Original Article

Buffalo Bulletin (January-March 2022) Vol.41 No.1

MORPHOLOGICAL FEATURES OF SUPERFICIAL AND DEEP DIGITAL FLEXOR TENDONS OF FORELIMB IN BUFFALO BULL *(Bubalus bubalis)* IN POST-NATAL STAGES

Sai Subhadra Ravali Kompella[1,*], Pramod Kumar Damaraju[2], Purushotham Gudepu[2] and Raghavender KBP[3]

Received: 27 January 2020
Accepted: 15 March 2022

ABSTRACT

Flexor tendons of forelimb play a major role in the locomotion of the animal and also in bearing 45% of the body wieght, thus making these tendons prone to several injuries. Current investigation was carried in three post-natal age groups of buffalo bulls to elucidate gross morphological and morphometrical features of superficial (SDFT) and deep (DDFT) digital flexor tendons of forelimb. Morphological studies revealed that they are shiny white fibrous structures bound by tough, durable fibrous sheath the 'flexor retinaculum' on palmar aspect of manus in all three groups (G) *i.e.*, 1 to 3 years (G I), 3 to 6 years (G II) and 6 years and above (G III). SDFT in cross sections at myo-tendinous junction was flat elliptical shaped in G I and G II whereas it was oval in G III specimens. At mid metacarpal region the SDFT was dorso-ventrally compressed and ring-shaped in digital region. Thickness increased in aged specimens at their origin, mid metacarpus and at insertion points. Lengths of the two slips of SDFT in buffalo gradually increased from inter digital space up to their insertion points from G I to G III. Cross sectional profile of DDFT in mid metacarpus was flat elliptical in outline in all groups. Thickness of the tendon steadily increased with age from G I to III. Length of DDFT from origin to its division and from division to insertion steadily increased.

Keywords: *Bubalus bubalis*, buffaloes, flexor tendon, metacarpus, fore limb

INTRODUCTION

Gait of the animal is dependent on limb musculature which in turn depends on ligaments and tendons which are appreciable superficially. Bovine body conformation and management practices practised in India make these structures prone to injuries. With advancing age, a mature tendon undergoes biochemical, cellular, mechanical, and pathological changes, which decreases its function and brings about structural changes in a tendon (Tuite, 1997). Amongst both pairs of limbs, the forelimbs play an active role in the gait of the animal. Injuries to the forelimb flexors are more common in performing animals and get traumatised mostly below carpus (Tyagi, 2012).

[1]Department of Veterinary Anatomy, College of Veterinary Science, Hyderabad, India, *E-mail: subhadraravali@gmail.com
[2]Department of Veterinary Anatomy, College of Veterinary Science, Telangana, India
[3]Department of Veterinary Surgery and Radiology, College of Veterinary Science, Hyderabad, India

MATERIALS AND METHODS

Present investigation on Age Related morphological changes of digital flexor Tendons of fore Limbs in the buffalo bull was carried out in the Department of Veterinary Anatomy, College of Veterinary Science, Rajendranagar, Hyderabad. Forelimbs of 36 apparently healthy buffalo bulls were collected from the level of carpus up to digits from local slaughterhouse and were grouped according to their ages as per dentition pattern FAO (1994) into Group I (1 to 3 years), Group II (3 to 6 years) and Group III (6 years and above). These specimens were preserved in 10% Neutral Buffered Formalin (NBF) solution for more than 24 h after which they were subjected to careful dissection to first expose the main arterial vessels at carpal level which in turn were gently flushed with warm saline solution and injected with Indian Ink Gelatin solution (Jee *et al*., 1960). The specimens were again preserved in 10% NBF. Post fixation, the specimens were dissected to study the vascular pattern of both SDFT and DDFT. Detailed dissection was done to study the structure behaviour such as origin, course, and insertion of SDFT and DDFT tendons respectively.

Morphometrical studies were done on all specimens to measure and record the following parameters with a thread, scale, and digital Vernier Calipers (Mitutoyo):

1. Length of each tendon in ‘cm’ from carpal level up to their division point at inter digital space and from inter-digital space up to insertion point.

2. Width (thickness) of each tendon at three levels *i.e*., at its point of origin (myotendinous junction), mid-metacarpus and insertion levels.

