# Clinical Anatomy of the Puboprostatic Ligament for the Safe Guidance for the Prostate Surgery

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**OBJECTIVE** To provide the anatomy of the puboprostatic ligament and related structures to save urogenital competence after prostatectomy.

**MATERIALS AND METHODS** Pelvic areas of 31 adult cadavers were dissected to figure out the shape, number, and location of the puboprostatic ligaments.

**RESULTS** The puboprostatic ligament was the most important support structure between the pubic bone and prostate gland. Puboprostatic ligaments were bilaterally single (61.3%), bilaterally double (19.4%), or mixed (19.4%). Ligaments were mostly I-shaped (53.8%). If ligaments had extra attachment to or from the arcuate line, the ligaments were $\lambda$-shaped (36.3%), or Y-shaped (8.8%). In one case, the ligament had a central fusion with an irregular shape. I-shaped puboprostatic ligaments were observed more frequently in specimens with double ligaments, while $\lambda$-shaped puboprostatic ligaments were observed more frequently in the cases with single ligaments. The average distance between both puboprostatic ligaments was 8.1 mm at the pubic site and 14.2 mm at the prostate site. The distance was narrower when the specimen had double puboprostatic ligaments on both sides. The neurovascular bundle ran beneath the puboprostatic ligament. If the ligament was the $\lambda$-shaped type, the neurovascular bundle frequently pierced the lateral band of the ligament.

**CONCLUSION** Puboprostatic ligaments hold and stabilize the prostate against the pubic bone. It is believed that a pelvis with bilateral, double puboprostatic ligaments would have advantages in urogenital competence. The morphologic data of the shape, multiplicity, and location of the PPLs would help to make a plan to approach the prostate. UROLOGY 136: 190−195, 2020. 

The screening, diagnosis, and treatment of prostatic cancer are becoming one of the most important topics of health care in many countries. In Korea, the reported number of diagnosed prostatic cancer cases has been increasing sharply due to changes to Westernized diet patterns and prolonged life expectancy.[1] The introduction of prostate-specific antigen screening in 1990 also drove this increase as more cases were able to be identified earlier.

In the case of organ-confined disease, the treatment of choice for prostatic cancer is radical prostatectomy. Retropubic radical prostatectomy (RP) was first introduced at the beginning of 19th century. The major morbidities of this procedure are urinary incontinence and erectile failures.[2,3] The incidence of urinary incontinence after RP is reported in approximately 30% of the patients. It typically takes at least 2 years to stabilize the urinary continence mechanism.[4,5]

In 2001, robot-assisted laparoscopic radical prostatectomy (RALRP) was introduced and soon became the gold standard for prostatic cancer surgery. To achieve the trifecta—cancer free, potent, and continent—in RALRP, which is the "holy grail" of urologists,[6] a variety of surgical techniques has been applied including intrafascial neurovascular bundle saving,[7] membranous urethra maximization,[8] bladder neck preservation,[9] bladder neck reconstruction,[10] posterior reconstruction,[11] anterior retropubic suspension,[12] and lateral prostatic preservation.[13] RALRP shows similar oncological outcomes with less postoperative urogenital dysfunction than retropubic RP.[14]

The surgical outcomes of the RALRP can be enhanced by the application of the Retzius-sparing approach.[15] With this approach, the Retzius structures including the

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Santorini plexus, puboprostatic ligament (PPL), endopelvic fascia, and neurovascular bundles, can be avoided via the pouch of Douglas.[16,17]

Numerable variations in the size and shape of the prostate, fascial lining, ligamentous support, and neurovascular bundle related to the prostate have been reported to affect surgical outcomes greatly.[18-20] PPL, one of the structures related to the prostate, has been known as a pyramid- or band-shaped structure and is a part of the urethral suspensory mechanism that anchors the membranous urethra to the pubic bone. Damage of the PPL during surgery is associated with the injury of the dorsal vein complex and the neurovascular bundle.[21] Therefore, the variation in the anatomy of PPL is one of the important factors that affect the outcome of prostate surgery. However, to date, no clear-cut anatomical suggestion to save the PPL and neurovascular structures during prostate surgery has been made.

The initial report that PPL supports the bladder neck and is important for urinary continence after prostectomy,[22] has been followed by additional studies. However, the anatomical or functional study has been performed enough neither in the complete prostate removal cases nor in the PPL preserving cases during RP.

