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Original Research Article

Magnetic resonance imaging for detection of some foot lesions causing lameness in donkeys (Equus asinus)

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ABSTRACT

Magnetic resonance imaging (MRI) is a good useful imaging tool for diagnosing foot lameness in equine. Seventeen donkeys of age (6–12 years), gender admitted to the clinic unit of our collage with owners complained that the animals were suffered from incurable lameness in their forelimbs. All forelimb foots were collected at the level of fetlock joint after euthanasia for performing MR imaging .The results showed that, both normal anatomy to the foot using T1-weighted image sequence and detection of different lesions involving many parts of the foot such as collateral ligaments of the DIP joint, both DDFT core and border, both navicular bone medullary cavity and cortex, articular cartilage of DIP joint, distal sesamoidean impair ligament (DSIL) and suspensory ligament of the navicular bone that could not be diagnosed by other diagnostic tools such as X- ray, ultrasound and Computed Tomography. In conclusion, Using MRI in examination of donkey foot lameness is considered as a definitive and accurate diagnostic tool for design suitable treatment regimens for all affections.

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Introduction

Foot disease is one of the common causes of equine limb lameness, but accurate detection of the main cause is difficult. There is disputing about the commentary of radiographs of navicular disease **(Dyson *et al.*, 2007).**

Ultrasonography of the foot is confined to the sagittal midline, and with many artifacts which may confuse in interpretation of the foot affections **(Sage and Turner, 2000** and **Busoni and Denoix, 2001).**

There are many of affections which could not be detected by radiography, Ultrasound and CT but could be identified by using magnetic resonance imaging (MRI) in horses with foot diseases **(Denoix *et al.*, 1993 and Widmer *et al.*, 2000).** Recently MRI could be used for examining the bony and soft tissue structures of the foot **(Kleiter *et al.*, 1999).**

Accurate diagnosis of MRI requires excellent background of the anatomy and an understanding the abnormality that could be found in apparently healthy horses. There were pathological affections which may be diagnosed by using MRI in horses free from lameness due to signal abnormalities of the tissues **(Schramme *et al.*, 2005; Blunden *et al.*, 2006 and Murray et *al.*, 2006).**

All the previous studies were done on horses for diagnosis of any problems not on donkeys however; the donkeys have a great importance for the Egyptian farmers (**König *et al.*, 2007 and Budras *et al.*, 2012).**

Therefore, the aim of the present study is the diagnosis of some bone and soft tissue affections in donkey's foot by using MRI.

Materials and methods

Seventeen donkeys of age range (6–12 years), gender admitted to the clinic unit of our collage from January 2017 till June 2018 with owners complain that the animals were suffered from incurable lameness in their forelimbs. Each case was bought with collection of their forelimb digits at the level of fetlock joint after euthanasia then refrigerated at 4°C until the imaging procedures were performed.

MR imaging were performed within 1 hour after thawing of each foot from the refrigerator, to ensure the uniform temperature anywhere in the foot. All samples were scanned by T1W, T2W and STIR sequences. The magnetic resonance imaging was taken at sagittal and transverse plans.

Feets were imaged in a 1.5T Signa Echospeed closed short-bore magneta, (Siemens Medical So-lutionsz) with the limbs parallel to the static magnetic field.

Results

The magnetic resonances images illustrated the high intense signal areas (White and/or mobile proton) which corresponding to the high density of tissues and the low intense signal areas (black and /or non-mobile proton) which corresponding to the low density tissues. Many tissues appear as gray due to moderate proton mobility and moderate tissue dense.

The results, could be categories the animals of this study into five categories according to absence or presence of lesions, site of lesions and MRI appearance of lesions which tabulated in the following table **(Table 1)**

Table (1): Categories the animals according to absence or presence of lesions, site of lesions and MRI appearance of lesions

Group No.	Number of animals	absence or presence of lesion(s)	site of lesion	MRI appearance of lesions
1	Four	Absence of lesions (normal)	--------------	Normal appearance of all sites in the foot
2	Five	Present	Navicular bone	Low-intense signal line or spots or irregular of palmar border
3	Three	Present	DIP	Low-intense signal area or high-intense signal spot at the articular cartilage or high-intense signal spot at the medial collateral lig.
4	Four	Present	DDFT	hyper- intense signal spot in dorsal border or multiple hyper to intermediate-intensity signal lines or inter-mediate intense signal swelling
5	One	Present	DDFT, DSIL and suspensory lig.	hyper-intense signal at the dorsal border of the DDFT and in distal sesamoidean impair ligament (DSIL) and increase the size of the suspensory ligament

The results showed that, there are four cases of (6-8) year's old gives normal MRI appearance for all parts of the foot in sagittal T1-Weighted MR image, the DDFT was appeared as uniform low-intense signal with hyper-intense signal to tendon sheath. The navicular bone was appeared as hyper-intense signal cortex with inter-mediate –intense signal medulla. The most important area is the articular cartilage which appears as smooth, homogenous inter-mediate –intense signal at the pastern and DIP joint. All ligaments were appeared as inter-mediate –intense signal (**Fig. 1)**.

