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CHIRURGIE DE LA main
Chirurgie de la main 29 (2010) 155–166

Recent advance

The role and mechanical behavior of the connective tissue in tendon sliding

Le rôle et comportement dynamique du tissu conjonctif dans le glissement des tendons

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Abstract

After carrying out 215 in-vivo dissections, 65 of which were video-recorded, the authors propose that the current representation of the notion of the tendon sliding is incorrect. It is suggested that tendon sliding is explained by the existence of a mechanical adaptable multimicrovacuolar and fibrillar tissue. This tissue enables complete sliding without any dynamic influence on the surrounding tissues. The new theory is based on a polyhedric fibrillar framework, apparently chaotic and complex, subtending the microvacuolar gel, a concept that is to be found everywhere in the human body.

Keywords: Tendon; Carpal sheath; Sliding system; Tendon vascularization; Finger flexor reconstruction; Collagenic fibrillar framework; Microvacuole

Résumé

Aprés avoir réalisé 215 dissections chirurgicales dont 65 ont été enregistrées en vidéo, les auteurs remettent en question la description actuelle du glissement tendineux. Un nouveau modèle basé sur l'existence d'un système multifibrillaire et multimicrovacuolaire est proposé. Les unités fonctionnelles de ce modèle sont des microvacuoles. polyédriques, disposées en réseau, partout dans le corps humain. Sur plan biomécanique, ce réseau a des interconnections dont le comportement non linéaire permet une adaptabilité optimale à la contrainte.

Mots clés : Tendon fléchisseur ; Système de glissement ; Vascularisation tendineuse ; Reconstruction ; Maillage collagène fibrillaire ; Microvacuole

1. Introduction

For many years, the only scientific explanations concerning the natural mechanism of flexor tendon mobility in the fingers was a notion of virtual space or the existence of loose connective tissue organized in layers, but the biomechanical foundations for these theories were rather vague to say the least [1–3].

The strange biomechanical construction and odd histological configuration of this model cause utter confusion between the roles and the definitions of the paratendon, mesotendon, peritendon and sheaths, and has largely influenced present surgical procedures [4–9] (Fig. 1).

When surgical dissection is performed in vivo, visual magnification demonstrates the presence of a vast arrangement of tissue connections, a histological continuum with no clear separation between the skin, the hypodermis, the vessels, the aponeurosis and the muscles. Structures, which allow sliding to take place are present everywhere.

In this paper we present the physiology of flexor tendon sliding in human tissues. As a result of micro-anatomical

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1297-3203/$ – see front matter
doi:10.1016/j.main.2010.04.002

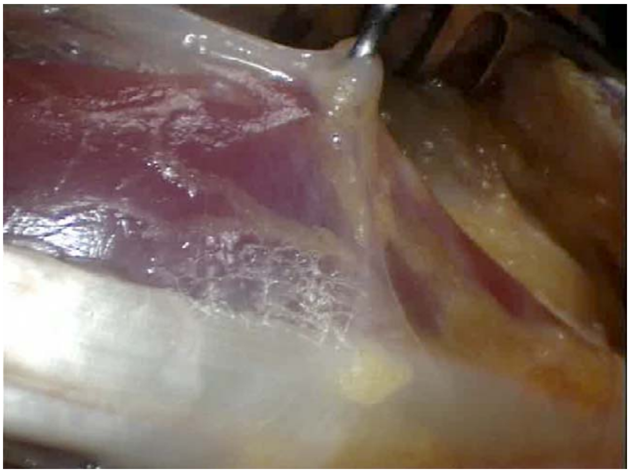

Fig. 1. When the tendon moves, its movement is barely discernible in the neighboring tissue. Tendon may go far and fast without any hindrance. There is an absorbing system (Video clip published online exclusively).

observations we made during video analysis, new hypotheses have emerged concerning the organization of the subcutaneous tissues.

2. Material and methods

2.1. In vitro study of the paratendon

This study was carried out on 30 human upper limb biopsies of flexor digitorum superficialis (FDS) and profundus (FDP) with their surrounding sheaths, and 26 animal samples including the flexor carpi radialis from cattle, in which the organization is very similar to that of the human flexor profondus (Fig. 2).

The preparation was treated with potassium bichromate, placed in formalin and finally in caustic soda, thus allowing softer and more complete hydrolysis (Pr J.-P. Delage, Inserm Laboratories, Bordeaux, France). Then it was frozen and freeze-dried under standard conditions for dehydration. Afterwards, it was dissected under a binocular loupe at 3.5 times magnification. Samples were taken, given a gold-metallic finish and then observed under the electron microscope. The Inserm Laboratories (Pr Herbage, Lyon, France) helped us to analyze the chemical components of this connective tissue.

2.2. In vivo study of digital zones III, IV and V by micro-anatomical videoendoscopic observation

The tendon gliding system was observed and recorded on video in 65 cases of tendon revascularization in Kleinert's zones III, IV and V after releasing the tourniquet.

All patients gave their consent before surgery. Of the 65 cases, 57 procedures were forearm island reverse flaps. The remaining eight procedures were axillary flaps. Static and dynamic observations were carried out using an endoscope with an attached Tricam 221030 fiberoptic camera and Xenon Nova 201315 light source at 25 times magnification.

Continuous sequences were captured on video during flexion of the digital flexors to allow subsequent analysis.

3. Results

3.1. In vivo observations

3.1.1. Macroscopic observations

When the flexor tendon moves, its movement is barely discernible in the palm. There is no dynamic repercussion of the movement on the skin surface. However, the flexor tendon

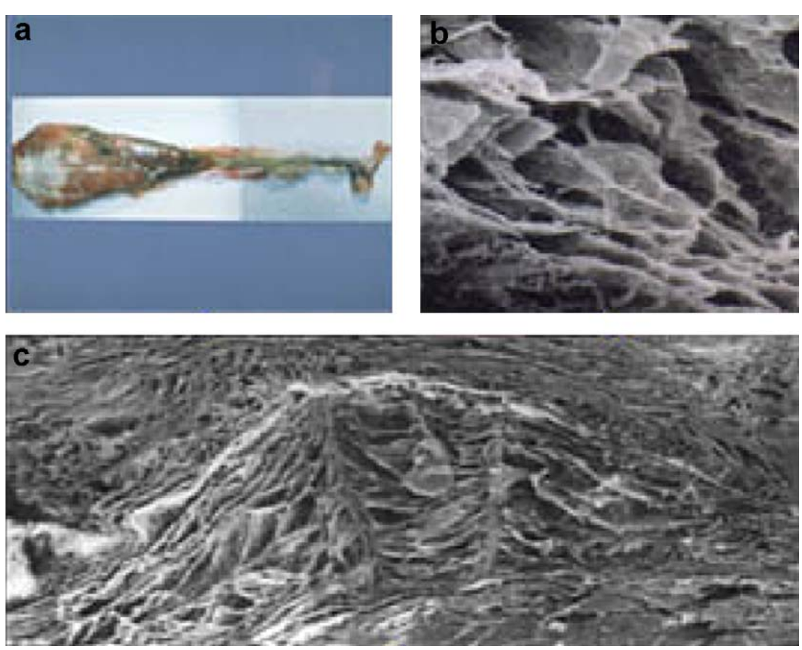

Fig. 2. MVCAS under the electron microscope; a: our basic experimental material: the Flexor Carpi radialis of cattle; b: surrounding tissues composed of microvacuoles; c: MVCAS under the electron microscope, the notion of continuous matter ruling out any lamellar organization.