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Research Article

Gross Anatomical Structure and Magnetic Resonance Images of the Carpal Joint in One Humped Camel (*Camelus dromedarius*) and Its Arterial Blood Supply

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ABSTRACT

Aim: The present study investigates the topographical approach of the carpal joint in one humped dromedary camel included a detailed anatomical description of the carpal bones, carpal joint, joint capsules, ligaments and its arterial blood supply in order to establish a basic reference data for clinical diagnosis, prognosis of the carpal joint affections and deciding the suitable surgical approach.
Materials and Methods: The current work was conducted on eight fresh fore limbs of one humped dromedary camel. The carpal joint compartments injected with different colored gum milk latex to identify their synovial sacs. MRI examination of the carpal joint was performed on cadaveric limb. Other specimens were injected through median artery for studying their arterial blood supply.
Results: There were seven carpal bones in dromedary camel arranged into two rows; the radial, intermediate, ulnar and accessory carpal bones in the proximal row. The distal row contained the second, third and fourth carpal bones. The carpal joint (complex joint) composed of three articulations; the radiocarpal, the intercarpal and the carpometacarpal. The radiocarpal sac was the largest one, while the intercarpal sac was limited and communicated with the carpometacarpal sac. The arterial supply of the carpal joints was mainly derived from the radial artery in the form of the dorsal and palmar carpal plexus.
Conclusion: There were three possible approaches for intra articular injection of carpal joint in camel; the dorso-medial, dorso-lateral and the lateral approaches. The dorso-medial one was the most accurate site and easily applied.

Key words: Gross anatomy, Carpal joint, Ligaments, Radial artery, MRI, Dromedary camel

INTRODUCTION

Camels have characteristic locomotor apparatus adapted for racing and travel on sandy soil. The carpal region suspected to several carpal affections such as carpitis, trauma and ulcerative dermatitis due to the prolonged pressure on the dorsal aspect of the carpal joint during recumbency or kneeling position (Badawy, 2011; Soroori *et al.*, 2011; Kassab, 2008; Khan *et al.*, 2003; Janis *et al*., 2002and Ramadan *et al*., 1986).

Anatomical descriptions of the synovial sacs for each joints of the carpus were studied for facilitating the arthroscopic access and giving information for researchers and surgeons in the field of camel medicine that was commonly used for administration of the intra-articular medication and anesthesia (Alsobayil *et al*., 2015; Tnibar *et al*., 2015; Mcllwraith, 2010 and Drevemo *et al.*, 1999) as well as contrast medium applied in diagnostic imaging (Gray *et al*., 2013).

Magnetic resonance imaging (MRI) gives a detailed information for both soft tissue (tendon; ligament, joint capsule) and bony structures. It was proved to be a diagnostic tool for the orthopedic problems in the carpus of camel.

A little information is known about the arterial supply of the carpal joint in one- humped camel, while there is extensive data about cow and equine species. Our purpose in this study described the detailed anatomical information of the carpus in one humped camel with emphasis about its arterial supply.

MATERIALS AND METHODS

The present study was performed on eight carpal regions of fresh fore limbs from four apparently healthy camels that collected from slaughter house. One specimen was used for preparation of carpal bones by removal of the soft tissues then boiling in dilute sodium bicarbonate

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and finally degreasing in ammonia solution and bleaching in 3% hydrogen peroxide within ten days. Two limbs were used to clarify the synovial sac of each joint with their palmar pouches by injected one with gum milk latex mixed with green color and other sac with blue color then preserved in freezer for one week and dissected for studying the gross anatomy of the carpal joint; articular surface, joint capsule and ligaments. One specimen was applied a sagittal section to illustrate the site of needle injection. Three specimens of camel's carpal joint were injected with red latex through the median artery for studying its arterial supply. MRI examination was used in one cadaveric limb after camel was slaughtered. This limb was exposed for MRI scan in dorso-palmar direction by using a high field (SIGNA Explorer, GE, 1.5 Telsa) by applying in transverse, sagittal, and longitudinal plane images with different slice thickening of 3-4.5 mm.

RESULTS

There were seven carpal bones (Figs. 1, 7, 8, 9) arranged in two rows; the radial (RC), intermediate (IC), ulnar (UC) and accessory carpal bones (AC) in the proximal row. The distal row contained the second, third and fourth carpal bones.

