The Palmar Fascia after Treatment by the Continuous Extension Technique for Dupuytren's Contracture

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THE PALMAR FASCIA AFTER TREATMENT BY THE CONTINUOUS EXTENSION TECHNIQUE FOR DUPUYTREN'S CONTRACTURE

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After complete elongation using the continuous extension technique the palmar fascia of four patients with Dupuytren's contracture was examined by light and electron microscopy and compared with non-elongated samples from 20 patients at the same clinical stage of the disease. Nodules and cords were no longer clinically recognizable after extension. The tissue contained collagen fibrils of uniform diameter (about 50 nm), densely packed in fibres parallel to the stretching force. Fine filaments (presumably proteoglycans) formed a network which was intermingled with and periodically bound to the collagen fibrils. Fibroblasts and myofibroblasts with an high biosynthetic activity and oxytalan-like microfibrils were aligned along the collagen fibres.

The results show that in Dupuytren's disease the contracted palmar fascia reacts to external forces with neoformation and reorientation of all tissue components by myofibroblasts.

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Dupuytren's disease is characterized by progressive shortening of the palmar fascia, reducing the function of the fingers. In 1991 Messina and Messina introduced the continuous extension technique for elongation of the contracted palmar fascia. In some cases, there was no recurrence of the contracture after this treatment. However, removal of the extended fascia was still necessary, especially if the contracture was severe. This can be done with a reduced risk of complications compared with the removal of the tissue from the contracted finger (Messina and Messina, 1993).

To gain insight into the reactions inside the palmar fascia during continuous extension and to analyse possible causes of recurrence of the contracture, samples of tissue from four patients treated by this method before surgery were compared with samples of fascia which had not been extended but came from 20 patients at the same stage of the disease.

METHODS

Four patients (three male and one female) with advanced Dupuytren's disease (clinical stages 3 and 4) were operated upon. (For a complete description of the procedure see Messina and Messina (1991).) In brief, two self-drilling pins were inserted transversely through the fifth and fourth metacarpal bones at their proximal and distal metaphyses. A Kirschner wire was then inserted transversely through the distal metaphysis of the middle phalanx or/and the proximal metaphysis of the distal phalanx of the contracted finger. The continuous extension-device – a stable construction of several interconnected rods (Biotek, Torino, Italy)–was fixed to the proximal pins and via a traction loop to the Kirschner wire (Fig 1a and b). A screw enabled the retracted finger to be extended 2 mm per day.

After 3 weeks the palmar fascia was fully extended. Since recurrence of the contracture was anticipated, the diseased fascia was dissected out. For comparison, contracted palmar fascia of 20 patients at the same clinical stage, but not treated by continuous extension, was used. All the specimens were immediately fixed to a piece of cork to avoid deformation and to maintain

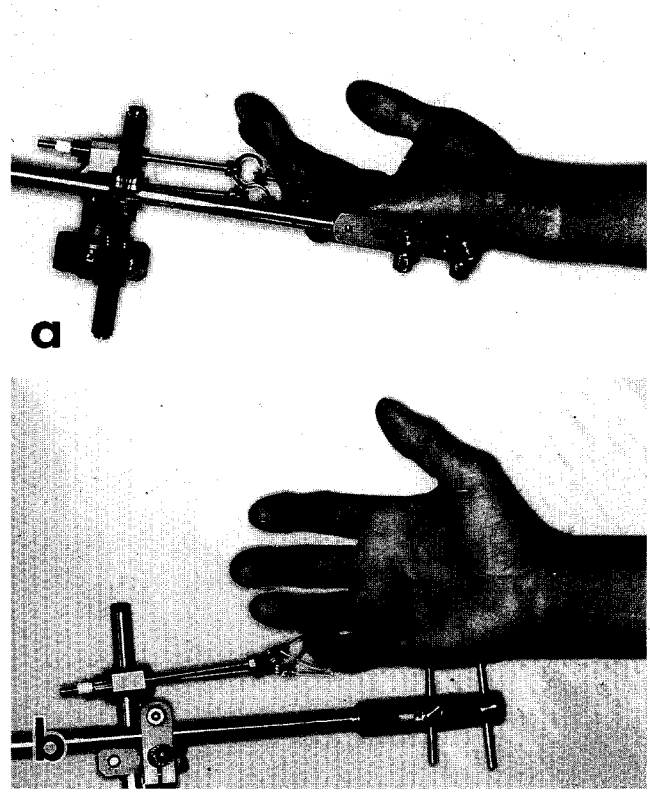

Fig 1 The continuous extension-device is fixed by two pins inserted through the fifth and fourth metacarpal bones at their proximal and distal metaphyses. View in (a) from the side, in (b) *en face*. The retracted finger is elongated by traction loops through the metaphyses of the middle and distal phalanges.

their orientation. They were placed in 2.5% glutaraldehyde (Polysciences, Warrington, PA, USA) diluted in 0.1 M sodium cacodylate-HCl buffer (Schuchardt, Hohenbrunn, Germany) at pH 7.3, for about 1 week. Small specimens of different parts of the fascia were chosen, rinsed in the same buffer and post-fixed in 1% osmium tetroxide and 1.5% potassium ferrocyanide in water for 1.5 hours (Karnovsky, 1971). After dehydration in graded alcohols the tissue blocks were embedded in Epon.

