DR. TIMOTHY AKINBOWALE OLUSA (Orcid ID : 0000-0001-9853-4788)

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Title: MORPHOMETRIC ANALYSIS OF THE INTERCARPAL LIGAMENTS OF THE EQUINE PROXIMAL CARPAL BONES DURING SIMULATED FLEXION AND EXTENSION OF CADAVER LIMBS

Running head: MORPHOMETRY OF INTERCARPAL LIGAMENTS IN HORSES

Authors: Timothy, A.O. Olusa[1]*; Akbar, Z[1]; Christina, M. Murray[1] & Helen, M.S. Davies[1]

Institution affiliations: [1]Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Werribee VIC 3030, Australia

*Corresponding author: Timothy A.O. Olusa,
Faculty of Veterinary and Agricultural Sciences,
University of Melbourne, Werribee VIC 3030, Australia
E-mail: olusat@unimelb.edu.au
timolusa1@gmail.com

ABSTRACT

Despite many reported cases of carpal lameness associated with intercarpal ligament injuries in horses, the morphometry, movement pattern and general intrinsic biomechanics of the carpus are largely unknown. Using osteo-ligamentous preparation of the carpus prepared from 14 equine cadaver forelimbs (aged 9.62±4.25 years), locomotory simulations of flexion and extension movements of the carpal joint were carried out to observed carpal biomechanics and thereafter, the limbs were further dissected to obtain morphometric measurements of the medial and lateral collateral ligaments (MLC and LCL); medial and lateral palmar intercarpal ligaments (MPICL and LPICL); intercarpal ligaments between radial (Cr) and intermediate (Ci) carpal bones (Cr-Ci ICL); and intercarpal ligaments between Ci and ulnar (Cu) carpal bones (Ci-Cu ICL).

The Cr, Ci, Cu and Ca are held together by a series of intercarpal ligaments and move in unison lateropalmarly during flexion, and mediodorsally during extension with a distinguishable proximo-distal sliding movement (gliding) of Cr and Ci against each other during movement. The mean length of MCL (108.82±9.64) was significantly longer ($p = 0.042$) than LCL (104.43±7.65). The Cr-Ci ICL has a dorsopalmar depth of 37.58±4.14 mm and a midpoint width of 12.05±3.09 mm and its fibers ran diagonally from the medial side of the Ci in a proximo-palmar disto-dorsal direction (i.e. palmarodistally) to the lateral side of the Cr.

The specialized movement of the Cr-Ci ICL which appeared to be further facilitated by a longer MCL suggest a biomechanical function by which carpal damage may be minimized in the equine carpus.

Keywords: Morphology, Locomotory simulation, Carpal joint, intercarpal ligaments, Equine carpus, Horses.

INTRODUCTION

Generally, joints can be classified based on their structure and function. The structural classification focuses on the nature of the material binding the bones together and whether a joint cavity is present or not, while the functional classification is based on the type and amount of movement allowed at the joint (Getty, 1975a). The equine carpal joint is structurally a synovial joint and functionally a composite joint, consisting of both freely movable (diarthrotic) joints such as the antebrachiocarpal and middle intercarpal joints; slightly movable (amphiarthrotic) joints such as the carpometacarpal joint and the many intercarpal joints between adjacent carpal bones; and non-movable (synarthrotic) joints such as the fused joints between the proximal ends of the second (MC2), third (MC3) and fourth (MC4) metacarpal bones (Getty, 1975a; Sisson, 1975).

The unique functional anatomy of the equine carpus is believed to help in reducing friction within the carpus and thus circumvent the destructive bone to bone impact that would occur if the joint was a simple two-bone articulation (Bramlage *et al.,* 1988; Deane & Davies, 1995). The carpus consists of the distal end of the radius, seven major or consistent carpal bones arranged in two (proximal and distal) rows and the proximal ends of the second, third, and fourth metacarpal bones (Getty 1975b; Sisson, 1975). The topographical anatomy of the articular surfaces of these bones are similar in that they are inversely reciprocal in a concavo-convex manner (i.e. having both curved/rounded concave and convex segments) to smoothly align and slides into congruity as the joints flexes and extends/loads during locomotion (Getty, 1975b; Sisson, 1975; Kainer, 2002). These multiple bones with their planar joint surfaces thus increase the total articular surface area, more volume for synovial fluid "acting as lubricant" to the joints and thus allow a degree of shock attenuation (Auer, 1980; von Boening, 1981; Bramlage *et al.,* 1988; Deane & Davies, 1995).

