The Musculature of the Mouse Tail is Characterized by Metameric Arrangements of Bicipital Muscles

By

Harumichi SHINOHARA

Division of Human Sciences, Toyama Medical and Pharmaceutical University, Toyama 930-0194, Japan

— Received for Publication, March 18, 1999 —

Key Words: Mouse tail, Muscular system, Bicipital muscle, Metameric arrangement

Summary: This is the first report, to our knowledge, of the full characterization of the musculature of the mouse tail. Bicipital muscles form a major part of the tail musculature. The tail tendons originate with fusiform muscle from the dorsal and ventral lumbo-sacro-coxal regions and are inserted into the coccygeal vertebrae (extrinsic muscles of the tail). Each coccygeal vertebra has short muscles that terminate on the adjacent vertebrae (intrinsic muscles of the tail). The short muscle and its corresponding tail tendon are joined, thereby forming a bicipital muscle that is inserted into the coccygeal process. A geographical correspondence is strictly maintained between the origin of the tendon in the lumbo-sacro-coxal region and the insertion of the bicipital muscle in the coccygeal vertebrae. In other words, the organization of the tail musculature is based upon repetitions of fusion between the extrinsic and intrinsic muscles at each coccygeal vertebral level. This design is referred to as the metameric arrangement of the bicipital muscles. The organization, arrangement and function of muscles in the tail have features in common with those muscles in the digits of the human extremities.

The tail occupies a special position in development (Holmdahl, 1925; Griffith et al., 1992). A mass of pluripotent mesenchymal cells, the tail bud, is believed to give rise to the ectodermal, mesodermal and endodermal tissues of the tail (see the discussion section). Genetic approaches have been made to define the role of the tail bud in organogenesis of the tail (Takeda et al., 1994; Matsuura et al., 1998). Recently, Gofflot et al. (1997) examined the genetic patterning of the developing mouse tail at the time of closure of the posterior neuropore. They observed continuity of the expression of several genes from the primitive streak and node into subpopulations of the tail bud and caudal axial structures prior to their histological differentiation of these structures. However, these attempts have been hampered by the fact that the anatomical organization of the mouse tail has not yet been fully characterized.

Useful descriptions of the musculature of the mouse are largely lacking. There are several textbooks of mouse anatomy, but they do not contain descriptions of the musculature (Cook, 1965; Hummel et al., 1966). Cook (1983) stated that the muscle arrangements of the mouse and rat are very similar and that descriptions of the muscular system of the rat are applicable to the mouse. There are two standard textbooks of rat anatomy: Anatomy of the Rat (Greene, 1968) and Anatomy and Embryology of the Laboratory Rat (Hebel and Stromberg, 1986). A description of the tail musculature is included only in the latter textbook. Strocchi et al. (1985) examined histologically organization of the tail tendons and their connective tissue investments but did not clarify the gross anatomical aspects of the tail musculature, e.g., where do the tendons originate from and terminate. The present study was performed to clarify the muscular organization of the mouse tail.

Materials and Methods

Six mice, C57BL/6 strain, of 20–25 weeks of age, were used without regard to male or female for dissection and examination of tail muscles. Mice

Part of this work was supported by a Grant-in-Aid for Scientific Research no. 0167-0010 and a Grant from Yokota Foundation in Toyama Medical and Pharmaceutical University.
were killed by inhalation of ethyl ether vapor. They were skinned, fixed in 10% formalin for one week and rinsed in tap water for a day or two. Tails were removed from two animals and kept in a 0.5 M solution of EDTA sodium salt (4Na), pH 7.4, for three months. Each tail was cut, perpendicularly to the long axis, into slices of 1–2 mm in thickness with a pair of razor blades and each slice was defatted in absolute ethanol for one day. The slices were then hydrated in distilled water and stained faintly in a weak solution of alizarin red (i.e., a few drops of 0.01% alizarin red in 100 ml of distilled water). The bodies of the remaining four animals were cut into the cranial and caudal halves at the thoraco-lumbar border and the caudal half was placed in a weak solution of alizarin red in order to stain bone tissues. They were dissected under a dissecting microscope.