Sections 1 μm thick were stained with 1% Toluidine blue (Merck, Darmstadt, Germany) and 1% sodium tetraborate (Riedel-de Häen AG, Seelze, Germany) in water and examined by light microscopy. Thin sections were analysed in a Siemens Elmiskop 101 electron microscope after staining with uranyl acetate and lead citrate.

RESULTS

As reported in previous studies (Luck, 1959; Nezelof, 1974; McFarlane et al, 1990) the non-extended palmar fascia displayed nodules and cords.

The nodules predominantly contain myofibroblasts (Fig 2a). These cells are in different functional states: some with a prominent cytoskeleton of microfilaments and intermediate filaments, others with extensive rough endoplasmic reticulum and Golgi apparatus (Brandes and Reale, 1993). The cells are surrounded by a tight mesh of fine filaments (presumably proteoglycans), in which collagen fibrils about 50 ± 10 nm thick are intermingled (Fig 3a). Further away from the cells, collagen fibrils with an irregular outline in cross section and measuring up to 100 nm in diameter are orientated in different directions. The interfibrillar space is filled by a tight mesh of fine filaments, which are connected to the collagen fibrils. Bundles of oxytalan-like microfibrils, about 12 nm thick, and small elastic fibres are also present.

The cords are composed of waved large bundles of thick collagen fibres (Fig 2b). In these bundles the collagen fibrils, with an irregular contour and varying diameter from 50 to 350 nm, are densely packed in different directions (Fig 3b). The interfibrillar space contains tiny filaments connected to the collagen fibrils, and bundles of oxytalan-like microfibrils. Within the cords only a few fibroblasts and myofibroblasts with scanty organelles are seen.

After continuous extension the dissected palmar fascia has a uniform, smooth, ribbon-like appearance. It consists of large, parallel bundles of collagen fibres with numerous cells in between which are orientated according to the stretching forces (Fig 2c). Electron microscopy shows that these cells are fibroblasts and myofibroblasts (Fig 4a) with a euchromatic nucleus, extensive rough endoplasmic reticulum and a large Golgi apparatus. The cytoskeleton of both fibroblasts and myofibroblasts (Fig 4b) is arranged parallel to the collagen fibrils.

The collagen fibrils have a uniform diameter of about 50 nm, while fibrils up to 200 nm thick with an irregular outline are only rarely seen (Fig 4c and d). In the interfibrillar spaces fine filaments (presumably proteoglycans) form a network interconnecting the neighbouring fibrils. Oxytalan-like fibres run inside the collagen fibres parallel to the fibrils (Fig 4d).

DISCUSSION

Despite the small number of tissue samples studied, the results were remarkably consistent. After continuous elongation the morphology of the palmar fascia is notably changed in comparison with the non-extended tissue. The collagen fibres and their fibrils, the oxytalan-like microfibrils together with the cells and their cytoskeletal components are all orientated parallel to the stretching force generated by the extension-device. Since this treatment was applied when an established contracture was present, and histologically there was evidence of neither interruption of collagen fibres nor haemorrhage, the increase in the length of the fascia must be a dynamic biological process.

Several observations support the hypothesis that the extracellular matrix is newly formed. Both cell types present, fibroblasts and myofibroblasts, show cytological aspects which suggest increased biosynthetic activity.

The biochemical analysis of the elongated palmar fascia reveals an increase in the turnover of collagen (Bailey et al, 1994). The predominance of the small unimodal fibrils suggests also their new synthesis, and degradation of the thicker fibrils with varying diameter.

