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Macroscopic Investigation of Muscles Affecting The Ankle (*Articulatio Tarsi*) And Digit Joints (*Articulationes Digiti Pedis*) in Quail (*Coturnix Coturnix*) and Pigeon (*Columba Livia*)

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Abstract

The locomotor system consists of two separate parts, the passive motion system and the active locomotor system. While the passive locomotor system consists of bones and joints, the active locomotor system consists of muscles. The strongest connection between bones, joints and muscles is seen in the feet. Feet help different functions in poultry. One of these functions is the activity of the perch. Perching is an instinctive behavior, especially in chickens. There are different views on the perch. Among these views, the mechanisms reported as TKM and ODFM support each other. In our study, the muscles acting on the ankle and digit joints of quails and perching pigeons that do not have the ability to perch were examined macroscopically. For this purpose, hind legs of 20 adult quails and 20 adult pigeons were used. Live weights were determined with a precision scale. They were euthanized by cervical dislocation. After the right and left legs of the euthanized animals were separated from the body, their left legs were fixed in 10% formaldehyde solution for dissection. Dissection was carried out simultaneously for both species. As a result of the study, it was determined that MFDL and MFHL muscle tendons, cartilage protrusions at the level of the metatarsophalangeal joint and pits in the tendon sheaths were more prominent in pigeons than in quails. If these protrusions and pits perform the perching activity by locking together like a zipper, it can be interpreted that pigeons are more suitable for perching activity than quails anatomically.

Keywords: Pigeon (*Columba Livia*), Quail (*Coturnix Coturnix*), Leg Muscles, Perching mechanism

Introduction

The locomotor system consists of two important parts, passive and active.[1-5] Static and dynamic functions are formed.6 The passive elements of the locomotor system are bones and joints, while the active elements are muscles. The strongest relationship between bones, muscles and joints is seen in the feet. It is not so tight in other organs.[1] In mammals, the feet not only perform the walking function but also provide weight bearing. In poultry, the forelimbs have taken the form of wings, as the main principle for displacement is to fly. The hind legs are shaped according to the work they do in animals. [2,6]

The bipedal nature of humans and birds allows only the two feet to make contact between the ground and the body, and as a result, the feet must provide grip and balance in bipeds.[7,8] Basically, depending on the type of poultry, the hind legs help the swimming function in animals such as ducks, while they provide the walking function in chickens. The arrangement of fingertips in birds gives them the ability to perch,[9,10] climb, hang and move easily in trees and on the ground. In addition, psittacids have a highly manipulative ability, using their hind legs for feeding, grabbing small food items with one foot and supporting themselves with the other.[11,12]

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Mammalian muscles are distributed throughout the skeleton. So they stay close to the joints with which they move. In mammals, tendons are usually short connective tissue structures that move in straight lines across a single joint. However, in birds, the muscles are often far from the joints and the legs are slender and rod-like shaped. Thus, muscles often extend far from the point of motion and have long tendons to carry out the motion. The muscles that flex the toes are located on the upper of leg and the two deep flexor tendons (*musculus flexor digitorum longus (MFDL) and musculus flexor hallucis longus (MFHL)*) control movement from the toes to the knees.[13] Hens have an instinctive desire to roost perch and when the chicks reach the age of three weeks they begin to jump to high places. A chicken's claw provides a firm grip when perching and prevents it from falling, even when the chicken is asleep. There are many studies on perching in different birds. These studies mainly focused on flexor muscles.[14-22] There are three different views on the perch. The first remark is the automatic digital flexor mechanism (ODFM). The second view is the digital tendon locking mechanism (TKM). These first two views have been gathered under the name of automatic locking mechanism in most sources to support each other.[15,18,23] As a third view, the arrangement of the muscles and the tendons that form them has been counted.[4,5]

