

## Journal of the Hellenic Veterinary Medical Society

Vol 66, No 4 (2015)



### Clinical application of adipose-derived stromal vascular fraction in 3 Thoroughbred horses with superficial digital flexor tendonitis: Case Report

P. TYRNENOPOULOU (Π. ΤΥΡΝΕΝΟΠΟΥΛΟΥ), N. DIAKAKIS (Ν. ΔΙΑΚΑΚΗΣ), S. ANGELOPOULOU (Σ. ΑΓΓΕΛΟΠΟΥΛΟΥ), A. PYRROS (Α. ΠΥΡΡΟΣ), E. MPAROUS (Ε. ΜΠΑΡΟΥΣ), G. KOLIAKOS (Γ. ΚΟΛΙΑΚΟΣ), M. KARAYANNOPOULOU (Μ. ΚΑΡΑΓΙΑΝΝΟΠΟΥΛΟΥ)

doi: [10.12681/jhvms.15865](https://doi.org/10.12681/jhvms.15865)

Copyright © 2018, P TYRNENOPOULOU, N DIAKAKIS, S ANGELOPOULOU, A PYRROS, E MPAROUS, G KOLIAKOS, G KARAYANNOPOULOU



This work is licensed under a [Creative Commons Attribution-NonCommercial 4.0](https://creativecommons.org/licenses/by-nc/4.0/).

#### To cite this article:

TYRNENOPOULOU (Π. ΤΥΡΝΕΝΟΠΟΥΛΟΥ) P., DIAKAKIS (Ν. ΔΙΑΚΑΚΗΣ) N., ANGELOPOULOU (Σ. ΑΓΓΕΛΟΠΟΥΛΟΥ) S., PYRROS (Α. ΠΥΡΡΟΣ) A., MPAROUS (Ε. ΜΠΑΡΟΥΣ) E., KOLIAKOS (Γ. ΚΟΛΙΑΚΟΣ) G., & KARAYANNOPOULOU (Μ. ΚΑΡΑΓΙΑΝΝΟΠΟΥΛΟΥ) M. (2018). Clinical application of adipose-derived stromal vascular fraction in 3 Thoroughbred horses with superficial digital flexor tendonitis: Case Report. *Journal of the Hellenic Veterinary Medical Society*, 66(4), 215–222. <https://doi.org/10.12681/jhvms.15865>

**Clinical application of adipose-derived stromal vascular fraction in 3  
Thoroughbred horses with superficial digital flexor tendonitis:  
Case Report**

**Tyrnenopoulou P.<sup>1</sup>, Diakakis N.<sup>1</sup>, Angelopoulou S.<sup>2</sup>, Pyrros A.<sup>2</sup>, Mparous E.<sup>2</sup>,  
Koliakos G.<sup>3</sup> and Karayannopoulou M.<sup>4</sup>**

<sup>1</sup>*Equine Unit, Companion Animal Clinic, School of Veterinary Medicine, Faculty of Health Sciences,  
Aristotle University of Thessaloniki, Thessaloniki, Greece*

<sup>2</sup>*Veterinary Clinic, Athens Racetrack, Greece*

<sup>3</sup>*Department of Biochemistry, Medical School, Faculty of Health Sciences, Aristotle University of Thessaloniki, Greece*

<sup>4</sup>*Surgery and Obstetrics Unit, Companion Animal Clinic, School of Veterinary Medicine, Faculty of Health Sciences,  
Aristotle University of Thessaloniki, Greece*

**Κλινική εφαρμογή κλάσματος βλαστοκυττάρων προερχόμενων από λιπώδη  
ιστό σε ίππους της Αγγλικής καθαρόαιμης φυλής με τενοντίτιδα του επιπολής  
καμπτήρα των φαλάγγων μυός: Αναφορά σε 3 περιστατικά**

**Τυρνενοπούλου Π.<sup>1</sup>, Διακάκης Ν.<sup>1</sup>, Αγγελοπούλου Σ.<sup>2</sup>, Πύρρος Α.<sup>2</sup>, Μπαρούς Ε.<sup>2</sup>,  
Κολιάκος Γ.<sup>3</sup> και Καραγιαννοπούλου Μ.<sup>4</sup>**

<sup>1</sup>*Μονάδα Ιπποειδών, Κλινική Ζώων Συντροφιάς, Τμήμα Κτηνιατρικής, Σχολή Επιστημών Υγείας, Α.Π.Θ*