Besides the morphology of the carpal bones, the functions of the equine carpal joints are also largely dependent on the several intercarpal ligaments that provide both stability and elasticity to the equine carpus (Getty, 1975b; Sisson, 1975; Dyce *et al.,* 2002). The bones of the proximal carpal row: radial (Cr), intermediate (Ci), ulnar (Cu) and accessory (Ca) carpal bones are held together by a series of intercarpal ligaments which enable the synergy of movements observed at the antebrachiocarpal and the middle carpal joints during flexion and extension of the carpus. These intrinsic movements of the carpal bones are fundamental to the effective functioning of the carpal joint. It is believed that the amount of movement that will be allowed within a joint, and the directions of its constituent bones' displacements during movements depends on the length, elasticity, and orientations of the connecting fibers (Sledge, 1993). It has been observed that the bones of the proximal carpal row are subjected to more displacement than the distal row of carpal bones during locomotion (Bramlage *et al.,* 1988) and a greater incidence of carpal damage has been reported in the middle carpal joint (Park *et al.,* 1970; Thrall *et al.,* 1971; Palmer, 1986; Schneider *et al.,* 1988; Stephens *et al.,* 1988; Bramlage *et al.,* 1988; Young *et al.,* 1991; Palmer *et al.,* 1994). Therefore, measuring the gross length, width and depth of the intercarpal ligaments of the proximal row of carpal bones, observing the orientation of their fibers and observing the direction of movement of the carpal bones during simulation of flexion and extension of the carpus in cadaveric limbs will increase our understanding of normal carpal function and the pathogenesis of carpal damage in horses.

The aims of this study were: i) to provide gross morphometric data for the intercarpal ligaments of the proximal row of carpal bones; ii) to observe the fiber orientations of these ligaments during simulation of flexion and extension of ligamentous preparations of the equine carpal joint and iii) to monitor the changes in the positional direction of movement of the radial and intermediate carpal bones (Cr and Ci) during simulation of carpal motion.

MATERIAL AND METHODS

Animal specimens: 14 equine cadaver forelimbs (11 limbs from 6 Thoroughbred horses and 3 limbs from 2 Standardbred horses) were collected from both the post-mortem room of Faculty of Veterinary and Agricultural Sciences, University of Melbourne and a local knackery in Melbourne (horses aged 9.62±4.25 years). The horses had either died or were euthanized for reasons not associated with this study. The limbs were transected at the antebrachial midshaft (about 12-15 cm proximal to antebrachiocarpal joint) and stored at -20°C (wrapped in plastic bags) until required. The carpi appeared to be healthy with no history or radiological signs of carpal damage (as each limb was radiographed at both standing and flexed dorsopalmar and lateromedial views/positions to rule out carpal damage).

Ethical animal research: Approval from the University of Melbourne Animal Ethics Committee was not required as specimen were collected from animals that had either died or were euthanized for reasons not related to the study.

Osteo-ligamentous preparation of the limb: The skin, fascia, extensor retinaculum, all muscle group along with their tendons and carpal sheath were all carefully dissected away from the deeper and closely adhered dorsal and palmar carpal ligaments to expose the bones and the ligaments directly associated with the articulations of the carpal joint. Morphometric measurements of the intercarpal ligaments of the proximal row of carpal bones were made and simulation of flexion and extension of the carpus was carried out, using an osteo-ligamentous preparation of the carpus for each of the 14 limbs.

Loading Press/Rig: A commercial press (TTi 20,000kg Hydraulic floor press, Total Tools, Derrimut, VIC 3030, Australia) fixed with a custom-built radial cup and metal platform was used for holding the proximal end of the specimen limb for simulation of flexion and extension motions in this study.