Coturnix Coturnix (quail), is found in the family Phasianidae, in the order Galliformes.[24] It is in the anisodactyl group in terms of foot structure.[25] The *Columba Livia* (pigeon) is an anisodactyl, similar to altricial birds known to have symmetrical inner muscles of the foot.[12] Anisodactyl structure organization is ideal for a bird to successfully perch and balance. In Schmit's[26] experimental study in 1997, reported that quails were not perched for 12 nights and that perches were not necessary for their coops. However, in pigeon breeding, the construction of the perch, the flexor muscles of the domestic pigeon (*Columba Livia*) playing an active role in perching, and the high perch of the dominant side in the species indicate that the animal is perching.[12,27] The leg muscles of poultry, which have an important place in our diet, have been studied both morphologically and functionally.[28-34]

The aim of the study was to dissect the muscles affecting the wrist and finger joints in quails and pigeons and to determine macroscopic similarities and differences. Also, the connections of the muscles with the perching mechanism were tried to be determined. The results obtained will contribute to the anatomy literature.

Material and Method

Supply of Animals, Measurement of Live Weights, Euthanasia and Fixation

Macroscopic examination was carried out in Bursa Uludag University Veterinary Faculty Anatomy Department Laboratory. The material of the study consisted of a total of 40 poultry, including 20 adult quails (10 males 10 females) and 20 adult pigeons (10 males 10 females). Quails were obtained from Bursa Uludağ University Veterinary Faculty Farm and pigeons were obtained from Bursa Pigeon Breeders Association. Pigeons and quails were fed ad libitum bait and free water.

The live weights of the animals were determined with a precision scale (Weightlab, WL-303L, Turkey). Then they were euthanized by cervical dislocation. After the right and left legs of the euthanized animals were separated from the body, the left legs were fixed in 10% formaldehyde solution for dissection (immersion fixation). Following this, a dissection of the muscles was performed.

Dissection

Dissection procedures were carried out simultaneously in both species. Anatomical differences between leg muscles were determined by macrosopic examination. In two species, the hind leg muscles were spesifically dissected for the muscles acting on the wrist and fingers. The origin, insertion points and structures of the muscles were determined. Dissection studies were carried out in more detail in these parts since the muscles affecting the wrist and finger joints were located on the crus and tarsometatarsal bones.

The procedures in the study were approved by the Uludag University Experimental Animal Breeding and Research Center Committee with the ethics committee report dated 15.04.2019 and numbered 2019-05/04.

Nomina Anatomica Avium[35] was taken as a guide in determining muscle nomenclature, origin and insertion points.

Results

Intertarsal Joint Muscles

The origin, insertio and functions of the intertarsal joint muscles (*musculus tibialis cranialis, m. gastrocnemius pars lateralis, pars intermedia and pars medialis, m. fibularis longus, m. fibularis brevis and m. plantaris*) were given in Table 1.

Also, it was determined that *m. fibularis longus* tendon was shaped as wide and flat in quail, narrow and round in pigeon and stronger in pigeon. It was determined that the

Table 1. Origin, insertion and functions of intertarsal joint muscles.

Name of muscle	Origin	Insertion	Functions
M. tibialis cranialis	**Caput tibiale;** cranial cnemial crest, patella and also, lateral cnemial crest in pigeon, **Caput femorale;** the distal of lateral condyle of the femur, the craniodistal in the pigeon, and the lateral cnemial crest	In the dorsoproximal of tarsometatarsus, in the tuberosity *m. tibialis cranialis*	Flexes the tarsal joint.
M. gastrocnemius	**Pars lateralis;** tuberculum *m. gastrocnemialis lateralis*, located in the caudolateral of the lateral condyle of the femur, **Pars intermedia;** medial and proximal of the medial condyle of the femur, **Pars medialis;** the cranial and medial of the patella, proximomedial part of proximal extremitas of the tibiotarsus and proximocranial of the tibial crest in pigeon	**Pars lateralis;** in quail, it passed to the tendon in the distal ¼ of the tibiotarsus, in the distal 1/3 of the pigeon, at the level of the tibial cartilage and joins the tendo *m. gastrocnemius*, **Pars intermedia;** participates in the formation of the middle part of the tendon *m. gastrocnemius*, **Pars medialis;** in quail, it passes to the tendon in the distal 1/3 of the tibiotarsus, in the middle of the pigeon and joins the tendon *m. gastrocnemius*	Stretches the tarsal joint.
M. fibularis longus	The craniolateral of the proximal part of the tibiotarsus	Half of the tarsometatarsus in quail, in the upper 1/3 in pigeon, joins the tendon of the *m. flexor perforatus digiti III*	It supports the tibial cartilage and provides stretching of the tarsal joint.
M. fibularis brevis	The proximal 1/3 of the tibiotarsus in pigeons, and the intersection of the proximal and middle 1/3 in quails.	In the proximocaudal part of tarsometatarsus, in the tuber called tuberocity *m. fibularis brevis*	Turns the tarsal joint inward.
M. plantaris	The proximal of the caudomedial of the tibiotarsus and the upper 1/3 of the corpus tibiotarsi in quails	The proximomedial of the tibial cartilage	Stabilizes the tibial cartilage.

