

Morphometric and Computed Tomographic Investigation of Ligamentum Sacrotuberale in Dogs

Köpekte Ligamentum Sacrotuberale'nin Morfometrik ve Bilgisayarlı Tomografik İncelenmesi

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ABSTRACT

The ligamentum sacrotuberale is an anatomical structure that is frequently used in clinical hip dislocations and perineal hernias in dogs. However, various differences have been identified in the description of its anatomical location in the literature. The aim of this study is to contribute to the literature by determining the accuracy of different information specified in the literature and determining its morphology. The study was performed on the cadavers of 7 healthy adult dogs (3 females and 4 males). Three-dimensional reconstruction of the ligamentum sacrotuberale was performed on the images obtained by computed tomography in dogs. Dogs were then dissected and morphometric measurements were made. As a result of the analyses performed, no statistical difference was found when the right and left ligamentum sacrotuberale were compared ($P > .05$). In our study, it was determined that in all of our dissections performed on dogs, ligamentum sacrotuberale originated from the caudolateral surface of the last sacral vertebra and the cranio-lateral of the first tail vertebra and ended on the dorsal surface of the tuber ischidicum.

Keywords: Computed tomography, dog, 3D modeling, ligamentum sacrotuberale

Öz

Ligamentum sacrotuberale köpeklerde klinik kalça çıkıkları ve perineal fıtıklarda sıklıkla kullanılan anatomik bir yapıdır. Ancak literatürde anatomik yerleşiminin tanımlanmasında çeşitli farklılıklar tespit edilmiştir. Bu çalışmanın amacı, literatürde belirtilen farklı bilgilerin doğruluğunu ve morfolojisini belirleyerek literatüre katkı sağlamaktır. Çalışma 7 yetişkin köpeğin (3 dişi ve 4 erkek) kadavrası üzerinde yapıldı. Köpeklerde bilgisayarlı tomografi ile elde edilen görüntüler üzerinde lig. sacrotuberale'nin üç boyutlu rekonstrüksiyonu yapıldı. Köpekler daha sonra diseke edildi ve morfometrik ölçümler yapıldı. Yapılan analizler sonucunda sağ ve sol ligamentum sacrotuberale karşılaştırıldığında istatistiksel olarak fark bulunmadı ($P > .05$). Çalışmamızda köpeklerde yaptığımız tüm diseksiyonlarda lig. sacrotuberale'nin son sakral omurun kaudolateral yüzeyinden ve birinci kuyruk omurunun craniolateral yüzeyinden köken aldığı ve tuber ischidicum'un dorsal yüzeyinde sona erdiği belirlendi.

Anahtar Kelimeler: Bilgisayarlı tomografi, köpek, 3D modelleme, ligamentum sacrotuberale

INTRODUCTION

Ligamentum (lig.) sacrotuberale, in the form of a fibrous cord, was used in surgical operations in dogs.¹⁻⁴ Traumatic coxofemoral luxation was a common problem in dogs, and for the treatment of luxation, transposition method of the lig. sacrotuberale was used as an intra-articular procedure. This technique provided latero-medial stability of the joint.^{5,6} Besides sacrotuberale hip dislocations, it was also used in muscle hernias. Depending on the type of herniation, simple placement of the abdominal muscles was not possible due to atrophy of the perineal diaphragm muscles in most cases; therefore, the lig. sacrotuberale was often included in surgical operations to close the ventral and lateral part of the hernial deficit.^{7,8} Although lig. sacrotuberale was used in surgical operations performed in the perineal

region, different definitions were given in the literature review to describe its anatomical location.