Five cases aged (6-10) year's old were suffered from lameness with lesions that affect the navicular bone such as was evident at Sagittal T2-Weighted MR image which with presence of irregularity at the palmar cortex of the navicular bone which appear as focal hypo- intense signal area (White arrows) **(Fig. 2&3)**.

While in Transverse T2-weighted MR image and in sagittal T2-weighted MR image of notice that there is irregular line (decreased signal intensity or black line) discontinuity of the homogeneous intermediate-intense signal of the medullary cavity of the navicular bone (Red arrow) **(Fig. 4 and 5).**

Also the result showed in sagittal STIR-weighted MR image notice that presence of two hypo-intense signal spots (Black area) at the distal third of the medullary cavity of the navicular bone (Red arrow) with presence of hyper- intense signal line at the middle longitudinal axis the medullary cavity of navicular bone **(Fig. 6)**.

The results showed that, three cases were suffered from severe lameness, aged from (8-11) year's old. MRI showed that presence of many lesions which affect the DIP joint and its ligaments such as in sagittal STIR-Weighted MR image revealed loss of continuity of the homogeneous intermediate-intense signal of articular cartilage and replaced with hypo-intense signal area at the palmar aspect of DIP joint (Red arrow) **(Fig. 7)**. Also**,** in Sagittal T2-Weighted MR image revealed that presence of hyper- intense signal area at the medio-caudal part of the inter-mediate intense signal of the articular cartilage of the DIP joint **(Fig. 8)**. While in transverse T1-Weighted MR image showed, the presence of hyper-intense signal spot area in the medial collateral ligament of the DIP joint (Red arrows) **(Fig. 9).**

Also, the results noticed that found of four cases were suffered from imperfect flection in forelimbs in cases aged from (6-9) year's old. MRI revealed, DDFT affection which appears in transverse T2 -weighted MR image with hyper-intense signal spot in dorsal border of the DDFT (white arrow) **(Fig. 10)**. Also, the transverse T1-Weighted MR image indicated, the presence of core lesion which appeared as multiple hyper to intermediate-intensity signal lines of white or grey colour within the normally low-intensity signal of the DDFT (Red arrows) **(Fig. 11)**.

While in transverse T2-weighted MR image indicated, the loss of the hyper-intense signal continuity of the dorsal border of the DDFT which appears as hypo-intense signal spot (Red arrow) **(Fig. 12).** In transverse T1-Weighted MR image showed, the presence of inter-mediate intense signal swelling in the medial lobe of DDFT (Red arrow) **(Fig. 13)**.

Only one case of 12 years old which suffer from lameness and by MRI showed in sagittal T2-

Weighted MR image a hyper-intense signal at the dorsal border of the DDFT (Green arrow) and in distal sesamoidean impair ligament (DSIL) (White arrow). There is increase the size of the collateral (suspensory) ligament of the navicular bone at its distal part with increasing in its intense signal (Red arrow) (**Fig. 14)**.

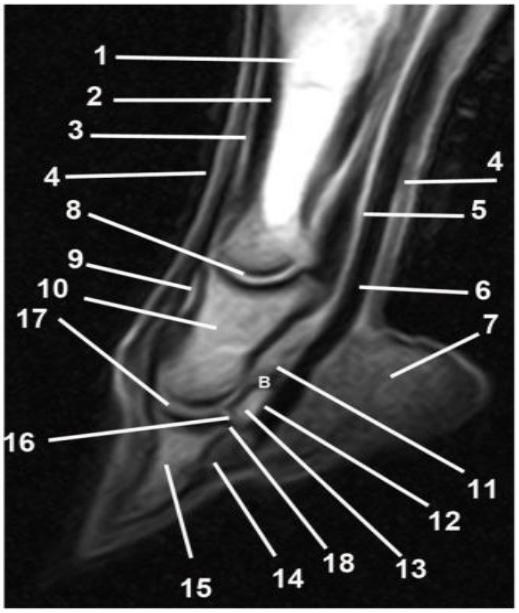


Fig. (1)