widest region of the muscle venter was approximately 2 cm in quails and 1 cm in pigeons.

Long Muscles of the Fingers

Long muscles of the fingers (*m. flexor perforans and perforatus digiti II, m. flexor perforans and perforatus digiti III, m. flexor perforatus digiti II, m. flexor perforatus digiti III, m. flexor perforatus digiti IV, m. long flexors flexor hallucis longus, m. extensor digitorum longus and m. popliteus*) origin, insertion and functions were given in Table 2.

Also, it was determined that the flexor perforans et perforatus digiti III muscle exited of two heads, muscular-tendon in pigeons and muscular in quails.

It was determined that the *m. flexor digitorum longus* muscle has a stronger structure in pigeons than in quail.

It was observed that the tendon structures of *m. flexor digitorum longus* and *m. flexor hallucis longus* muscles, at the level of the metatarsophalangeal joint, tubercle protrusions and pits were stronger and more prominent in pigeons.

The muscles located in the crus region generally had a thin, long and narrow structure in pigeons, while in quails they were generally found as broad and short muscles, gathered in the proximal 2/3 of the tibiotarsal region. It was determined that the biggest difference was the location of the muscles in the tibiotarsal region. In pigeons, beam structures were observed to be stronger in general. Thus,

Table 2. Origin, insertion and functions of long muscles of the digits.

Name of muscle	Origin	Insertion	Functions
M. flexor perforans et perforatus digiti II	Caudolateral and distal of the lateral epicondyle in quail and lateral and distal in pigeons.	Proximal of the basis of the 2nd phalanx of the 2nd digit	Allows flexion of the 2nd digit and stretching of the intertarsal joint.
M. flexor perforans et perforatus digiti III	**Caput proximale;** lig. patella and lateral cnemial crest, **Caput distale;** proximal of fibulae	Lateral and medial to the 3rd phalanx of the 3rd digit	Allows the 3rd digit to bend.
M. flexor perforatus digiti II	**Caput fibulare;** the inner side of caput fibulare of *m. flexor perforatus digiti III,* **Caput intermedial;** medial of the lateral epicondyle, **Caput femorale;** popliteal fossa	Proximolateral face of the 1st phalanx of the 2nd digit	Allows the 2nd digit to bend.
M. flexor perforatus digiti III	**Caput fibulare;** caudolateral of the proximal of the fibula, **Caput femorale;** medial of the popliteal fossa of the femur	Lateral and medial of the 2nd phalanx of the 3rd digit	Allows the 3rd digit to bend.
M. flexor perforatus digiti IV	**Caput fibulare;** cranial of proximal extremitas of fibula, **Caput intermedial;** lateral epicondyle, **Caput femorale;** intercondylar fossa of the femur and fossa poplitea, In quail, the muscle has two heads. **Caput fibulare;** proximal part of fibula and sticking tendon of *m. ambiens*, **Caput femorale;** popliteal fossa of femur	Plantar side of II, III and IV. phalanges of 4th digit	Allows the 4th finger to bend.
M. flexor digitorum longus	**Caput fibulare;** part of proximal and caudal fibula, **Caput tibiale;** caudomedial of proximal part of tibiotarsus, caudal of corpus and caudal part of fibula lengthwise	The proximal part of each phalanx of 2nd, 3rd and 4th digits	Bends the 2nd, 3rd and 4th digits and stretches the tarsal joint.
M. flexor hallucis longus	**Caput proximale;** the basis of lateral condyle of the femur, **Caput distale;** intercondylar fossa	Flexor tuberculum of the distal phalanx of the first digit	Bends the 1st digit and stretches the tarsal joint. Since it connects with the MFDL, it indirectly contributes to the bending of the other digits.
M. extensor digitorum longus	**Caput craniale;** between the lateral cnemial crest and the medial cnemial crest, **Caput caudale;** caudal cnemial crest	Extensor tuberculum of the 2nd, 3rd and 4th digits	It stretches the digits and helps flex the tarsal joint.
M. popliteus	Caudal side of caput fibula	Proximocaudal face of the tibia	Stabilizes the caput fibula.