There were literatures stating that the lig. sacrotuberale was located between the caudo-lateral of the sacrum and the tuber ischiadicum,^{1,2,9} while there were literatures stating that it was located between the caudolateral of the sacrum and the processus transversus of the first tail vertebrae and the lateral surface of the tuber ischiadicum.^{3,10,11} In another article, it was reported that the lig. sacrotuberale extended from the last sacral vertebra and the first 2 tail vertebrae to the outer surface of the tuber ischiadicum. The ligament partially or completely serves as the origin of the musculus abductor cruris caudalis, musculus biceps femoris, musculus gluteus superficialis, and musculus piriformis.⁴ Ligamentum sacrotuberale has a very sensitive and important anatomical position. Due to its anatomical location, many surgeons use this ligament in the treatment of various ailments in dogs.^{5,12,13}

In this study, a dissection procedure was applied in dogs and 2-dimensional (2D) images were obtained by computerized tomography (CT) imaging methods, and a 3-dimensional (3D) model on a computer program was created to determine the anatomical location of the lig. sacrotuberale. The aim of this study was to contribute to the literature by determining the accuracy of different information specified in the literature and determining its morphology.

MATERIALS AND METHODS

The study was conducted on cadavers of 7 adult healthy dogs of age between 1 and 10 years old (3 female Pariah dogs—mongrel and 4 male Pariah dogs—mongrel). This study was carried out on cadavers that died in the animal shelter of Konya Metropolitan Municipality Environmental Protection and Control Department for various reasons and were given as cadavers to Selcuk University Veterinary Faculty Anatomy Department. The ethical approval for investigation was obtained from Karamanoglu Mehmetbey University Faculty of Health Science Ethics Committee (October 27, 2021/06-34).

Computed Tomography Scanning

Images were obtained by placing the dogs in the prone position on multi-detector computed tomography (Siemens Dual Source, Somatom Definition Flash, Germany). Images were kVp 120, mAs 150-200 and parallel slice thickness of 0.6 mm, reconstruction interval of 0.5 mm, diameter FOV (field of view) of 30 cm, and interval value between 1 and 1.5. Computerized tomography images of dogs were recorded on CD-ROMs in digital imaging and communication in medicine (DICOM) format.¹⁴⁻¹⁹

Segmentation and 3-Dimensional Modeling

Three-dimensional reconstructions of os coxae, os sacrum, first coccygeal vertebra, and lig. sacrotuberale were obtained using Mimics 20.01 (The Materialize Group, Leuven, Belgium). First, images in DICOM format were opened with the Mimics 21.0 (The Materialize Group),²⁰ and 3D models were created by adjusting the threshold feature of the bones forming the pelvis cavity to a gray level of 220-3050 HU. Then, the gray level threshold was set to 410-2170 HU, and lig. sacrotuberale was manually marked using the editing mask feature of the program and a 3D model was created (Figure 1).

Macro-Anatomic and Cross-Sectional Anatomy Study

In the dissection performed on canine cadavers, an incision was made in the caudodorsal skin from the caudal aspect of the

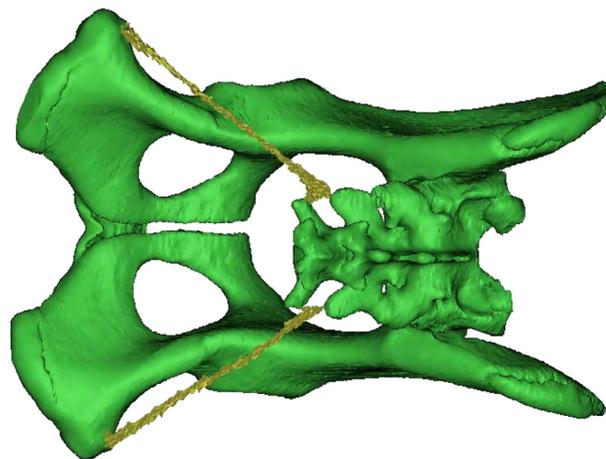


Figure 1. Modeling of the lig. sacrotuberale with the Mimics program.

greater trochanter to the last sacral vertebra. In order not to damage lig. sacrotuberale, blunt dissection of the muscles was performed by palpating between the processus transversus of the last sacral vertebra and the tuber ischiadicum (Figure 2). After the ligament was exposed, the thickness of the origin, midpoint, insertio, and length of the ligament were measured by a digital caliper. The height of dogs was obtained by measuring the tip of the nose from the tuber ischiadicum.^{21,22} Following the dissection procedure, previously obtained CT images and dissection findings were compared and anatomical formations were named on the CT images (Figures 3 and 4). The nomenclature was made according to Nomina anatomica veterinaria.

