout its curved course, the ligament attaches to both the fasciae of iliopsoas and the internal obturator muscle. However, dorsally, these fasciae pass free from the bone, while the pectineal ligament itself is adhered to it. The organ fasciae are seen apart from the pectineal ligament and its connections. The pectineal ligament seems to form a connective tissue junction between the anterior and medial compartment of the thigh. This ligament, however, is free to other compartments arisen from the embryonal gut and to the urogenital ridge. These features of the pectineal ligament are important to consider during orthopedic and trauma surgical approaches, in gynecology, hernia and incontinence surgery, and in operations for pelvic floor and neovaginal reconstructions. Clin. Anat. 32:961–969, 2019. © 2019 Wiley Periodicals, Inc.

Key words: tendinous arch of levator ani, iliopubic tract; obturator fascia; pectineal ligament, pectineal fascia; Waldeyers' fascia; Gerota's fascia; Zuckerkandl's fascia; Toldt's fascia

INTRODUCTION

There is agreement among orthopedic and trauma surgeons that certain ligaments are of great importance for maintaining the stability of the posterior pelvic ring. In contrast, little is known about the role of most ligaments and other soft tissues of the anterior pelvic ring, in spite of these structures gaining recent attention in the literature, particularly in relation to abdominal and gynecological surgery (Becker et al., 2010). With respect to the anterior pelvic ring, the soft tissues of the superior pubic ramus including the thick periosteum and fascial structures serve as anchor points in hernia repair as well as in urinary anti-incontinence operations and neovaginal reconstruction

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Received 20 May 2019; Revised 31 July 2019; Accepted 1 August 2019

Published online 21 August 2019 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/ca.23445

(Burch, 1961; McVay, 1974; Perdu et al., 1998; Chen et al., 2018). Such thickened connective tissue was originally described by Cooper as "a ligamentous expansion, which forms a remarkably strong ridge above the iliopectineal line" (Cooper, 1804). Later, this structure was named Cooper's pubic ligament or the pectineal ligament (or in Latin: Ligamentum pectineum; Federative Committee on Anatomical Terminology, 1998).

Anatomical knowledge regarding the contribution of the pectineal ligament to the stability of the anterior pelvic ring is sparse and the extent of its attachments to surrounding anatomical structures is also unclear (Faure et al., 2001; Becker et al., 2010). This knowledge becomes important, for example, when suturing the pectineal ligament during surgical procedures. It is reported that the pectineal ligament adheres to the periosteum of the superior pubic ramus, covers the pectineal line of the pubis, and stretches dorsally from the pubic tubercle and the iliopubic eminence (iliopubic ramus; Faure et al., 2001).

Ventrally, the pectineal ligament connects to the pectineal fascia. Faure et al. (2001) further observed that "its lateral portion, however, was more difficult to define as it rapidly thinned to blend with the periosteum". In contrast, the lateral dorsal portion of pectineal ligament is also delineated as an extension of the transverse fascia, passing the inguinal ligament as the femoral sheath (Cooper, 1807). Dorsally, the pectineal ligament passes close to the internal obturator muscle (Hazewinkel et al., 2009), but its connections to the obturator fascia and the medial levator ani fascia remain unclear. A greater understanding of this relationship is of practical importance, particularly when perforating the internal obturator muscle with the surrounding fascia as it is routinely performed in transobturator approaches (de Leval, 2003; Hazewinkel et al., 2009).

The aim of this study was to describe the detailed anatomy of the pectineal ligament including the extent of its connections to surrounding structures using a variety of novel anatomical methods including dissection, plastination, and histological approaches.

MATERIAL AND METHODS

Specimens

We used a combination of unfixed, alcohol-fixed and Thiel-fixed specimens from four male (age range 69–93 years) and six female (age range 81–95 years) body donors (Table 1). While alive, all donors had given consent for the use of bodies for teaching and scientific purposes at the Institute of Anatomy, University of Leipzig in accordance with the Saxonian Death and Funeral Act of 1994.

Dissection

Dissection of the areas of the superior pubic ramus of both sides was undertaken in seven specimens using a standardized protocol (Steinke et al., 2010).

TABLE 1. Body donors and methods used for this research

Sex/age in years	Figures	Method
♂ 69a	1a,b	Dissection both sides, alcohol fixation
♀ 95	1c	Dissection both sides, unfixed
♂ 77, ♀ 81a, ♀ 81b, ♀ 87	2	Dissection of both sides, alcohol fixation
♂ 69b	3	Dissection of both sides, Thiel fixation
♂ 77, ♀ 81a, ♀ 81b	4a–c	Histology of both sides, alcohol fixation
♀ 91	5	Fresh frozen pelvis block sagittal cut/PAS stained/plastinated
♀ 89, ♂ 93	6 and 7	Fresh frozen pelvis blocks frontal cut/PAS stained / plastinated

Abbreviation: PAS, Periodic acid–Schiff.

Five alcohol-fixed specimens were dissected manually with a focus on the connections of pectineal ligament (three female and one male; Table 1). In another unfixed specimen, the ligaments were removed *en bloc* from a female body. In addition, one male Thiel-fixed specimen was available from a recent fascia atlas project (Steinke, 2018).