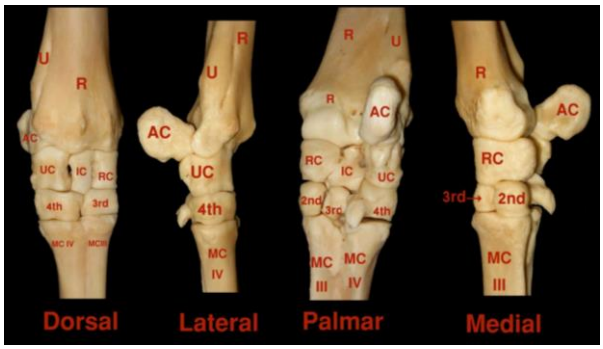

Fig. 1: Photograph showing the carpal bones of the right camel's carpus.

The carpal joint

The carpal joint was a complex joint composed of three horizontal articulations; the radiocarpal joint(Fig.4 /1) located between the distal articular surface of radius and ulna and the proximal row of carpal bones, the intercarpal joint (Figs. 4/2) was placed between the proximal and distal row of carpal bones and the carpometacarpal joint (Fig. 4/3) situated between the distal row of carpal bones and the proximal articular surface of third and fourth metacarpal bone. There were three inner synovial sacs that located underneath the extensor retinaculum and in between the extensor tendons. The radiocarpal sac was separate and the largest one, while the intercarpal sac was limited and communicated with carpometacarpal sac (Fig. 2, 4, 7/6). The radiocarpal sac (Fig. 2, 4, 7/4) appeared with green cast while the intercarpal and carpometacarpal sacs (Fig. 2, 4, 7/5, 6, respectively) appeared blue cast.

The radiocarpal synovial sac was pouched palmary by large pouch (lateral palmar pouch) and small palmaro-medial pouch (Fig.4, 7/4a, 4b, respectively). The lateral palmar pouch extended latero-palmarly at the level of the accessory carpal and was presented laterally to the the carpal canal. The intercarpal synovial sac occupied the spaces between the individual bones of the two rows and formed the palmarolateral and palmaromedial pouch (Fig.4, 7/5a, 5b) just distal to the accessory carpal bone. The carpometacarpal sac was the smallest one that extended laterally in distal direction by palmarodistal pouch (Fig.4, 7/6a).

Tendons and ligament

The carpal joint was capped externally by the carpal pad and supported by the extensor retinaculum (Fig. 2, 3/7) that surrounded the extensor tendon on the dorsal aspect of the carpus and the flexor retinaculum (Fig. 3/8) on the palmar aspect.

The carpal joint was covered dorsally by the carpal extensor tendons: the extensor carpi radialis (Fig. 2, 9/9) was large and wide, common digital extensor (Fig. 2, 9/10) had a medial and lateral parts (Fig. 2/10a, 10b) that were parallel as they passed over the dorsal aspect of the carpus, the lateral branch was slightly greater than the medial one and the lateral digital extensor (Fig.2, 9/11) which located at the lateral aspect of carpal joint then turned dorsally on the metacarpal bone.

The carpal joint was bounded caudolaterally by the ulnaris lateralis and flexor carpi ulnaris tendon (Fig. 3/12, 13, respectively), while covered palmary by the flexor carpi radialis tendon (Fig. 3/14). The carpal canal included the superficial digital flexor tendon, deep digital flexor tendon, median artery and nerve (Fig. 3/15, 16, 17, 18). The superficial digital flexor tendon was enveloped separately from deep digital flexor tendon by its own tendon sheath.

The carpal collateral ligament represented as the medial and lateral collateral ligament. The medial collateral ligaments were long and short one, the long collateral ligament (Fig. 5/19) was extended from the distal extremity of radius to the proximal extremity of metacarpal bone and divided into superficial and deep part, while the short one (Fig. 5/20) was passed from the radio carpal bone to the proximal extremity of metacarpus. The lateral collateral ligament was visualized on the lateral aspect of the joint under the ligaments of the accessory carpal bone and formed by the superficial and deep one (Fig. 5, 8/21, 21a). The former extended between the distal extremity of ulna and the ulnar carpal bone, the latter attached from the ulnar carpal bone to the proximal extremity of metacarpus.

There were four ligaments of the accessory carpal bone at lateral side; the accessory ulnar ligament (with distal extremity of ulna), the accessory carpoulnar ligament with ulnar carpal bone, the accessory ligament of the fourth carpal bone and the accessory metacarpal ligament with fourth metacarpal bone (Fig. 5, 8/22, 23, 24, 25, respectively). While at medio palmar aspect, it attached to intermediate carpal bone to form the accessory carpal ligament (Fig. 4,6 /26).