Measurement protocol

i. ***Simulation of flexion and extension of the carpus:*** the dissected preparation of each equine carpal joint was fixed at the antebrachial midshaft to the radial cup on the loading rig using 8 screws that penetrated through the cup and onto the bone (Figure 1). 3 screws each were on both the dorsal and palmar surfaces, while the medial and lateral sides were each held with 1 screw. The carpus was then flexed as much as possible (to a palmar angle of about 85° - 90°) and held in that position using a rope tied to the pastern region of the limb and passed over the crossbar of the rig and handheld (Figure 1b). The free end of the rope (in the hand-held position) was gradually released so that a controlled fall due to gravity brought the carpus into an extended position (with dorsal carpal angle of about 165° - 150°). Photographs were taken at different stages of the controlled fall and the direction of movement of the carpal bones was traced/monitored from the serial photographs. A reverse pulling of the rope from a fully extended carpus produced similar carpal bones' movement within the joint.

ii. ***Gross morphometry of intercarpal ligaments of the proximal carpal row:*** The length, width, and thickness of the intercarpal ligaments were measured using a digital Vernier caliper with depth gauge. Further dissections were carried out as necessary to measure the depth of the ligaments and to observe fiber orientations. Attempts were made where feasible to measure the width of each ligament at three locations viz: at the origin, at mid length and at its insertion. The following ligaments were measured:

a) Collateral ligaments (medial and lateral): the length of the medial collateral ligament (MCL) was measured from its origin on the distal radial physis to its insertion on the MC2 and MC3 while its width at the insertion and origin were also measured. Width at the middle was measured at the level of its attachment to the Cr. The MCL was incised at its origin and sharply dissected away from all its attachments to the distal radius and Cr and the thickness of MCL was measured at its region of freed attachment to the Cr (Figure 2). Using its own respective landmarks, the lateral collateral ligament (LCL) was measured in the same way as described for the MCL. The superficial and deep layers of both collateral ligaments were measured together as a single entity.

b) Medial palmar intercarpal ligament (MPICL): the length of the MPICL was measured from its most proximal attachment on the proximal carpal row to its most distal insertion on the distal carpal row while the antebrachiocarpal joint was held in maximal extension (Figure 3a). The mediolateral width and dorsopalmar thickness were measured on the stump of the ligament after it was severed in the middle from its proximal and distal attachments (Figure 3b).

c) Lateral palmar intercarpal ligament (LPICL): using its own respective landmarks, the LPICL was measured in the same way as described for the MPICL.

d) Dorsal intercarpal ligament band between Cr, Ci and Cu (Cr-Ci-Cu DICL): detailed dissection revealed that the intercarpal ligament that connects the dorsal surfaces of the proximal carpal row bones ran across the dorsal surfaces of these bones from the MCL to the LCL. This ligament was measured from its most medial attachment to the MCL to its most lateral attachment to the LCL (Figure 4). Its proximo-distal width was measured at 2 locations (the Cr-Ci and Ci-Cu articulations).

e) Intercarpal ligaments between Cr and Ci (Cr-Ci ICL): although the Cr-Ci ICL courses distopalmarly, there was no distinct gross morphological difference between the fibers of Cr-Ci-Cu DICL and Cr-Ci ICL at their juncture but an apparent continuation of one into another (Figure 5a). Thus, the depth of Cr-Ci ICL was measured distopalmarly from its most dorsal border on the Cr-Ci-Cu DICL to its most palmar end (Figure 5b). The width was measured at 3 locations (dorsal, midpoint and palmar) on the medial aspect of Ci. The dorsal width was measured at its most dorsal surface on the DICL while its midpoint width was measured at the level of the middle of the Cr-Ci groove on the Ci. The palmar width was measured at its palmar region at its most caudal attachment to the Ci (Figure 5b). The length of Cr-Ci ICL could not be measured directly because it was inaccessible to a caliper. It was however measured indirectly as previously described (Olusa, 2018; Olusa et al., 2019), by using radiography to assess the groove width/diameter of the Cr-Ci intercarpal ligament (GD.Cr-Ci ICL).

f) Intercarpal ligaments between Ci and Cu (Ci-Cu ICL): this was measured using a similar procedure/protocol used to measure the thickness (depth) and widths of Cr-Ci ICL.

Statistical analysis: All ligament morphometric measurements were expressed in simple descriptive statistics and presented as Mean ± SD (Standard deviation). A paired Student t-test was used to compare the length between the MCL and LCL. A 95% confidence interval was used and values where $P < 0.05$ were considered significant.