While some researchers have obtained promising results regarding urinary continence following PPL-sparing RP,[23,24] cases of incomplete dissection of the apical margin, leading to high rates of positive surgical margin results, have also been reported.[25]

The aim of this study was to provide the precise anatomy of the PPL and related structures for the preservation of urinary continence and the prevention of erectile failure after prostatic surgery.

## MATERIALS AND METHODS

Specimens of the pelvic and perineal regions from 31 male adult cadavers in Korea were used for this study. None of the specimens were from donors who had undergone surgery in these regions. The average age of the cadavers was 79.6 years (range, 61-96 years). All specimen from the routine formalin embalmed cadavers except one soft embalmed cadaver.[26] The part of the pelvis posterior to the ischial tuberosity was removed to expose the retropubic space from the posterior view. After the endopelvic fascia in front of the urinary bladder was divided, the dorsal vein of the penis and its venous tributaries were identified in the retropubic space. Next, the puboprostatic ligament was identified under a surgical microscope. To obtain enough space for the observation, the attachments of the levator animuscle to the middle point of the sacrum and the tip of the coccyx were preserved.

The anatomical observation was made on the shape and components of the ligaments at their attachment sites. The shapes of the PPLs were divided into groups according to their type of attachment to the pubic bone and prostate gland. The following measurements were made: the width of the PPL attachment sites, minimal width of the PPL, vertical distance between the PPL and superior border of pubic bone, and the distance between the PPLs in both sides. The differences in each measurement between the left and right sides were verified by Student's *t* tests. The differences between the morphologic groups of the PPL were verified by chi-square tests. After the measurements were made, the specimens underwent hemisection to obtain the medial view of the arrangement of the structures.

## RESULTS

### Number and Shape of the Puboprostatic Ligament

The number of PPL in a hemipelvis was 1 or 2 (Supplementary Table 1). Bilateral appearance of a single PPL was observed in 61.3% of cadavers, while bilateral appearance of double PPLs was observed in 19.4%. In the rest of cadavers (19.4%), the number of PPLs was different between both sides so that 1 PPL was on one side and 2 PPLs were on the other side. No statistically significant difference in the number of PPL was observed between the left side and the right side. Total number of PPLs found in this study with 31 male cadavers was 80.

The PPLs were divided into 4 types according to their morphologic attributes (Supplementary Table 2). In the most common type was I-shaped PPLs (53.8% of 80 PPLs), both ends of the ligament were attached in small areas on the pubic bone and prostate. This type of PPL was found in 56.5% of the hemipelvises (38.6% of the single PPL hemipelvises and 100.0% of the double PPL hemipelvises). The I-shaped PPLs were further divided into 2 subgroups (Fig. 1A,B): vertically thick and horizontally thin ligaments (53.5% of I-shaped PPLs), and horizontally thick and vertically thin ligaments (46.5%).

The second most common type (36.2% of 80 PPLs) was made up of the $\lambda$-shaped PPLs (Fig. 1C,D). This type of PPL was found in 46.8% of the hemipelvises (43.2% of the single PPL hemipelvises and 55.6% of the double PPL hemipelvises). In addition to the main part of the ligament between the pubic bone and the prostate, the $\lambda$-shaped PPLs had an accessory ligamentous part connecting the pubic bone and the arcuate arch. The $\lambda$-shaped PPLs were further divided into one of 2 subgroups — a single posterior attachment to the prostate (27.6% of the $\lambda$-shaped PPLs, Fig. 1C), and double posterior attachments to the prostate (72.4%, Fig. 1D).

The third group (8.8% of 80 PPLs) comprised the Y-shaped PPLs that had 2 anterior attachments, one of which was to the pubic bone and the other was to the arcuate arch (Fig. 1E). Y-shaped PPL was found only in the single-PPL hemipelvises. Finally, in a hemipelvis (1.2%), multiple anterior and posterior attachments were present, which gave the single PPL an irregular appearance (Fig. 1F).

In the cases with $\lambda$-shaped PPLs and Y-shaped PPLs, the neurovascular bundle passed through the lateral slip of the ligaments.

### The Association Between the Number, Shape and Relationship With Adjacent Structures of the PPL

The number of PPLs was associated with the shape of the PPL (Table 1). In the hemipelvises with single ligament, the $\lambda$-shaped PPL was found most frequently (43.2%).