it was thought that the muscles could easily carry the body weight. Weak beam structures in quails suggested that the leg may be weaker in bearing body weight.

It was observed that the beams of *mm. flexores perforati digiti II, III et IV* and *mm. flexores perforantes et perforati digiti II et III* in the pigeon had oval-like, cartilaginous formations in the metatarsophalangeal joint region. It was determined that these cartilaginous formations, which were in the shape of a boat, were hollow on the side facing the bone and flat on the outside. The cartilaginous parts of the other flexor tendons in front of them were seated in these pit parts of the tendons. In this way, the flexor beams, which fit into each other's pits in different ways, had a structure that could be intertwined in all three fingers. Although it has been reported in the studies that these structures do not only have an effect on perching and were found in every bird that performs the grasping activity, these cartilage structures were accepted as the biggest assistant of the perching behavior. These structures were seen weakly in quails.

Flexing the knee and tarsal joints while perching will passively stretch the flexor tendons. Thanks to these intertwined cartilage structures, the endurance of the muscles will increase. Thus, it is thought that the perch can be grasped more easily and it is possible for the pigeons to stay and sleep in the perch for a long time without getting tired.

3.1.3. Tarsometatarsus Region (Short Muscles of the Fingers) Muscles

Short muscles of the fingers (*m. extensor hallucis longus, m. abductor digiti II, m. extensor brevis digiti III, m. extensor brevis digiti IV, m. extensor proprius digiti III, m. flexor hallucis brevis, m. adductor digiti II, m Abductor digiti IV* and *m. lumbricalis*) origin, insertio and their functions were given in Table 3.

Also, it was determined that the tendon structure of the extensor hallucis longus muscle was stronger in quail than in pigeons.

It was determined that extensor brevis digiti III muscle was absent in pigeons, while it was detected that the extensor proprius digiti III muscle was absent in quails.

Table 3. Origin, insertion and functions of short muscles of the digits.

Name of muscle	Origin	Insertion	Functions
M. extensor hallucis longus	The proximomedial part of the tarsometatarsus and sulcus extensorius	Flexor tuberculum of 2nd phalanx of 1st digit	Stretches the 1st digit.
M. abductor digiti II	The dorsomedial of tarsometatarsus, distal 1/3 in pigeons, distal ¼ in quails.	Dorsomedial of the basis of the 1st phalanx of the 2nd digit	It is the abductor and extensor of the 2nd digit.
M. extensor brevis digiti III	The level of the middle of tarsometatarsus Muscle is not found in pigeons.	The extensor tuberculum located proximal to the dorsal aspect of the 1st phalanx of the 3rd digit.	Stretches the 3rd digit.
M. extensor brevis digiti IV	The proximal extremitas of tarsometatarsus	Proximomedial of the 1st phalanx of the 4th digit	It is the adductor of the 4th digit.
M. extensor Proprius Digiti III	The insertion level of *m. tibialis cranialis* and dorsoproximal of tarsometatarsus It is not found in quail.	Dorsal corner of the proximal end of the 1st phalanx of the 3rd digit	Stretches the 3rd digit.
M. flexor hallucis brevis	Medial parahypotarsal fossa	The proximal to the plantar part of the phalanx I of the hallux.	Bends the 1st digit.
M. adductor digiti II	Distal 1/3 of the plantar side of the tarsometatarsus	Proximomedial of the plantar side of the 1st phalanx of the 2nd digit	It is the adductor of the 2nd digit.
M. abductor digiti IV	Proximolateral of the plantar side of the tarsometatarsus	Lateral of the 1st phalanx of the 4th digit	It is the abductor of the 4th digit. It also helps in stretching.
M. lumbricalis	Distal 1/3 of tarsometatarsus and bone-facing side of MFDL tendon	The lig. plantaria of the 2nd and 3rd digits in quail in the pigeon to the lig. plantaria of the 3rd and 4th digits	Pulls lig. plantares the upwards.

