

**UNIVERSIDADE FEDERAL DE SANTA MARIA  
CENTRO DE CIÊNCIAS RURAIS  
PROGRAMA DE PÓS-GRADUAÇÃO EM MEDICINA VETERINÁRIA**

**ASSOCIAÇÃO DE ACHADOS  
ULTRASSONOGRÁFICOS E  
ANATOMOPATOLÓGICOS DE LESÕES DA  
ARTICULAÇÃO METACARPOFALANGEANA  
EQUINA**

**DISSERTAÇÃO DE MESTRADO**

**Grasiela de Bastiani**

**Santa Maria, RS, Brasil  
2014**

**ASSOCIAÇÃO DE ACHADOS ULTRASSONOGRÁFICOS E  
ANATOMOPATOLÓGICOS DE LESÕES DA ARTICULAÇÃO  
METACARPOFALANGEANA EQUINA**

Por

**Grasiela de Bastiani**

Dissertação apresentada ao Curso de Mestrado do Programa de Pós-Graduação em Medicina Veterinária, Área de Concentração em Cirurgia e Clínica Médica, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para obtenção do grau de **Mestre em Medicina Veterinária**

**Orientador: Prof. Flávio Desessards de La Côte**

Santa Maria, RS, Brasil  
2014

## **Ficha Catalográfica**

**Universidade Federal de Santa Maria  
Centro de Ciências Rurais  
Programa de Pós-Graduação em Medicina Veterinária**

**A Comissão Examinadora, abaixo assinada, aprova a Dissertação de  
Mestrado**

**ASSOCIAÇÃO DE ACHADOS ULTRASSONOGRÁFICOS E  
ANATOMOPATOLÓGICOS DE LESÕES DA ARTICULAÇÃO  
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elaborada por  
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como requisito parcial para obtenção do grau de  
**Mestre em Medicina Veterinária**

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Santa Maria, 29 de janeiro de 2014

## **AGRADECIMENTOS**

Com todo o meu amor e carinho a minha família que embarcou neste projeto junto comigo. Pelo apoio e ajuda sem medir esforços, pelas palavras de consolo e incentivo nos momentos de dúvidas em que, muitas vezes costumamos a crer que uma simples ideia poderá dar origem à inúmeras ideias e a várias respostas. São eles nossos pais que incondicionalmente se tornam nossos maiores incentivadores.

Ao meu namorado Anibal pela paciência.

Ao meu orientador Flavio de La Côte o meu obrigado não somente por ter acreditado na ideia e ter feito inúmeros esforços para que a mesma virasse realidade, mas sim pela amizade, pelo sentimento de acolhida e generosidade dedicado a cada um de seus orientados.

As professoras Karin Brass e Mara Battistela Rubin por todo o apoio.

Ao Laboratório de Patologia Veterinária em especial a Professora Glaucia Kommers e sua equipe que com trabalho e dedicação exemplares tornaram este projeto real. A Professora Glaucia Kommers meu muito obrigado serei uma eterna admiradora do teu trabalho.

A família Shafer que me recebeu em Santa Maria de braços abertos, a sua acolhida, amizade, a sinceridade em seus sorrisos e com certeza as orações da Dona Lucia.

Aos amigos que a idealização deste projeto me proporcionou, Andressa Shafer, Marília Oliveira, Verônica Fernandez, Thirsa Grando, Roberta Pereira, Felipe Libardoni, Liomara Amaral, Vanessa Gass e Dario Cáceres meu muito obrigada.

As eternas margaridas pela amizade que plantamos e seguimos colhendo até hoje.

Aos colegas de trabalho e amigos Marcos, Miguel, Roberta, Liomara e Gabrielle.

Ao frigorífico Foresta pelo material doado ao experimento e em especial a Dra. Neide Severo e sua equipe que sempre com muito bom humor me abriram as portas.

A equipe de estagiários do Professor Flavio de La Côte em especial a Camila Cantarelli, Amanda Bragatto e Mariana Cocco que também fizeram parte deste projeto.

A equipe do Laboratório Embryolab.

A secretária do PPMG, nossa Maria que sempre muito me ajudou com muito carinho meu muito obrigado.

## RESUMO

Dissertação de Mestrado  
Programa de Pós-Graduação em Medicina Veterinária  
Universidade Federal de Santa Maria, RS, Brasil

### **ASSOCIAÇÃO DE ACHADOS ULTRASSONOGRÁFICOS E ANATOMOPATOLÓGICOS DE LESÕES DA ARTICULAÇÃO METACARPOFALANGEANA EQUINA**

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**ORIENTADOR: FLAVIO DE LA CÔRTE**

Data e Local da Defesa: Santa Maria, 29 de janeiro de 2013.

O objetivo deste estudo foi avaliar e estabelecer a relação entre achados ultrassonográficos e alterações anatomopatológicas que contribuíssem para o diagnóstico das lesões da articulação metacarpofalangeana equina e suas estruturas correspondentes. Setenta membros torácicos equinos, obtidos em instalações frigoríficas, foram submetidos a exame ultrassonográfico *post mortem*. Destes, 37 apresentaram imagens ultrassonográficas consideradas suspeitas ou anormais quando comparadas às imagens normais utilizadas como controle. Posteriormente foi realizada a dissecação dos mesmos e o estudo anatomopatológico. A relação entre ambos foi estabelecida através da combinação das imagens ultrassonográficas e os achados das análises macroscópica e microscópicas. As alterações de tamanho, forma, arquitetura e ecogenicidade das estruturas ligamentosas, tendinosas, cápsula articular e superfícies ósseas da articulação metacarpo-falangeana observadas nas imagens ecográficas corresponderam a achados anatomopatológicos anormais.

**Palavras-chave:** articulação metacarpofalangeana, ultrassom, alterações anatomopatológicas, equinos.

## **ABSTRACT**

Dissertação de Mestrado  
Programa de Pós-Graduação em Medicina Veterinária  
Universidade Federal de Santa Maria, RS, Brasil

### **ASSOCIATION OF ULTRASOUND AND ANATOMOPATHOLOGICAL FINDINGS OF EQUINE METACARPOPHALANGEAL LESIONS**

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**ADVISER: FLAVIO DE LA CÔRTE**

**Date and Place of Defense: Santa Maria, 29<sup>th</sup> january 2013.**

In order to assess and establish the association between ultrasonographic and anatomopathological findings, ultrasonographic examinations were performed, *post mortem*, on the fetlock and associated structures of 37 equine forelimb specimens. All these specimens showed abnormal images or images identified as suspicious on the ultrasound examination. Subsequently, these limbs were dissected and underwent an anatomopathological study. The association between ultrasonographic and anatomopathological findings was established by comparing data obtained by both methods. Ultrasonographic changes in size, shape, architecture and echogenicity of ligaments, tendons, joint capsule, articular cartilage and bony surfaces of the metacarpophalangeal joint were associated with the anatomopathological findings.

**Key words:** metacarpophalangeal joint, ultrasound, anatomopathological changes, equine.

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## 1. INTRODUÇÃO

A articulação metacarpo/metatarsofalangeana equina pode ser caracterizada como um sistema de amortecimento de impacto, armazenamento de energia e um estabilizador do membro distal (CLAYTON et al., 1998; COLBORNE et al., 1998). Funcionalmente a articulação metacarpo/metatarsofalangeana é especializada na realização de movimentos de flexão e extensão no plano sagital devido à forma condilar do terceiro metacarpiano/metatarsiano, a presença de uma proeminente crista sagital e a força congruente dos ligamentos que a cercam (BARONE, 1989). A articulação do boleto equino é submetida à alta tensão biomecânica durante a locomoção, especialmente durante a parte intermediária da fase de apoio, quando ossos e tecidos moles que a compõem sofrem extrema tensão. Este estresse é responsável pelo aparecimento de lesões que envolvem as diferentes estruturas desta articulação (DENOIX; BOUSSEAU; CREVIER, 1993).