3. Fresh ink impressions of ‘cross sectioned’ tendons were taken on clean paper from their origin, mid-course and insertion points to note their tentative shapes.

RESULTS AND DISCUSSIONS

SDFT and DDFT tendons of Indian buffalo were shiny white fibrous structures located on palmar aspect of manus in all three groups. Both tendons were bound by tough, durable fibrous sheath the ‘flexor retinaculum’ which provided ample support and protection. Presence of thick fascia on palmar aspect of metacarpus and digits in this study suggests that it helps in transferring compressional forces to extra epimysial tissue. Our observation endorses the opinion of Huijing (2007), who stated that there is an increasing awareness that muscles transmit forces beyond epimysial envelope.

SDFT

SDFT was located on palmar aspect of large metacarpal (III and IV) from the carpal tunnel downwards. The latter was bordered by accessory carpal, which over hanged the carpal canal (Figure 1). Embedded within were two digital flexor tendons of the limb of which the superficial part of SDFT was placed above its deeper part and DDFT. It was directed from lateral edge of carpus downwards onto palmar surface of large metacarpal in flexor retinaculum and passed medially up to inter-digital space (Figure 1).

In between the retinaculum and lateral edge of SDFT were the main blood vessels. Superficial fascia overlying this tendon displayed very fine blood vessels on its volar surface in metacarpal region. Delicate vascular branches were observed on inner surface of the superficial division of SDFT (Figure 2). Above findings are in accordance with the description of SDFT in forelimbs of ruminants by Getty (1975); Nickel *et al*. (1985); Dyce *et al*. (2010). These authors stated that fascia palmaris consisted of transverse fibres, which crossed the flexor aspect of the carpus to form the flexor retinaculum on palmar aspect of metacarpus in mammals.

Cross sections of SDFT in fore limbs in this study were flat and elliptical in Groups I and II at myo-tendinous junction respectively and oval shaped in Group III. At mid metacarpal region it was dorso-ventrally compressed and ring shaped in digital region (Figure 3).

These findings are akin to the results of Takahashi *et al.* (2018) in bovine forelimbs *i.e*., 'oval' at myotendinous junction, 'semi-oval' at middle metatarsus and 'ring-shaped' at tendon bone interface. Cross sectional areas of bovine SDFT in hind limbs reported by Takahashi *et al.* (2018) at three levels were 129.9±8.85, 98.2±11.97 and 14.7±13.83 mm² thick respectively. In the present study the thickness of buffalo SDFT of forelimbs were measured and their average cross-sectional area was 187.9 mm² (4.9 cm in G I) at origin point (Figure 6).

Thickness of the tendon increased in aged specimens at three levels *i.e*., at origin (myo-tendinous junction), mid metacarpal region and at insertion point. Increased thickness of the digital flexor of forelimb in buffalo reaffirms the fact that these tendons have to be stronger and tougher because of their functional aspect of bearing more body weight in contrast to the hind limb which biomechanically acts like a 'catapult' structure.

Change in colour in transversely cut fresh SDFT in Group I from much paler to dark brownish appearance in later Groups II and III in this study are similar to the reports of Webbon (1978) in equines, wherein he stated that with advancing age transversely cut surface of fresh flexor tendons became darker from pearly white in neonates to yellow brown in old horses which might be due to lipid or pigment deposits with advancing age.

The SDFT in Groups I to III of this study were round to elliptical in its shape which is in agreement with observations of Benjamin *et al.* (2008) in tendons of human hand. They cited that as a general rule, extensor tendons are more flattened than flexor tendons which tend to be round or oval. This is clearly seen in flexor tendons of forelimb of buffalo wherein they were oval and less flattened in their course on palmar aspect of manus. Lengths of the two slips of SDFT in buffalo gradually increased from inter digital space up to their insertion point across G I (9.1±0.3 cm) to G II (10±0.2 cm) and G III (11.3±0.7 cm) respectively (Figure 7).

This portion of SDFT is apparently very strong and elliptical white fibrous structure which is capable of receiving compressional and frictional forces as noted by Evanko and Vogel (1990) in bovine flexor tendons.

DDFT

Palmar surface of the DDFT was shallow in proximal two thirds of the metacarpus in buffalo forelimbs and it was closely attached to suspensory ligament of the limb which is true with the description of this tendon by Getty (1975); Nickel *et al.* (1985); Budras and Habel (2003) in bovines and Dyce *et al.* (2010) in large ruminants and pigs. They opined that this tendon is the stronger of the two digital flexors in these animals.