<sup>2</sup>*Κτηνιατρική Κλινική, Ιππόδρομος Αθηνών*

<sup>3</sup>*Εργαστήριο Βιολογικής Χημείας, Τμήμα Ιατρικής, Σχολή Επιστημών Υγείας, Α.Π.Θ.*

<sup>4</sup>*Μονάδα Χειρουργικής και Μαιευτικής, Κλινική Ζώων Συντροφιάς, Τμήμα Κτηνιατρικής, Σχολή Επιστημών Υγείας, Α.Π.Θ.*

*Correspondence:* Tyrnenopoulou P.  
Aristotle University of Thessaloniki, Faculty of Health Sciences,  
School of Veterinary Medicine, Companion Animal Clinic,  
11 St. Voutyra str., 546 27 Thessaloniki, Greece;  
E-mail address: giwtatyr@gmail.com

*Υπεύθυνος αλληλογραφίας:* Τυρνενοπούλου Π.  
Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Σχολή Επιστημών Υγείας  
Τμήμα Κτηνιατρικής Κλινική Ζώων Συντροφιάς  
Στ. Βουτυρά 11, Θεσσαλονίκη 54627  
E-mail: giwtatyr@gmail.com

*Date of initial submission: 01.08.2014*  
*Date of revised submission: 17.03.2015*  
*Date of acceptance: 19.03.2015*

**ABSTRACT.** Tendon injuries are considered major causes of wastage in active Thoroughbred racehorses as they are among the most common musculoskeletal injuries in equine athletes. There has been considerable interest in the potential use of concentrated adipose tissue digest, such as stromal vascular fraction, in tendon overstrain injuries. It has been reported that the adipose-derived stem cells, which are present in stromal vascular fraction of adipose tissue, can promote neovascularization and improve healing process. The purpose of this study was to evaluate the potential effects of intralesional use of autologous adipose-derived stromal vascular fraction on tendon healing in three Thoroughbred active racehorses with moderate to severe superficial digital flexor tendonitis. Based on the results of this report it seems that intratendinous injection of autologous adipose-derived stromal vascular fraction leads to marked clinical improvement and reduction of rehabilitation period in racehorses suffering from superficial digital flexor tendonitis.

**Keywords:** adipose-derived stem cells; horse;stromal vascular fraction;tendonitis

**ΠΕΡΙΛΗΨΗ.** Οι τενοντίτιδες, μια από τις πιο συχνές μυοσκελετικές παθήσεις των ίππων αθλητικής ιππασίας, αποτελούν σημαντική αιτία πρόωρης αποχώρησης από την αθλητική δραστηριότητα των δρομώνων ίππων. Την τελευταία δεκαετία, υπάρχει έντονο ερευνητικό ενδιαφέρον όσον αφορά στη χρήση βλαστοκυττάρων προερχόμενων από το λιπώδη ιστό σε τραυματισμούς των τενόντων. Έχει αναφερθεί ότι τα βλαστοκύτταρα τα οποία προέρχονται από λιπώδη ιστό προάγουν την νεοαγγείωση και επιταχύνουν τις επουλωτικές διεργασίες. Σκοπός της παρούσας μελέτης ήταν η αξιολόγηση της αποτελεσματικότητας της ενδοτενόντιας έγχυσης αυτόλογου κλάσματος βλαστοκυττάρων προερχόμενων από λιπώδη ιστό σε 3 αθλητικούς ίππους της Αγγλικής καθαρόαιμης φυλής με μέτριου έως σοβαρού βαθμού τενοντίτιδα του τένοντα του επιπολής καμπτήρα των φαλάγγων μύος. Η ενδοτενόντια χορήγηση αυτόλογου κλάσματος βλαστοκυττάρων του λιπώδους ιστού φαίνεται πως βελτιώνει την κλινική εικόνα ίππων με τενοντίτιδα του επιπολής καμπτήρα των φαλάγγων μύος, μειώνοντας σημαντικά τη διάρκεια του χρόνου αποκατάστασης.

**Λέξεις ευρετηρίασης:** βλαστοκύτταρα, κλάσμα βλαστοκυττάρων προερχόμενων από λιπώδη ιστό, ίππος, τενοντίτιδα

## INTRODUCTION

Tendon over-strain injuries are the most common musculoskeletal injuries (46% of limb injuries) in athletic horses. A longitudinal study in United Kingdom reported an incidence rate of tendon or ligament injury of 2.77 cases per 1,000 race starts, in flat racing Thoroughbreds (Williams et al., 2001). In a 12-year epidemiological study conducted in racing Thoroughbreds in Hong Kong, tendon injury has emerged as the most common cause of retirement (Lam et al., 2007).