Plastination and Staining

For plastination, we dissected three pelves (two female and one male) which were precooled down to +3°C and then immersed in a mixture of acetone and water (85: 15) which was cooled to −85°C.

The blocks were quickly frozen and then sectioned using a cold sawing room into around 1-mm thick slices (Steinke, 2001). Afterwards, they were transferred to acetone at −25°C.

For the staining, we employed a macroscopic protocol that uses the periodic acid–Schiff reaction with subsequent plastination to distinguish collagen types (red to pink; Steinke et al., 2018) from muscle (unstained, ochre; Mulisch and Welsch, 2015). A red precipitation demarcates Type I collagen and a pink color stains Type II collagen. After the reaction, we transferred the slices to pure acetone which was renewed daily until the slices contained <2% water (Steinke et al., 2018).

A standard plastination technique using E12 epoxy resin (Biodur, Heidelberg, Germany) was then deployed (Hagens, 1986; Steinke, 2001). The stained slices were scanned with a high-resolution scanner (600–1,240 dpi, Scanner EPSON Perfection V750PRO, Epson Deutschland GmbH, Meerbusch, Deutschland).

Histology/Fresh Specimens

The pectineal ligament was removed bilaterally from the pelvic bones of three ethanol-fixed body donors (two female and one male; Table 1; Hammer et al., 2012) and processed through wax for microscopy. The samples were stained with hematoxylin–eosin and van Gieson (Mulisch and Welsch, 2015) and examined using light microscopy using a ProgRes C3 Camera and the ProgRes Capture Pro v2.8.8 Software (Jenoptik GmbH, Jena, Germany).

RESULTS

Dissection

The pectineal ligament appeared as a thickening on the linea terminalis (Fig. 1a). The ventral part of the ligament connected to the superior pubic ligament and to the superior and posterior aspects of the pubic symphysis. Cranially, the inguinal ligament is connected to the pectineal ligament by the lacunar ligament.

The pectineal ligament spreads dorsolaterally, accompanied by fine vessels and nerves on its medial side. These are seen both with dissection and histologically (see below). The ligament passes over the superior pubic ramus to merge with the palpable iliopubic eminence (iliopubic ramus) laterally. Dorsolaterally, muscle fibers of the internal obturator muscle blend with the pectineal ligament seen macroscopically (Fig. 1b). When the ligament was removed sharply from its bony attachments in the *en bloc* dissections of the unembalmed tissues, the internal obturator muscle was observed to attach to its dorsal surface, while ventrally the thick pectineus muscle takes origin (Fig. 1c). Ventrally, vessels and nerves pass through the pectineal ligament and the adjacent obturator fascia (Fig. 1b). The obturator fascia is attached to the ventral aspect of the pectineal ligament. Dorsally, the obturator fascia is separate from the ligament; however, it merges with the iliopsoas fascia (Fig. 2). Thus, the dorsal aspect of the pectineal ligament divides from both fasciae by remaining to the bone. Dissections of the greater pelvis show the fascia in relation to the iliac fascia and to the pectineal ligament (Fig. 3). These dissections are part of the recently published fascial topography atlas (Neuhuber, 2018). From the anterior superior iliac spine, the inguinal ligament passes mediocaudally.

By resecting the transverse fascia together with its dorsocaudal thickening, the iliopubic tract (Eisner's tract) and the iliopsoas fascia were revealed. This covers the femoral and genitofemoral nerves and the tendon of the psoas minor muscle. In addition, we showed that the renal fasciae layers covering the iliac fascia can be removed. The fascia renalis posterior (Zuckerkandl's fascia) is cut horizontally onto iliac fascia. The fascia renalis anterior (Gerota's fascia) fuses to the latter. Onto these two layers of the renal fascia other layers can be distinguished, the peritoneum and the containing suspensory fascia of duodenum (Treitz-fascia). Figure 3 shows this complex layout. From the mesocolic radix, one side of the peritoneal layer was removed and flipped cranially. On the other side of the mesocolic radix, the peritoneal layer was also removed partly from the anterior renal fascia. Some remaining peritoneal layers can be still seen as fine lines flipped to this fascia. Therefore, being free of any peritoneal coverage, the sigmoid colon still adheres to another structure containing vessels and nerves—the sigmoid mesentery.