In lower third of large metacarpal the DDFT divided into two slips *i.e*., one each for axial and abaxial digits which emerged from the cuff like tunnels of SDFT and were inserted to respective tubercles on phalanx III (Figure 4).

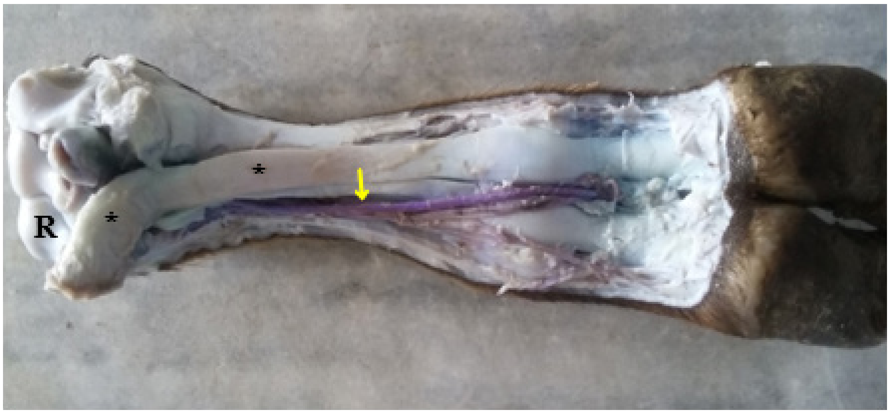

Figure 1. SDFT (*) position in relation to the proximal row of carpals in buffalo in Group I, (R) Radial carpal, (→) Palmar metacarpal artery III (Indian ink preparation).

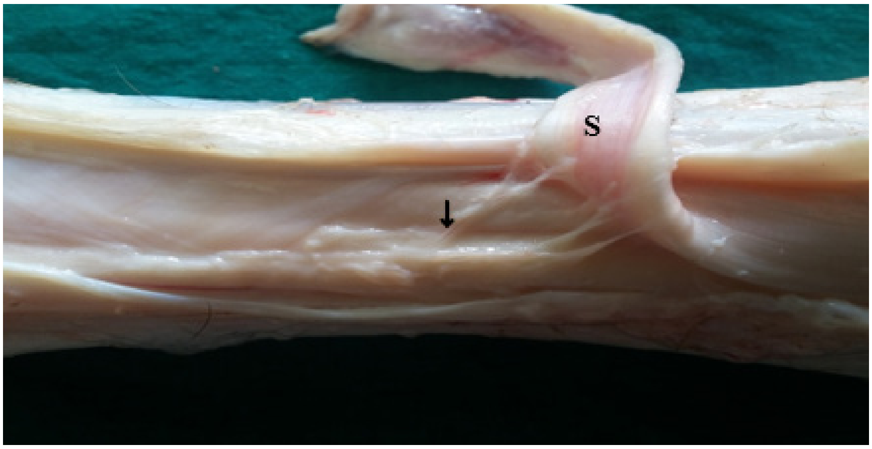

Figure 2. Palmar aspect of the metacarpus of buffalo forelimb showing fine vessels (→) to reflected SDFT (S) in Group II.