**Results**

**Preliminary Results**

Some aspects of the skeletal organization of the mouse tail are included in this report because they are important for considerations of the functions of the tail muscles in movements of the tail (see Shinohara, 1999 for details). The tail usually consists of 29 coccygeal vertebrae (Co1–Co29). Each coccygeal vertebra consists of a body, cranial and caudal articular processes, cranial and caudal transverse processes and cranial and caudal hemal processes. The vertebral arch is formed from Co1 to Co4 but is not formed at Co5. Thus, a spinous process is present from Co1 to Co4 but is not at vertebrae caudal to Co5. Adjacent vertebrae are connected by two joints, one that involves the articular processes and the other that involves the intervertebral discs. The second and third coccygeal vertebrae are connected by both joints but the third and fourth coccygeal vertebrae lack the former connection. Thus, the vertebrae distal to Co4 are connected end-to-end only via intervertebral discs. The connection via the articular processes limits the direction and extent of skeletal movements. Loss of this articulation between Co3 and Co4 and distal to Co4 guarantees the freedom of tail movements. One pair of sesamoid bones is found at each intervertebral level. The first pair appears between Co1 and Co2 and at least 25 paris can be distinguished under a dissecting microscope. The second pair usually fuses and forms a single, wing-nut-shaped (sesamoid) bone. Thus, there are usually 49 sesamoid bones in the tail. The sesamoid bones are sites of insertion of the ventral tendons of the tail.

**Overall View**

The tail is defined osteologically as the coccygeal region that extends from the lumbo-sacro-coxal region. It consists of a base and a body but the border between them is not clearly defined (Figs. 1, 2 and 3). Muscles are distributed in the lumbo-sacro-coxal region. The region can be divided roughly into three portions: medial, intermediate and lateral (Figs. 4, 5 and 6). The body of the tail has eight stripes along its long axis. These stripes consist of four fasciculi of tendons and four stripes of non-tendinous tissue that are arranged alternately.

The non-tendinous tissue is composed principally of muscles. These muscles are short muscles that span two or three coccygeal vertebrae. The dorsal short muscles originate from the midsagittal fascia and cranial articular process and they are inserted into the cranial articular process at more distal vertebrae. The lateral short muscles originate from the caudal transverse process and they terminate on the transverse process at more distal vertebrae. The medial short muscles originate from the cranial hemal process and they are inserted into the cranial hemal process of the next vertebra. Some muscle fibers of the proximal short muscle usually extend beyond the insertions and participate in the formation of the short muscles at more distal vertebrae. Thus, a long stripe, composed of continuous short muscles, is formed.

There are two fasciculi of tendons on each (left or right) side, and the transverse process divides them into the dorsal and ventral fasciculi (Figs. 1, 2 and 3). The dorsal fasciculus (Fig. 7) consists of tendons that are inserted into the cranial articular process. The most proximal insertion of the dorsal tendons is at Co5. The ventral fasciculus includes two categories of tendons, the lateral and medial tendons. The lateral tendons (Fig. 8) are inserted into the cranial transverse process at Co6 and more distal levels. The medial tendons (Fig. 9) converge on the ipsilateral sesamoid bones and are inserted into the cranial hemal processes. The most proximal insertion of the medial tendon is at Co6. Clearly, Co5 (or Co6) is the landmark coccygeal vertebra for the attachment of the tail tendons. The region proximal to this landmark is tentatively defined as the tail base and the region distal to it is the tail body. All vertebrae distal to Co6 are attached to the three (dorsal, lateral and medial) tendons. Therefore, when a tail consists of 29 coccygeal vertebrae, 73 tendons (25 dorsal tendons, 24 lateral tendons and 24 medial tendons) pass on one (left or right) side of the fifth coccygeal vertebra, 70 tendons on one side of the sixth coccygeal vertebra and 67 tendons on one side of the seventh vertebra.
Vertebral body and ventral connective-tissue septum divide the tail into left and right hemispheres (Figs. 10, 11 and 12). Each hemisphere is further divided into dorsal, lateral and ventral compartments by the articular and transverse processes. The dorsal and lateral compartments are occupied by the dorsal short muscle. The ventral compartment is buried by the lateral and ventral short muscles. The artery and vein of the tail are located in the ventral connective-tissue septum. The cut ends of tail tendons are arranged from the central part. In the ventral compartment, a row of tendons separates the lateral short muscle from the ventral short muscle. If a tail consists of 29 ventral compartments, the cross section of Co29 contains one or no (according to the section plane) dorsal tendon per hemisphere. Therefore, if a hemisphere contains 20 dorsal tendons, the section is assumed to be originated from Co10 or Co9, which is the twentieth vertebra counted down the tip of the tail. The cut ends of the tail tendons are arranged with remarkable precision.