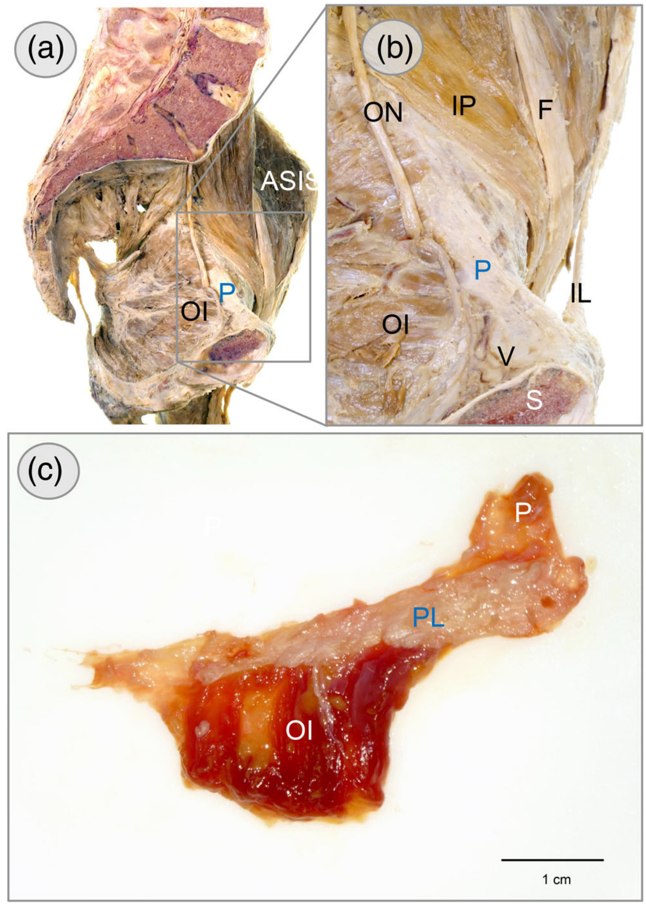

Fig. 1. The gross morphology of the pectineal ligament. (**a**) Dissected left male pelvis (alcohol fixed specimen, 69 years) with the fasciae of the greater and lesser pelvis removed, to reveal the PL and its relationship to the pelvic nerves and muscles (magnification ×0.2). (**b**) Magnified view of (a), showing the dorsolateral extent of the PL, which blends with fibers of the internal obturator muscle (OI; magnification ×1.0). Note the V between the PL and OI that supply the posterior pubis. (**c**) Cranial view of an isolated pectineal ligament (unfixed female specimen, 95 years) showing its attachments to OI and P. ASIS, anterior superior iliac spine; F, femoral nerve; IL, inguinal ligament; ON, obturator nerve; P, pectineus muscle; PL, pectineal ligament; S, pubic symphysis, cut median; V, vessels; OI, internal obturator muscle [Color figure can be viewed at wileyonlinelibrary.com]

Histology

Histologically, the fibers of the pectineal ligament are seen arranged in parallel (Figs 7a–c). Superficially,

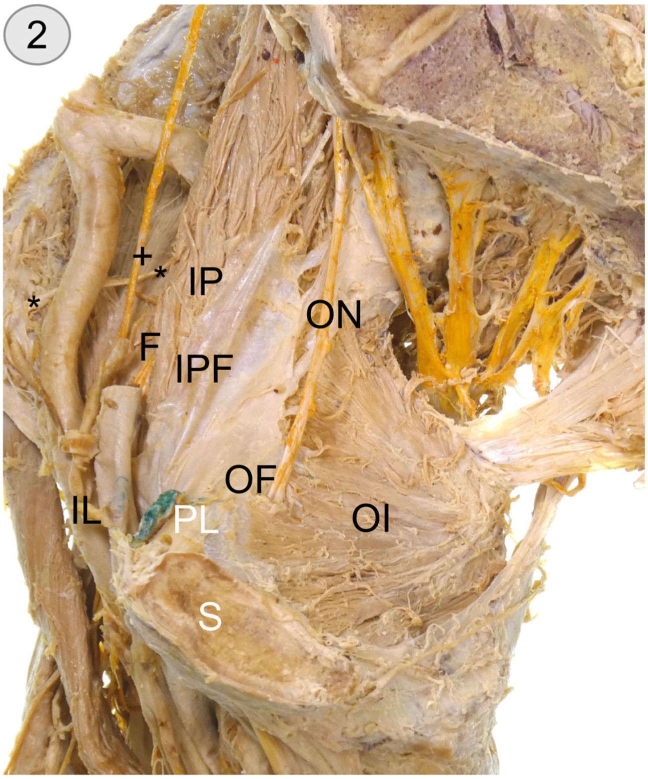

Fig. 2. Fascial coverage of the dorsolateral pectineal ligament (right hemipelvis, medial view, alcohol fixed female specimen, 87 years, ×0.3 magnification). The PL is exposed near the S. All organs have been removed from the lesser pelvis to reveal the OI and the ON. Dorsally, the pectineal ligament reaches the depth of the pelvic bone, spreading to the dorsal margin of the linea terminalis. In this dorsal region, the pectineal ligament is covered by the OF. Ventrally, the OF attaches to the PL. Laterally, the OF is connected to the (laterally and superficially). Part of the iliopsoas fascia has been removed to reveal the genitofemoral nerve (+), the lateral cutaneous nerve of thigh (*), and the FN near the IP. Ventral to the pectineal ligament in the direction of the cut symphysis, the Rosenmüller lymph node is stained green, demarcating the medial corner of vascular lacuna, also detectable by the cut and lifted iliac vessels. Maneuvering also lifts the IL. FN, femoral nerve; IL, inguinal ligament; IP, iliopsoas muscle; IPF, iliopsoas fascia; OF, obturator fascia; OI, internal obturator muscle; ON, obturator nerve; PL, pectineal ligament; S, symphysis [Color figure can be viewed at wileyonlinelibrary.com]

the pectineal ligament is bordered by thin connections to an empty space (Fig. 1a). The ligament covers a deeper layer filled with fat and the muscle fibers of internal obturator muscle (Fig. 1b,c). Confirming the dissection findings, the internal obturator muscle inserts into the pectineal ligament with fibers angled in a lateral to medial direction. Nearby, vessels and nerves pass on the deep surface of the ligament together with the adherent fascia (Fig. 7c) as already noticed on macroscopic level (Fig. 1b).