RESULTS

Simulation of flexion and extension of the carpal joint

A consistent pattern of movement of the bones of the proximal carpal row was observed in all the 14 limbs that were studied. As the limbs were being flexed, signified by the opening of the radiocarpal and middle carpal joints, the bones of the proximal carpal row (Cr, Ci and Cu) moved laterally and palmarly (lateropalmarly) in relative to the distal carpal row. A reversed mediodorsal directional displacement of Cr, Ci and Cu was observed during extension.

This movement was clearly observable by the displacement of the Cr and Ci in relation to the sagittal ridge of C3 and C4 respectively (Figure 6a-e). A proximo-distal sliding movement (gliding) of Cr and Ci against each other was also observed as the carpus was flexed and extended (Figure 6c-e). This gliding movement was further explored when the proximal carpal row (Cr-Ci-Cu) was dissected out from the entire carpal joint and independently flexed and extended. The distal view of the proximal carpal row revealed 3 distinct bundles of the Cr-Ci ICL located from the middle to palmar regions of Cr and Ci (Figure 7). The intercarpal ligament between Cr-Ci (Cr-Ci ICL) connected these two carpal bones (Cr and Ci) to form a gliding joint. Considerable gliding movement of up to 10 mm was observed between Cr and Ci during flexion and extension. No apparent gliding movement was noticed between the Ci and Cu suggesting that the intercarpal ligaments between them were shorter and more firmly held.

Intercarpal ligaments of the proximal carpal row

Gross morphometric data of the measured intercarpal ligaments are presented in table 1. The superficial and deep layers of the medial collateral ligaments (MCL) and lateral collateral ligaments (LCL) respectively provided a medial and lateral boundary that limited carpal joint movement to a single plane of flexion and extension. The length of the MCL (108.82±9.64) was significantly longer ($p = 0.042$) than that of the LCL (104.43±7.65) (Table 2). The orientations of the fibers of the collateral ligaments were diagonally interwoven in a crisscross manner cranio-proximally to caudo-distally.

The dorsal intercarpal ligament (DICL) coursed from its attachment on the MCL to the LCL while attaching with its deeper surface to the Cr, Ci and Cu. The intercarpal ligament between Cr and Ci (Cr-Ci ICL) coursed dorsopalmarly. At its dorsal border, the Cr-Ci ICL appeared as an attachment to or a continuation with the DICL, while at its palmar border it attached distally to the MPICL (Figure 8). The fibres ran diagonally between Cr and Ci from the medial side of the Ci in a proximo-palmar disto-dorsal direction (i.e. palmarodistally) to the lateral side of the Cr. Although it was difficult to exactly ascertain its origin and insertion, the Cr-Ci ICL appeared to have originated from Ci and insert onto Cr. The fibre orientation of the intercarpal ligament between Ci and Cu (Ci-Cu ICL) appeared similar to that of the Cr-Ci ICL but the fibers were shorter and more firmly held together.

DISCUSSION

The structural framework for the stability of the equine carpus are its cuboidal shaped carpal bones. This study showed that the pattern of movement of the carpal bones on the proximal carpal row during flexion and extension are fundamental to the functional mechanism of the carpus and may help to understand the pathogenesis of injury of the carpal joint in the horse. The larger convex medial facet of the articular surface of the distal radius articulates with the concave proximal articular surface of Cr while the smaller convex lateral facet of distal radius articulates with the concave surfaces of the Ci and Cu, and at the same time, the concave distal articular surfaces of the Cr, Ci and Cu articulate with the convex rounded surfaces of the C2, C3 and C4 respectively. This unique morphology and alignment permit a simultaneous palmarodorsal and lateromedial sliding of the proximal row of carpal bones over the articular surfaces of the radius and the distal row of carpal bones as the carpus is loaded during full extension into the close-packed position for weight bearing. However, despite the corresponding curved and concave articular surfaces of the distal radius and the carpal bones arranged in two rows, movement within the carpus would still have been restricted or limited to a single vertical plane without the observed gliding joint between the Cr and Ci created by Cr-Ci ICL. The length of the Cr-Ci ICL provides elasticity for this joint and support for these bones during flexion and extension that enables the joint to permit gliding movement between Cr and Ci. The Cr-Ci intercarpal joint appeared to have initiated and facilitate the complex unison movement pattern observed within the carpus because by its motion, this gliding joint centrally "open up" the entire carpus, and facilitated the transverse movement of each carpal bone on the proximal carpal row that ultimately enables the smooth articular surfaces of the distal radius and other carpal bones to slide, flex and load appropriately. The Cr-Ci intercarpal joint in conjunction with the curved/rounded caudal portions of the articular surfaces of the carpal bones thus appeared to provide for a true rolling or pitch rotation of Cr relative to that of Ci/Cu during flexion and extension of the carpus.