Dorsal Muscles

The medial portion of the lumbo-sacro-coxal region (Fig. 4) is bordered medially by the fascia that connects the adjacent spinous processes (mid-sagittal fascia or interspinous ligament) and laterally by the fascia that extends from the articular processes (articular fascia). The intermediate portion is bordered by the articular fascia and the fascia that extends from the distal end of the transverse process (transverse fascia). The lateral portion is enveloped by the transverse fascia and its lateral extension.

The intermediate portion is the site of the muscular origins of the dorsal tendons. The fusiform muscles originate from the articular fascia, transverse process and transverse fascia between levels at the fourth lumbar vertebra (L4) and Co2. The muscles are replaced by tendons and the tendons are inserted into the cranial articular processes at Co5 and more caudal vertebrae. A geographical correspondence is strictly maintained between the level of the muscular origins and the level of the tendinous insertions. For example, the muscular origins of the dorsal tendons that are inserted from Co11 to Co29 are situated orderly on the transverse processes from the first sacral vertebra (S1) to Co2, namely, the tendon that originates at a higher (= more cranial) level in the lumbo-sacro-coxal region inserts at a higher level of the coccygeal vertebrae. The dorsal tendons are the extrinsic muscles of the tail. The dorsal tendons join with corresponding dorsal short muscles (intrinsic tail muscles) to form bicipital muscles (see below, next paragraph). The dorsal tendons might be involved in dorsal flexion of the tail body.

The muscles of the medial portion originate from the mid-sagittal fascia, articular processes and dorsal aspect of the vertebrae. They run caudolaterally and reach the articular fascia and cranial articular process. This portion is divided into three parts according to the insertion of muscle and, possibly, according to function. The first part is composed of muscles that are inserted into the articular fascia and articular processes of four sacral vertebrae. These muscles usually originate from the mid-sagittal fascia at a level cranial to L6. The muscles are not separable according to their origins or sites of insertion. Thus, they form a great mass of muscle. In rats, this muscle mass is described as the multifidus muscle (Hebel and Stromberg, 1986) but it is not analogous in morphology to the multifidus in man. Contraction of this part might elevate the pelvis. The second part is composed of muscles that are inserted into the cranial articular processes from Co1 to Co4 (the tail base). They originate from level S1 to Co2. The muscle bundles in this part are clearly separated from one another. The muscles in the second part might be involved in dorsal flexion of the tail base. The third part is composed of the dorsal short muscles that are inserted at Co5 or more distal vertebrae. Their origins are vertebral distal to Co3. They join the dorsal tendon and are inserted into the cranial articular process of the adjacent coccygeal vertebra. For example (Figs. 13 and 14), the dorsal short muscle that is found at Co3 and Co4 (intrinsic muscle of the tail) joins the dorsal long tendon that originates from L3-L4 of the intermediate portion (extrinsic muscle of the tail) and ends in the cranial articular process at Co5. In other words, the intrinsic and extrinsic muscles fuse to form a bicipital muscle (Fig. 15). The dorsal bicipital muscles of the tail are formed in a similar manner at all levels caudal to Co5. Contraction of the dorsal short muscles might pull the dorsal tendon medially and enhance the efficacy of action of the dorsal tendon. The dorsal short muscles might also be involved in regional dorsiflexion of the tail.