Lesões da articulação metacarpo/metatarsofalangeana já foram amplamente documentadas por meio da histologia (DENOIX et al., 1990) e ultrassonografia (DENOIX; BOUSSEAU; CREVIER, 1993). A ultrassonografia do aspecto palmar/plantar da articulação metacarpo/metatarso falangeana equina é indicada quando há sinais físicos como distensão da bainha digital e espessamento da face palmar/plantar, simultaneamente podendo ser observadas, lesões de tecidos moles (tendinopatias distais do metacarpo/metatarso, lesões dos ramos distais do ligamento suspensório) ou artropatias (DENOIX, 1996).

Neste estudo foram documentadas através da ultrassonografia e técnicas anatomopatológicas as estruturas que compõem a articulação metacarpofalangeana, tais como cartilagem articular do III osso metacarpiano, cápsula articular, ramos distais do ligamento suspensório, ligamento anular palmar, bainha digital, tendão flexor digital superficial, tendão flexor digital profundo, mânica flexora, ligamento intersesamoideano ou palmar e ossos sesamoides.

## 2. REVISÃO DE LITERATURA

A articulação metacarpofalangeana possui, no aspecto dorsal, uma espessa cápsula que mede aproximadamente 1 mm e distalmente 0,5mm. As superfícies da cartilagem articular e do osso sub-condral podem ser visualizadas com o membro na posição vertical, apoiado sobre o solo mas, a avaliação do aspecto distal destas superfícies exige flexão da articulação. Exceto pelo aparelho suspensório (músculo interósseo III ou ligamento suspensório), ossos sesamoides proximais, ligamento intersesamoideano e ligamentos sesamoideanos, esta articulação apresenta dois ligamentos colaterais simétricos formados por duas camadas, uma superficial, curta e oblíqua e outra, longa. Ela possui um recesso dorsal fibroso próximo dorsalmente que contém pouco líquido sinovial em articulações sadias e outro recesso próximo palmar com inúmeras vilosidades sinoviais (DENOIX, 2009).

O aspecto dorsal da superfície articular proximal da primeira falange em contato apenas com o III metacarpo/metatarso está sujeito a cargas muito elevadas e sofre altos picos de pressão (BRAMA et al., 2001). As principais limitações da ultrassonografia da articulação metacarpofalangeana são a dificuldade de produzir imagens da superfície articular proximal da primeira falange e da superfície articular palmar/plantar do III metacarpiano/metatarsiano (DENOIX; AUDIGIE, 2001).

### 2.1 Cartilagem e cápsula articular

A cartilagem articular aparece como uma linha regular hipocogênica localizada entre a membrana ou fluido sinovial e o osso sub-condral que aparece hipercogênico. A diminuição na espessura da cartilagem articular é indicativo de fibrilação da mesma. Já a degeneração cartilaginosa induz a perda local ou difusa de espessura. Em secções transversais, irregularidades da superfície articular podem ser produzidas por erosões cartilaginosas lineares dos côndilos metacarpianos (DENOIX, 2009). Histologicamente, a cartilagem articular de cavalos adultos é dividida em camadas contendo condrócitos de diferentes formas. A camada superficial ou tangencial contém condrócitos achatados ou

ovóides e as fibras de colágeno são orientadas tangencialmente. Na camada intermediária ou de transição, os condrócitos possuem dimensões maiores e as fibras de colágeno únicas ou em conjunto estão orientadas aleatoriamente. Já na camada profunda ou radial, os condrócitos estão dispostos em colunas verticais separadas por fibras de colágeno com um arranjo radial (McILWRAITH, 2001).

Em secções ultrassonográficas longitudinais e transversais da face dorsal da articulação metacarpofalangeana, a cápsula articular está localizada entre os tendões extensores do dedo e o III metacarpiano, que produzem imagens ecogênicas e hiperecogênicas, respectivamente. No aspecto dorsal dos côndilos metacarpianos, o seu limite distal é separado do osso sub-condral hiperecogênico por uma fina membrana sinovial hipocogênica e pela cartilagem articular anecóica. Achados ultrassonográficos anormais de cápsulas articulares incluem modificações na espessura, ecogenicidade e alterações em suas inserções ósseas (DENOIX et al., 1995). O espessamento da cápsula articular é um achado comum. Imagens hipocogênicas podem ser identificadas, além do aumento de espessura da cápsula. Geralmente, cápsulas articulares possuem uma forma assimétrica bem como no seu aspecto lateral e medial e são localizadas no aspecto dorsolateral ou dorsomedial da crista sagital do côndilo metacarpiano (DENOIX, 1996). Microscopicamente, os sinoviócitos se apresentam hipertróficos e quantidade variável de células linfoplasmocíticas e macrófagos podem estar presentes no estroma subintimal da cápsula articular (POOL, 1996).

## **2.2 Ligamentos colaterais**

Os ligamentos colaterais medial e lateral são compostos de uma parte superficial e uma profunda. A parte superficial se origina proximal, no aspecto distal do metacarpo, e segue distalmente se inserindo no aspecto proximal lateral/medial da primeira falange. A parte profunda é triangular e se origina na fossa condilar abaxial correndo oblíqua na direção palmar distal se inserindo na primeira falange e nos ossos sesamoides (VANDERPERREN et al., 2008). Os ligamentos colaterais são fáceis de examinar quando se inicia localizando-os no plano sagital para em seguida avaliá-los no plano transversal. Ambas as partes superficial (longa) e profunda (curta) dos ligamentos colaterais

apresentam fibras paralelas e espessura semelhante entre os aspectos medial e lateral da articulação na secção transversal. O ligamento colateral longo ou superficial é facilmente examinado, pois se estende no mesmo plano desde a parte distal do metacarpo até a primeira falange. A obtenção de imagens do ligamento colateral curto ou profundo se torna mais difícil devido à sua orientação oblíqua. Esses ligamentos são examinados de forma independente porque estão em planos diferentes (REEF, 1998). Ligamentos sadios têm uma aparência ecogênica. Desmopatias de inserção (entesopatias) possuem achados acompanhados de alterações ósseas, tais como superfície irregular, áreas de osteólise e a presença de osteófitos (entesófitos) no local da inserção (DENOIX, 2009). Os ligamentos contêm 85% de colágeno tipo I presente no tecido conectivo e quantidades menores dos tipos III e V (AMIEL et al., 1984).

### **2.3 Ligamento suspensório**

Os ramos distais lateral e medial do ligamento suspensório ou músculo interósseo III possuem uma forma arredondada, mas na sua inserção no bordo apical e abaxial dos sesamoides proximais adquirem forma trapezoide. Ambos os ramos do ligamento suspensório apresentam aparência heterogênea na inserção dos sesamoides proximais onde se encontra o recesso sinovial palmar (VANDERPERREN et al., 2008). Na região distal do III metacarpiano, o ligamento suspensório divide-se em dois ramos distintos adotando a forma de halteres nas imagens transversais. Devido ao efeito refratário resultante da sombra criada pelos bordos dos tendões flexores, os ramos podem não serem visualizados de forma adequada a partir do aspecto palmar do membro e, portanto, o transdutor deve ser movimentado lateral/medialmente ao longo da localização dos ramos do ligamento suspensório (SMITH, 2008). Microscopicamente, o ligamento suspensório apresenta um arranjo linear das fibras, similar ao dos tendões, com entrada vascular entre as fâscias que circundam os fascículos (DYSON, 2000). Na desmíte crônica progressiva do ligamento suspensório em equinos ocorre falha no suporte da articulação metacarpofalangeana, pois o processo de reparação altera-se ocorrendo morte dos desmócitos ou sua transformação em condrócitos devido ao isolamento dos feixes de colágeno a partir do fornecimento sanguíneo (WHITE; HEWES, 2008).