The above observation could provide some explanation or confirm previous reports of congruity and sliding into close packed position during weight bearing (Bramlage *et al.,* 1998; Stashak & Hill, 2002). Although the carpus consists of 2 rows of carpal bones, it was the additional gliding joint, located between Cr and Ci which was shown to provide a central gliding carpal movement, that enabled the carpus to effectively slide into the "close-packed locked up position" during loading. Furthermore, the MCL was apparently drawn laterally through its medial attachment to the Cr during carpal joint flexion. A longer and less constrained MCL (in relative to LCL) would readily permit increased transverse movement of the Cr as it was observed in this study. This provides some explanation to the earlier observation by Bramlage *et al.,* (1988), that the Cr is one of the most mobile bones within the carpal joint. Although the results of the current study cannot unequivocally permit conclusions to be made about all the functions of this central gliding joint within the carpus, it is reasonable to suggest that this mechanism would ensure resistance to compressional load and redistribution of impacting forces. This is because a 2-row carpal joint without this central gliding joint would be less effective, unable to withstand the strain of compressional loading and prevent force redistribution within the carpus for two reasons. Firstly, in such a loading conformation without transverse movement, the articular surfaces of the carpal bones would have been evenly flattened. Such a morphology would reduce the loading surface area that has otherwise been increased by the angulation/curvature of the carpal bone surfaces. These angulations facilitate wedging of the carpal bones and thus the congruity that provides limits to excessive extension and thus greater stability. Secondly, the entire compressional loads would have been borne vertically along the long axes of these bones without the option of sliding which decreased the rate of strain on the articular surfaces. The impacting forces are spread out and attenuated because of these transverse movements. Such high impacting forces would produce increased strain on the carpal bones and thus more frequent damage to the carpal joint in a non-angular, non-sliding carpal conformation.

The major ligament at the centre of the "gliding carpal joint" within the equine carpus was termed the "radio-intermediate carpal bone intercarpal ligament (Cr-Ci ICL)". With the fiber bundles oriented palmarodistally from Ci to Cr and a dorsopalmar depth of 37.58±4.14mm, this ligament provided a tough yet elastic articulation for the joint that permitted a proximo-distal sliding pattern of movement. The incidence of injury to the Cr-Ci ICL is not known. This is either because natural damage to Cr-Ci ICL does occur but is difficult to diagnose and thus has not been reported, or because damage to Cr-Ci ICL does not occur in horses. It appears that the carpus would completely lose its function if this ligament were to be completely transected. This was observed during dissection when the ligament was severed; the carpus completely lost its functional integrity despite intact collateral ligaments (MCL and LCL), palmar carpal ligaments and palmar intercarpal ligaments (MPICL and LPICL). The proximal carpal row was out of alignment and could no longer slide into position during simulation of flexion and extension of the carpal joint.

The mechanism of carpal damage would not be unrelated to uneven carpal loading and carpal hyperextension during repetitive high-speed exercise (Palmer *et al.,* 1994; Bramlage *et al.,* 1998; Burn *et al.,* 2006; Olusa *et al.,* 2019). During loading, axial compression of the dorsal articular surface of the carpus would occur as the proximal row of carpal bones slides into position across relatively congruent articular surfaces of the Cr and C3 (Bramlage *et al.,* 1998; Olusa *et al.,* 2019). This sliding movement under maximum compressive load will exerts more pressure on the dorsal articular surfaces of Cr and C3 (Colahan *et al.,*1987; Bramlage *et al.,* 1998; Olusa *et al.,* 2019). These movements under such high loading tension create shear forces on the articular surfaces that likely contribute to osteochondral fractures along the dorsal margins of the carpal bones during hyperextension of the carpus (Colahan *et al.,*1987; Clayton *et al.,* 2013). The forelimb carries over 60% of the weight of the horse and the centre of gravity is in between the forelimb (Clayton *et al.,* 2013), so during high-speed exercise, a relatively higher compressive load is placed on the Cr than the Ci and Cu, which then get transferred to C3. This would account for a higher incidence of injury to the middle carpal joint.