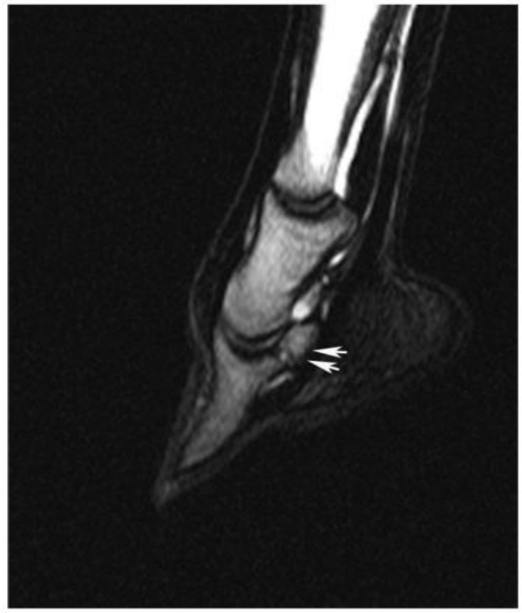
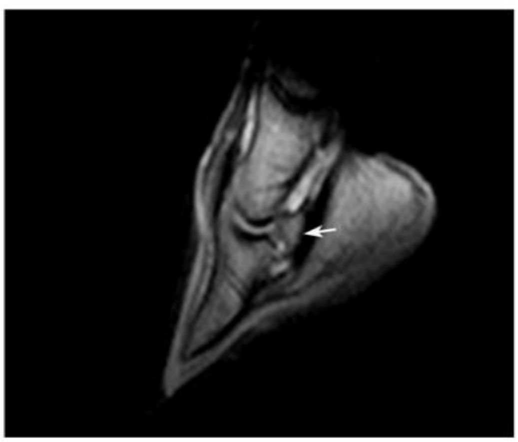


Fig. (2)



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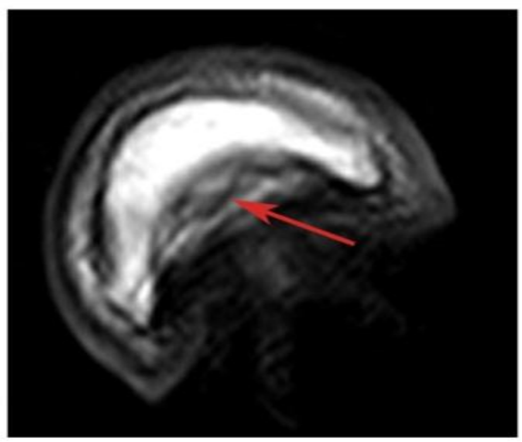


Fig. (4)

Fig. (1). Sagittal T1-Weighted MR showed the normal anatomy of the digit (Cadaver) 1= Medullary cavity of proximal phalanx; 2= Cortex of proximal phalanx; 3= Vascular connective tissue; 4= Connective tissue and fat of subcutis; 5= Distal sesamoidean ligament (DSL); 6= Deep digital flexor tendon (DDFT), 7= Digital cushion; 8= Proximal interphalageal joint (PIP); 9= Common digital extensor tendon; 10= Medullary cavity of middle phalanx; 11= Collateral (suspensory) ligament of navicular bone; 12=Cortex of the navicular bone; 13= Medullary cavity of navicular bone; 14= Compact bone forming the solar aspect of the pedal bone and the site of insertion of the DDFT; 15= distal phalanx; 16=Synovial fluid of the DIP; 17= Distal inter phalangeal joint (DIP); 18= distal sesamoidean impair ligament; B= Navicular bursa.

Fig. (2). Sagittal T2-Weighted MR showed one focal low-intense signal at the palmar border of the navicular bone (White arrows).

Fig. (3). Sagittal T2-Weighted MR image showed that irregularity of the palmar cortex of the navicular bone which appear as focal low-intense signal area (White arrows).