## 2.4 Ligamento anular palmar

O ligamento anular palmar/plantar se encontra imediatamente abaixo da pele e do tecido subcutâneo. Ele é uma estrutura fibrosa muito fina (menos de 1mm de espessura) que circunda o aspecto palmar/plantar do tendão flexor digital superficial. O ligamento anular palmar/plantar se insere nos bordos dos sesamoides proximais e se estende lateral e medial ao longo dos bordos do ligamento palmar/plantar (DENOIX, 2000). Na secção transversal sagital, o ligamento anular palmar/plantar é espesso ficando mais fino na sua inserção lateral e medial na superfície flexora dos ossos sesamoides proximais; as superfícies flexoras aparecem neste local como duas linhas curtas, ligeiramente convexas e hiperecogênicas, produzindo sombras acústicas na parte dorsal. Com orientação oblíqua dos feixes através de uma imagem negativa do tendão flexor digital superficial mostra uma arquitetura com três camadas, duas fibrocartilaginosas e ecogênicas localizadas dorsalmente e no aspecto palmar/plantar separadas por uma espessa camada fibrosa hipoeecogênica (SEIGNOUR et al., 2012). No entanto, o afastamento do transdutor lateral e medialmente da linha média (onde o ligamento anular está unido por um vínculo ao tendão flexor digital superficial, chamado de mesotendão) proporciona melhor definição e diferenciação entre o tendão e o ligamento, devido à hipoeecogenicidade sinovial (SMITH, 2008). Ligamentos consistem de tecido conectivo regular denso, onde as fibras de colágeno possuem um arranjo em ondas paralelas (GARTNER; HIATT, 1997).

A bainha digital flexora é uma cavidade complexa na qual se situam o tendão flexor digital superficial, o tendão flexor digital profundo e suas estruturas associadas às pregas sinoviais (sinovial plicae), mesotendão e mânica flexora. Ela se estende a partir da face distal do metacarpo/metatarso até a segunda falange. No aspecto palmar/plantar da articulação metacarpo/tarso falangeana, a bainha digital flexora passa por um canal inelástico criado pelo ligamento anular palmar/plantar, pela superfície palmar/plantar dos sesamoides proximais e pelo ligamento intersesamoideano ou palmar/plantar (WRIGHT; McMAHON, 1999). Na região distal do metacarpo, dentro da bolsa proximal da bainha digital, as pregas sinoviais abaxiais se conectam ao tendão flexor digital profundo na parede da bainha digital tanto no aspecto lateral como medial. Embora, normalmente a bainha digital não seja visível é possível identificá-la quando a mesma está distendida. As pregas sinoviais não deve ser confundidas com aderências, mas são estruturas úteis para

avaliar o estado da membrana sinovial (SMITH, 2008). Alterações na ecogenicidade ou aumento na espessura das pregas sinoviais associada com o tendão flexor digital profundo na margem proximal da mânica flexora podem refletir patologias da bainha digital flexora (WRIGHT; McMAHON, 1999).

## **2.5 Tendões flexores**

Na face proximal dos ossos sesamoides proximais, o tendão flexor superficial digital envolve o tendão flexor digital profundo, formando um anel chamado de mânica flexora. O aspecto distal da mânica flexora está localizado abaixo do ligamento anular palmar (WILDERJANS, 2008). No aspecto palmar do boleteo (linha média palmar/plantar do tendão flexor digital superficial), o tendão flexor digital superficial está ligado sagitalmente à bainha digital flexora pelo mesotendão (DIK; DYSON; VAIL, 1995). Dorsal ao ligamento anular palmar/plantar, os tendões flexores são circundados pela bainha digital flexora, que contém uma pequena quantidade de fluido em animais saudáveis. No aspecto palmar/plantar, a bainha digital flexora apresenta um mesotendão fino que liga sagitalmente o tendão flexor digital superficial ao ligamento anular palmar/plantar. O tendão flexor digital superficial é plano e se torna progressivamente mais amplo lateromedialmente (DENOIX, 2000; SCHARAMME; SMITH, 2003). O tendão flexor digital superficial é composto por feixes de fibras paralelas alongadas que, na vista sagital, se apresentam como ecos longos e brancos distribuídos uniformemente. Já na vista transversal, eles aparecem como ecos brancos pontuais (REEF, 1998). O tendão flexor digital superficial retém um grande volume de fibras musculares funcionais, mas o comprimento reduzido de suas fibras o torna incapaz de gerar um trabalho mecânico. Ele é vulnerável à sobrecarga porque é o único componente remanescente que pode responder ativamente à diminuição na ação do tendão flexor digital profundo (BUTCHER et al., 2007). O tendão flexor digital superficial em cavalos de corrida adultos possui fibras musculares extremamente curtas (3–12 mm) dispostas em forma multipenada (BROWN et al., 2003).

Na altura dos ossos sesamoides proximais, os bordos do tendão flexor digital superficial são ligeiramente colaterais e estão em contato próximo com os bordos do

tendão flexor digital profundo. Na região metacarpo/metatarsiana, o tendão flexor digital profundo adquire forma oval e se torna mais largo e triangular distalmente no aspecto palmar/plantar do boleto. Juntamente com a mânica flexora, desliza pelo scutum proximal, composto pelo ligamento anular palmar e os dois ossos sesamoides proximais (DENOIX, 2000). Todas as estruturas de tecidos moles têm a mesma ecogenicidade, mas os tendões flexores apresentam um padrão arquitetônico de pontos enquanto o ligamento anular palmar/plantar e o ligamento intersesamoideano ou palmar/plantar apresentam um padrão linear. O tendão flexor digital profundo apresenta bordas lisas e bem delimitadas. Sua ecogenicidade é ligeiramente maior que a do tendão flexor digital superficial com arquitetura fibrilar mais definida (SEIGNOUR et al., 2012).

Tendões são compostos de água, colágeno, e matriz de proteoglicanos que compõem a substância fundamental. Além disso, existe uma população esparsa de tenócitos. Os tendões flexores de animais em crescimento apresentam uma alta concentração de matriz protéica oligomérica cartilaginosa e são encontradas em níveis mais elevados em tendões submetidos a grandes tensões (SMITH et al., 2002). Tropocolágeno é o produto final principal do colágeno tipo I produzido e organizado em moléculas helicoidais triplas que formam as fibrilas de colágeno. Ligações cruzadas covalentes estabilizam estas fibrilas, que, por sua vez, se tornam fibras tendinosas. A população de fibrilas de colágeno é afetada pela idade devido ao aumento de reticulações que ocorrem com o amadurecimento e envelhecimento (GILLIS et al., 1997). Os tendões contêm uma fração celular relativamente pequena e uma matriz extracelular correspondente grande. Eles são compostos por filamentos de colágeno densamente empacotados e embebidos pela matriz hidrofílica rica em proteoglicanos que proporciona aos tendões suas propriedades características. Vasos sanguíneos chegam aos tendões por meio da junção miotendínea, inserção osteotendinosa e via paratendão. Entretanto, o suprimento sanguíneo é escasso e diminui ainda mais com o amadurecimento e a carga mecânica (BOSCH, 2010). Os tenócitos são encontrados em alinhamento linear ao longo das fibras tendíneas, agrupados em subunidades visíveis chamadas de fascículos (SMITH; GOODSHIP, 2004). Os fascículos são circundados por tecido conectivo contendo vasos sanguíneos, nervos, vasos linfáticos e fibras elásticas. O tecido conectivo denominado tenão envolve cada fibra (endotendão), cada fascículo (epitendão) bem como todo o tendão (peritendão). O tecido conectivo em todo o tendão permite o movimento das fibras tendíneas e dos fascículos durante o alongamento do tendão quando submetido a

sobrecargas (WHITE; HEWES, 2008).

As lesões dos tendões flexores podem ser causadas por tensão intratendinosa com a ruptura de fibras de colágeno ou por trauma, compressão e laceração extratendinosa (GENOVESE et al., 1986). Embora ainda não tenham sido descritos em equinos, os danos iniciais ocasionados nas fibras tendíneas criam uma reação inflamatória que resulta no fechamento de vasos capilares e na indução e liberação de citocinas catabólicas (HOSAKA et al., 2005). Em lesões de grau II, a hemorragia se estende do epitendão ao peritendão. Em lesões de grau III, o peritendão está espessado e o tendão está significativamente aumentado de tamanho. Não ocorre suprimento vascular da lesão. As regiões lesionadas são desprovidas de tenócitos e permanecem assim durante a fase de maturação e cura. Em casos subagudos e crônicos, o número de vasos aumenta na área da lesão juntamente com a quantidade de células mesenquimais e fibroblastos que formam o tecido de granulação (STROMBERG, 1971). Ligamentos lesionados sofrem o processo normal de reparação incluindo inflamação com remoção de tecido lesado, proliferação e migração de fibroblastos que produzem tecido colágeno e remodelação do ligamento (SMITH; GOODSHIP, 2004). A remodelação das fibrilas de colágeno progride com a cura até que haja um aumento no número de ligações cruzadas entre as moléculas de colágeno e o realinhamento das fibrilas (FRANK, 1996).