Superficial digital flexor tendonitis represents a substantial cause of wastage within the horse industry, with an incidence of 8-43% in racing Thoroughbreds (Dowling et al., 2000), whereas most of the published data are related to flat racing

horses (Genovese et al., 1996; Gibson et al., 1997). Superficial digital flexor tendon (SDFT) injuries have prolonged healing process and their prognosis is best described as guarded, since only a 20-60% of the affected horses return to racing and up to 80% of them subsequently sustain re-injury (Sawdon et al., 1996; Dowling et al., 2000).

Recently, there has been a considerable interest in the potential use of autologous biological products for the treatment of tendinopathies. Cell based and biologic autologous therapies, such as adipose-derived stem cells (ADSCs), have been rapidly popularized over the past 10 years for the treatment of overstrain tendon injuries (Caplan and Bruder, 2001; Hildebrand et al., 2002; Schnabel et al., 2007). It is currently known that concentrated adipose

tissue digest (e.g. stromal vascular fraction; SVF), derived from manipulation of adipose tissue such as homogenization, enzymatic of mesenchymal stem contains a large number of mesenchymal cells (MSC) that can promote tissue healing (Gimble et al., 2011). The purpose of this study was to present and evaluate the outcome of the intralesional administration of adipose-derived SVF in three Thoroughbred racehorses suffering from superficial digital flexor tendonitis.

### Case description

All 3 Thoroughbred horses were geldings presented with acute onset of severe lameness in a forelimb due to a moderate to severe tendon injury. One horse had competed one day prior to the onset of lameness. The cross-sectional areas of the tendonitis lesions were obtained at the site of maximal injury and were recorded as the percentage of the total tendon area. All horses included in this study, achieved high performance levels during the last 6 months.

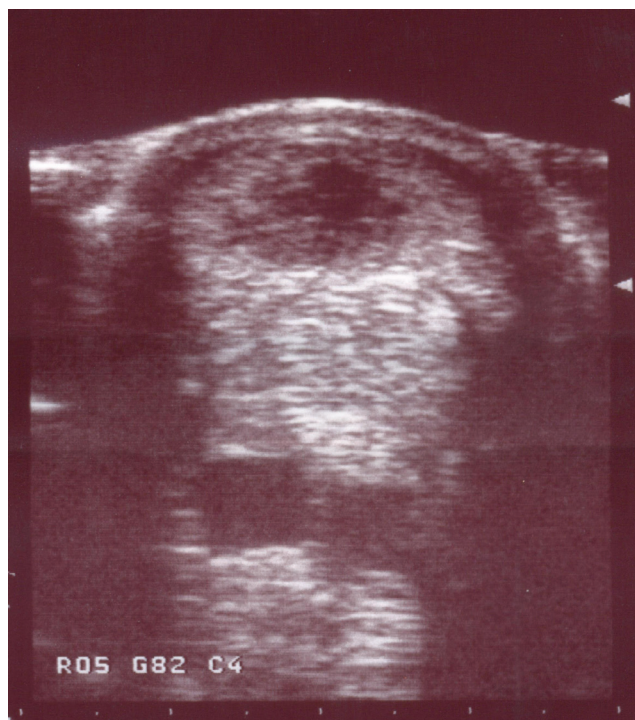


Figure 1.

## CLINICAL EVALUATION

### Case 1

A 5-year old Thoroughbred gelding was examined for lameness evaluation 5 days after racing. Palpation of the right forelimb revealed an enlarged SDFT over the middle and distal third of the left metacarpal region. In the same region, oedema and pain on palpation were also detected. The horse, first examined at walk and trot on a straight line, revealed severe lameness on the right forelimb, 3/5 according to AAEP scale (Anon, 1991).

The forelimb was prepared in a routine manner and ultrasonographic examination of the palmar metacarpal region with a 7,5MHz linear transducer was performed, including longitudinal and transverse views. Ultrasonography of the flexor tendons revealed enlargement of SDFT and a hypoechoic core lesion, covering approximately 60% of the cross-sectional area extending from region 1B to 3A (Genovese 1986), with the widest point in region 1B (Fig.1)

### Case 2

A 4-year old Thoroughbred gelding was presented the day after a 1400m flat race with severe lameness (3/5 according to AAEP scale) on the left forelimb. Clinical examination revealed swelling of the proximal third of the palmar metacarpal area, localized heat and pain upon palpation. Cross-sectional size of the flexor tendons was evaluated; an extended anechoic core lesion (Zone 2A and B) covering approximately 50% of the cross-sectional area was detected (Fig.2).