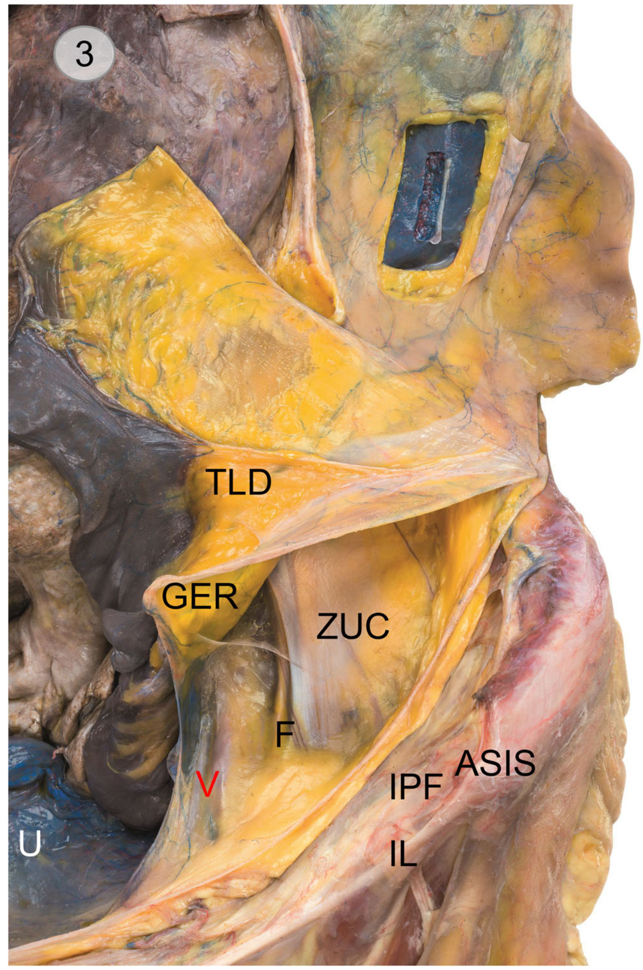

Fig. 3. Ventral view of the left greater pelvis with the fascial layers (Thiel dissection, male specimen, 69 years, ×0.5 magnification). Dorsal to the ASIS, the fibers of the obliquus externus abdominal muscle are seen on iliac crest. From the ASIS the IL reaches mediocaudally. The IPF attaches to IL. The F nerve is covered by the IPF. The iliac V pass medially. The anterior layer of the renal fascia (GER) is reflected, following division of this tissue from the posterior layer of the renal fascia which has been resected horizontally (ZUC). This provides a view into a gliding space (filled with fat) in-between both fascial layers. The GER is covered by the parietal peritoneum, reflected by the white layer partly removed from the surface of GER. The sigmoid radix can be seen, covered by peritoneum, which was flipped cranially, named mesocolon. Another connective is seen enveloped by these two peritoneal layers, the mesentery (TDL). ASIS, anterior superior iliac spine; IL, inguinal ligament; IPF, iliopsoas fascia; F, femoral; V, vessel; GER, Gerota's fascia; ZUC, Zuckerkandl's fascia; TDL, Toldt's fascia [Color figure can be viewed at wileyonlinelibrary.com]

Plastination

Sagittal plastinates revealed the oblique insertion of the internal obturator muscle into the pectineal ligament (Fig. 4). At the level of the acetabular notch, the middle portion of the pectineal ligament appears thickened. A space which is free of dense tissue is located cranially. Dorsal to this space connective tissues are stained. These connective tissues divide the tendinous arch of levator ani.

The obturator vessels and nerves pass caudally to the pectineus muscle. Due to the orientation of this sagittal slice, the origin of this muscle from the pectineal ligament remains invisible. However, this is visible on the frontal plastinates, in the plane of the pubic symphysis (Fig. 5). In addition, continuity between the pectineal ligament medially and the inguinal ligament laterally is observed. In this ventral region, the origin of rectus abdominis muscle merges medially, the transverse fascia cranially and the fascia lata caudally with its superficial lamina.

In frontal slices, cut in the plane of the ventral acetabulum, the dorsal fanning of the pectineal ligament is seen toward the cranial border of the lesser pelvis (Fig. 6). Cranial to the obturator canal, the flattened pectineal ligament stretches to the pelvic bones. In this dorsal aspect, the pectineal ligament is covered by the arising internal obturator muscle fibers and the iliopsoas muscle with its fascia as seen in the dissections (Figs. 1 and 2). The fasciae of both of these muscles pass separately, medially from the lateral pectineal ligament. The tendinous arch of levator ani reaches the superficial obturator fascia cranially and the tendinous arch of the pelvic caudally (Fig. 6).

In the dorsal region, the obturator fascia remains apart from the pectineal ligament (Figs. 2 and 6), which receives muscle fibers of internal obturator muscle (Figs. 1, 4, 6, and 7).