In standard veterinary texts and literature, very little information has been provided about the carpal ligaments. Detailed anatomical studies of the equine carpal ligaments are only occasionally reported (Philips & Wright, 1994; Whitton *et al.,* 1997). The findings of the current study on the anatomy and morphometry of the MPICL and LPICL are similar to previous studies (Philips & Wright, 1994; Whitton *et al.,* 1997). Two separate fiber bundles of the MPICL (Philips & Wright, 1994) were more consistently observed in this study while a few specimens with a larger dorsopalmar width might have possessed 4 bundles (Whitton *et al.,* 1997). Although the significance of the numbers of fiber bundles and the width of the

PICL cannot be fully ascertained yet, these features are likely to contribute to their overall elasticity and restraint of dorsal displacement of the proximal carpal row as earlier suggested (Whitton & Rose, 1997).

The morphometric data on some carpal ligaments provided by this study could be useful to help assess the mechanical properties of these ligaments. This may also be of some generalized future value while planning for surgical repair of ligament rupture. Furthermore, this information would be of particular interest for 3-D modeling of the equine carpus and validation of finite element analysis (FEA) of such a model. 3-D models of the carpus may provide a useful complementary method to study the complex functional mechanism and pathogenesis of carpal damage in horses.

In conclusion, the directional movement of the carpal bones (especially the Cr, Ci and Cu) as enabled by the intercarpal ligaments and the topographical anatomy of the articular surfaces of the carpal bones during cyclic repetitive flexion and extension (loading) of the carpus, similar to that which occurs during locomotion, has now been described. These directional movements corresponded to the fibre orientations of the respective supporting intercarpal ligaments between the carpal bones. The palmarodistal fibre orientation of the Cr-Ci ICL allows this ligament to facilitate a central proximo-distal sliding movement within the carpus which enables transverse movement of carpal bones. Although further studies to investigate the actual elastic and other biomechanical properties of the Cr-Ci ICL and other ligaments of the carpal proximal row would be beneficial, these current observations will improve our understanding of the normal carpal functions and the pathogenesis of carpal damage.

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CONFLICT OF INTEREST

No conflict of interest is declared for this work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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Table 1: Morphometric measurements (mean dimensions) of the intercarpal ligaments of the proximal carpal row in 14 equine cadaveric limbs

S/no	Parameters (mm)		Mean ± SD (mm)
1	**Medial collateral ligament (MCL)**	Length (proximo-distal)	108.82±9.64
		Depth (mediolateral)	6.95±1.85
		Width at origin (distopalmar)	30.49±5.26
		Width at midpoint (distopalmar)	35.08±6.78
		Width at insertion (distopalmar)	34.01±5.65
2	**Lateral collateral ligament (LCL)**	Length	104.43±7.65
		Depth	5.39±1.276
		Width at origin	30.04±3.74
		Width at midpoint	25.68±4.14
		Width at insertion	26.78±7.28
3	**Medial palmar intercarpal ligament (MPICL)**	Length	14.90±2.60
		Width at midpoint	15.08±4.78
		Depth	4.82±1.21
4	**Lateral palmar Intercarpal ligament (LPICL)**	Length	13.46±3.38
		Width at midpoint	13.55±3.46
		Depth	4.78±1.69
5	**Dorsal intercarpal ligament btw Cr, Ci & Cu (Cr-Ci-Cu DICL)**	Length	88.51±9.19
		Width @ Cr-Ci	14.45±2.16
		Width @ Ci-Cu	15.41±3.17
6	**Intercarpal ligaments btw Cr and Ci (Cr-Ci ICL)**	Depth	37.58±4.14
		Width at Dorsal	14.43±2.04
		Width at Midpoint	12.05±3.09
		Width at Palmar	15.67±3.04
7	**Intercarpal ligaments btw Ci and Cu (Ci-Cu ICL)**	Depth	29.81±4.65
		Width at Dorsal	15.45±3.04
		Width at Midpoint	11.19±2.27
		Width at Palmar	15.73±3.80