### Case 3

A 5-year old Thoroughbred gelding was presented with severe lameness, 4/5 according to AAEP scale, on the left forelimb. According to history data, a diagnosis of SDFT tendonitis had been made 6 months previously and the horse had returned to training three months prior to presentation. Upon clinical examination there was evidence of a localized chronic swelling on the middle



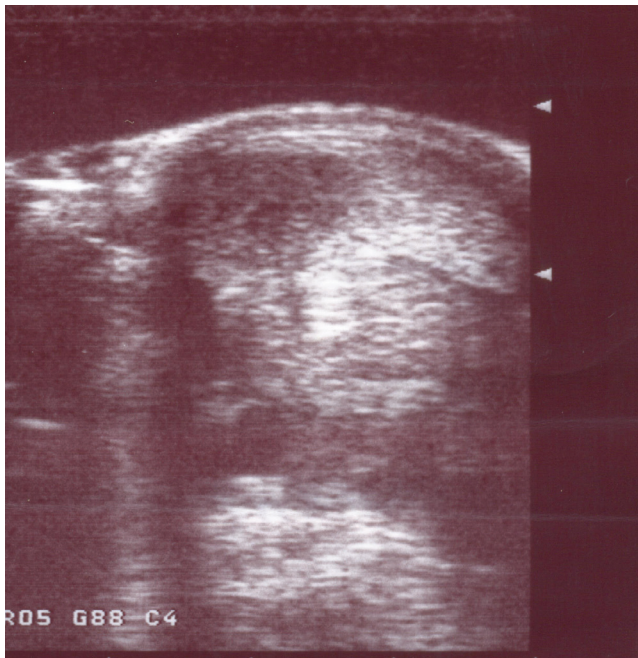


Figure 2.

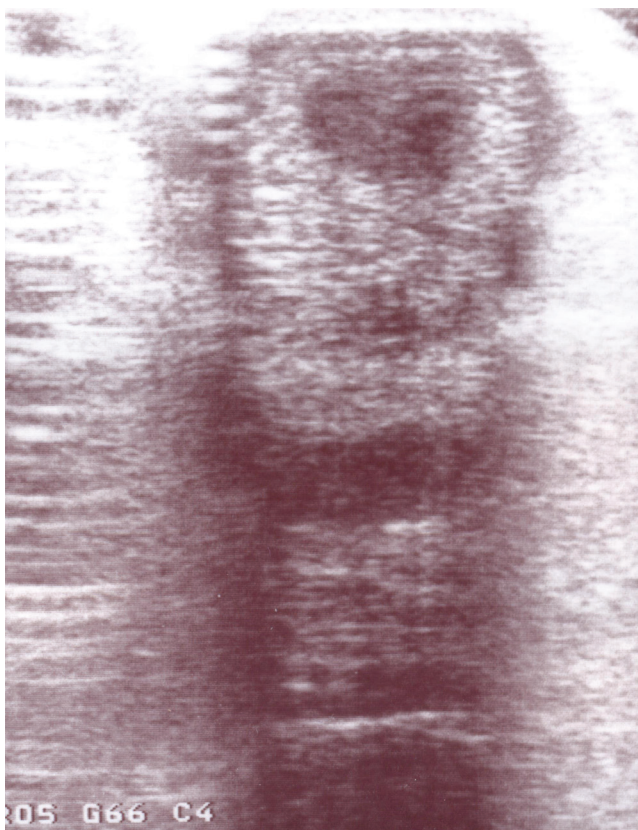


Figure 3.

and distal third aspect of the palmar metacarpal region. Ultrasonographic examination revealed poor definition of tendon margins, enlargement of the cross-sectional area, ectopic fibrosis and a hypoechoic core lesion extending to 70% of the total cross-sectional area (**Fig. 3**).

In all horses, initial treatment included stall confinement, supportive bandaging, cold hosing and NSAIDs medication for 5 days (phenylbutazone  $4.4\text{mg kg}^{-1}$  bw iv).