There were two radiocarpal ligaments (Fig. 6, 7, 8/27, 28, respectively); the first was short that extended from the medial aspect of the distal extremity of radius to the radio carpal bone. While palmary, the second one was long that attached to intermediate carpal bone.

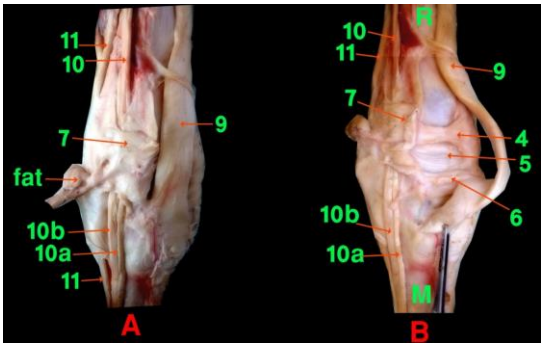

Fig. 2: Photograph showing the dorsal aspect of the camel's carpus.

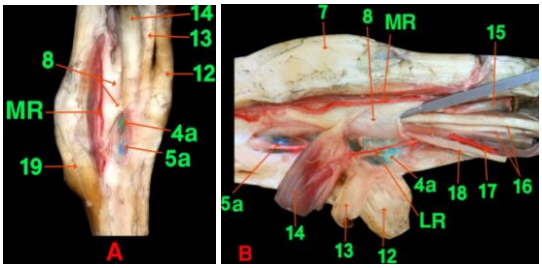

Fig. 3: Photograph showing the palmar surface of the camel's carpus.

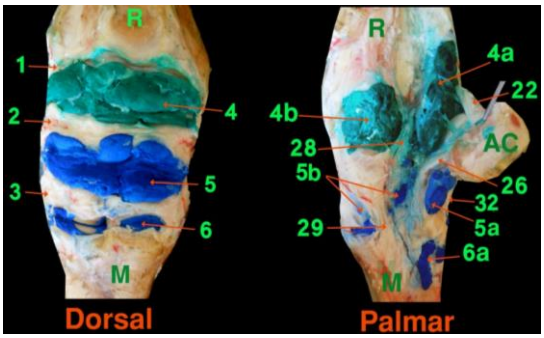

Fig. 4: Photograph showing the carpal synovial sacs in camel.

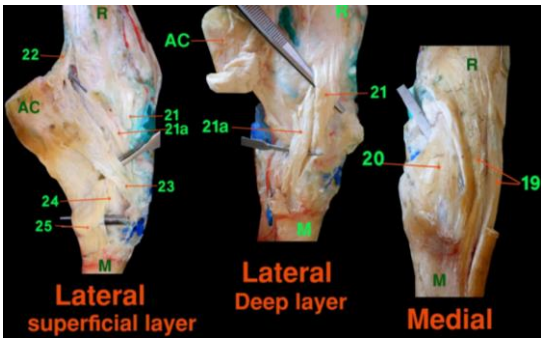

Fig. 5: Photograph showing the ligaments of camel's carpus.

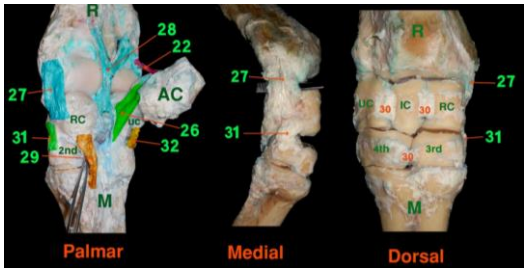

Fig. 6: Photograph showing the ligaments of camel's carpus.

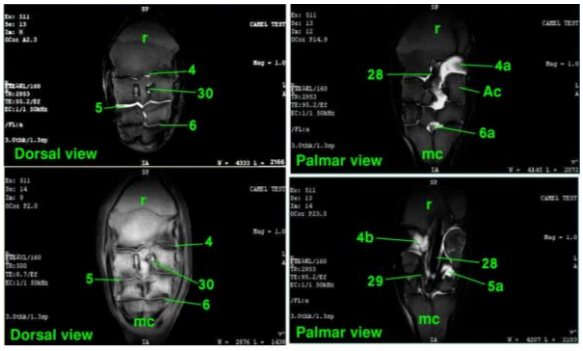

Fig. 7: Photograph showing the MRI of the camel's carpus (longitudinal plane).