The lateral portion consists of muscles that arise from the lateral extension of the transverse fascia and from the distal end of the transverse processes from S1 to Co4 (Figs. 4 and 6). The muscles are replaced by tendons and inserted sequentially into the cranial articular processes at Co3, Co4 Co5 and Co6. A considerable number of tendon fibers radi-
ates into and intermingles with the peritendinous fascia that expands between the articular and transverse processes. Thus, the tendons of the lateral portion and their radiating fibers form an arch that closes the lateral opening between the articular and transverse processes. Passing under the arch of the lateral portion, most of the bicipital muscle tendons ran caudally, but some of them (for example, the bicipital muscle tendons to Co9) penetrated the tendon of the lateral portion at Co5 (Fig. 16). This relationship between the tendons of the lateral portion and some bicipital muscle tendons is similar to that between the perforatus tendon of the flexor digitorum superficialis muscle and the perforans tendon of the flexor digitorum profundus muscle in human hand. The tendons of the lateral portion hold fast the tendons of the bicipital muscles and prevent them from going off track at the base of the tail. Contractions of the muscles of the lateral portion might be involved also in ipsilateral flexion of the tail base.

**Ventral Muscles**

In the ventral lumbo-sacro-coxal region, the lateral, medial and intermediate portions are bordered by deep intermuscular grooves but are not enveloped by fascia (Fig. 5). Both the medial tendons that terminate at the cranial hemal process and the lateral tendons that terminate at the cranial transverse process are originated from the medial and intermediate portions.

The muscle of the lateral portion is a large mass that extends from the inner surface of the coxal bone (Fig. 6). It is replaced by a tendon, converges on the ispsilateral sesamoid bone and is inserted primarily into the cranial hemal process at Co5. The medial short muscle at Co4 joins the tendon. Some tendon fibers radiate towards and intermingle with the fascia at this level. The tendon forms a strong arch over the transverse process of Co5. All tendons of the ventral fascicle pass under the arch with the exception of the tendon that is inserted at Co6. The tendon inserted at Co5 is penetrated by the tendon inserted at Co6 (Fig. 17, arrows), and the tendon inserted at Co6 is further penetrated by the tendon inserted at Co7 (Fig. 17, open arrows). There is a perforatus-perforans relationship among the ventral tendons, as there is among dorsal tendons. The muscle of the lateral portion prevents the ventral tendons from going off track and functions in the ipsilateral flexion of the tail base.

The medial portion is composed of two parts: one proximal to Co3 and one distal to Co5. The distal part is composed of medial short muscles. The proximal part consists of eight fusiform muscles. The fusiform muscle that originates from the vertebral body at Co2–Co3 is replaced by a tendon, penetrates the tendon of the lateral portion at Co5, converges on the sesamoid bone and ends at the cranial hemal process of Co6 (Figs. 18 and 19). The medial short muscle at Co5 joins the tendon and is inserted with is at Co6 (Fig. 16, arrows). Therefore, this fusiform muscle, too, forms a bicipital muscle with extrinsic and intrinsic heads (Fig. 19). Similarly, the fusiform muscles that originate independently at Co1, S4 and S3 are replaced by (medial) tendons, join the corresponding medial short muscles to form bicipital muscles, converge on the sesamoid bones and end at Co7, Co8 and Co9 respectively. The remaining four fusiform muscles that originate independently from S2 to L6 are replaced by (lateral) tendons, join with the corresponding lateral short muscles to form bicipital muscles and terminate at the cranial transverse processes at Co6, Co7, Co8 and Co9 (Figs. 20, 21 and 22). The proximal part of the medial portion is unusual. The lateral and medial bicipital muscles that are inserted at the same level originate at different levels in this part (Figs. 18 and 20, the areas encircled by a broken line and the cross).