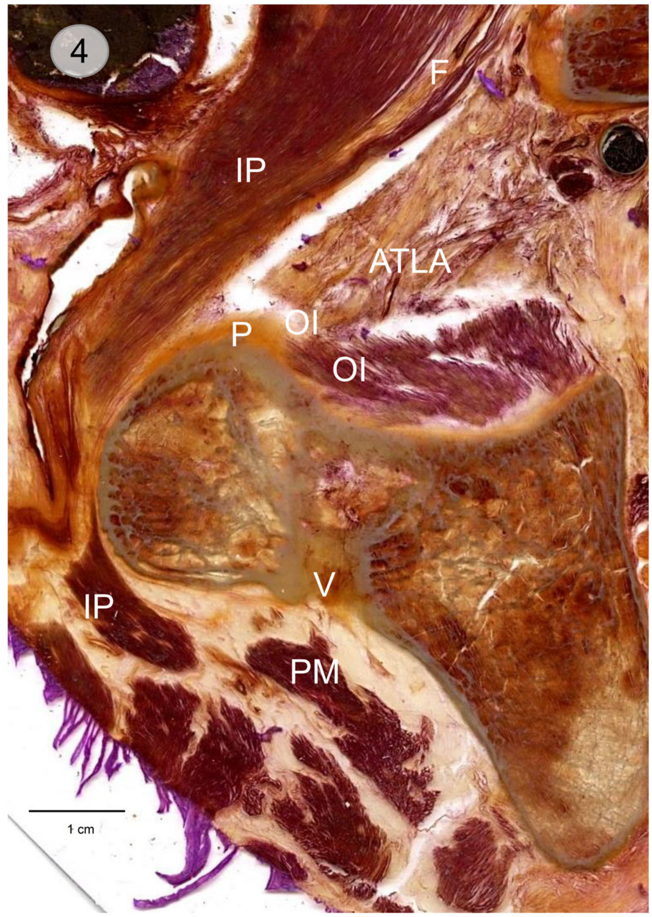

Fig. 4. Sagittal plastinate cut in the plane of the iliopubic eminence/acetabular notch (left: ventral, periodic acid–Schiff stained, female 91 years, ×0.5 magnification). The PL reaches dorsolaterally from the iliopubic eminence. Near to this eminence the IP passes. The PL is seen bordering the muscular lacuna in its dorsocaudal parts. Dorsal to the pectineal ligament the OI comes to view. Fine muscle fibers are distinguishable together with the ATLA. Ventrally, the levator ani muscle attaches via ATLA to OI via the OF to reach the ventral pectineal ligament. Cranially, the levator ani is covered by Denonvillier's ligament and Denonvillier's organ fasciae (superior facies of pelvic diaphragm) and caudally by Waldeyer's fascia (inferior facies of pelvic diaphragm). Between the muscle with its two fascial layers and OI, the ischioanal fossa is seen with containing pudendal structures. Caudally, to the acetabular notch, obturator nerve branches spread out with V. It covers the MP. ATLA, tendinous arch of levator ani; IP, iliopsoas; MP, pectineus muscle; OF, obturator fascia; OI, internal obturator muscle; PL, pectineal ligament; V, vessels [Color figure can be viewed at wileyonlinelibrary.com]

DISCUSSION

The Connections of the Pectineal Ligament

The pectineal ligament covers the pectineal line of the pubis (Fig. 1, Cooper, 1804). It is connected to the iliopectineal fascia, which is the cranial extension of the deep layer of fascia lata (Fig. 5; Becker et al., 2010). When the pectineal ligament reaches medially onto the pubic bone from the iliopubic eminence to the pubic tract it is connected to the inguinal ligament via the lacunar ligament, to the tendinous origin of rectus abdominis muscle and the iliopubic tract (Fig. 5; Becker et al., 2010; McKernan and Laws, 1993).

The pectineal ligament spreads out laterally covering the bone, as Faure points out (Figs. 1 and 6; Faure et al., 2001). We have seen this ligament giving rise for the internal obturator muscle (Figs. 1–2, 4, and 6). Leval defines the pectineal ligament "as it rapidly thinned to blend with the periosteum in this curved course" (de Leval, 2003). However, the pectineal ligament attaches ventrally to both the iliopsoas fascia and the obturator fascia, while both are free of the pectineal ligament dorsally. Therefore, a gliding space occurs over the pectineal ligament (Figs. 4 and 7). It is covered by obturator and iliopsoas muscles and fasciae (Figs. 2, 4, and 6).