## **2.6 Ligamento intersesamoideano ou palmar**

O ligamento intersesamoideano ou palmar/plantar é uma forte estrutura fibrocartilaginosa que se insere no plano sagital, no aspecto axial da superfície flexora de cada osso sesamoide (SEIGNOUR et al., 2012). Proximalmente, o ligamento palmar/plantar se estende entre os dois ramos distais do ligamento suspensório, prevenindo o contato entre os côndilos do metacarpo/metatarso e os tendões flexores durante a hiperextensão do boleto (DENOIX et al., 1997). O ligamento palmar sagitalmente é ecogênico e preenche o espaço do tendão flexor digital profundo e as superfícies flexoras hiperecogênicas dos ossos sesamoides proximais bem como, o bordo sagital do III metacarpiano/metatarsiano. Sua espessura diminui distal e colateralmente. O espaço entre os dois sesamoides proximais, cuja distância mínima é de 3-6 mm, pode ser



avaliado e comparado com o contralateral. As superfícies flexoras são oblíquas, e a parte lateral/medial do ligamento palmar parece menos ecogênica do que a parte sagital quando é utilizado um transdutor linear. Leves irregularidades nos sesamoides proximais, sem a presença de pontos ecogênicos na profundidade do osso sub-condral, são comumente visualizados e representam variações anatômicas que não devem ser confundidas com entesiotopias do ligamento palmar/plantar (SEIGNOUR et al., 2012).

## **2.7 Ossos sesamoides proximais**

Os ossos sesamoides proximais têm uma forma piramidal, ápice trifacial, base proximal ampla e são um pouco ásperos (BARONE, 2000). Eles são compostos de água (20%), sais minerais (45%) e de substância orgânica (35%). Os componentes orgânicos são 90% colágeno, 4% glico-aminoglicanos e 6% proteínas. Os sais minerais são responsáveis pela força e a dureza do osso. O tecido ósseo é composto por uma substância fundamental inter-fibrilar e por células conjuntivas especializadas (MARCELLI; SEBERT, 1993). A aparência anatômica e ultrassonográfica do aspecto palmar/plantar do boleto variam conforme o movimento distal na altura da mânica flexora, proximal ao ápice, o corpo, superfície flexora e base dos ossos sesamoides proximais (SEIGNOUR et al., 2012). Alterações detectadas pela ultrassonografia incluem efusão do tendão flexor digital superficial, alterações na ecogenicidade, redução ou espessamento e ruptura do ligamento palmar/plantar (usualmente assimétricos) com desprendimento dos sesamoides proximais e alargamento da distância entre os sesamoides proximais e margem irregular dos mesmos (DENOIX et al., 1997).

### 3. ARTIGO 1

TRABALHO A SER SUBMETIDO PARA PUBLICAÇÃO

Periódico: Journal of Equine Veterinary Science

**ASSOCIATION OF ULTRASOUND AND  
ANATOMOPATHOLOGICAL FINDINGS OF EQUINE  
METACARPOPHALANGEAL LESIONS**

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## **Abstract**

In order to assess and establish the association between ultrasonographic and anatomopathological findings, an ultrasonographic examination was performed, *post mortem*, on the fetlock and associated structures of 37 equine forelimb specimens. All these specimens showed abnormal images or images identified as suspicious on the ultrasound examination. Subsequently, these limbs were dissected and underwent an anatomopathological study. The association between ultrasonographic and anatomopathological findings was established by comparing data obtained by both methods. Ultrasonographic changes in size, shape, architecture and echogenicity of ligaments, tendons, joint capsule, articular cartilage and bony surfaces of the metacarpophalangeal joint were associated with the anatomopathological findings.

**Keywords:** metacarpophalangeal joint; ultrasound; anatomopathological changes, equine.

## **1. Introduction**

Functionally, the metacarpophalangeal joint (MP) shows high mobility that is necessary during locomotion of sport horses and, consequently, a frequent site of lameness [1]. Its angular design renders it the capacity to support extreme hyperextension, as well as it is subject of highly compressive, tensile and torsion forces of hard athletic work making it susceptible to injuries [2]. Its anatomy is relatively simple and the lack of periarticular muscles makes the region easily accessible by ultrasound imaging, in comparison with the more complex anatomy of hock or stifle joints [1].

Ultrasonography has shown to be of great value to evaluate and diagnose soft tissue injury. Its real-time dynamic capabilities offers a major advantage compared with other imaging techniques, based on criteria such as size, shape, echogenicity, architecture

and entheses [3]. The main limitations of ultrasonography of the MP joint are the lack of imaging of the deep bone and proximopalmar proximal articular surface of the third metacarpal (McIII) bone [4].

The present study aimed to describe the ultrasonographic changes found on the MP joint and compare them with their respective anatomopathological findings. Abnormal images were presented in order to demonstrate the clinical capability of ultrasonography to point out injuries. It is important to note that no medical history of the horses was obtained, just the physical changes of the MP joints upon inspection were considered.

## **2. Materials and Methods**

At a slaughterhouse in southern Brazil, 37 forelimbs were collected for this study which were selected by presenting physical changes at inspection and palpation such as, deformation of the dorsal profile of the MP joint and digital sheath distension, thickening of the suspensory ligament branches (SL) and flexor tendons. To enhance water absorption by the skin tissues and allowing better propagation of the ultrasound waves, the routine preparation consisted of clipping the hair and soaking the area to be scanned with tepid water. Acoustic coupling gel was then applied to the skin and with the help of an assistant, the MP joints were scanned as if the limb was bearing full weight, simulating normal biomechanic position. Transverse and longitudinal sections were performed using palmar/dorsal and latero/medial palmar oblique approaches, as described by Denoix et al. [1]. Ultrasound scans were performed with a portable machine equipped with a 7.5 MHz linear and 10MHz sector transducers. A hand-held stand-off pad was used to enhance the contact with the palmar, dorsal, lateral and medial aspects of the MP joint. The ultrasound images were classified as abnormal or suspicious, as described by Denoix et al. [1], in

comparison with the contralateral forelimb always examined. On the dorsal surface of the MP joint, an ultrasound transverse section was obtained to evaluate the proximal half of the metacarpal condyle. The transducer was moved from the near-distal surface of the McIII condyles towards the proximal phalanx, visualizing the insertion of the joint capsule examined on the flexed fetlock. On the lateral/medial surfaces, transverse and longitudinal sections were performed to scan the collateral ligaments (CL). At the level of the proximal sesamoid bones, transverse and longitudinal images of the SL branches were produced. On the palmar surface of the MP joint, transverse and longitudinal sections were produced. On the transverse section, the transducer was oriented laterally and medially in order to obtain images of the insertion the palmar annular ligament (PAL) and the transducer was moved up and down in order to obtain positive and negative images facilitating the visualization of scarred areas on the flexor tendons.

Structural changes in size, shape, architecture and echogenicity identified on the MP joints had their images recorded and identified. Thereafter, the structures visualized on ultrasound were dissected, and underwent a systematic macroscopic study. Changes in size, shape, consistency, color and presence of adhesions were observed [5]. Gross lesions were photographed, collected and fixed in 10% buffered formalin for a period of 14 days. The soft tissue samples were then routinely processed for histopathology. Sections were prepared (3  $\mu$ m) and stained by hematoxylin and eosin and Alcian blue (on selected section to better demonstrate the cartilaginous tissue). After fixation, bone tissue samples were decalcified in a formic acid-sodium citrate aqueous solution and routinely processed for histopathology.

The histological findings were analyzed and then compared with their ultrasonographic and macroscopic counterparts, establishing their relationship. The forelimbs were identified from 1 to 37 whereas, if the same forelimb showed more than

one abnormal structure, a superscript letter was added to the number, facilitating the organization of the study. They are indicated in brackets in the article.