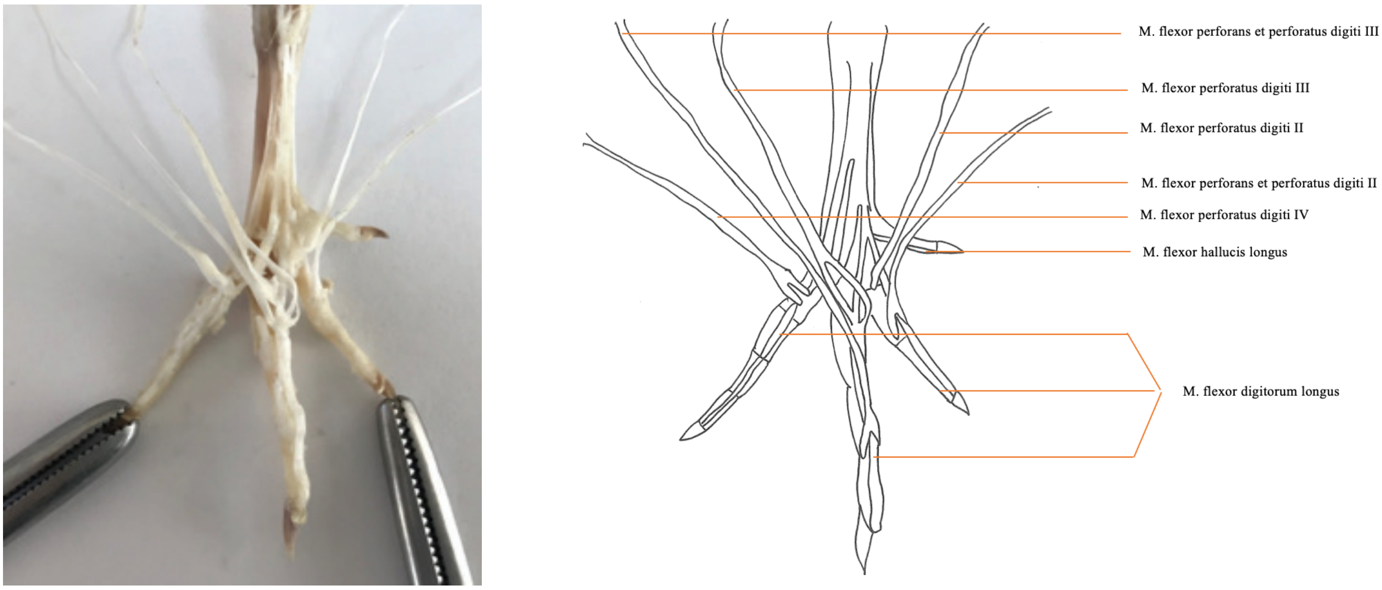

Figure 1: Plantar view of long toe flexor tendons (Quail).