The morphology of the interfibrillar material bound to the collagen fibrils and presumably consisting of proteoglycans is also changed after continuous extension in comparison to the non-extended tissue. Reduced OsO_4 precipitates the glycoconjugates as particles and/or filaments (Karnovsky, 1971; Coltoff-Schiller and Goldfischer, 1981; Reale, 1986) which can be correlated with the chemistry of these macromolecules by comparison with the staining pattern after specific enzymatic digestion of the glycosaminoglycans (Brandes and Reale, 1994). The comparison of the different reaction products confirmed that the nodules are characterized by an increase in the amount of proteoglycans (Flint et al, 1982; Tunn et al, 1988), whereas in the cords the interfibrillar proteoglycans are reduced dramatically (Brandes et al, 1991). In the elongated fascia the network of these macromolecules formed around the collagen fibrils appears tighter than in the cord present before the extension. The interaction of the proteoglycans with the collagen fibrils is important for the correct assembly of the fibril within the matrix (Scott, 1991). The newly formed collagen fibrils in the palmar fascia treated by continuous extension have a uniform morphology compared with the irregular outline and diameter of the

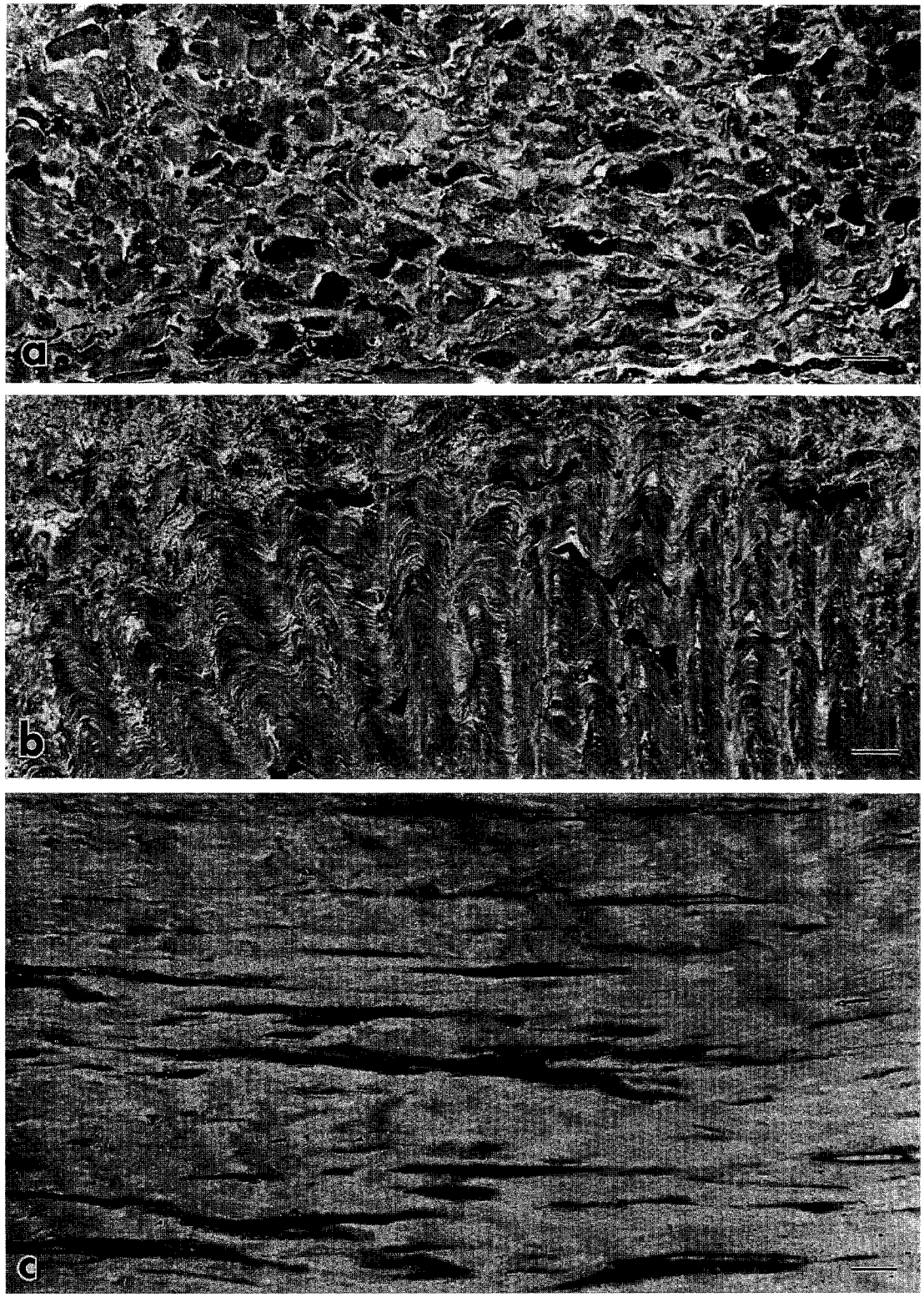

Fig 2 In (a) and (b) the non-elongated palmar fascia of Dupuytren's disease. (a) Nodule with high number of myofibroblasts. (b) Cord with waved collagen fibres and scattered cells. In (c) the palmar fascia treated by continuous extension. Collagen fibres and cells (fibroblasts and myofibroblasts, as seen by electron microscopy of the same samples) are arranged parallel to the stretching force. All figures × 806; bar = 10 μm.