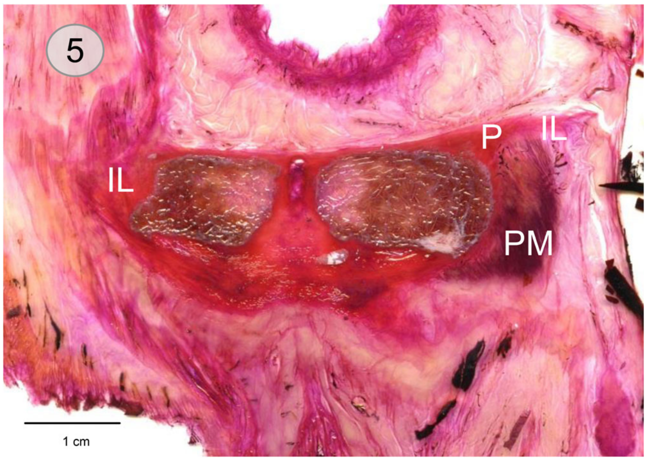

Fig. 5. Frontal plastinates cut in the plane of the pubic symphysis (PAS stained, female specimen, 89 years, ×5 magnification). Due to a slightly oblique plane, the femoral vein is seen on the right. On the left the skin is cut. Thus, left in view is the insertion of rectus abdominis muscle; not on the right side. The LI originates from the PL cranially medially. The superior symphyseal ligaments and the IL are seen merging to PL. Caudally, the PM arises from the PL. LI, inguinal ligament; PAS, Periodic acid–Schiff; PL, pectineal ligament; PM, pectineus muscle [Color figure can be viewed at wileyonlinelibrary.com]

This superficial extension of the transverse fascia, passing the inguinal ligament as the femoral sheath, which Cooper originally described, must therefore belong to the ventral portion of the ligament (Cooper, 1807). The dorsal periosteal part as described by Leval was not recognized to be important (de Leval, 2003). However, the pectineal ligament is in contact with the internal obturator muscle and fascia (Figs. 4 and 6).

This dorsal deep part is merged profoundly with fibers of the internal obturator muscle (Figs. 1c and 7) and also with branches of obturator nerve and vessels (Figs. 1b and 7).

Fascial Coverages of the Pectineal Ligament

The pectineal ligament and the adherent iliopsoas fascia are covered by other fascial layers (Figs. 3 and 4). The two layers of renal fascia fuse here. The ventral layer of the anterior renal fascia envelopes the renal space. The dorsal layer (posterior renal fascia) closes it. Both layers can be removed from the iliopsoas fascia (Fig. 3). Apart from these layers of the urogenital crest, intestinal layers cover the space of the pectineal ligament. Due to gut rotation, a suspension occurs from the embryonal mesentery referred to as mesentery (Coffey and O'Leary, 2016; Moore et al., 2016). This fascia contains the vessels and nerves for the gut. The part of the mesentery, which is covered by peritoneum (Fig. 6), contributes to the "mesocolon." Thus the "mesocolon" is restricted to the abdominal cavity, while mesentery

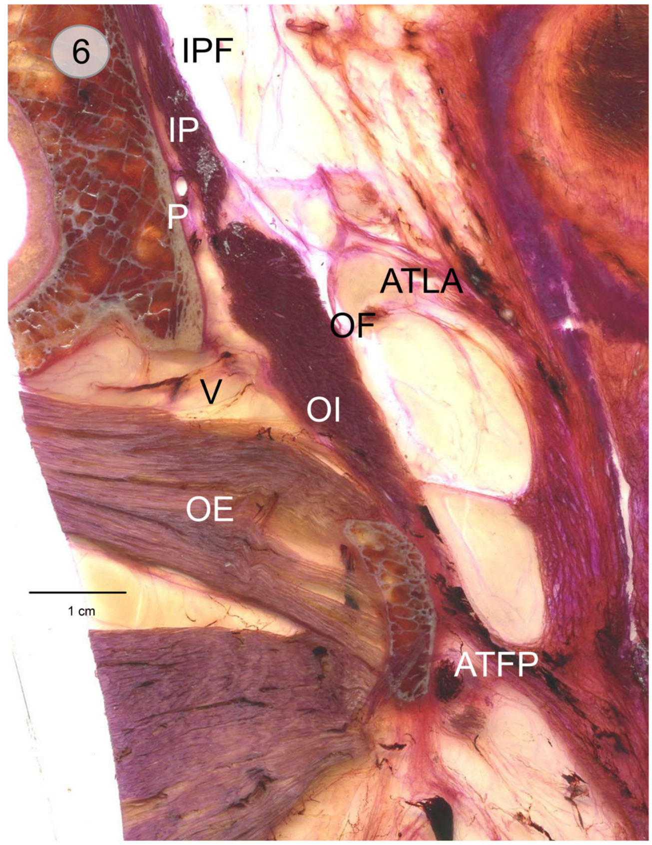

Fig. 6. Frontal plastinate cut in the plane of the ventral acetabulum (left: lateral, PAS stained, male specimen, 93 years, ×5 magnification). On the dorsal aspect, the PL is seen ending at the pelvic bone. It ends to a gap. This gap is covered by the IP cranially and OI caudally. The OI is covered by OF and the IP by the IPF; both are connected. Caudomedially, the OF is continuous with the ATLA. A space occurs between PL, the ischium near the acetabulum (seen cut in the left border of this slice), and the external OE. To this space branches of the obturator nerve are seen passing with accompanying V reaching the acetabular notch. Attached to ATLA small muscle fibers of levator ani muscle (brown fibers) are covered by two thicker fascial layers. The upper layer is Denonvillier's ligament spreading out to the U named Denonvillier's organ fasciae (superior facies of pelvic diaphragm). Caudally, Waldeyer's fascia (inferior facies of pelvic diaphragm) reaches the ATFP. Caudal of ATFP, the pudendal structures reach from the ischioanal fossa. ATFP, tendinous arch of pelvic fascia; ATLA, tendinous arch of levator ani; IP, iliopsoas muscle; IPF, iliopsoas fascia; OE, obturator muscle; OF, obturator fascia; OI, internal obturator muscle; PAS, periodic acid–Schiff; PL, pectineal ligament; U, Uterus; V, vessels [Color figure can be viewed at wileyonlinelibrary.com]