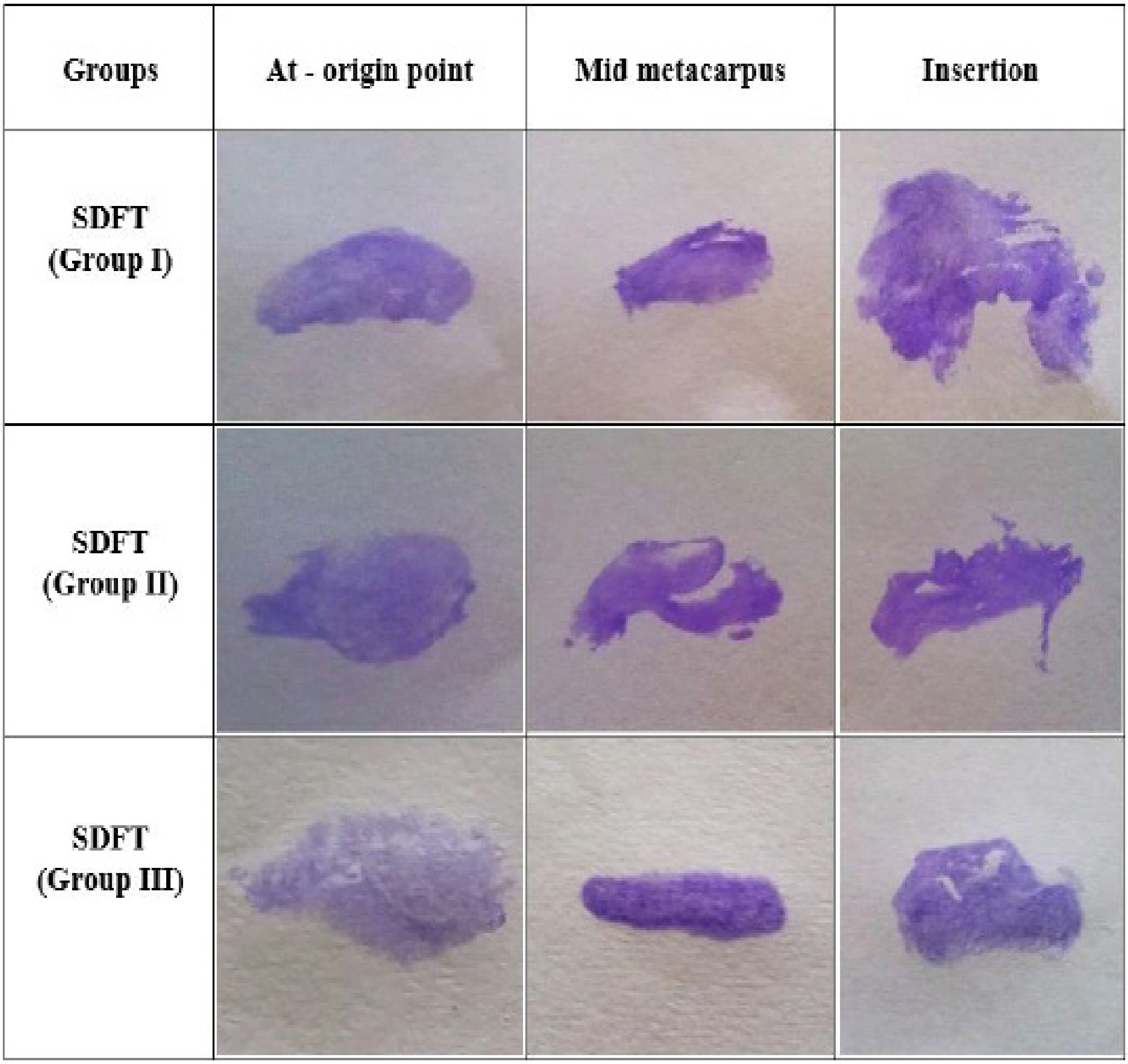

Figure 3. Cross-sectional ink impression profiles of SDFT of all groups at three levels *i.e*., at origin, mid metacarpal and close to insertion.