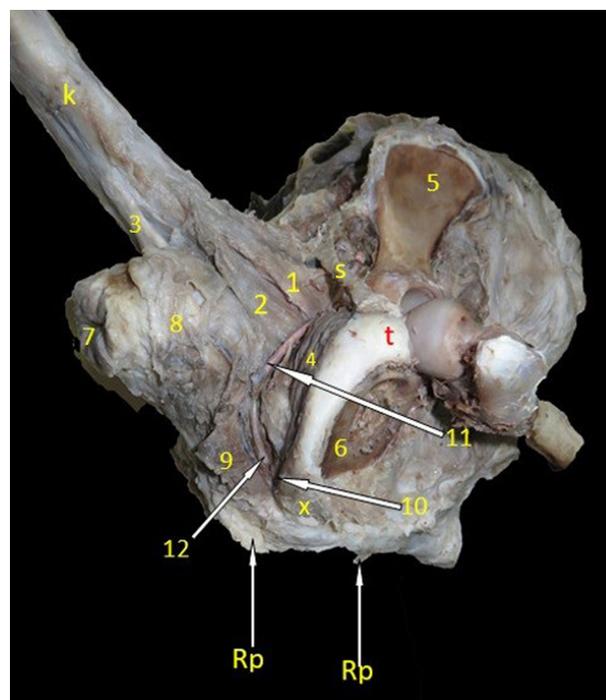


Figure 2. Regio perinealis topography. 1: M. coccygeus, 2: M. levator ani, 3: M. rectococcygeus, 4: M. obturatorius internus, 5: Ala ossis ilii, 6: Ala ossis ischii, 7: Anus (zona cutanea), 8: M. sphincter ani externus, 9: M. bulbospongiosus, 10: M. ischiourethralis, 11: A. pudenda interna, 12: A. dorsalis penis, x: M. ischiocavernosus, s: Lig. sacrotuberale, t: Tuber ischiadicum, k: Caudae, Rp: M. retractor penis.

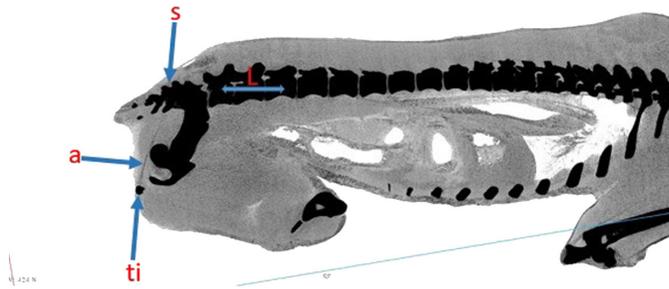


Figure 3. Position of the ligamentum sacrotuberale in horizontal section of the computerized tomography. a: Lig. sacrotuberale, s: 3.Sacral vertebrae, L: Vertebrae lumbales, ti: Tuber ischiadicum.