Table 2: Comparison of length between the Medial collateral ligament (MCL) and the Lateral collateral ligament (LCL)

Length of collateral ligament	Mean±SD (mm)	Paired differences (t-test)		
			95% CI of the difference	Sig

		Mean Diff. ±SD	lower	upper	(p<0.05)
Medial collateral ligament (MCL)	108.82±9.64	4.40±7.31	0.17	8.62	0.042
Lateral collateral ligament (LCL)	104.43±7.65				

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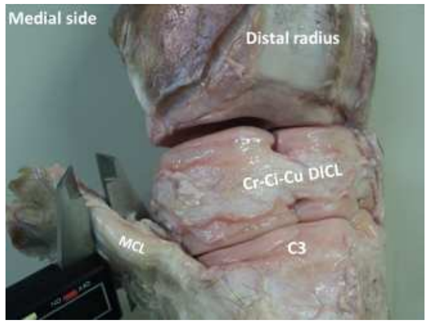

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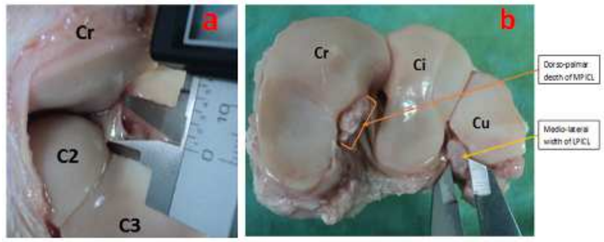

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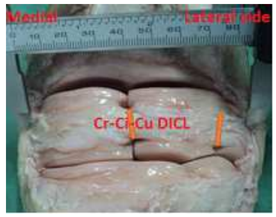

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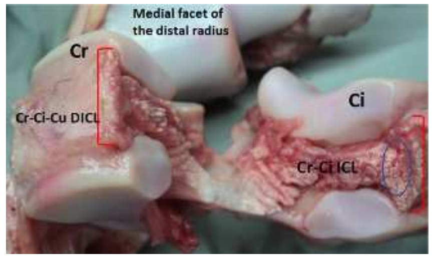

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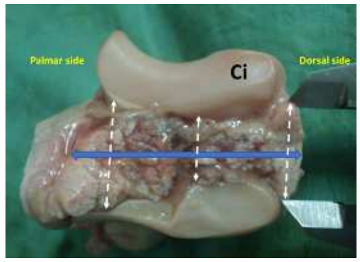

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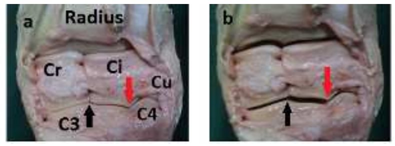

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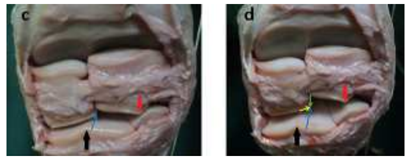

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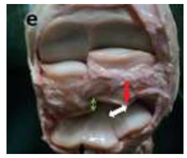

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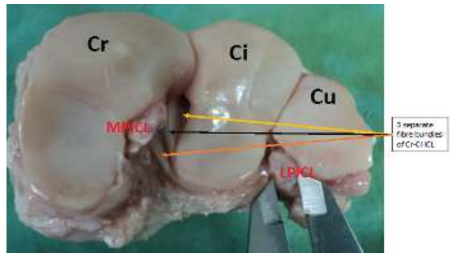

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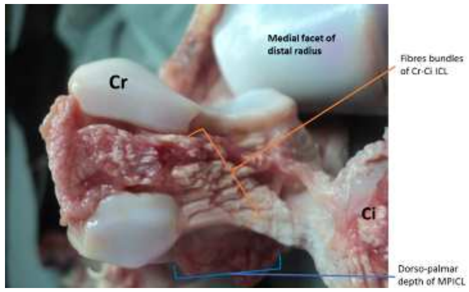

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