Fig. (4). Transverse T2-weighted MR image showed irregular linear (decreased signal intensity or black line) discontinuity of the homogeneous intermediate-intense signal of the medullary cavity of the navicular bone

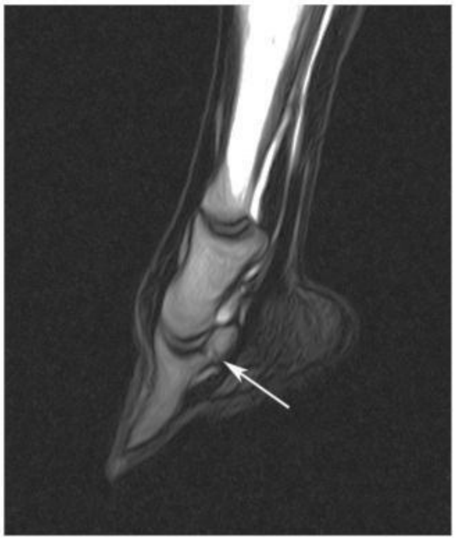


Fig. (5)

Fig. (6)

Fig. (7)

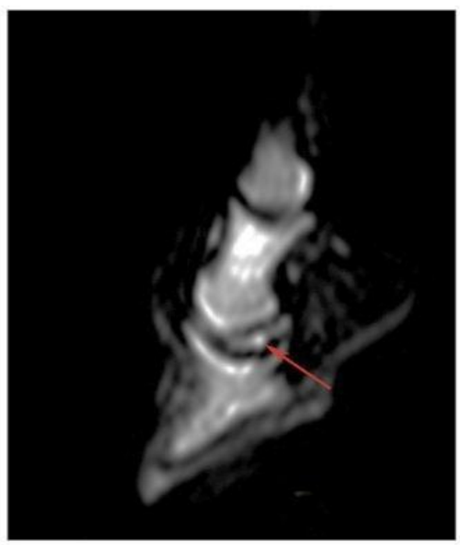


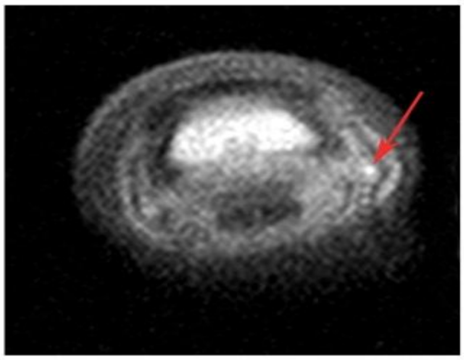
Fig. (8)

Fig. (5). Sagittal T2-weighted MR image presence low-intense signal line cross the homogeneous intermediate-intense signal of the medullary cavity of the navicular bone (white arrow).

Fig. (6). Sagittal STIR-weighted MR image, presence of two hypo-intense signal spots (Black area) at the distal third of the medullary cavity of the navicular bone (Red arrow) with presence of linear hyper- intense signal at the middle longitudinal axis the medullary cavity of navicular bone.

Fig. (7). Sagittal STIR-Weighted MR image, showed loss of continuity of the homogeneous intermediate-intense signal of articular cartilage and replaced with hypo-intense signal part at the palmar aspect of DIP joint (Red arrow)

Fig. (8). Sagittal T2-Weighted MR image showed hyper-intense signal area at the medial aspect of the inter-mediate-intense signal of the articular cartilage of the DIP joint.



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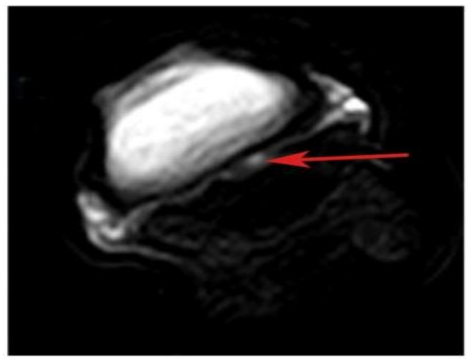

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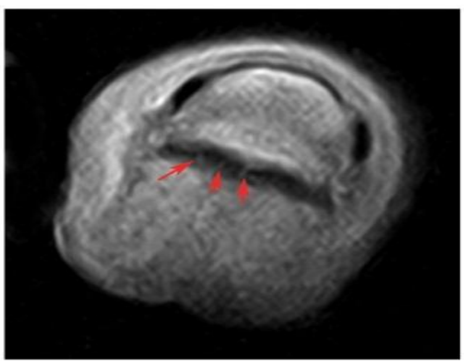

Fig. (11)

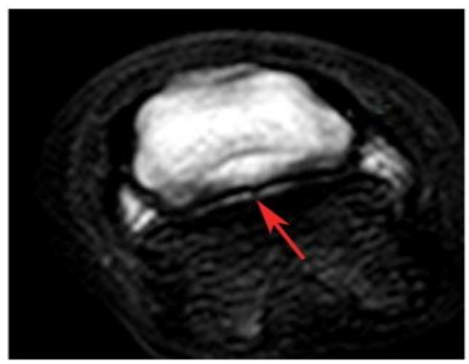

Fig. (12)