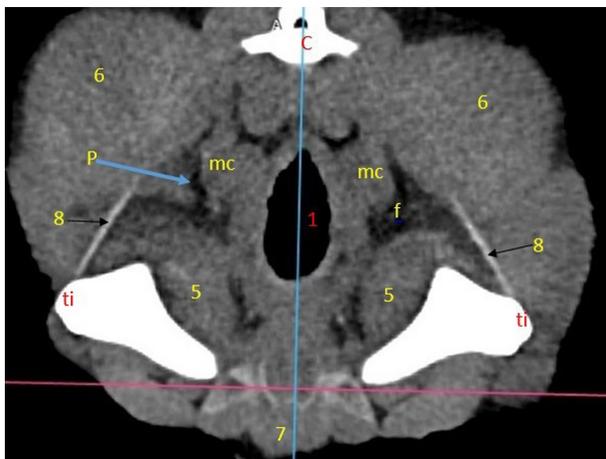


Figure 4. Ischioanal fossa computerized tomography transversal section. mc: Coccygeal muscle, ti Tuber ischiadicum, 1: Rectum, C: 2. caudal vertebra, 5: M. obturatorius internus, f: Fossa ischioanal, 6: M.gluteus superficialis, 7: M. bulbospongiosus, 8: Lig. sacrotuberale, P:Canalis pudendalis.

Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 21.0. (IBM SPSS Corp.; Armonk, NY, USA). The conformity of the variables to the normal distribution was examined using visual and analytical methods. Data obtained from the right and left lig. sacrotuberale were compared with paired sample *t*-test. $P < .05$ was accepted statistically significant. Data are expressed as mean \pm standard error (mean \pm SE).

RESULTS

Information about age, height, and weight of male and female animals used in the study is given in Table 1, and morphometric

Table 1. Age, Body Height, and Weight of the Animals Used in the Study

	Breed	Age	Height (cm)	Weight (kg)
First male	Pariah dog–mongrel	8-10	86	23
Second male	Pariah dog–mongrel	6-8	94	25
Third male	Pariah dog–mongrel	1-3	80	17
Fourth male	Pariah dog–mongrel	1-3	89	14
First female	Pariah dog–mongrel	5-7	107	22
Second female	Pariah dog–mongrel	1-3	92	15
Third female	Pariah dog–mongrel	3-5	105	24

measurements of lig. sacrotuberale are given in Table 2. In the study, the average height of the dogs was 93.28 ± 3.70 cm and their average weight was 20.00 ± 1.72 kg.

In the thickness measurements made in the lig. sacrotuberale, the mean origo thickness was 12.20 ± 1.37 mm on the left, 12.06 ± 1.34 mm on the right, the mean midpoint thickness was 4.30 ± 0.48 mm on the left, 4.21 ± 0.48 mm on the right, the mean insertio thickness was 8.60 ± 1.18 mm on the left side, and 8.57 ± 1.19 mm on the right side. The mean length of the left ligament was 93.39 ± 4.33 mm, and 93.51 ± 4.32 mm on the right. When the lig. sacrotuberale length of the right and left sides were compared, no statistical difference was found ($P > .05$).

In all of our dissections performed on dogs in the study, it was determined that the lig. sacrotuberale originated from the caudolateral surface of the last sacral vertebra and the cranio-lateral of the first coccygeal vertebra and had a termination point on the dorsal surface of the tuber ischiadicum (Figures 1-3). It was observed that it started in the form of a flat fan from the caudolateral of the last sacral vertebra, which was the starting point of the ligament, and progressed in a rounder and thicker manner after approximately 25-35 mm. The ligament termination on the tuber ischiadicum was wide and flattened like at the origin point, but the ligament was thinner and weaker than the origin in this region. In the measurements made regarding the lig. sacrotuberale, it was observed that the length value of the ligament increased and took on a wider and more flexible structure, while the width of the insertio increased significantly with the advancing age of dogs. In the study, it was determined that the nerve ischiadicus was located 25-40 mm craniomedial from the midpoint of a 45° straight line drawn between the last sacral vertebra and the tuber ischiadicum and was 50-70 mm deep of the region muscles (musculus gluteus superficialis and musculus biceps femoris (Figures 5 and 6)). The vascular nerve bundle consisting of nerve pudendus, arteria pudenda interna, and vena pudenda interna was located 40-50 mm inside the fat

Table 2. Ligamentum Sacrotuberale Measurement Values (Mean \pm Standard Error)