By contrast, in the hemipelvises of double ligaments, the medially located ligament was always I-shape. In the cases of double ligaments, $\lambda$-shaped lateral ligament was observed more frequently than the I-shaped lateral ligament (Supplementary Figure 1). Y-shaped ligament was not found in any of double PPL hemipelvises.

In the hemipelvises with double PPLs, double I-shapes combination was more frequent in the left side, and I + $\lambda$ combination was more frequent in the right side, without any statistical significance ($P$ = .34, Supplementary Table 3).

The PPLs were narrowest at their anterior end and widest at their posterior end, thus forming a trapezoid shape. The

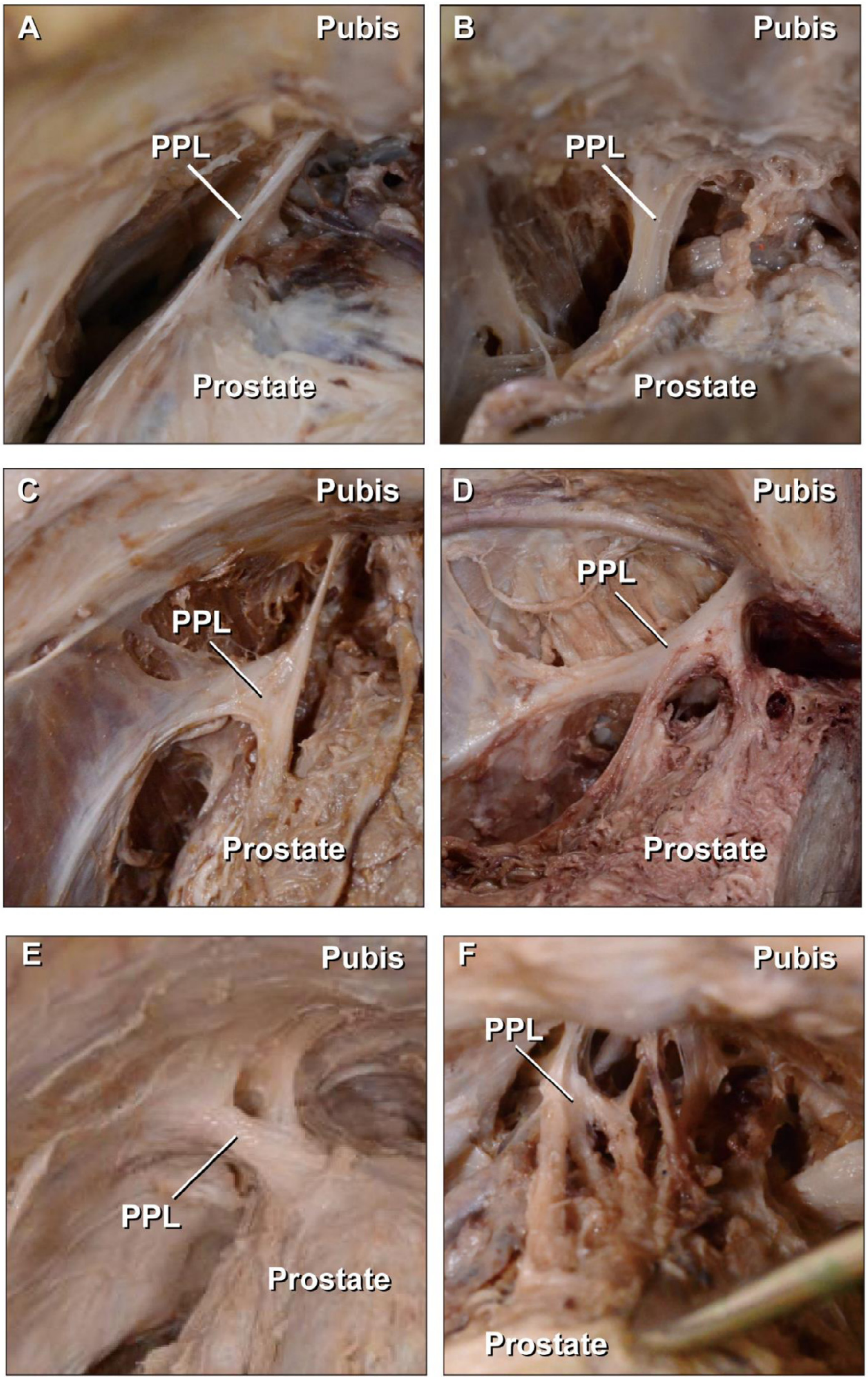


**Figure 1.** Variations of the puboprostatic ligaments (PPLs) in left hemipelvises. (**A**) An I-shaped PPL of narrow and deeply attached type. (**B**) An I-shaped PPL of wide and shallow type. (**C**) A $\lambda$-shaped PPL with single prostatic attachment. (**D**) A $\lambda$-shaped PPL with double prostatic attachment. (**E**) A Y-shaped PPL with an accessory fiber from the arcuate arch that reinforces the prostatic attachment. (**F**) A PPL with irregular shape.