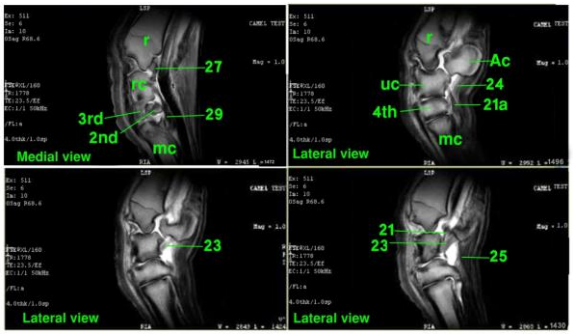

Fig. 8: Photograph showing the MRI of the camel's carpus (sagittal plane).

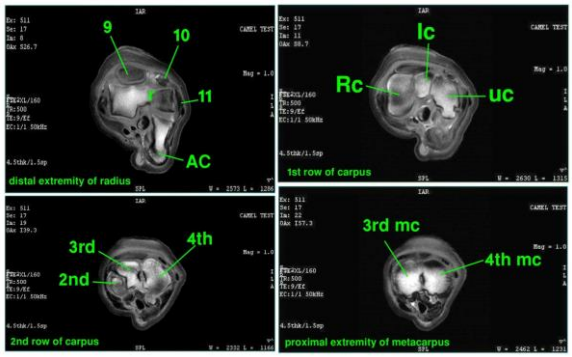

Fig. 9: Photograph showing the MRI of the camel's carpus (transverse plane).

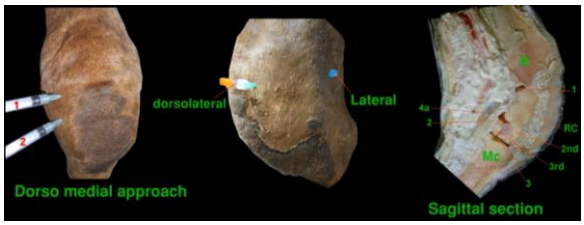

Fig. 10: Photograph showing the different site of intra articular injection in the camel's carpus.

Legand from Figures (2-10): R) Radius, M) Metacarpus, 1) Radiocarpal joint, 2) Intercapal joint, 3) Carpometacarpal joint, 4) Radiocarpal sac, 4a) lateral palmer pouch, 4b) palmro-medial pouch, 5) Intercarpal sac, 5a) Palmrolateral pouch, 5b) Palmromedial pouch, 6) carpometacarpal sac, 6a) palmarodistal pouch, 7) Extensor retinaculum, 8) Flexor retinaculum, 9) Tendon of extensor carpi radialis, 10)Common digital extensor tendon, 10a)

Medial part, 10b) Lateral part, 11) Lateral digital extensor tendon, 12) Ulnaris lateralis M., 13) Flexor carpi ulnaris tendon , 14) Flexor carpi radialis tendon, 15) Superficial digital flexor tendon, 16) Deep digital flexor tendon, 17)Median artery, 18) Median nerve, 19) long collateral ligament, 20) Short collateral ligament, 21) lateral collateral ligament (superficial part), 21a) lateral collateral ligament(deep part), 22) Accessory ulnar ligament, 23) Accessory carpoulnar ligament, 24) Accessory ligament of the fourth carpal bone, 25) Accessory metacarpal ligament 26) Accessory carpal ligament, 27) and 28) Radiocarpal ligament, 29) Carpometacarpal ligament, 30) Dorsal intercarpal ligaments, 31) Medial palmar intercarpal ligament, (32) Lateral palmar intercarpal ligament. MR) medial branch of radial artery, LR) lateral branch of radial artery.

The carpometacarpal ligament (Fig. 6, 7, 8/29) was a short palmar ligament coursed from the palmar aspect of the radio carpal bone to the proximal extremity of 3rd metacarpus.

The intraarticular ligaments of the carpus (intercarpal ligaments) can be grouped into dorsal and palmar ligaments. The dorsal intercarpal ligaments (Fig. 6, 7/30) were smaller and originated transversely between the radiocarpal and intermediate carpal, ulnar carpal bones, 2nd and 3rd and 4th carpal bones, while the palmar ligaments were stronger that included the medial and lateral one. The medial palmar intercarpal ligament (Fig. 6/31) extended from the radial carpal bone to the second carpal bone. The lateral palmar intercarpal ligament (Fig. 6/32) originated from the ulnar carpal bone and inserted on fourth carpal bones.