The lateral and medial tendons that are inserted at Co10 to Co29 (40 tendons in all on one side, if the tail has 29 coccygeal vertebrae) arise as fusiform muscles from the intermediate portion. The fusiform muscles are distributed on the transverse processes between levels L4 and Co2. Similarly to the dorsal tendons, a geographical correspondence is strictly maintained between the level of the muscular origins and the level of the tendinous insertions. For example, the muscular origins of the lateral and medial tendons that are inserted from Co15 to Co29 are situated orderly on the transverse processes from S1 to Co2, namely, the tendon originated at a higher level in the lumbo-sacro-coxal region inserts at a higher level of the coccygeal vertebra. The lateral and medial tendons that are inserted at the same level usually occur side by side on the same transverse process; the fusiform muscle for the lateral tendon is situated laterally and that for the medial tendon is situated medially. The tendons join the corresponding short muscles to form bicipital muscles.

The sites of origin and insertion of the bicipital muscles are schematically illustrated in Figure 23.

**Discussion**

The anatomy of the rat has been described in several standard texts (Greene, 1965; Hebel and Stromberg, 1986), but almost no descriptions for the anatomy of the mouse are available. Cook
(1983) suggested that an extensive study of the mouse skeletal musculature might not be necessary since the arrangement of skeletal muscles in the mouse is similar to that in the rat. Hebel and Stromberg (1986) stated that the tail of the rat has seven muscles, as follows: sacroccygeus dorsalis medialis and lateralis, sacroccygeus ventralis medialis and lateralis, intertransversarii caudae, coccygeus lateralis and medius. Some of the tail muscles of the mouse observed in the present study are similar but not identical to these muscle in the rat in terms of origins, insertions or arrangement. It seems clear, therefore, that the musculature of the mouse should be studied independently of that of the rat.

The present study revealed that the muscular system of the tail has three striking features. First, the tail muscles are principally bicipital muscles. There are dorsal, lateral and medial bicipital muscles and each has extrinsic and intrinsic heads. The extrinsic heads originate from the vertebral bodies and transverse processes in the lumbo-sacro-coxal region and they become the numerous long tendons of the tail. The intrinsic heads originate at C04 or at more distal coccygeal vertebrae. The extrinsic and intrinsic muscles are fused and terminate on the same coccygeal processes. This relationship between the extrinsic and intrinsic muscles is similar to that in the human extremities, namely, the relationships between the extensor digitorum (extrinsic) and interosseus (intrinsic) muscles in the hand, and the flexor digitorum longus (extrinsic) and quadratus plantae (intrinsic) muscles in the foot. Second, the tendons of muscles that originate from the coxal bone are usually perforated by the tendons of the bicipital muscles. This perforans-perforatus relationship is comparable to that between the flexor digitorum profundus (perforans) and flexor digitorum superficialis (perforatus) muscle in the hand and the flexor digitorum longus (perforans) and flexor digitorum brevis (perforatus) muscles in the foot. Third, the bicipital muscles on the flexor side of the tail converge on the sesamoid bones and are then inserted into the proximal ends (the cranial hemal processes) of the coccygeal vertebrae. This type of insertion resembles the insertions of the abductor pollicis brevis and flexor pollicis brevis muscle on the sesamoid bones in the human hand and of the abductor hallucis and flexor hallucis brevis muscles in the human foot (Frick et al., 1991; Bannister et al., 1995). The muscular organization of the mouse tail is remarkably similar to that of the digits of the human extremities.