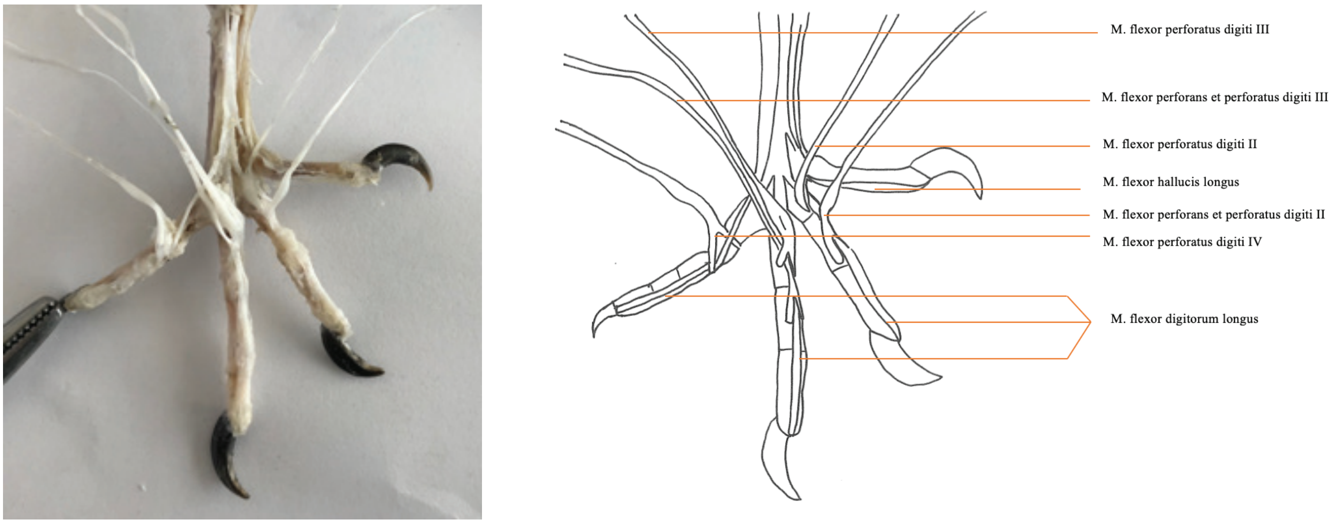

Figure 2: Plantar view of long toe flexor tendons (Pigeon).

Discussion and Conclusion

Leg muscles have been studied in detail in different poultry to date.[18,30] In our study, although there are certain differences, the starting points, course and attachment points of the intertarsal joint muscles, long and short muscles of the digits were found to be compatible with the literature.[3,16,28,29,36]

Gangl et al.[29] state that the two heads of the tibialis cranialis muscle join in the proximal 1/3 of the tibiotarsus, similar to Hudson et al.[30] it was observed that the heads combined at the level of the middle of the tibiotarsus. In addition to the literature, it was determined that the fibularis longus muscle emerged from craniolateral of proximal of the tibiotarsus. Although Gangl et al.[29] and Cracraft[12] stated that it passed to the tendon at the distal end of the tibiotarsus, it was found that it passed to the tendon at the distal 1/3 of the tibiotarsus. As Getty[3] pointed out, firstly, the intermedial head and medial head tendons of the gastrocnemius muscle unite and the common tendon forms the tendon *m. gastrocnemius*. It was determined that all three parts of the muscle formed a hard leaf that held the flexor tendons in the plantar of the metatarsus.

As Gangl et al.[29] stated, *m. extensor digitorum longus* in the distal 1/3 of the tibiotarsus in pigeons, but, in quails, it was found that it passed to the tendon just above the wrist joint. Although it was stated in the literature that the tarsometatarsus divides into two branches in the distal 2/3,[12,30] in the present study, it was determined that it was divided into branches going to the 2nd finger in the distal 1/3 and the 3rd and 4th fingers in the distal 1/5 in quail. Also, in pigeons, as Gangl et al.[29] stated, it was determined that the tendon structure was divided into three distal parts of the tarsometatarsus.

Although the *m. flexor perforatus digiti II* was mentioned in two heads in the literature,[16,28] it was found to be composed of three separate heads in our study. In the proximal of the tarsometatarsus, of tendon, It was determined that it was pierced and bifurcated by *m. flexor perforans et perforatus digiti II* and MFDL. Although Cracraft[12] reported that the venters of the *m. flexor perforatus digiti III* converged proximal to the tibial cartilage, this union was found to be in the proximal 1/3 of the tibiotarsus. It was determined that the tendon descending distally in the caudal of the leg, approximately in the middle of the tibiotarsus, was connected with the tendon of *m. flexor perforans et perforatus digiti III* with a vinculum tendineum flexorum. It was found that at the tarsometatarsal joint level, the tendon was pierced by *m flexor perforans et perforatus digiti III* and MFDL and branches ended in the lateral and medial of the 2nd phalanx of the 3rd digit.[12,16] It was determined that flexor perforatus digiti IV muscle had two heads in quail and three heads in pigeons. As Carril et al.[16] stated that, it was found that the tendon in the distal of the tibiotarsus was pierced by the tendon of the MFDL.