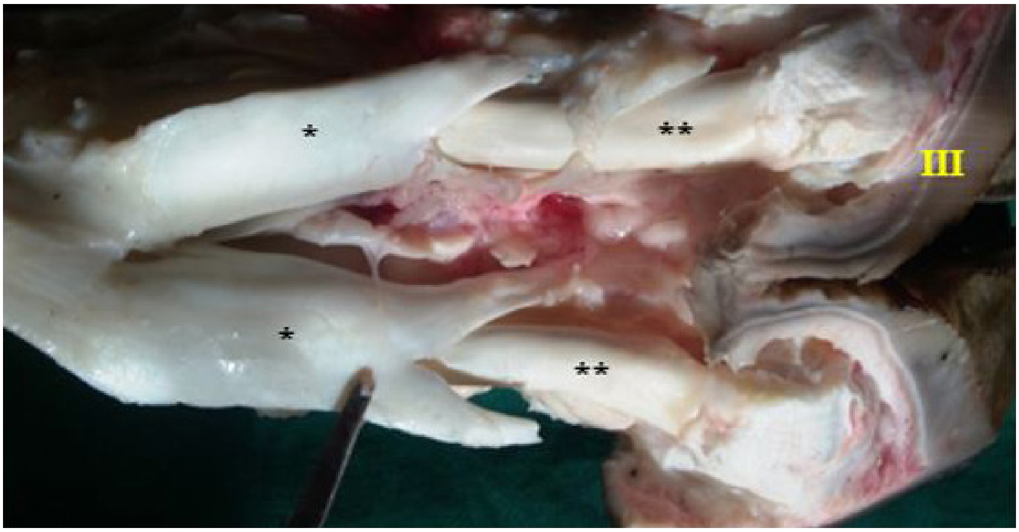

Figure 4. Two DDFT slips (**) inserted to phalanx III after passing through the tunnels formed by SDFT (*) in Group II.

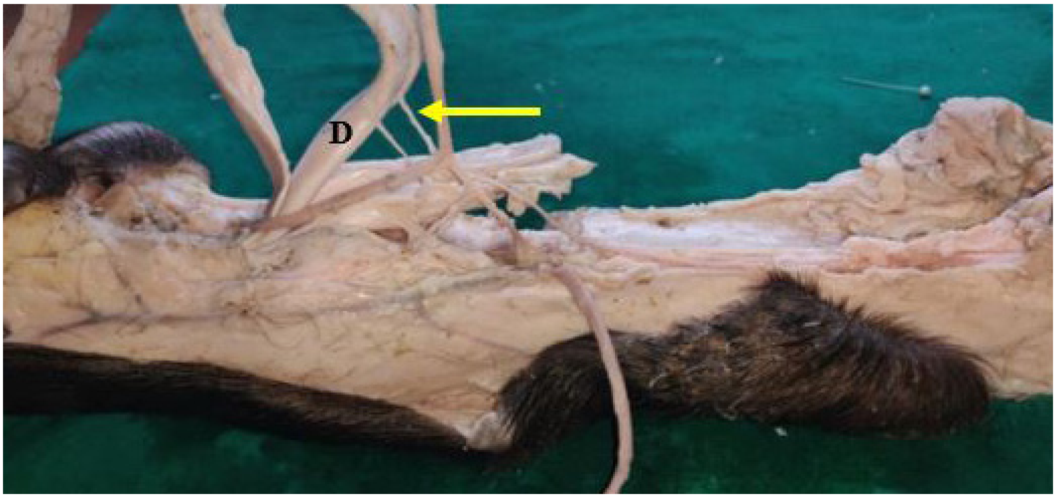

Figure 5. Photograph showing dissected suspensory apparatus exposing fine blood vessels (→) from deep volar arch penetrating through suspensory ligament to the DDFT (D) in Group III.

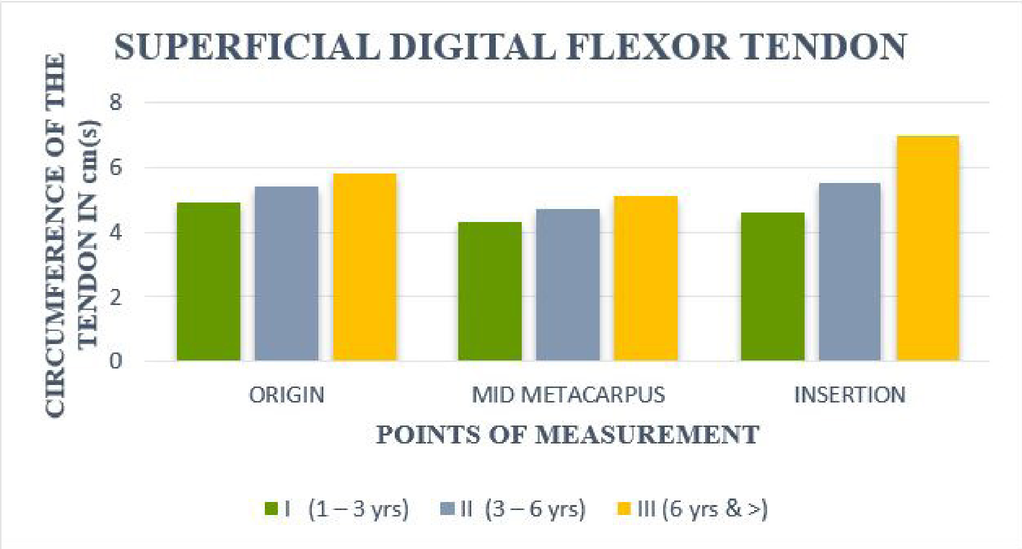

Figure 6. Morphometric changes in the circumference of the SDFT at different regions from young (Group I) to aged (Group III).