Seven days after each case diagnosis, it was decided to enhance healing by injecting autologous adipose-derived SVF. A routine harvest of adipose tissue from the region above the dorsal gluteal muscles was performed. The horse was sedated using romifidine ( $40\mu\text{g kg}^{-1}$  bw iv) in combination with butorphanol ( $80\mu\text{g kg}^{-1}$  bw iv). After surgical preparation, the skin and subcutaneous tissues were desensitized by local anesthetic infiltration (lidocaine HCl 2%). A 6-8cm incision, parallel to the spine, was made and 16gr of supragluteal subcutaneous adipose tissue were harvested. A routine closure using nylon suture material was performed.

The isolation of adipose-derived stem cells was performed based on standard reported techniques for human adipose-derived SVF isolation. The adipose tissue was minced with a No11 surgical blade and washed with phosphate-buffered saline solution (PBS) to remove blood. Adipose tissue was treated in equal volume of PBS containing 100U/ml type I collagenase (Biochrom, Berlin, Germany) for one hour, under constant agitation. The digested tissue was then centrifuged at  $300g$  for 30 minutes in order to isolate the SVF in pellet form. The SVF pellet was then re-suspended in PBS and washed twice. The final pellet was re-suspended in a mixture of 10% autologous serum, 10% dimethyl sulfoxide (DMSO) and 2% hydroxyethylstarch (Haes-steril 200®) in PBS. Viable nucleated cells were counted using a Newbauer plate and trypan blue. A mean total of  $1 \times 10^6$  viable nucleated cells per gram of adipose tissue were isolated. The cell suspension was placed in a cryovial, gradually cooled at a rate of  $1^\circ\text{C}$  per minute up to  $-80^\circ\text{C}$  and then stored in

liquid nitrogen until use. On the day of adipose-derived SVF application the cryovial was rapidly defrozen for 1 min at 40°C, washed once with PBS and re-suspended in 2ml autologous serum.

Ten days after adipose tissue harvesting the palmar metacarpal region was prepared for aseptic injection. Following standing sedation (romifidine, kg<sup>-1</sup> bw iv) and local analgesia (lidocaine HCl 2%), 1-2ml of the adipose-derived SVF were implanted into the core lesion of the SDFT under ultrasonographic guidance. A sterile bandage was applied for 4 days, after SVF injection.

A routine standardized rehabilitation program according to Athens racetrack was performed in all three horses. It consisted of an initial period of two months' box rest followed by gradually increasing levels of exercise (trot, canter, gallop) depending on the healing progress of each individual case. Ultrasonographic examinations were performed one and two months post implantation and subsequently at four-month intervals for one year.

**FOLLOW-UP**

All horses responded positively to the treatment described above and were able to race again within 4 months (Case 1 and Case 2) and 7 months (Case 3) of implantation. Ultrasonographic examination revealed improved density of the fibre pattern, normal fiber alignment, marked improvement in echogenicity and restoration of tendon margins (Fig. 4-6). During the recovery period, no complications such as local oedema or pain at the site of injection were recorded. Furthermore, no signs of recurrence were detected during the 1 year follow-up period. All horses were able to race again achieving high performance levels 18 months post treatment.

**DISCUSSION**

Soft tissue injuries, such as tendonitis of the SDFT, represent an important cause of wastage in racehorses, taking into consideration the prolonged

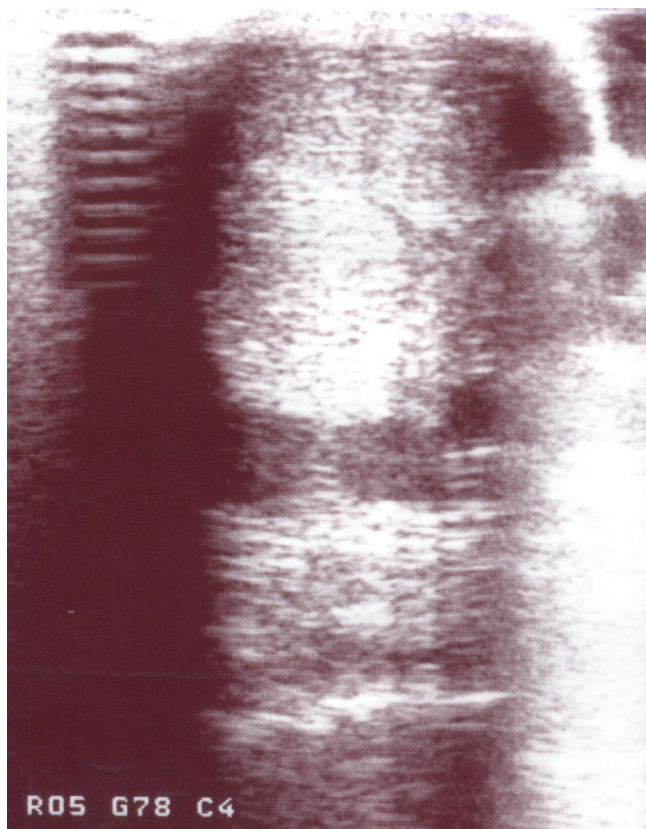


Figure 4.