### **3. Results**

Out of the 37 forelimbs evaluated, 54 abnormal structures were identified on ultrasound and confirmed by gross examination. These 54 abnormal structures were: joint capsule (n=14), articular cartilage of the McIII and sesamoid bones (n=8), superficial and deep flexor tendons (n=13) and suspensory, collateral, annular palmar and intersesamoidean ligaments (n=19) (Table 1).

#### **3.1. Joint capsule and articular cartilage**

Joint capsule changes were detected on 7 forelimbs (12, 17<sup>a</sup>, 22<sup>a</sup>, 25<sup>a</sup>, 27<sup>a</sup>, 31<sup>a</sup> e 32<sup>a</sup>). All of them were thickened and accompanied by changes in the dorsal articular cartilage and bone surface of the McIII. Only one case (32<sup>a</sup>) showed a hypoechogenic medial zone that corresponded macroscopically to a hardened nodular structure and a reddish synovial pad. Microscopically, there was multifocal lymphoplasmacytic and neutrophilic synovitis. Three joints (18<sup>a</sup>, 27<sup>a</sup>, 31<sup>a</sup>) had a yellowish-white or pale yellow, thickened joint capsule of hard consistency, with a reddish synovial pad. Histologically, there were multifocal areas of mild hyperplasia of synoviocytes in some cases. Joint 12 showed extensive area of cartilaginous metaplasia of the fibrous capsule. Changes observed on 8 forelimbs were considered anatomical variations, as they presented thickening of the joint capsule in comparison to the contralateral joint yet without echogenicity or histological changes.

The anechoic space composed of the articular cartilage at the McIII condyles was severely reduced showing severe irregularity in the subchondral metacarpal bone surface on 2 forelimb specimens (17<sup>b</sup>, 18<sup>b</sup>). Only joint 17b presented a hyperechogenicity and a discontinuity zone of the metacarpal bone surface that corresponded to the presence of a mineralized fragment adhered to the capsule (Figure 1A). This fragment was of an Alcian blue-positive hyaline cartilage on histological examination (Figure 1B). The synovial pad was also reddish and significantly thickened. It was diagnosed histologically as a mild hyperplasia of synoviocytes and subsynovial congestion. Loss of the articular cartilage with exposure of the subchondral bone associated with a dark red color and strong presence of linear grooves in the metacarpal condyles were identified grossly in this case (Figure 1C). Histologically, focally extensive severe fibrillation (Figure 1D) and eburnation (Figure 1E) of the articular cartilage were found. On 4 forelimbs (25<sup>b</sup>, 27<sup>b</sup>, 31<sup>b</sup>, 32<sup>b</sup>), echogenic lines parallel to the subchondral bone surface were located in an anechoic space, corresponding macroscopically to moderate cartilaginous grooves or irregularities of yellowish pink color and that histologically represented an area of focally extensive moderate fibrillation. Similar changes yet, less pronounced, were identified on forelimb 22<sup>b</sup>, corresponding to a milder injury.

### 3.2. Ligaments and tendons

Four forelimb specimens (2, 4, 9, 24<sup>b</sup>) showed increased ultrasound thickness of the lateral or medial insertion of CL with the joint capsule. However, no changes in echogenicity, bone surface irregularities or articular osteophytes were noticed. Grossly, the ligament was thickened when compared to the contralateral limb, but showing normal color that ranged from white to yellowish. Histologically, multifocal mild collagenolysis and focally extensive cartilaginous metaplasia were observed. Case 24 also presented focal

mild bone metaplasia. On the remaining examined fetlocks, no histological abnormalities were found.

Lateral or medial branch changes of the SL were identified on 3 forelimbs. On ultrasound they had increased size and were asymmetric that resonated in the distal part of the body of the ligament (23, 30<sup>c</sup>, 37). Hypoechoic zones and lack of fiber parallelism were identified on 2 forelimbs (23, 30<sup>c</sup>). Macroscopically, these zones corresponded to red areas in the transversal section of the ligament, and histologically, to hypertrophy of the fascicles of dense connective tissue on forelimb 23, while on case 30, presented moderate cartilaginous metaplasia. Changes of echogenicity consisted of well-defined hyperechoic zones, desmopathy signals of the ligament insertion with irregular bone surface of the lateral sesamoid bone on case 37 (Figure 2A). Grossly, the lateral branch of the SL (37) was surrounded by white fibrous tissue and on the transversal section there also was a peripheral white translucent zone (Figure 2B); histologically, a multifocal severe cartilaginous metaplasia of the dense connective tissue was identified (Figure 2C and 2D).

The hypoechoic space composed by the palmar annular ligament (PAL) was increased in size on the transversal section, and medially as well as laterally, at the insertion of the proximal sesamoid bones (7, 11, 25<sup>c</sup>, 26, 30<sup>b</sup>, 33, 36<sup>a</sup>). Likewise, the echogenic space between PAL and skin, composed of loose connective tissue, was also thickened (Figure 3A). Grossly, there were thickened areas of hard consistency and adhesions between PAL and superficial digital flexor tendon (SDFT). One forelimb (11) showed yellow pigmentation on the palmar view of the ligament, in close contact with the SDFT (Figure 3B). With the exception of the limb 36<sup>a</sup>, where the ligament was strongly adhered on his length and the color varied from yellow to dark red, all the remaining ligaments were white. Histologically, this limb presented lympho-histioplasmacytic



desmitis with focally extensive severe fibrosis. On limb 7, a moderate multifocal fibrosis with abundant vascularization was found, whereas on cases 11 (Figure 3C) and 25<sup>c</sup>, collagenolysis and multifocal moderate cartilaginous metaplasia of the dense connective tissue were found. Focally extensive areas of fibrosis were noted only on limb 11. The echogenic space between PAL and skin, on the 14<sup>b</sup> and 24<sup>c</sup> limbs was increased in size, composed macroscopically of connective tissue, with no changes in the ligament structure on histological examination.

Superficial digital flexor tendon (SDFT) changes included increased size (19, 21, 36<sup>b</sup>) and presence of irregular hypoechogenic zones that corresponded to an increase in volume and asymmetry of the medial edge on the macroscopic evaluation. On limb 36<sup>b</sup>, the tendon was filled with dark yellow soft areas. Multifocal cartilaginous metaplasia and areas of collagenolysis were observed on the forelimbs 19 e 21, while on case 36<sup>c</sup>, a lympho-histioplasmocitic tendinitis with focally extensive severe fibrosis and cartilaginous metaplasia was diagnosed.

Deep digital flexor tendon (DDFT) changes were found on 4 forelimbs (1, 5, 6, and 16), that included changes in echogenicity, with hypoechogenic zones in the center of the tendon, and irregular edges. The diffuse hypoechogenic zones corresponded to hemorrhagic infiltration, the fibers of the peritendon and endotendon were thickened. Asymmetry and marked ridges were observed on the palmar surface of the DDFT in contact with the SDFT. Mild (1) and moderate multifocal fibroplasia and collagenolysis (5, 16) of the endotendon and peritendon and cartilaginous metaplasia (6) were observed. The DDFT (36<sup>c</sup>) showed changes of delineation of the edges, increased size and asymmetric shape, with well-defined hypoechogenic zones (Figure 4A). The macroscopic view showed soft consistency and red to dark yellow ranging color (Figure 4B). This

corresponded histologically to multifocal lympho-histioplasmacytic tendinitis with severe necrosis, hemorrhage and fibrosis (Figure 4C).

Only one forelimb (3) showed intersesamoidean ligament (IL) changes, where the space between the sesamoid bones was ultrasonographically increased and hyperechogenic. Grossly, this ligament was white-yellow and with fiber irregularity. Histologically, moderate multifocal collagenolysis was associated with moderate cartilaginous metaplasia.

### 3.3. Proximal sesamoid bones

The proximal sesamoid bones of limb 36<sup>d</sup> presented irregularities on all their extension. Macroscopic findings on these structures were white to pink grooves on the dorsal surface. The palmar surface of the sesamoid bones presented necrotic dark red zones and microscopically, severe periosteal hemorrhages were found.