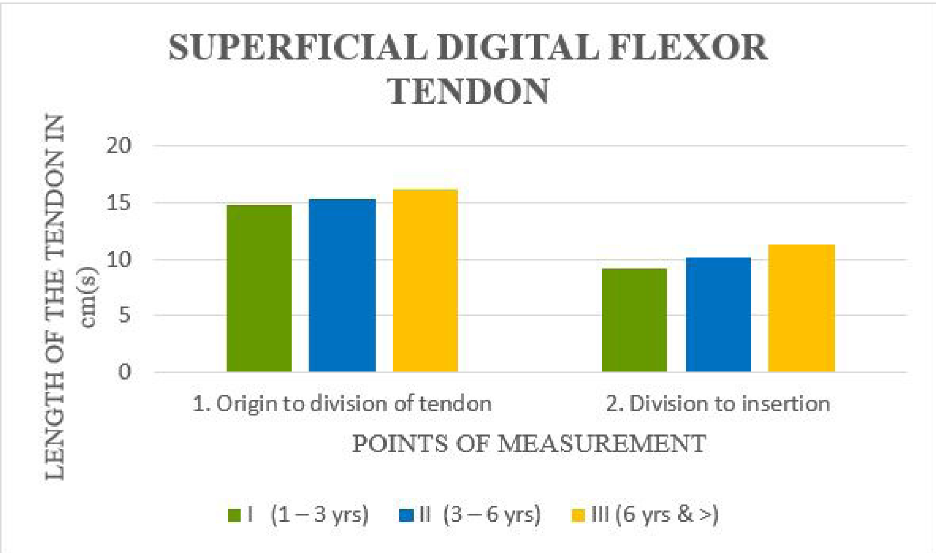

Figure 7. Morphometric changes in the length of the SDFT from origin to its insertion from young (Group I) to aged (Group III).

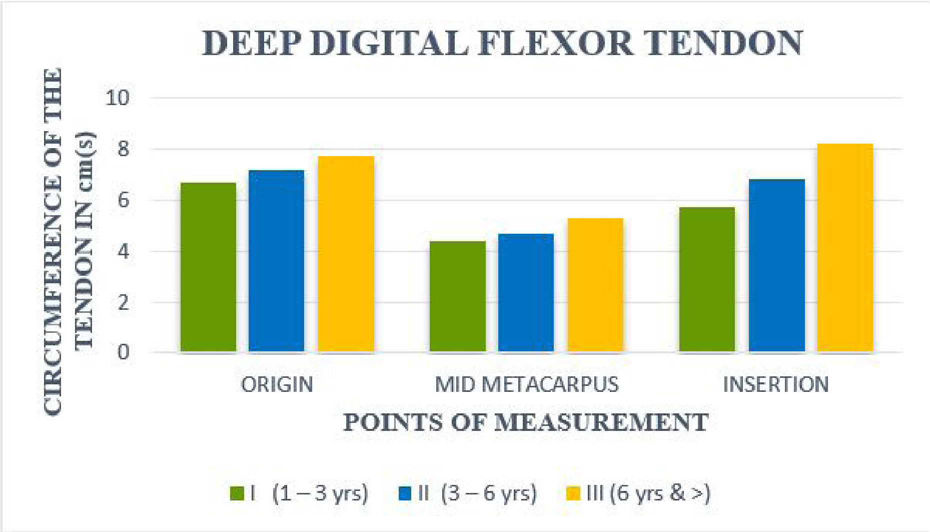

Figure 8. Morphometric changes in the circumference of the DDFT at different regions from young (Group I) to aged (Group III).