The palmar carpal ligament (Fig. 11/PCL) was a thick fibrous layer, formed the dorsal wall of the carpal canal. It originated proximally just above the distal third of caudal surface of the radius and inserted to the palmar aspect of the metacarpus.

The arterial blood supply of the carpal joint

The most arterial supply of the carpal joints in camel was derived from the radial artery in the form of dorsal and palmar carpal plexus that was located under the dorsal carpal and palmar carpal ligament which responsible for supplying the carpal joint, capsule, bones and ligaments.

The Radial artery

The Radial artery (Fig. 12/1) was the main artery responsible for supplying the carpal joint. It was the largest branch derived from median artery at the final third of caudal surface of the radius. It gave two large main branches at palmar surface; the first one, lateral branch, (Fig. 12, 3/2, LR) was lied at the lateral side under the ligament of deep digital flexor muscles, at the medial surface of accessory carpal bone and crossing the lateral palmar pouch. Other artery, the medial branch (Fig.3/MR) and (Fig. 12/3) was passed on the medial side crossing the sheath of superficial digital flexor tendon.

The lateral branch of the radial artery gave off several branches along its course: dorsal interosseous, dorsal and palmar carpal branches.

Dorsal interosseous artery (Fig. 11/4) derived from the lateral branch of the radial artery at caudo distal third of the radius then crossed to its dorsal surface through the distal interosseous space, between the ligaments of common digital extensor and extensor carpi radialis. It gave off some branches connected to the dorsal carpal arterial plexus.

The dorsal carpal plexsus arose formed the dorsal carpal branches which derived from the lateral branch and the medial branch of the radial artery.

Dorsal carpal branches

There were three dorsal carpal branches derived from the lateral branch of the radial artery; the proximal lateral dorsal branch (Fig. 11/5) passed under the accessory ulnar ligament to arrive dorsal surface supplying radio-carpal joint with small arterioles and anastomosed with the dorsal interosseous artery, the middle lateral dorsal branch (Fig. 11/6) arose below the level of the accessory carpal bone to supply the inter carpal joint and its capsule and the distal lateral dorsal artery (Fig. 11/7) was located at the proximal extremity of metacarpus to supply the carpo-metacarpal joint. These arteries joined together to form the dorsal carpal plexus.

The medial branch of the radial artery gave two dorsal carpal arteries that passed cranio-dorsally under the medial carpal collateral ligaments; the proximal medial dorsal branch (Fig. 11/8) supplied the radio-carpal joint and the distal medial dorsal artery (Fig. 11/9) supplied the carpo-metacarpal joint. Both branches gave small arterioles to the inter carpal joint and were joined to form the dorsal carpal plexus.

Palmar carpal branches

The lateral branch of the radial artery gave proximal, middle and distal palmar carpal branches; two large proximal palmar carpal arteries (Fig. 12/10) was parallel together on the palmar surface of the distal extremity of radius then descend ventrally to reach the palmar surface of carpus and divided into several smaller branches. Two middle palmar carpal artery; the first one (Fig. 12/11) located dorsal to the lateral palmar pouch and the second branch (Fig. 12/11a) lied beside the accessory carpal ligament. The distal palmar carpal artery (Fig. 12/12) was the smallest branch located at level of the carpometacarpal joint.

The medial branch of the radial artery gave three palmar carpal branches (Fig. 12/13) that passed within the palmar carpal ligament in the carpal canal and were joined to palmar carpal arterial plexus.

After the medial and lateral branch of the radial artery gave dorsal and palmar carpal arteries, each one continued distally below the level of carpus joint and divided into superficial and deep proximal palmar metacarpal artery. The superficial branches (Fig. 12/14, 15) connected to the median artery while the deep branches (Fig. 12/16, 17) passed between the suspensory ligament and the metacarpal bone to anastomose together forming deep palmar arch (subcarpal arch) (Fig. 12/18) that continues as palmar metacarpal artery (Fig. 12/19).

The deep proximal palmar metacarpal artery of the medial branch of radial artery gave a small branch (ascending palmar carpal branch) (Fig. 12/16a) directed upwards between the 3rd and 4th metacarpus to anastomose with palmar carpal branches to form palmar carpal plexuses.