## 4. Discussion

In this study, the selection criteria of the forelimb specimens submitted to ultrasound examination were different from those applied in clinical routine workup. It was based on the detection of changes by inspection and palpation of the forelimbs after slaughter and not by lameness problems. Certainly we might have missed forelimbs injuries unapparent to palpation and that perhaps could have been responsible for locomotor problems. Similarly, we may have selected forelimbs with injuries, but without clinical manifestations. Denoix et al. [5] cites the clinical value and its relationship with the macroscopic and histological findings demonstrates that necrotic tissues appearance, angiomatous or edematous tissue and presence of hemorrhagic infiltrates represent a little

significant value in the production of musculoskeletal problems. However, fibroplasia has significant value. Findings such as cartilaginous metaplasia, whitish gelatinous tissue may determine defects in elasticity of the tendons and ligaments. The anatomopathological examination in this study was the reference method used to evaluate the ultrasound sensitivity of the dorsal, lateral/medial and palmar surface of the MP joint, contributing with consistent morphological and histological information and having the advantage of being fast, demonstrative and of low cost. Identified lesions were found to be of traumatic, degenerative, chronic and, in one case, possibly of septic origin. The main interest of this study is to demonstrate the sensitivity and specificity of ultrasonography to document injuries of the MP joint, whatever the clinical significance of these lesions (Table 2).

Abnormal ultrasonographic findings of the joint capsule include modifications in thickness and echogenicity, and bone insertion alterations [6]. On 6 abnormal joint capsules detected in this study, 5 limbs presented red and thickened synovial pad and all were accompanied by articular cartilage lesions. Probably, the injuries were the result of repeated trauma in the joint and may have been accompanied by synovial inflammation as well [7]. According to Santschi [8] synovial changes resulting from continued inflammation include hyperplasia and fibrosis. Occasionally, MP synovial pad proliferation is characterized histologically by fibrous proliferation, collagen necrosis, increased vascularity and cartilaginous metaplasia [9]. On case 17<sup>a</sup>, mild synoviocyte hyperplasia and subsynovial congestion were observed. Pool [10] mentioned that, microscopically, when synoviocytes appear hypertrophic different numbers of lymphocytes, plasma cells and macrophages may be present. This was checked in structure 32<sup>a</sup>, but the only difference found in this study was the presence of neutrophils and not of macrophages. Islands of synoviocyte metaplasia may form nodules of cartilage tissue called synovial chondromas [10]. However, this was not observed in case 12, where

cartilaginous metaplasia was observed inside the fibrous capsule and not in the synovial pad.

Linear cartilaginous erosions, such as the ones observed on the metacarpal condyle, induce an irregular cartilage surface on transverse section. Cartilage degeneration induces local or diffuse thinning of the articular cartilage [11]. Histological examination of the articular cartilage on cases 17<sup>b</sup> and 18<sup>b</sup> showed areas of degeneration (fibrillation) of the articular cartilage and areas of loss of the cartilage, with exposure of subchondral bone (eburnation). In 4 cases, the histological cartilage changes were less severe and consisted of focally extensive fibrillation of the articular cartilage with proliferation of chondrocyte islands. Ultrasound imaging is very effective for identifying articular cartilage lesions [3], including the macroscopically discrete abnormalities [1].

Axial deviation of the forelimbs, such as varus and valgus deformation, may predispose to an overload of compressive forces to the joint and increase tension on the collateral ligaments, predisposing them to get thickened. It is possible that this occurred on cases 02, 09, and 24<sup>b</sup> because, the medial or lateral CL were thickened, but the echogenic appearance was normal and no osteophytes were observed on the joint. Luxation of the MP joint is an uncommon disorder caused by trauma. An obvious valgus or varus deformation can be present [12]. In the above mentioned cases only valgus or varus deformation were evident and no histological changes were found. On the other hand, on forelimb 4, a thickened lateral CL was found, also with normal echogenicity. These findings are accompanied by bone lesions like irregular bone surfaces, osteophyte production and histological changes, in accordance with Denoix [11].

Hypoechoic zones visible in the center of the SL and reduced regularity on the fiber pattern were observed on two forelimbs (23, 30<sup>c</sup>) that would be compatible with hemorrhagic infiltration and edema. On another case (37), ultrasonographic findings

consisted of enlargement and asymmetry of the hyperechogenic cross-sectional areas, poor demarcation of the SL borders and focal mineralization, in agreement of Dyson [13]. Specimens from horses with severe desmopathy diagnosed by ultrasound had marked fiber disruption with focal acellular areas interspersed with hypercellular accumulations of disorganized fibroblasts [14]. According to White and Hewes [15], there is evidence of attempted regeneration by fibroplasia, but lack of healing is apparent in distinct focal areas, with no vascular supply and disorganized collagen, which appears immature. In this study, histological changes of the hyperechogenic zones of the SL branches consisted of the chondrocytes islands with severe cartilaginous metaplasia of the dense connective tissue and hypoechogenic zones corresponded to hypertrophy of the fascicles of dense connective tissue .

All palmar annular ligaments (PAL) with ultrasonographic findings were represented by an increased and thickened space occupied by them, where it was found adhered to the SDFT. Nevertheless, the thickness of PAL can be measured and this hypoechogenic representation helps identification of this structure [3]. Ultrasonography is effective in outlining soft tissues abnormalities, such as thickening of the synovial membrane and adhesions between SDFT and PAL [16]. The healing process results in fibrous thickening of the SDFT and/or the PAL [2]. This was evident on forelimb 11 where multifocal fibrosis zones of the SDFT and PAL were found on adhesion sites. The presence of fibrosis in association with PAL thickening may increase the pressure exerted on the contents of the fetlock canal, and had a significant negative effect on prognosis [19]. Effusion, thickening of the synovial sheath and adhesions with concurrent lesions of the PAL are described as ultrasonographic findings indicative of tenosynovitis [17]. These findings were observed on case 36<sup>a</sup>. The surface of the proximal sesamoid bones was very irregular and there was a lack of delineation of the edges and hypoechogenic zones on the

SDFT and manica flexoria. The DDFT (36<sup>c</sup>) also showed hypoechogenic zones and shape changes. The macroscopic evaluation to determine the precise variation in size, shape, architecture of the SDFT and DDFT on its way through the proximal scutum demonstrates that ultrasound is more sensitive and reliable than palpation to identify changes in those tendons [5]. This was true on the evaluation of forelimbs 1, 5, 6, 16, 19, 21, 36 where the association with histological findings confirmed the great sensitivity of ultrasound and macroscopic methods. In forelimbs 3 and 36<sup>d</sup>, ultrasonographic evaluation of the IL is based on the same criteria such as size, shape, echogenicity and bone surface irregularities, in accordance with Denoix [3]. Intersesamoidean or palmar ligament desmitis, in many instances, is initiated by an infection but can also be initiated by trauma [18]. Histological changes in this study of the IL consisted of moderate multifocal collagenolysis and was associated with moderate cartilaginous metaplasia.

## **5. Conclusion**

This study allowed the establishment of clear relation among ultrasonographic, gross and histological findings. These relations between the three methods proved to be particularly advantageous detecting osteoarticular changes, such as fibrillation and eburnation of the articular cartilage. In tendons, the most important condition detected was tendinitis. In ligaments, cartilaginous metaplasia was the most common finding.