Gender	Thickness of the Origo (mm)		Thickness of the Midpoint (mm)		Thickness of the Insertio		Length of the Ligament (mm)	
	Left	Right	Left	Right	Left	Right	Left	Right
First male	15.96	15.89	5.61	5.47	13.04	13.01	109.3	108.8
Second male	9.68	9.99	5.29	5.19	12.87	12.95	106.04	106.90
Third male	14.62	14.32	3.51	3.08	5.55	5.63	85.97	86.38
Fourth male	7.59	7.52	2.20	2.27	5.84	5.80	80.62	80.72
Mean \pm SE	11.96 ± 1.98	11.93 ± 1.93	4.15 ± 0.79	4.01 ± 0.78	9.32 ± 2.09	9.35 ± 2.09	95.48 ± 7.15	95.70 ± 7.12
First female	14.75	14.77	5.51	5.54	8.11	8.20	93.32	93.24
Second female	7.98	7.76	4.41	4.39	6.91	6.78	81.44	81.56
Third female	14.85	14.16	3.57	3.52	7.89	7.65	97.07	96.99
Mean \pm SE	12.53 ± 2.27	12.23 ± 2.24	4.49 ± 0.56	4.48 ± 0.58	7.64 ± 0.37	7.54 ± 0.41	90.61 ± 4.71	90.59 ± 4.64

SE, standard error.

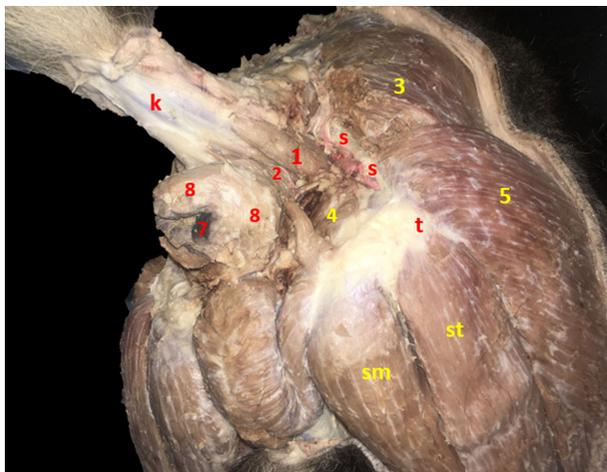


Figure 5. Position of the ligamentum sacrotuberale in male dog. 1: M. coccygeus, 2: M. levator ani, 3: M. gluteus superficialis, 4: M. obturatorius internus, 5: M. biceps femoris, sm: M. semimembranosus, st: M. semitendinosus, 7: Anus (zona cutanea), 8: M. sphincter ani externus, s: Lig. sacrotuberale, t: Tuber ischiadicum, k: Caudae.

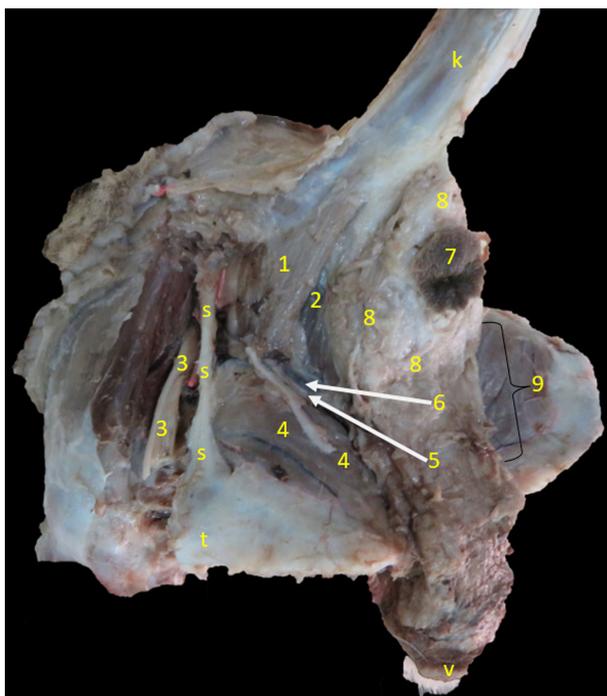


Figure 6. Position of the ligamentum sacrotuberale in female dog. 1: M. coccygeus, 2: M. levator ani, 3: N. ischiadicus, 4: M. obturatorius internus, 5: N. pudendus, 6: A. et V. pudenda interna, 7: Anus (zona cutanea), 8: M. sphincter ani externus, 9: Fossa ischiorectalis, s: Lig. sacrotuberale, t: Tuber ischiadicum, v: Vulva, k: Caudae.

layer filling the fossa ischiorectalis and caudolateral to the musculus coccygeus (Figure 6).