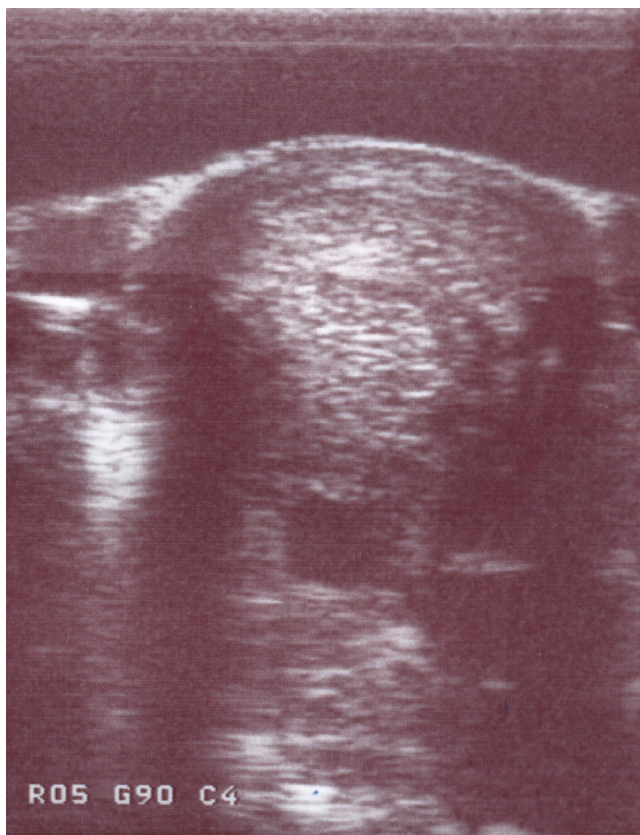


Figure 5.



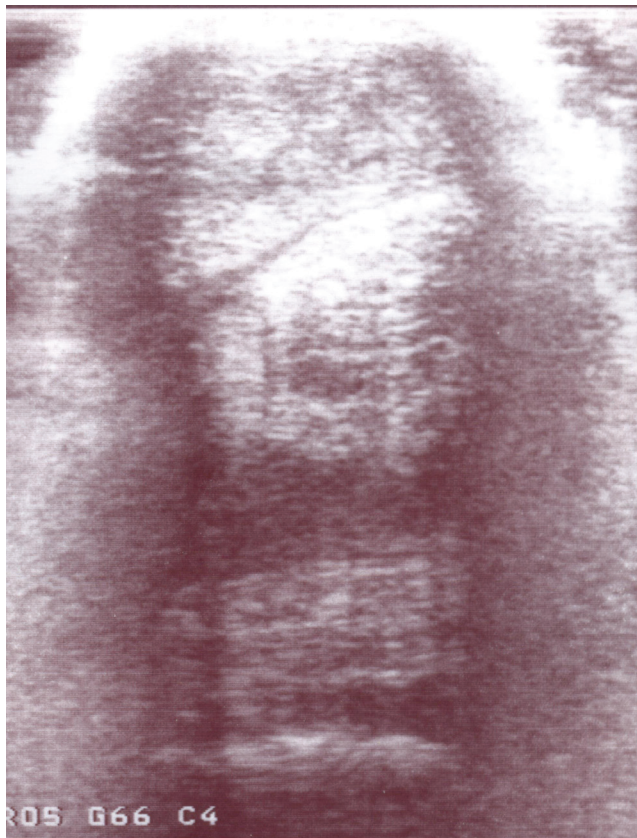


Figure 6.

recovery periods before their return in athletic activity or the possible retirement (Goodship et al., 1994). The cumulative incidence rate of flexor tendonitis among sport horses has been reported up to 66% with recurrent injury rate as high as 56% (Fortier et al., 2008). The majority of tendon injuries occur to the forelimbs (Kasashima et al., 2004; Lam et al., 2007), with the SDFT being more prone to injury in 75-93% of cases.