**Table 1.** Association between the number and type of the puboprostatic ligaments

| Number of Ligaments | Types of Ligament | | | | |
|---|---|---|---|---|---|
| Single (n = 44) | I<br>38.6% | $\lambda$<br>43.2% | Y<br>15.9% | Irregular<br>2.3% | Total<br>100.0% |
| Double (n = 18) | I + I<br>44.4% | | I + $\lambda$<br>55.6% | | Total<br>100.0% |

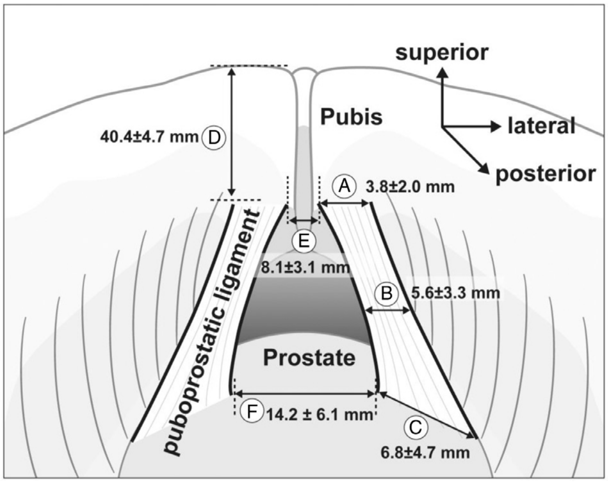


**Figure 2.** Diagram of the measurement of puboprostatic ligaments (PPLs) and neighboring structures. (**A**); width at pubic sites, (**B**) width at midpoint, (**C**) width at prostatic attachment, (**D**) distance between the PPL and superior border of the pubic bone, (**E**) distance between the pubic end of PPLs in both sides, (**F**) distance between the prostatic end of PPLs in both sides.

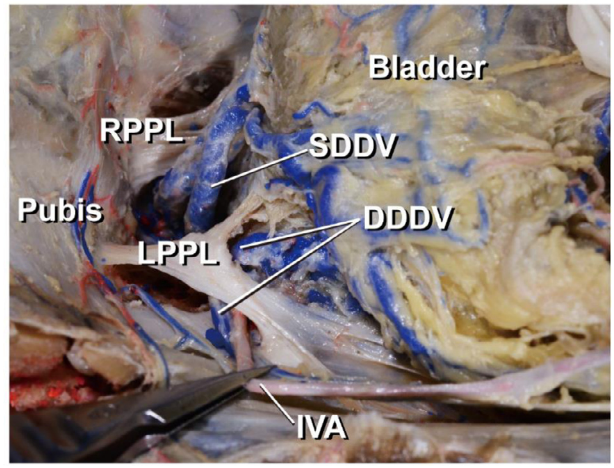


**Figure 3.** Deep dorsal vein (DDV) and puboprostatic ligaments (PPLs). The branches of deep dorsal vein are surrounded by the pubis anteriorly, the bladder posteriorly, and the right PPL (RPPL) and the left PPL (LPPL) in both sides. (Color version available online.)

average widths of the PPL at the anterior attachment to the pubic bone, at the midpoint, and at the posterior attachment to the prostate were 3.8 ± 2.0 mm, 5.6 ± 3.3 mm, and 6.8 ± 4.7 mm, respectively (Fig. 2). The widths were independent to the type of the PPLs, except that the λ-shaped PPL had a significantly wider midpoint (8.0 ± 3.6 mm) than the PPLs of other shapes ($P < .05$).

The average vertical distance between the superior margin of the pubic body and the pubic attachment of the PPL (Fig. 2D) was 40.4 ± 4.7 mm (range, 32.0-58.4 mm). In the hemipelvises with double PPLs, the attachment of the lateral PPL to the pubic bone was always higher than the attachment of the medial PPL.