DISCUSSION

Ligamentum sacrotuberale is used in cases of hip dislocation, which is frequently encountered in dogs.^{5,6,13} It can be used to strengthen repair, as the inclusion of the lig. sacrotuberale in a herniorrhage does not increase the risk of complications or nerve injury.^{7,23} In studies using the transposition method of the lig.

sacrotuberale, the ligament was cut from the origin point and directed to the coxo-femoral region, passed through the holes opened on the acetabulum, and served as a support.^{6,13} In order to contribute to the transposition method of the ligament applied by the surgeons, as a result of our dissections, placing additional support sutures along the fixed ligament would be a more complementary and long-lasting approach, since the tuber ischiadicum, where this ligament ended, was weaker on the apex surface. In the surgical operation that includes the method of placing sutures around the lig. sacrotuberale for perineal hernia, the position of the anatomical structures of nerve ischiadicus, nerve pudendus, arteria pudenda interna, and vena pudenda interna should be well known.^{7,12,24-27}

Evans and de Lahunta³ stated that the lig. sacrotuberale consisted of a flattened fibrous stripe at both ends and was extending between the caudolateral endpoint of the sacrum and the processus transversus of the first caudal vertebra to the lateral part of the tuber ischiadicum. Takci and Ozcan⁴ stated that the origin of lig. sacrotuberale started from the last sacral vertebrae and the first 2 coccygeal vertebrae. While the information obtained in the dissections and CT images in our study was compatible with Evans and de Lahunta,³ it was not in line with Takci and Ozcan.⁴

It was stated that the lig. sacrotuberale anatomically served as the origin for musculus abductor cruris caudalis, musculus biceps femoris, musculus Piriformis, and musculus gluteus superficialis.²⁻⁴ Similar findings were also reported in our study.

Takci and Ozcan⁴ reported that the length of the lig. sacrotuberale was 88 mm. In the present study, this value was determined to be 95.48 ± 7.15 mm on the right side and 95.70 ± 7.12 mm on the left side in male dogs, and in female dogs, 90.61 ± 4.71 mm on the left and 90.59 ± 4.64 mm on the right. It was concluded that the findings of Takci and Ozcan⁴ could only be found in small dogs. Miller^{3,28} stated that the midpoint width of the ligament in large dogs was at most 3 mm. In the present study, the midpoint width of the ligament was determined as 4.15 ± 0.79 mm on the left and 4.01 ± 0.78 mm on the right in male dogs and 4.49 ± 0.56 mm on the left and 4.48 ± 0.58 mm on the right in female dogs. This difference was thought to be due to the breed of dogs used.

In conclusion, it is critical to specify the anatomical dimensions of this ligament, its structure, and the position of adjacent anatomical structures in newly developed techniques such as perineal hernia repair and hip luxation treatment to be performed in dogs, using the lig. sacrotuberale. With the study, the exact location of the lig. sacrotuberale was determined by dissections and 2D radiological and 3D modeling on the CT images obtained,²⁴ and data of the ligament were created with morphometric measurements. With the present study, determining the location of the ligament with various methods has enabled the accuracy of different information specified in the literature to be tested, and it is thought that the measurement data created will be important in clinical studies. The data obtained will be able to contribute to the studies to be done in surgery and on the region.

Ethics Committee Approval: The ethical approval for investigation was obtained by Karamanoglu Mehmetbey University Faculty of Health Sciences Ethics Committee (Date: 27.10.2021, Decision No: 06-34).

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