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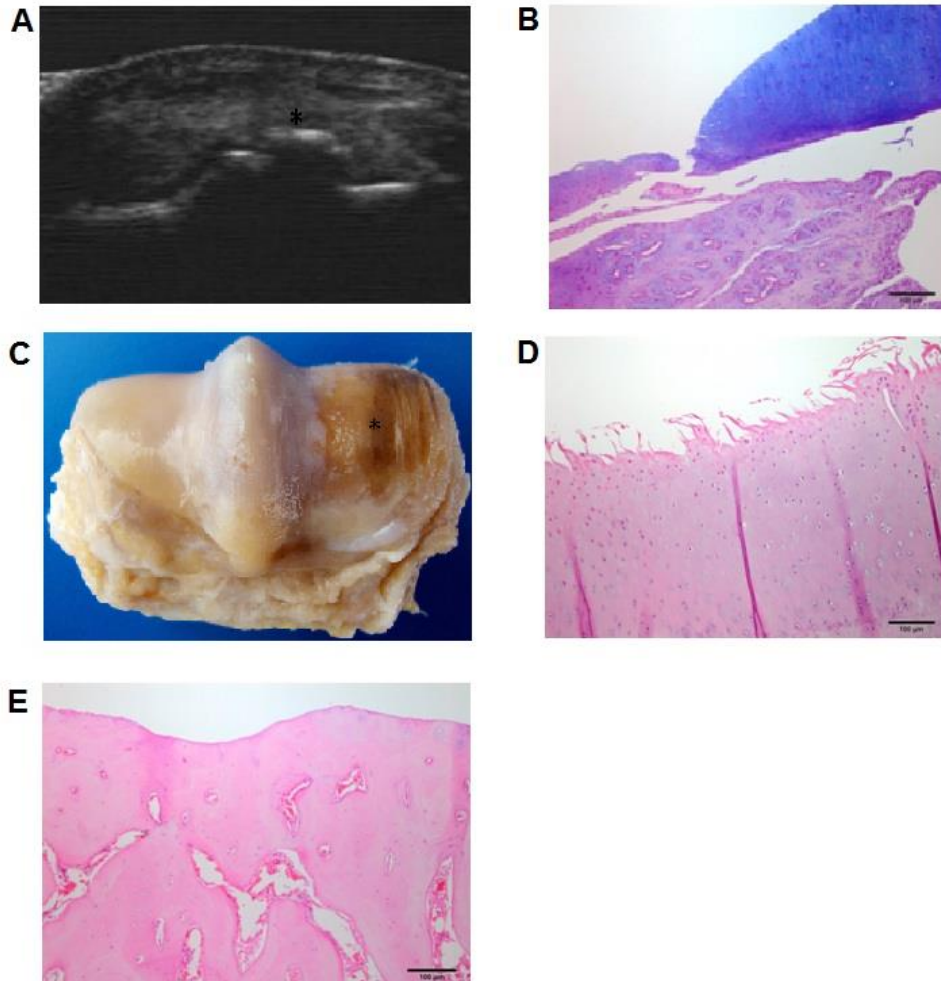
**Table 1.** Results for the 54 structures analyzed in this study

<b>Structures Analyzed in 37 Forelimbs</b>	<b>Number</b>
Joint Capsule	14
Articular Cartilage of the Condyles of the Metacarpal bone and Proximal Sesamoide Bone	8
Digital Flexor Tendons	13
Ligaments	19

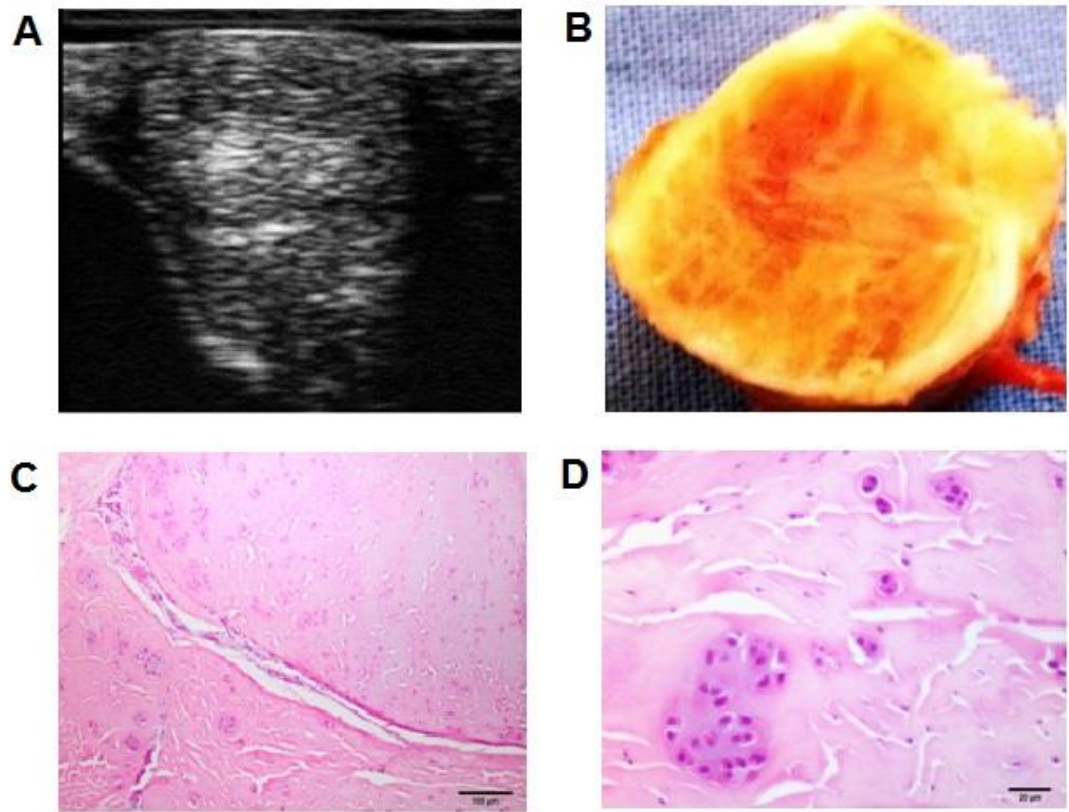
**Table 2.** Association of ultrasonographic images with macroscopic and histological findings in 37 post-mortem cases analyzed in this study.

<b>SUPENSORY LIGAMENT (SL)</b>		
<b>Echogenicity</b>	<b>Macroscopically</b>	<b>Histology</b>
Diffuse Hypoechoogenicity	Hemorrhagic Infiltration	Fascicles hypertrophy
Hyperechogenicity	White to Yellow Nodular Tissue	Severe cartilaginous metaplasia
<b>SUPERFICIAL DIGITAL FLEXOR TENDON (SDFT)</b>		
<b>Echogenicity</b>	<b>Macroscopically</b>	<b>Histology</b>
Focal Hypoechoogenicity	Dark Yellow Zones	Lymphohistioplasmacytic inflammation / Focally extensive severe fibrosis.
Hyperechogenicity	White to Dark Yellow Zones	Cartilaginous metaplasia
<b>DEEP DIGITAL FLEXOR TENDON (DDFT)</b>		
<b>Echogenicity</b>	<b>Macroscopically</b>	<b>Histology</b>
Diffuse Hypoechoogenicity	Hemorrhagic Infiltration	Fibroplasia
Focal Hypoechoogenicity	Red to Dark Yellow Zones	Lymphohistioplasmacytic perivascular inflammation/ Necrotic and hemorrhagic areas.
<b>PALMAR ANNULAR LIGAMENT (PAL)</b>		
<b>Echogenicity</b>	<b>Macroscopically</b>	<b>Histology</b>
Hyperechogenicity	Thickened areas/ Hard consistency/ Adherences to SDFT.	Moderate multifocal fibrosis/ Cartilaginous metaplasia.
Hypoechoogenicity	Strongly adhered/ Yellow to dark red color.	Lymphohistioplasmacytic and neutrophilic inflammation/ Focal extensive severe fibrosis
<b>ARTICULAR CARTILAGE</b>		
<b>Echogenicity</b>	<b>Macroscopically</b>	<b>Histology</b>
Hyperechogenicity/ Severe Irregular Surface/ Diffuse Thinning.	Linear Cartilaginous Erosions/ Exposure of Subchondral Bone	Focally extensive severe fibrillation and eburnation.
Hyperechogenicity/ Moderate Irregular Surface/ Diffuse Thickening.	Moderate Cartilaginous Grooves/ Yellowish Pink Color	Focally extensive moderate fibrillation.