There is, however, no more conspicuous feature than the repetition of origins and insertions, namely, the metameric pattern, of the bicipital muscles along the long axis of the tail. No such simple pattern of muscle distribution is found in other parts of the mouse body. The body of the vertebrate embryos is formed in two separate developmental processes: the primary and secondary processes. In the primary development of the body, the three germ layers are formed by gastrulation. In the secondary development of the body, a mass of pluripotent mesenchymal cells, namely, the tail bud, at the caudal end of the body gives rise to the neural tube caudal to the closed neuropore, the tail gut and, possibly, the notochord of the tail (Holmdahl, 1925; Gajovic et al., 1993 and 1995). The vertebral column and associated musculature of the tail are considered to be somitic derivatives formed by the tail bud (Holmdahl, 1925; Schoenwolf, 1978; Griffith et al., 1992; Matuura et al., 1998). The simple metameric arrangement of the tail bicipital muscle might reflect the developmental program of the tail bud, which is comparatively simple and which does not require specialization into three germ layers.

References


13) Matuura T, Narama I, Ozaki K, Nishimura M. Tomohiro
Explanation of Figures

Plate I

Figs. 1, 2 and 3. Dorsal (Fig. 1), left lateral (Fig. 2) and ventral (Fig. 3) views of the lumbo-sacro-coxal region (LSC), tail base (BA) and tail body (BO). The vertical lines indicate the approximate borders between regions. The border between the lumbo-sacro-coxal region and tail base is defined as being between the fourth sacral and first coccygeal vertebrae. The border between the tail base and body is tentatively defined as being at Co5. Note that the tail has eight stripes, which are alternately arranged along the long axis of the tail. There are four fasciculi of tendons, two on the dorsal side and another two on the ventral side (arrows). Bars = 1 cm.

Figs. 4 and 5. Both the dorsal (Fig. 4) and ventral (Fig. 5) lumbo-sacro-coxal regions are divided into the lateral (L, dorsal side; l, ventral side), intermediate (I, dorsal side; i, ventral side) and medial (M, dorsal side; m, ventral side) portions. Bars = 1 mm.

Fig. 6. Left lateral view of the dorsal lateral portion (L) and ventral lateral portion (l). Note that the two lateral portions are clearly divided by transverse processes (arrows). The broken line that encircles the acetabulum (asterisk) indicates the approximate origin of the ventral lateral portion. The pubis and ischium have been mostly removed to expose the ventral lateral portion. Bar = 1 mm.

Fig. 7, 8 and 9. Dorsal (Fig. 7), left lateral (Fig. 8) and ventral (Fig. 9) views of the tail body. White arrows indicate bony landmarks: the caudal articular processes in Figure 7; the cranial transverse processes in Figure 8; and the sesamoid bones in Figure 9. Black arrows indicate orientations of dorsal (Fig. 7), lateral (Fig. 8) and ventral (Fig. 9) short muscle fibers. Bars = 1 mm.
Plate II

Figs. 10, 11 and 12. Figure 10 shows the cross section of the tail at Co4. It is divided into the left and right hemispheres by the midsagittal fascia (open arrow), vertebral body (B) and ventral connective tissue septum (C). The dorsal short muscle (DS) is located dorsally with respect to the transverse process (T). The lateral short muscle (LS) and ventral short muscle (VS) are located ventrally with respect to the transverse process and are separated from each other by a row of ventral and lateral tendons (asterisks). The muscle of the lateral portion (L; dorsal side) is seen in this section (see Figure 6 for comparison). A: articular process. Solid arrow: artery of the tail. Figure 11 shows the section at Co9. There are 20 dorsal tendons on the right side (square). Figure 12 shows the section at Co26, demonstrating the presence of four dorsal tendons on the right side (square). It is noteworthy that the disposition of the short muscles and tendons is rigidly maintained to the tip of the tail and the number of tendons is determined precisely according to the vertebral level. Bars = 1 mm.