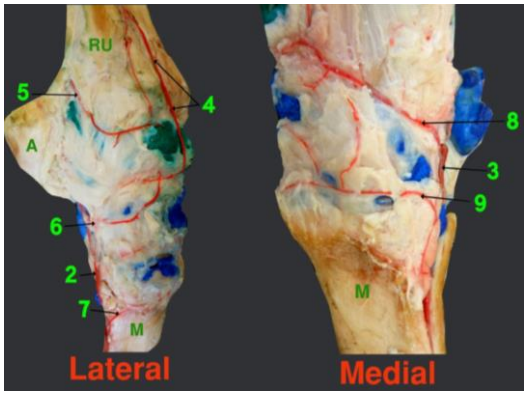

Fig. 11: Photograph showing the dorsal carpal arteries in the camel's carpus.

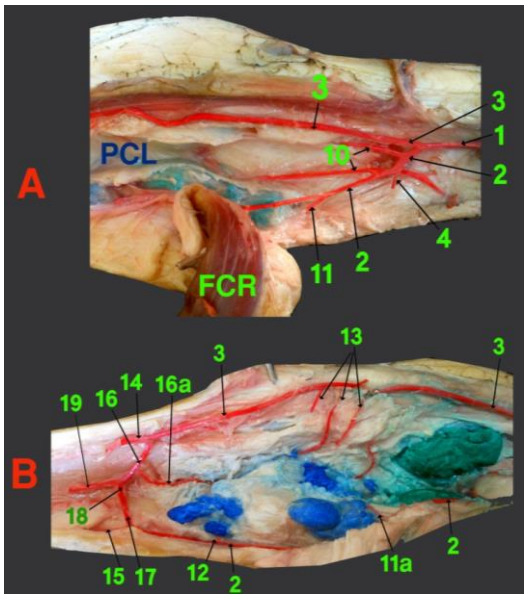

Fig. 12: Photograph showing the palmar carpal arteries in the camel's carpus.

Legand from Figures (11-12): PCL) Palmar carpal ligament, FCR) Flexor carpi radialis M., 1) Radial artery, 2) Lateral branch of radial A., 3) Medial branch of radial A., 4) Interosseous artery, 5) Proximal lateral dorsal branch, 6) Middle lateral dorsal branch, (7) Distal lateral dorsal branch, 8) Proximal medial dorsal branch, (9) Distal medial dorsal artery, 10) Proximal palmar carpal arteries, 11) the first middle palmar carpal artery 11a) the second middle palmar carpal artery 12) Distal palmar carpal artery, 13) Palmar carpal branches, 14) Superficial proximal palmar metacarpal artery of medial branch, 15) Superficial proximal palmar metacarpal artery of lateral branch, 16) Deep proximal palmar metacarpal artery of medial branch, 16a) small branch (ascending palmar carpal artery) 17) Deep proximal palmar metacarpal artery of lateral branch, 18) Deep palmar arch. 19) Palmar metacarpal artery.

DISCUSSION

The carpal joint of one humped camel was formed by the distal extremities of radius and ulna, 7 carpal bones (radial, intermediate, ulnar and accessory carpal bones in the proximal row, second, third and fourth carpal bones in the distal row) and the proximal extremity of the fused third and fourth metacarpal bones that statement in agreement with Kassab (2008), König *et al*. (2007), Getty (1975). while in equine the distal row formed of the first, second, third and fourth carpal bones (Alsafy *et al*. 2015, König *et al*. 2007), but in Friesian cattle, the distal raw consisted of the fused (second and third) and fourth carpal bones (Getty, 1975; König *et al*., 2007 and Al-akraa *et al*., 2015).

Regarding to our observation, the carpal joint composed of three articulations; the radiocarpal, intercarpal and carpometacarpal joint, each joint had its own inner synovial sacs. The radiocarpal sac was the largest sac and was separate, while the intercarpal sac was limited and communicated with carpometacarpal sac. This result was similar to Badawy and Eshra (2016) in dromedary camel, Alsafy *et al*. (2015), Butler *et al*. (2011) and Dyce *et al*. (2010) in equine.

In line with Badawy and Eshra (2016) in dromedary camel, Alsafy *et al*. (2015) and König *et al*. (2007) in equine, the carpal joint was covered dorsally by the extensor carpi radialis, common digital extensor and the lateral digital extensor. It was bounded caudolaterally by the ulnaris lateralis and flexor carpi ulnaris tendon, while palmary by the flexor carpi radialis tendon, these similar to that described by Badawy and Eshra (2016) and Alsobayil *et al*. (2015).