Tendon elasticity allows the horse to maintain high speed, storing and returning strain energy (McNeill Alexander, 2002). When a tendon is injured, the resultant scar tissue is functionally deficient in comparison to normal tendon and is also prone to re-injury at a rate of 56-66% (Dowling et al., 2000; Dyson, 2004); thus, repair process has important consequences for the affected horse in terms of athletic performance.

This primary need to restore functionality has emboldened research to the development of

regenerative therapies. In equine orthopedics, MSCs have been clinically used for bone fracture treatment, subchondral bone cysts, cartilage and tendon repair (Fortier et al., 2008). The crucial role of MSCs in tendon repair is further emphasized by several equine studies where in naturally occurring or collagenase induced core lesions treated with MSCs healing was greatly improved compared to horses treated with conventional methods and having similar rehabilitation protocol (Pacini et al., 2007; Nixon et al., 2008). Ferris and colleagues (2009), in a long term follow-up controlled study on horses with soft tissue injuries treated with MSCs, reported that 85% of the cases returned to full work presenting excellent ultrasonographic image and optimal racing results.

After their initial discovery in bone marrow, MSCs have been found in several adult and fetal tissues including adipose tissue, synovial fluid, dermis, periosteum, umbilical cord blood, placenta and amniotic fluid (Murphy et al., 2013). ADSCs have demonstrated ability to differentiate as the bone marrow-derived cells do, though to a slightly lesser degree (Im et al., 2005). In our study, the rationale of using adipose-derived SVF in order to improve tendon healing and rehabilitation is further supported by the study of Behfar and colleagues (2009) highlighting the improvement in structural properties of tendon repairs after intratendinous injection of SVF in New Zealand white rabbits. The use of MSCs, such as the ADSCs or their digest, in the treatment of tendon injuries is, therefore, well encouraged by the aforementioned studies.

The damage that follows trauma or repetitive loading of a tendon results in a prolonged period of athletic inactivity, whereas it is uncommon for the damaged tendon to restore its normal functional properties (Thorpe et al., 2010). In the present study, in horses suffering severe tendonitis of SDFT, the rehabilitation period was markedly shorter after SVF injection in the damaged tendon, compared to the mean one recorded in the Athens racetrack. The majority of horses with SDFT overstrain injuries require at least 9 months of rehabilitation before

resuming full athletic function, whereas in more severe cases, the rehabilitation is prolonged up to 18 months until the tendon restores its functionality (Davis and Smith, 2006). Apart from the clinical outcome assessed in terms of horses' return to their previous performance, the success of SVF injection in our study is further emphasized by the absence of re-injuries in the 1-year follow-up period.

Although further in vitro studies are necessary to determine the distribution and therapeutic

mechanisms of adipose-derived SVF in order to optimize its use as part of regenerative strategies, its effect on large tendon core lesions is clinically emphasized. Based on the results of this case study, despite the limited number of horses and the lack of control group, the beneficial role of SVF on accelerating the healing process is further established; the athletic success rates during the follow-up period reflect the quality of tendon repair and thus position the horse as a good long-term animal model for regenerative therapies.