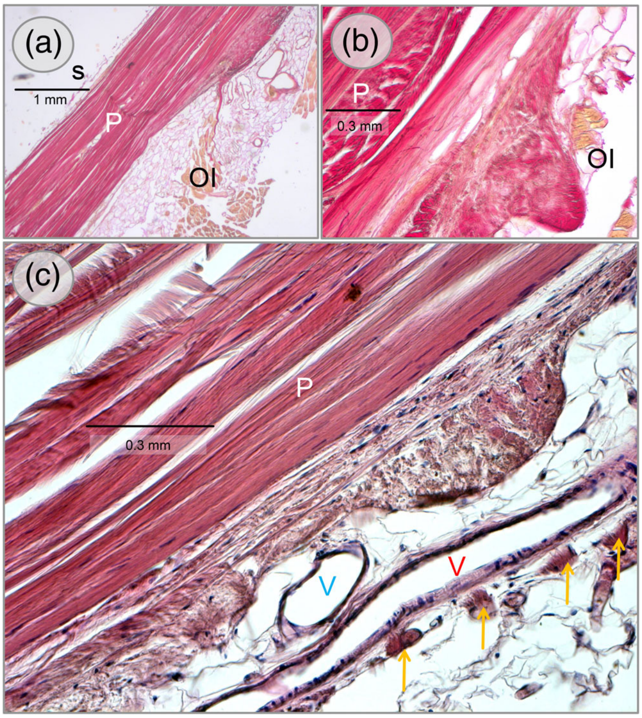

Fig. 7. Microscopic views of the pectineal ligament. (**a**) van Gieson staining reveals the PL, cut longitudinally. The collagen fibers are aligned in parallel, superficially (s). At the left upper corner, a superficial space is seen. In the right lower corner, a layer of connective tissues merge with fat, dividing the PL from the OI (×10); (**b**) A van Gieson-stained section of the deep PL magnifies the inserting (×3); (**c**) In this H&E-stained section, nerves (arrows) and V are covered by PL and the OI (×10). H&E, hematoxylin–eosin; OI, internal obturator muscle; PL, pectineal ligament; s, pubic symphysis; V, vessels [Color figure can be viewed at wileyonlinelibrary.com]

continues subperitoneally, which is the fascia of Toldt (Coffey and O'Leary, 2016).

The anatomy of the pectineal ligament is clinically relevant and some thoughts are provided below in relation to different types of surgical approaches.

Orthopedic and Trauma Surgery

For intrapelvic approaches (Stoppa approach) to the anterior pelvic ring and acetabulum, the pectineal ligament is a key guiding landmark when dissecting from medially along the superior pubic ramus toward the iliac fossa (Guy, 2015). Its connection to the upper symphyseal ligament is already known (Fig. 5; Becker et al., 2010). In this region, the ligament, which is seen here under tension from both the pectineus muscle and the cranial part of internal obturator muscle (Figs. 1c, 4, 6, and 7) may have a mechanical influence on the symphyseal load transfer system. Because the ventral part of the pectineal ligament is connected to the pubic ligament and fascia system (Becker et al., 2010), another potential role of the pectineal ligament is that of a secondary stabilizer in fractures of the superior pubic ramus (Matta, 1996) due to the dorsal counterpart in tension by obturator muscle and fascia (Figs. 1, 4, 6, and 7). As with clavicular fractures, the displacement of a superior pubic ramus fracture might depend on the integrity of the surrounding fascial layers, which were shown here.

The stabilizing effect of the pectineal ligament may also be used for percutaneous fixation of pelvic and acetabular fractures (Starr et al., 1998). As in extremity fractures, fascial attachments around the hip and pelvis can help to achieve closed or indirect reduction of a fracture by ligamentotaxis (Starr et al., 2001).

Dissecting strictly between the pubic ligament and the bone, it is evident that the pectineal ligament protects the iliac vessels that run cranially (Fig. 5).

This is an important consideration for guidance in infrapectineal plating (Qureshi et al., 2004). The pectineal ligament is also used as landmark for occlusion, preparation of a corona mortis or bleeding control (Sabuncuoglu et al., 2015; Ates et al., 2016).

If an additional buttress plate is used, the obturator vessels and nerve can be prepared and protected (Figs. 6 and 7; Karim et al., 2017; Laflamme et al., 2011; Sabuncuoglu et al., 2015; Tosounidis et al., 2015).