Consistent with the literature, the flexor perforans et perforatus digiti II muscle was observed to originate from the caudolateral and distal of the lateral epicondyle,[4,5] in quail and lateral and distal in pigeons. It was determined that in pigeon transition to the beam at the mid-level of the tibiotarsus and in the upper 1/3 of the tibiotarsus in quail. In our study, it was found that it pierced the *m. flexor perforatus digiti III* tendon at the level of the phalanx [I] of the 3rd finger. However, Cracraft[12] stated that it was at the level of tarsometatarsal joint. The pierce of the tendon by the beam of the MFDL was observed to be at the level of phalanx II, although Cracraft[12] and Hudson et al.[30] indicated that it was at the level of phalanx [I].

Similar to what Gangl et al.[29] reported, it was determined that the flexor digitorum longus muscle was connected to the MFHL via a vinculum in the middle of the tarsometatarsus. It was found that in quail, it was distal to the tarsometatarsus, and in pigeons, in the lower 1/3, it was divided into branches for the 2nd, 3rd and 4th fingers. It was determined that the *m. flexor hallucis longus* passed to the tendon in the distal 1/3 of the tibiotarsus in quail, in agreement with Gangl et al.[29] in pigeon, it was detected that it had passed to the tendon in the distal 1/5 of tibiotarsus. As opposed to Mosto[16] and Carril et al.[28] but, similar to Gangl et al.[29] it was observed to bind with MFDL in the middle of the tarsometatarsus via a vinculum.

The mechanism called TKM consists of the flexor muscles of the leg.[18] The most important muscles in this mechanism are MFDL and MFHL. These two flexors attach directly to the toes and allow the toes to automatically grasp the perch without any increased tension or muscle contraction.[15,17,37-39] When the bird sits on a branch, the cartilaginous protrusions of the MFDL and MFHL muscle tendons at the level of the metatarsophalangeal joint and the pits in the tendon sheaths form a zipper-like structure. With the intertwining of these formations, the foot digits are locked around the perch with the weight of the body, thanks to the flexor muscles.[15,18,37,40,41] Similarly, in our study, we determined the presence of tubercles and sheath structures in the tendons of the MFDL and MFHL muscles, which were responsible for the formation of this zipper-like mechanism. At the same time, we think that these structures were stronger and more pronounced in pigeons (Figures 1 and 2).

In addition to the literature, it was determined that the extensor hallucis longus muscle emerged from the sulcus extensorius. It was observed that the tendon was stronger in quail than in pigeons. *M. extensor brevis digiti III* was absent in pigeons. In quail, it was determined to be compatible with the literature. It was determined that extensor brevis digiti IV muscle was stronger in pigeons. While the extensor proprius digiti III muscle was not observed in quail, it was found to be compatible with the literature in pigeons.

In addition to the literature, it was seen that the origin of the *m. flexor hallucis brevis* was fossa parahypotarsalis medialis. Although Hudson et al.[30] and Getty[3] reported that the tendon was punctured by MFHL on tarsometatasus, in our dissection, it was found that in the plantar of basis of the phalanx I was pierced by the insertion tendon of the MFHL. It was determined that the muscle venter of *m. abductor digiti IV* extended to the distal of tarsometatarsus in pigeons, while it was located in the proximal 1/3 of the tarsometatarsus in quails. *M. lumbricalis*, König, et al.36 as stated, it terminated in the plantar ligament of the metatarsophalangeal joint of the 2nd and 3rd fingers in quails and in the plantar ligament of the 3rd and 4th fingers in pigeons.

In the dissection study, it was observed that the half-moon-shaped cartilage structures in the metacarpophalangeal joint region of the MFHL and MFDL muscles were more prominent and stronger in pigeons. As stated in the literature, if these structures form a zipper-like mechanism and enable the fingers to be locked on the perch while perching, the fact that the cartilage structures were strong in pigeons suggested that they have a more favorable musculature for perching behavior.

Based on these results, we think that pigeons have a more anatomically favorable structure than quails for perching behavior.

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