## REFERENCES

- Anon (1991) Guide for Veterinary Service and Judging of Equestrian Events, 4th edn., American Association of Equine Practitioners, Lexington, Kentucky. pp 19
- Behfar M, Sarrafzadeh-Rezaei F, Hobbenaghi R, Delirez N, Dalir-Naghadeh B (2009). Effects of uncultured adipose derived stromal vascular fraction on tendon healing in rabbits: a histological and immunohistochemical study. *Iranian Journal of Veterinary Surgery*, 4(1/2);25-36.
- Caplan AI and Bruder SP (2001) Mesenchymal stem cells: building blocks for molecular medicine in the 21st century. *Trends Mol. Med.* 7;259-264.
- Davis CS, Smith RKW (2006). Diagnosis and management of tendon and ligament disorders. *Equine surgery*, 1098-1109.
- Dowling BA, Dart AJ, Hodgson DR, Smith RKW (2000). Superficial digital flexor tendonitis in the horse. *Equine Vet J*, 32(5);369-378.
- Dyson SJ (2004) Medical management of superficial digital flexor tendonitis: a comparative study in 219 horses (1992-2000). *Equine Vet J*, 36(5);415-419.
- Ferris DJ, Frisbie DD, Kisiday JD, McIlwraith CW, Hague BA, Major MD, Schneider RK, Zubrod CJ, Watkins JJ, Kawcak CE and Goodrich LR (2009) Clinical follow-up of horses treated with bone marrow derived mesenchymal stem cells. *Proc. Am. Ass. equine Practnrs.* 55;59-60
- Fortier LA, Smith RK (2008) Regenerative medicine for tendinous and ligamentous injuries of sport horses. *Veterinary Clinics of North America: Equine Practice*, 24(1);191-201.
- Genovese RL, Rantanen NW, Hauser ML, Simpson, BS (1986) Diagnostic ultrasonography of equine limbs. *The Veterinary clinics of North America. Equine practice*, 2(1);145-226.
- Genovese RL, Reef V, Longo K, Byrd J and Davis W (1996) Superficial digital flexor tendonitis: Long term sonographic and clinical study of racehorses. In: *Proceedings of the Dubai International Equine Symposium: The Equine Athlete: Tendon, Ligament and Soft Tissue Injuries*, Eds: Rantanen N and Hauser, M Rantanen Design, California. pp 187-200.
- Gibson K, Burbidge H and Pfeiffer D (1997) Superficial digital flexor tendonitis in Thoroughbred racehorses: outcome following non-surgical treatment and superior check desmotomy. *Aust. vet. J.* 75;631-635.
- Gimble JM, Bunnell BA, Chiu ES, Guilak F (2011). Concise Review: Adipose-Derived Stromal Vascular Fraction Cells and Stem Cells: Let's Not Get Lost in Translation. *Stem Cells*, 29(5);749-754.
- Goodship AE (1993) The pathophysiology of flexor tendon injury in the horse *Equine vet. Educ.* 5;23-29
- Goodship AE, Birch HL, & Wilson AM (1994) The pathobiology and repair of tendon and ligament injury. *The Veterinary clinics of North America. Equine practice*, 10(2);323-349.
- Hildebrand KA, Jia F, Woo SL (2002) Response of donor and recipient cells after transplantation of cells to the ligament and tendon. *Microsc. Res. Tech.*, 58;34-38
- Im GI, Shin YW, Lee KB (2005) Do adipose tissue-derived mesenchymal stem cells have the same osteogenic and chondrogenic potential as bone marrow-derived cells?. *Osteoarthritis and cartilage*, 13(10);845-853.
- Kasashima Y, Takahashi T, Smith RKW, Goodship AE, Kuwano A, Ueno T, Hirano S (2004) Prevalence of superficial digital flexor tendonitis and suspensory desmitis in Japanese Thoroughbred flat racehorses in 1999. *Equine Vet J*, 36(4);346-350.
- Lam KH, Parkin TDH, Riggs CM, Morgan KL (2007) Descriptive analysis of retirement of Thoroughbred racehorses due to tendon injuries at the Hong Kong Jockey Club (1992-2004). *Equine Vet J*, 39(2);143-148.
- McNeill Alexander R (2002) Tendon elasticity and muscle function.



- Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 133(4);1001-1011.
- Murphy MB, Moncivais K., Caplan AI (2013). Mesenchymal stem cells: environmentally responsive therapeutics for regenerative medicine. *Experimental & molecular medicine*, 45(11);e54
- Nixon AJ, Dahlgren LA, Haupt JL, Yeager AE, Ward DL (2008) Effect of adipose-derived nucleated cell fractions on tendon repair in horses with collagenase-induced tendinitis. *American journal of veterinary research*, 69(7);928-937.
- Pacini S, Spinabella S, Trombi L, Fazzi R, Galimberti S, Dini F, Carlucci F, Petrini M (2007) Suspension of bone marrow-derived undifferentiated mesenchymal stromal cells for repair of superficial digital flexor tendon in race horses. *Tissue engineering*, 13(12);2949-2955.
- Sawdon H, Yovich JV, Booth T (1996) Superficial digital flexor tendonitis in racehorses: Long term follow up of conservatively managed cases. *Aust. equine vet.* 14;21-25.
- Schnabel LV, Mohammed HO, Miller BJ, McDermott WG, Jacobson MS, Santangelo KS, Fortier LA (2007) Platelet rich plasma (PRP) enhances anabolic gene expression patterns in flexor digitorum superficialis tendons. *Journal of orthopaedic research*, 25(2);230-240.
- Thorpe CT, Clegg PD, Birch HL (2010) A review of tendon injury: why is the equine superficial digital flexor tendon most at risk?. *Equine Vet J*, 42(2);174-180.
- Williams RB, Harkins LS, Hammond CJ, Wood JLN (2001) Racehorse injuries, clinical problems and fatalities recorded on British racecourses from flat racing and National Hunt racing during 1996, 1997, and 1998. *Equine Vet J*, 33:478 – 486.