The horizontal distance between the PPL on both sides was 8.1 ± 3.1 mm (range, 3.2-7.8 mm) at their pubic attachments (Fig. 2E) and 14.2 ± 6.1 mm (range, 4.0-25.2 mm) at their prostatic attachments (Fig. 2F). The gap was significantly narrower in the specimens with double PPLs on both sides than in the specimens with a single PPL on both sides ($P < .05$).

The neuromuscular bundles to the prostate, bladder, and penis were located under the PPL so that the PPLs were protecting the branches of deep dorsal vein. Usually the venous branches were found between the left PPL and the right PPL, and between the pubic symphysis and the bladder (Fig. 3). The PPLs in λ-shape were frequently pierced by the neurovascular structure.

In the midsagittal sections, it was clearly demonstrated that the PPL was the only supporting structure between the pubic bone and the prostate gland (Supplementary Figure 2). No other dense structure above or below the PPL in the endopelvic fascia was observed.

## DISCUSSION

The results of this study made the information about the shape and arrangement of the PPL clearer than before. The PPL has been described as a discrete band or a pyramid-shaped structure by former studies.[21] In an anatomical study that classified the relationship between the PPLs of both sides, they were grouped into 4 types,[27] including a parallel group, V group, and inverted V group. However, according to the results of our study, there are only 3 types of PPL shapes — I-shape, λ-shape, and Y-shape, as well as their combinations. Most of the PPLs could be described with these types and combinations. The lateral band of the λ- or Y-shaped PPLs were frequently found in our study (45.1%). In some text book, the accessory band described as a lateral puboprostatic ligament. The lateral sling of the PPL is not the part of the endopelvic fascia. It contributed to make the suspension plate of the prostate.[28] However, the lateral sling is not found in every specimen,[29] the further grouping of the PPLs according the shape is needed to understand the sustainability of prostate.

The categories in this study may allow for easy communication between surgical professionals about the shape of the PPL.

The importance of the shape and number of PPLs after RP can be explained by the mirroring of the hammock hypothesis in the female urethra. The hammock hypothesis is one of the proposed mechanisms of urinary incontinence inhibition in women.[30] The hypothesis suggests that a hammock-like structure firmly supports the back of the urethra and increases abdominal pressure, which causes the urethra to collapse when the anterior wall becomes pressed, thereby preventing urinary incontinence. After RP, male patients lose the sphincter force of the prostate. In this circumstance, for reasons similar to the hammock hypothesis, the suspension mechanisms for the urethra would gain importance. In the present study, the PPL was observed to be firmly connected and fixed from the posterior side of the prostate to the bladder neck, further supporting the aforementioned hypothesis. Because the sagittal section of the samples showed the absence of a structure anterior to the membranous urethra that supports the urethra near the midsagittal plane, the removal of the PPL in RP is expected to increase the instability of the urinary bladder and urethra and negatively affect the recovery of urinary continence.

The shape of the PPL has an implication for its function, which should be considered during prostate surgery. The PPLs in λ-shape or Y-shape, which were observed in 45.0% of the hemipelvises, may have an advantage in the suspension of the urethra as they are connected to the arcuate ligament, which is also a part of the urethral suspensory mechanism. For a similar reason, the dual appearance of the PPL may also contribute to continence after surgery. Especially when a PPL on one side has been lost, the other PPL could remain to keep the suspension.

We also found out that the lateral part of λ- and Y-shaped PPLs pass through the neurovascular bundle. If the ligament showed the lateral band (λ- and Y-shaped), during resection of the lateral part, care should be taken to avoid damaging the neurovascular bundle under the ligament.

Considering the protective effect of the PPLs on the enclosed structures, the space between the PPLs on both sides should be kept safely because dorsal venous complex passes through this area. In the present study, the space was broader in cases with a single PPL than in the cases with double PPLs. It suggests that the existence of double PPLs may be helpful for the preservation of the dorsal venous complex, not only because the number of protective ligaments are double but also because the dorsal venous plexus would be safely confined in a narrower space than in cases with a single PPL.

In conclusion, the PPLs were observed by varying numbers and morphologies in the retropubic space and were confirmed to be important structures that firmly hold and stabilize the prostate. The morphologic data of the shape, multiplicity, and location of the PPLs would help to make a plan to approach the anterior and lateral compartment around the prostate. The dual appearance of PPLs and the additional lateral slip of the PPL would likely give more advantages for urinary continence.

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## SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urology.2019.10.015.

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