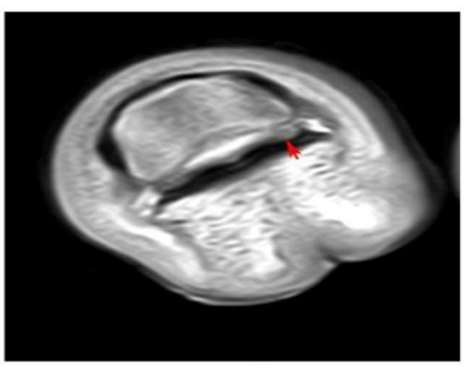

Fig. (13)

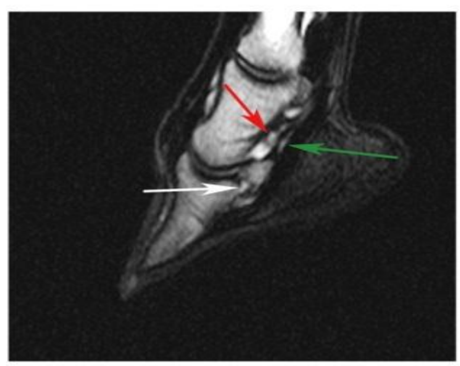

Fig. (14)

Fig. (9). Transverse T1-Weighted MR image, presence of hyper-intense signal spot area in the medial collateral ligament of the DIP joint (Red arrows)

Fig. (10). Transverse T2 -weighted MR image notice hyper- intense signal spot in dorsal border of the DDFT (white arrow)

Fig. (11). Transverse T1-Weighted MR image, presence of multiple lines of white or grey (high-intensity signal) within the normally intensity signal of the DDFT (Red arrows)

Fig. (12). Transverse T2-weighted MR image, notice loss of the hyper-intense signal continuity of the dorsal border of the DDFT appears as hypo-intense signal area (Red arrow)

Fig. (13). Transverse T1-Weighted MR image, presence of inter-mediate intense signal swelling in the medial lobe of DDFT (Red arrow).

Fig. (14). Sagittal T2-Weighted MR image, presence of hyper-intense signal at the dorsal border of the DDFT (Green arrow) and in distal sesamoisean impair ligament (DSIL) (White arrow). There is increase the size of the collateral (suspensory) ligament of the navicular bone at the distal part with increasing in its intense signal (Red arrow)

Discussion

The use of donkey forelimb digits for this study was important due to the lack of scan studies (MRI) of donkey's digits suffered from different affections.

No trails were done to record T1 and T2 relaxation time in the postmortem digits. All vascular structures have high-intense signal in cadavers' digits. MRI gives different signal intensities according to tissue density such as bone marrow, connective tissue, fat, synovial and vascular tissues which produced high intense signal images while compact bone, articular cartilage, tendons and ligaments produced low intense signal. This finding is in correlation with **(Park *et al.*, 1987)** in horse.

MRI has the ability to illustrate the foot-originated pain lameness; explain and detect many of soft tissue injuries that had been difficulty to be recognized and has a great benefit to our comprehension to the pathological affections of the navicular bone **(Dyson *et al.*, 2007)** in horse**.**

MRI has many more advantages rather than the other imaging techniques, such as radiography, ultrasonography, and computed tomography. MRI does not use ionizing radiation and provides multilane, 3D imaging capabilities for both hard and soft tissues. **(Whitton *et al.*, 1998** and **Tietje *et al.*, 2001)** in horse**.**

Normally, navicular bone has a clearly demarcated cortex and medulla. This is in agreement with **(Dyson *et al.*, 2005 and Dyson *et al.*, 2006).**

Palmar cortex of the navicular bone has localized hypo-intense signal area due to focal fibrocartilage loss. This is in agreement with **(Dyson *et al.*, 2007)** who attributed this case to presence of degenerative changes at this region in horse.

The results showed that, the presence of irregular palmar border of the navicular bone which appears as focal low-intense signal area. This is in correlation with **(Park *et al.*, 1987)** who recorded that, defects in the flexor cortex of the navicular bone usually had focal adhesions to the DDFT.