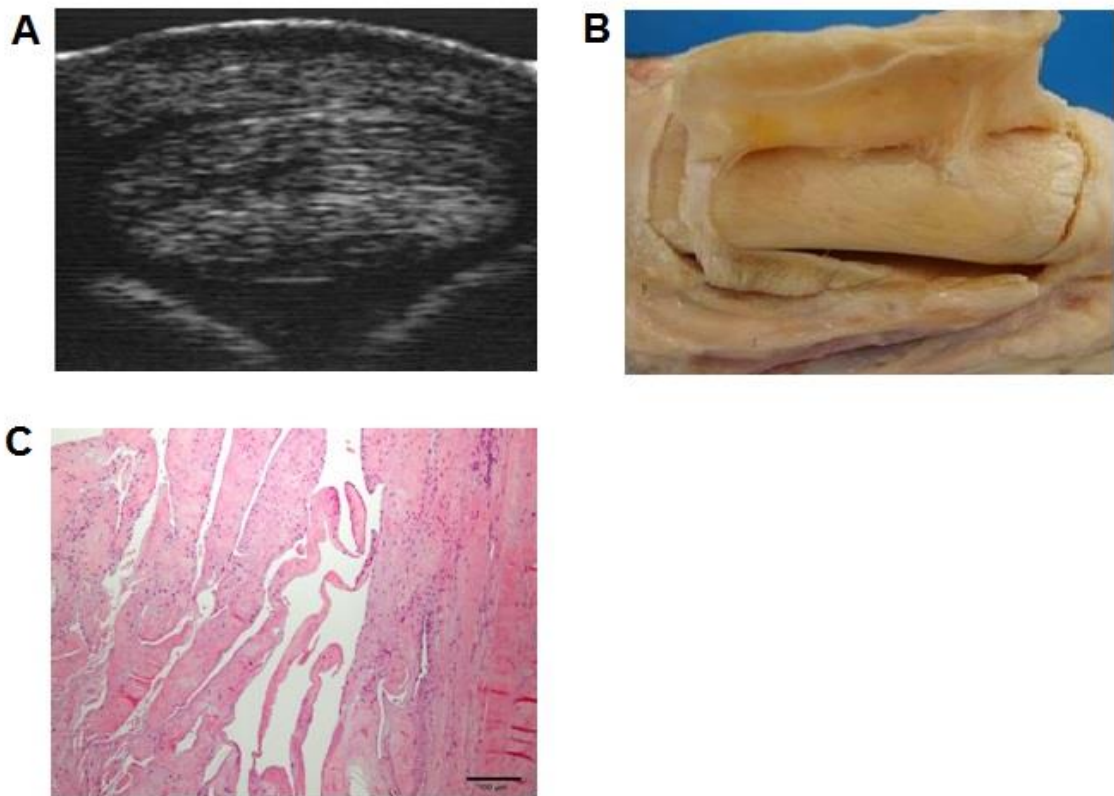
## Figures



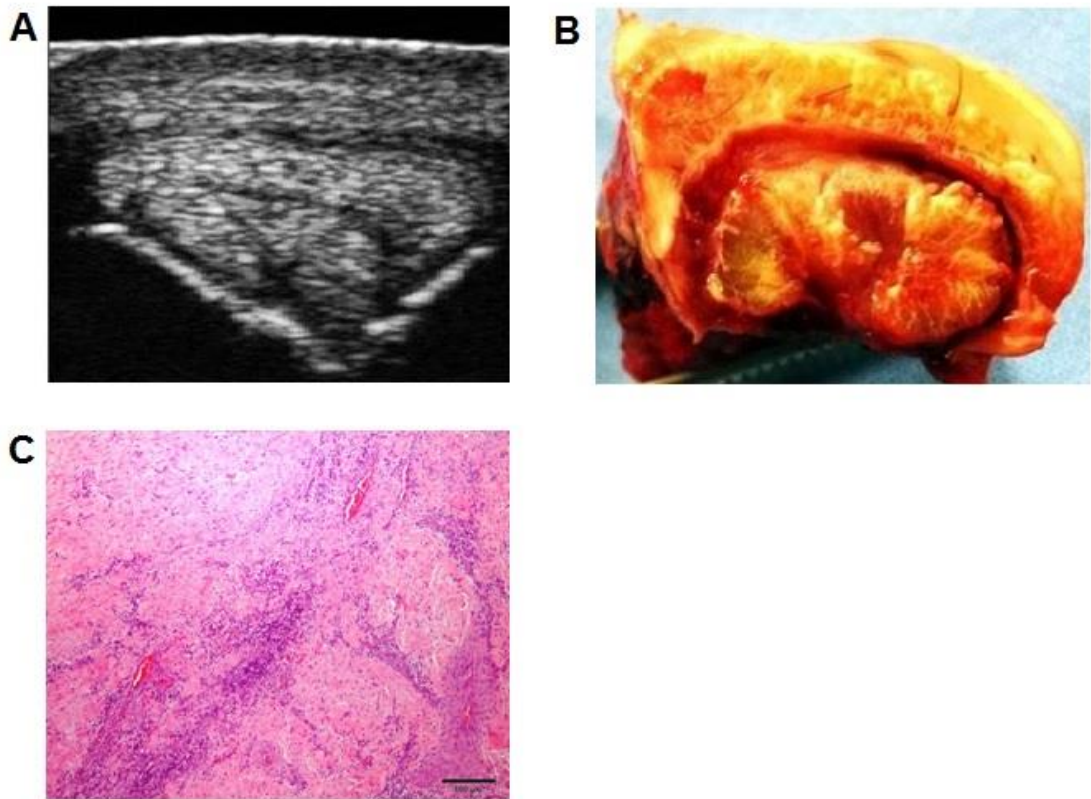
**Fig. 1-** Articular cartilage changes of the III metacarpal bone (McIII). A- Transverse section. The anechoic space composed of the articular cartilage at the condyles of McIII is severely diminished with severe irregularity in the subchondral metacarpal bone surface. There is a discontinuity zone of the metacarpal bone surface that corresponded to a mineralized fragment (asterisk). B- A mineralized fragment of an Alcian blue-positive hyaline cartilage. Bar = 100 $\mu$ m. C- Loss of the articular cartilage with exposure of subchondral bone associated with a dark red color and strong presence of linear grooves in the McIII (asterisk). D- Focally extensive severe fibrillation of the articular cartilage surface. E- Focally extensive severe eburnation of the articular cartilage. Only the subchondral bone is shown. H&E. Bar = 100 $\mu$ m.



**Fig. 2-** Cartilaginous metaplasia of the suspensory ligament (SL). A- Transversal section. A round hyperechogenic zone is observed in the distal portion of the ligament. Note the irregular bone surface of the lateral proximal sesamoid bone and enlarged SL. B- The SL is surrounded by white fibrous tissue and on transversal section there is a peripheral white translucent zone. C- Multifocal severe cartilaginous metaplasia of the dense connective tissue is present. H&E. Bar = 100 $\mu$ m. D- Higher magnification of figure 2C. H&E. Bar = 20 $\mu$ m.



**Fig. 3-** Adhesions between the palmar annular ligament (PAL) and the superficial digital flexor tendon (SDFT). A- Transverse section. There is a hypoechoogenic space composed by the PAL. The PAL was thickened. B- Multifocal areas of adhesions are observed between PAL and SDFT. C- On the right side is the PAL and on the left side is the adhesion with the SDFT (not shown). H&E. Bar = 100 $\mu$ m.



**Fig. 4-** Changes in the palmar surface of the metacarpophalangeal joint. A-Transverse section. The hypoechoic space composed by the palmar annular ligament is increased in size. Presence of irregular hypoechoic zones, increase in volume and asymmetry of the superficial digital flexor tendon (SDFT). Changes of delineation of the edges, increased size and asymmetric shape, with well-defined hypoechoic zones of the deep digital flexor tendon (DDFT). Irregularities of the proximal sesamoid bone surface. B- Both, SDFT and DDFT, have dark yellow soft areas randomly distributed. C- Multifocal lympho-histioplasmacytic infiltration with fibrosis of the DDFT. H&E. Bar = 100 $\mu$ m.

#### **4. CONSIDERAÇÕES FINAIS**

Este estudo ecográfico e anatomopatológico de lesões presentes na articulação metacarpofalangeana e seus componentes demonstra a sensibilidade da técnica ultrassonográfica em tecidos ligamentosos e tendinosos bem como, em tecidos ósseos. Imagens anaecóicas, hiperecogênicas, hipoecogênicas histologicamente podem representar diferentes tipos de tecidos. Metaplasias cartilaginosas foram encontradas nas estruturas ligamentosas produzindo imagens hiperecogênicas; por outro lado, infiltrados inflamatórios observados nas estruturas tendinosas produziram imagens hipoecogênicas.



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