The carpal collateral ligament represented as the medial and lateral collateral ligament, that result was similar to Al-akraa *et al*. (2015) in Frisian cattle, Gray *et al*. (2013) in equine, Kassab (2008) in camel. The lateral collateral ligament was visualized on the lateral aspect of the joint under the ligaments of the accessory carpal bone while Al-akraa *et al*. (2015) in cattle mentioned that ligament located caudomedial to lateral digital extensor tendon. The lateral collateral ligament was divided into superficial and deep part. While Sisson and Grossman (1953) in cattle revealed that it was divided into short and long one. In our result, the deep part was similar to the long one in cattle that attached from the ulnar carpal bone to the proximal extremity of metacarpus. Moreover, the superficial ligament and short one had different insertion. The superficial ligament extended to the ulnar carpal bone but the short one in cattle was inserted in the accessory carpal bone.

The medial collateral ligaments were long and short one, the long collateral ligament was extended from the radius to the metacarpal bone that agreement with König *et al*., (2007) in horse. Moreover, our result observed that the short medial collateral ligament was extended from the radio carpal bone to the proximal extremity of metacarpus but (König *et al*., 2007) in equine it was divided into part the proximal and distal one, the former one extended from the distal extremity of radius to the radio carpal bone and the latter extended from the second carpal bone to the proximal of metacarpus.

There were four ligaments of the accessory carpal bone; the accessory ulnar ligament, accessory carpoulnar ligament, accessory ligament of the fourth carpal bone and the accessory metacarpal ligament, in addition to two radiocarpal ligaments and the carpometacarpal ligament that in the line with (König *et al.*, 2007) in equine and (Getty, 1975) in cattle.

According to (Gray *et al.*, 2013 and Dyce *et al.*, 2010), the intercarpal ligaments were grouped into dorsal and palmar ligaments. The dorsal intercarpal ligaments

were originated transversely but (König et al., 2007) in equine showed another three oblique ligaments crossed from the second row of carpal bones and the proximal extremity of metacarpal bones while Sisson and Grossman (1953) in cattle reported the present of two oblique ligaments; the first one attached between the distal extremity of radius and the ulnar carpal bone and the second ligament extended from the radiocarpal bone and the fourth carpal bone.

The present investigation was in agreement with Sajjadian *et al.,* 2015 in dromedary camel and Jian-Lin *et al.,* (2000) in Bactrian camel. The arterial supply of the carpal joint originated from the radial artery. While (Dyce *et al.,* 2010, Budras *et al.*, 2009, Zheng Ming Xie 1987, Nickel *et al.*, 1981, Getty, 1975) mentioned that the carpal joint in the ox was supplied by the dorsal interosseous, median, collateral ulnar and radial arteries. Moreover, in horse it supplied by the common interosseous, median, transverse cubital and radial arteries.

The radial artery gave two large main branches at palmar surface; lateral and medial branch that agreed with Jian-Lin *et al*., (2000), but Sajjadian *et al.,* 2015 reported that, the radial artery gave thick palmar branch at lateral side and its direct continuation was at medial side. While (Dyce *et al.,* 2010, Nickel *et al*., 1981 and Getty, 1975) in horse recorded that it joined with the lateral palmar artery at the palmar surface of the metacarpus forming the proximal deep palmar arch.

Our study agreed with Jian-Lin *et al.,* (2000) who mentioned that, the dorsal interosseous artery arose from the lateral branch of the radial artery, while Nickel et al., 1981 and Getty, 1975 reported t in cow, it was considered as one branch derived from the cranial interosseous artery.

The dorsal and palmar carpal plexus was derived from radial artery and located under the dorsal and palmar carpal ligament which responsible for supplying the carpal joint. That result was similar to Sajjadian *et al.,* 2015 and Jian-Lin *et al.,* (2000).

Conclusion

The current study will help the surgeons for deciding the suitable methods for treatment or diagnosis of carpitis. Based on our results, there were three possible approaches for intra articular injection of carpal joint in camel; the dorso-medial, dorso-lateral and the lateral approaches. The dorso-medial one was the most accurate site and easily applied due to the tendon of the extensor carpi radialis was easily palpated and assisted identification of the site of needle insertion so it considered as a guide marks for the dorsomedial approaches.

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