Figs. 13, 14 and 15. The dorsal bicipital muscle. The tendon (asterisks in Figs. 13 and 14) occurs with a fusiform muscle from the intermediate portion at L4-L3 (Fig. 13, encircled by a broken line) and is inserted into the cranial articular process at Co5 (Fig. 14, open arrow). The dorsal short muscle at Co4 (Fig. 14, closed arrows) joins the tendon. The tendon was isolated as a bicipital muscle with extrinsic and intrinsic heads (Fig. 15). The area enclosed by the broken line in Figure 15 shows the origin and corresponds to the area enclosed by a broken line in Figure 13. The open arrow in Figure 15 shows the site of insertion that corresponds to the site indicated by the open arrow in Figure 14. Bars = 1 mm.

Figs. 16 and 17. The perforatus-perforans relationship on the dorsal side (Fig. 16) and on the ventral side (Fig. 17). In Figure 16, the tendon of the lateral portion (L) is inserted into the cranial articular process at Co5 (open arrow). This tendon (closed arrows) is penetrated by the dorsal tendon (asterisk) that is inserted into Co6. In Figure 17, the tendon of the lateral portion converges on the sesamoid bone (closed triangle). The tendon (closed arrows) is penetrated by the ventral tendon (asterisk) that is inserted into the cranial articular process at Co6 (open triangle). The latter tendon (open arrows) is further penetrated by the tendon (double asterisks) that is inserted into Co7. Bars = 1 mm.

Figs. 18 and 19. The medial bicipital muscle. The medial tendon (Fig. 18, asterisk) that originates from the vertebral body at Co3 and Co2 (encircled by the broken line) converges on the sesamoid bone (open arrow). The medial short muscle at Co5 (closed arrows) joins the tendon. Figure 19 shows the isolated medial bicipital muscle. The broken circle, asterisk and open arrow correspond to those in Figure 18. The cross in Fig. 18 corresponds to that in Fig. 20. Bars = 1 mm.
Plate III

Figs. 20, 21 and 22. The lateral bicipital muscle. The lateral tendon (asterisks in Figs. 20 and 21) originates with fusiform muscle from the vertebral body at S2-S1 (Fig. 20, enclosed by a broken line) and is inserted into the cranial transverse process at C06 (Fig. 21, open arrow). The lateral short muscle that arises from the caudal transverse process of C04 (triangle) joins the tendon (closed arrows) to form a bicipital muscle. Note that the origin of the lateral tendon (area enclosed by a broken line) and the origin of the medial tendon to C06 (a cross in Fig. 20) are linearly arranged at different vertebral levels. The lateral bicipital muscle was isolated and it is shown in Figure 22. The area enclosed by broken line indicates the site of origin. Bars = 1 mm.
Fig. 23. Schematic presentation of the dorsal, lateral and ventral bicipital muscles. The extrinsic heads of the dorsal bicipital muscles originate from the intermediate portion (yellow) of the dorsal lumbo-sacro-coxal region. The dorsal tendon (asterisk) is continuous to the dorsal short muscle (vermilion in the right upper drawing) to form a bicipital muscle and terminates at the cranial articular process. Green, multifidus muscles; Blue, muscles of the medial portion that function dorsiflexion of the tail base; Violet, muscles of the lateral portion that function in ipsilateral flexion of the tail base and prevent the dorsal tendons from going off track.

On the ventral side, the lateral and medial bicipital muscles that are inserted at Co5–Co9 originate from the medial portion (blue). The lateral and medial bicipital muscles that are inserted at Co10 to Co29 (or Co31) originate from the intermediate portion (yellow). In the intermediate portion, the lateral and medial bicipital muscles that are inserted into the same coccygeal vertebra originate side by side at the same level, the former being located more laterally (cross) than the latter (bar). The lateral tendon (cross) is continuous to the corresponding lateral short muscle (vermilion in the right middle drawing) and inserted into the cranial transverse process. The medial tendon (bar) is continuous to the corresponding medial short muscle (vermilion in the right lower drawing), converges towards the sasamoid bone and is inserted into the cranial hemal process. Violet, the muscle of lateral portion. The perforatus-perforans relationship is omitted in this Figure.