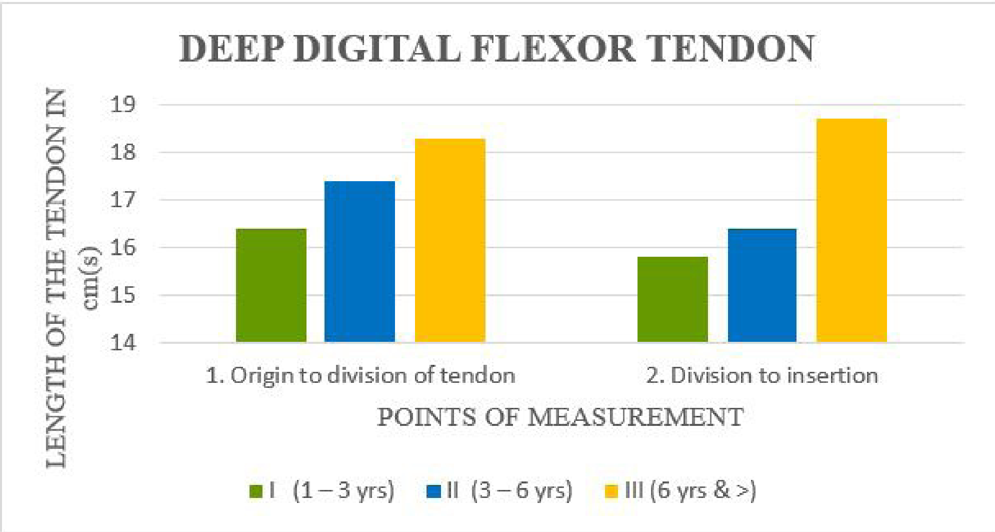

Figure 9. Morphometric changes in the length of the DDFT from origin to its insertion from young (Group I) to aged (Group III).

Figure 4. Two DDFT slips (**) inserted to phalanx III after passing through the tunnels formed by SDFT (*) in Group II.

Our observations are in total agreement with descriptions of 'digitorum profundus' by Getty (1975), Nickel *et al*. (1985); Budras and Habel (2003) in bovines and Dyce *et al*. (2010) in large ruminants. They stated that in pigs and large ruminants the 'digitorum profundus' or DDFT after passing through fetlock glided over the sesamoids surrounded by cuff like sheath formed by corresponding tendon of SDFT. At level of first phalanx the deep tendon perforated the twin branches of the superficial tendon to end on palmar aspect of the third phalanx. The DDFT of buffalo can be treated as a wrap-around tendon because of its close and extensive association with thick palmar fascia. At inter-digital space the tendon was stretched over the sesamoids of fetlock to pierce through respective cuff like tunnels of SDFT and get inserted to third phalanx. This observation reaffirms the opinion of Merrilees and Flint (1980); Okuda *et al*. (1987a, 1987b); Evanko and Vogel (1990). They stated that flexor digitorum profundus tendon of rabbits, dogs and cows is a "wrap around" tendon which received compressional and frictional forces besides transmitting the tension exerted by its muscle.

Fine vascular branches to DDFT from medial deep volar metacarpal artery in this study over the fetlock was surrounded by delicate fascia which resemble the 'vinculae' (Figure 5) described by Edwards (1946), who stated that blood vessels enter the mesotenon to supply tendons surrounded by true synovial sheaths. He mentioned that in digital region the mesotenon is reduced to isolated cord-like 'vinculae'.

Getty (1975); Nickel *et al*. (1985); Konig and Liebich (2007); Dyce *et al*. (2010) reported that in ruminants palmar metacarpal artery III arose from dorsal carpal rete and descended along medial border of suspensory apparatus to supply skin, suspensory apparatus and tendons in the region. Palmar metacarpal artery II passed in the long groove of large metacarpal and anastomosed with the former to form deep volar arch above fetlock between the bone and suspensory ligament. The arterial distribution was similar and clearly observed in this study wherein vascular arches existed underneath the suspensory ligament at the fetlock. Presence of blood vessels in connective tissue (epi, meso and peritenon) is an advantage to the flexors of the limb in times of injury. The DDFT thickness was more than the SDFT in this study and similarly the length of the tendon from inter-digital space up to digits was also longer than the SDFT (Figure 8 and 9).

Inference

Both the superficial and deep digital flexor tendons of forelimbs in this study were shiny white fibrous structures located on palmar aspect of manus, bound by tough durable fibrous sheath the 'flexor retinaculum' which provided ample support and protection. This anatomical feature helps in transferring compressional forces to extra epimysial tissue. Thus, our opinion reaffirms that load bearing is satisfactorily facilitated by digital flexor tendons which have thick fascia palmaris adjacent to metacarpal bone in large ruminants.