The results showed in sagittal STIR-weighted MR images of two digits revealed, the presence of two hypo-intense signal spots (Black area). This is in agreement with **(Mair *et al.*, 2005)** who attributed this to consistent with mineralization within the navicular bone. Also, the presence of low- intense signal irregular line in the central part of the navicular bone is compatible with increased mineralization, possibly the result of a fracture. This is in correlation with **(Dyson *et al.*, 2002)** in horse.

The articular cartilage has inter-mediate-intense signal and in T2-weighted images which is clearly defined by the adjacent high intensity signal of synovial fluid. This is in correlation with **(Dyson *et al.*, 2002)**

Focal cartilage defects were not associated changes in the adjacent sub-chondral bone. The articular cartilage appeared with focal decrease in signal intensity, or cartilage surface irregularity. This is in correlation with **(Park *et al.*, 1987)** in horse**.**

In sagittal STIR-Weighted MR image of three digits, there were loss of continuity of the homogeneous intermediate-intense signal of articular cartilage and replaced with hypo-intense signal part at the palmar aspect of DIP joint. This is in correlation with **(Dyson *et al.*, 2005)** who noticed that, focal cartilage defects may be missed unless there are associated changes in the adjacent sub-chondral bone. Cartilage pathology in the horse is usually associated with focal decrease in signal intensity, surface irregularity in horse.

Sagittal T2-Weighted MR image of one digit showed hyper- intense signal area at the medial aspect of the inter-mediate intense signal of the articular cartilage of the DIP joint. This is in correlation with **(Dyson *et al.*, 2006)** who recorded that focal osseous cyst-like lesions have been seen associated with the proximal articular surface of the distal phalanx, characterized by focal high signal in fat suppressed images within the sub-chondral and adjacent cancellous bone, in the T1- and T2-weighted images.

Normal DDFT has uniform, low signal intensity with tendon fascicles which were separated by lines of higher signal intense. This is in agreement with **(Murray *et al.*, 2004)** in horse**.**

Lesion was detected as dorsal border irregularity and identified only in transverse T1-weighted images due to degenerative changes which appear as high-intense signal spot or due to dorsal abrasion which appear as low-intense signal area. Core lesion was associated with swelling of the affected lobe associated swelling of the digital flexor tendon sheath (DFTS) which appear as area of white or grey (high-intensity) signal within the normally intensity signal of the tendon. This is in agreement with (**Mair *et al.*, 2005)** in horse**.**

In transverse T1-Weighted MR image of three digits showed that presence of core lesion which appear as multiple lines of white or grey (high-intensity) signal within the normally intensity signal of the tendon. This is in agreement with **(Kristoffersen et al., 2004)** who mentioned that in transverse SPGR image of a DDFT at the level of the middle phalanx, with a dorsal core lesion and swelling of the medial lobe and there is a sagittal split in the axial aspect of the lateral lobe of the DDFT in horse.

Collateral ligaments of the DIP Joint has uniform, low intensity signal. Our results showed that, the presence of hyper-intense signal spot in the medial one and which may be attributed to repeat trauma and acute inflammation which causes in increasing signal intensity of this lesion and could be identified only in Transverse T1-weighted images. This is in correlation with **(Schneider, 2003)** who mentioned that, Lesions identified only in T1-weighted images may be chronic or degenerative. Transverse images were the most sensitive in horse.

A normal CSL has a uniform low intensity signal in all images sequences and is symmetrical in thickness medially and laterally. Its borders are clearly demarcated by the high signal intensity of fluid in the palmar recess of the DIP joint and the navicular bursa. Acute injuries of CSL were characterized by enlargement of the ligament and increased signal intensity in all images sequences. This is in agreement with **(Murray *et al.*, 2006)** who recorded that, there was sometimes focal increased signal intensity in the navicular bone at the ligament's insertion in fat suppressed images, or linear increased signal intensity extending through the bone to the origin of the DSIL in horse.

Normal DSIL has a heterogeneous appearance on transverse images. Lesions were characterized by enlargement of the ligament, with larger areas of low-intense signal in T1-weighted images and high signal intensity in T2-weighted and fat sup-pressed images. In acute injury, there was sometimes increased signal intensity in fat suppressed images at the ligament's origin in the navicular bone. This is in agreement with **(Dyson *et al.*, 2007)** in horse.

In **conclusion,** Using MRI in examination of donkey's digits has been possible to identify many lesions that may be considered as a cause of lameness in donkeys. MRI results were of more accurate identification to the causes of foot lesions; more suitable treatment regimens could be established.

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