Hernia Surgery

To remedy hernias, the pectineal ligament is tied or sutured to the iliopubic tract (McKernan and Laws, 1993). This tract is the lower aponeurosis of transverse abdominis muscle, which is fused the pectineal ligament and thus with internal obturator muscle cranially (Figs. 1, 3, and 6). The fused anterior and posterior renal fasciae are separated by fat from the iliopubic tract. The anatomical feature of the pectineal ligament with the iliopsoas fascia and the iliopubic tract allows preperitoneal mesh techniques in surgery (Figs. 3 and 6; McKernan and Laws (1993). Some of these methods directly approach the pectineal ligament and may also use the considerable connection of ligament to the iliopsoas fascia (Figs. 2 and 6; Andresen and Rosenberg, 2017). However, any approach of the peritoneal or renal fascial layers must be avoided, because these layers pass remarkably close to the femoral and inguinal channels.

Neovaginal Reconstruction/Gynecology

In the case of a vaginal wall descent, uterovaginal prolapse, or neovaginal constructions, the pectineal ligament provides an anchor point (Figs. 1–2, and 4–6; Freundt et al., 1994; Neron et al., 2017).

In Mayer–Rokitansky–Küster–Hauser syndrome (which affects approximately 1/4500 women), aplasia of the uterus and the upper part of the vagina is seen. In such cases, a neovagina is created with sigmoid grafts (Morcel et al., 2007). The pectineal ligament is the target for neovaginal attachment. The connected iliopsoas fascia may also give stability as we reveal this thicker fascia is connected to the pectineal ligament.

As seen in a frontal view (Fig. 6) at the plane of the uterus, the iliopsoas fascia is thick, while the dorsal spread out of the pectineal ligament becomes a smaller periosteal layer, as Leval (de Leval, 2003) describes. Both renal fasciae, covering the iliopsoas fascia, must not be injured in neovaginal constructions (Fig. 3). As a consequence, Morcel's group points out that such graft procedure is only effective, if the fascial layers of the kidney can be dissected properly (Morcel et al., 2007).

Incontinence Surgery/Reconstruction of the Pelvic Floor

Based on the connection of the pectineal ligament to the tendinous arch of levator ani and to the obturator fascia (Figs. 2, 4, and 6) any attempt of suturing the pelvic floor to this dorsal region in incontinence surgery seems logical.

Burch (1961), for example, sutured incontinence slings to the white line of the tendinous arch of levator ani in his early operations. Dorsally, the pectineal ligament lies deeper than the arch, near to the bone, and may also provide some stability, which was chosen by Burch (Burch, 1961) as target later on. Interestingly, fibers of the internal obturator muscle adhere to the pectineal ligament in this region (Figs. 1b,c, 4, and 7).

This muscle is approached in the tension-free vaginal tape–obturator procedure in female urinary incontinence. It is important that the obturator muscle is passed without perforating the levator ani muscle nearby or the adherent pelvic fasciae or the obturator nerve (Fig. 6; de Leval, 2003). The main stem of this nerve passes ventrocaudally to the pectineal ligament in this region (Figs. 1 and 2). However, we have seen dorsolateral branches reaching the hip joint by the acetabular notch lateral to the muscle (Figs. 4 and 6). This configuration could explain the (rare) cases of postoperative groin pain after tension-free vaginal tape–obturator procedure (Hazewinkel et al., 2009).

The Pectineal Ligament Is Underestimated

Adhering to the internal obturator muscle, branches of the obturator nerve supply the pectineal ligament (Figs. 1c and 7c; Hébert-Blouin et al., 2014). Because the pectineal ligament is connected to the pectineus muscle, which is innervated by both the obturator and femoral nerves, pain from the pectineal ligament may be referred via one of these nerves, for example, to the groin (Hazewinkel et al., 2009).

Moreover, because the dorsal deep compartment of the pectineal ligament at the ischial bone merges with nerves (Fig. 6), the pectineal ligament may also refer pain to the ischial compartment following Hilton's law (Hébert-Blouin et al., 2014). The pectineal ligament is seen forming a transition between these three compartments. Thus, the redefining of the fascial borders of the pectineal ligament with its innervation is pending. The biomechanical functions of the pectineal ligament may also be underestimated as, while we better the understanding of its anatomical form using modern methods, we do not currently fully understand its function.

Study Limitations

Our study has several limitations. First, the number of cadavers dissected for macroscopic anatomical investigations (20 pectineal ligaments from 10 body donors) is relatively small and we have provided qualitative rather than a quantitative data. However, because the same characteristics of the pectineal ligament were observed in all cases, the sample size was deemed sufficient. In addition, we used several different and advanced techniques (such as whole-pelvis slicing) to corroborate our dissection findings. Our histological investigation was limited to samples from three body donors only, prohibiting firm generalizations of these data. We did not perform any biomechanical experiments (e.g., elasticity testing) to explore the potential role of the pectineal ligament in dynamic and static force transmission and the inferences regarding its stabilizing role in the pelvis remain speculative. However, such information might be of clinical relevance and could form the basis of future experimental studies. Finally, while we observed nerves and nerve fibers using standard dissection and light transmission microscopy alone, we did not investigate the nature of these nerves any further.

ACKNOWLEDGMENTS

Our sincere thanks are due to Professor Niels Hammer and Professor Stephanie Woodley (University of Otago) for proofreading and restructuring of this manuscript. Anna-Katharina Rowedder photographed the specimen of Figure 3 which was dissected for the Atlas of Human Fascial Topography (2018). Marie Lynn Speckert and Anne Süße made the stained plastinates for Figs. 4–6. Thank you for your commitment.

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