REFERENCES

Benjamin, M., E. Kaiser and S. Milz. 2008. Structure-function relationships in tendons: A review. *Journal of Anatomy*, **212**(3): 211-228. DOI: 10.1111/j.1469-7580.2008.00864.x

Budras, K.D. and R. Habel. 2003. *Bovine Anatomy: An Illustrated Text*, 1st ed. Schlütersche GmbH and Co. KG, Hannover, Germany.

Dyce, K.M., W.O. Sack and C.J.G. Wensing. 2010. *Text Book of Veterinary Anatomy*, 4th ed. Elsevier, Saunders, London, UK. 834p.

Edwards, D.A.W. 1946. The blood supply and lymphatic drainage of tendons. *J. Anat*., **80**(3): 147-152.

Evanko, S.P. and K.G. Vogel. 1990. Ultrastructure and proteoglycan composition in the developing fibrocartilaginous region of bovine tendon. *Matrix*, **10**(6): 420-436. DOI: 10.1016/S0934-8832(11)80150-2

FAO. 1994. A manual for primary animal health care worker. p. 1-51. *Corporate Documentary Repository Chapter 3: Cattle, Sheep, Goats and Buffalo. Unit 9: How to Age Sheep, Goats, Cattle and Buffalo*. Food and Agriculture Organization, Rome, Italy. Available on: www.fao.org/ docrep/t0690e/t0690e05.html

Getty, R. 1975. *The Anatomy of Domestic Animals*, 5th ed. WB Saunders 1298, Philadelphia, USA.

Huijing, P.A. 2007. Epimuscular myofascial force transmission between antagonistic and synergistic muscles can explain movement limitation in spastic paresis. *J. Electromyogr. Kines*., **17**(6): 708-724. DOI: 10.1016/j.jelekin.2007.02.003

Jee, W.S. and J.S. Arnold. 1960. India ink-gelatin vascular injection of skeletal tissues. *Stain Techn*., **35**(2): 59-65. DOI: 10.3109/10520296009114717

König, H.E. and H.G. Liebich. 2007. Veterinary *Anatomy of Domestic Mammals: Textbook and Colour Atlas*, 4th ed. Schattauer Verlag, Germany.

Merrilees, M.J. and M.H. Flint. 1980. Ultrastructural study of tension and pressure zones in a rabbit flexor tendon. *Am. J. Anat*., **157(**1): 87-106. DOI: 10.1002/aja.1001570109

Nickel, R., A. Schummer, E. Seiferle, H. Wilkens, K.H. Wille and J. Frewin. 1985. The anatomy of the domestic animals, p. 378-380. *The Locomotor System of Domestic Mammals*, Verlag Paul Parey, Berlin, German.

Okuda, Y., J.P. Gorski, K.N. An and P.C. Amadio. 1987a. Biochemical, histological, and biomechanical analyses of canine tendon. *J. Orthop. Res*., **5**(1): 60-68. DOI: 10.1002/jor.1100050109

Okuda, Y., J.P. Gorski and P.C. Amadio. 1987b. Effect of postnatal age on the ultrastructure of six anatomical areas of canine flexor digitorum profundus tendon. *J. Orthop. Res*., **5**(2): 231-241. DOI: 10.1002/jor.1100050209

Takahashi, N., T. Hirose, J.A. Minaguchi, H. Ueda, P. Tangkawattana and K. Takehana. 2018. Fibrillar architecture at three different sites of the bovine superficial digital flexor tendon. *J. Vet. Med. Sci*., **80**(3): 405-412. DOI: 10.1292/jvms.17-0562

Tuite, D.J., P.A.F.H. Renström and M. O'brien. 1997. The aging tendon. *Scand. J. Med. Sci. Spor*., **7**(2): 72-77. DOI: 10.1111/j.1600-0838.1997.tb00122.x

Tyagi, R.P.S. and J. Singh. 2012. *Ruminant Surgery.* CBS Publishers and Distributors Pvt. Ltd. New Delhi, India. p. 167-174.

Webbon, P.M. 1978. A histological study of macroscopically normal equine digital flexor tendons. *Equine Vet. J*., **10**(4): 253-259. DOI: 10.1111/j.2042-3306.1978.tb02275.x