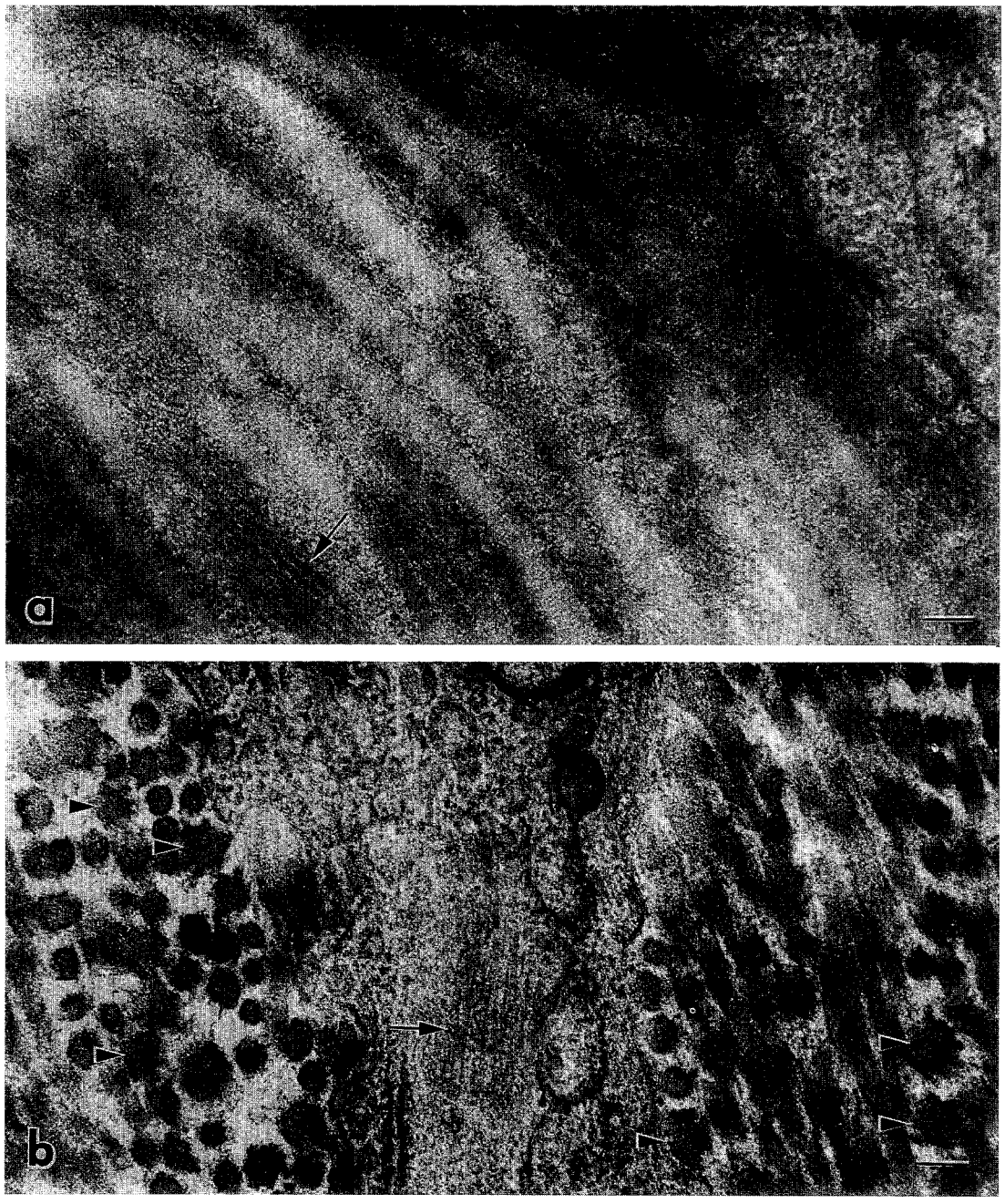

Fig 3 Non-elongated palmar fascia of Dupuytren's disease. (a) Nodule. Collagen fibrils surrounded by a tight mesh of fine filaments and intermingled with oxytalan-like microfibrils (arrow). (b) Cord. Collagen fibrils with varying diameter and frequently irregular contour (arrowheads) having a different orientation to the microfilament bundle inside the myofibroblast (arrow). Tiny filaments are seen in the interfibrillar space. Both figures × 80,000; bar = 0.1 μm.

fibrils in the cord, probably due to the influence of the interfibrillar proteoglycans on the aggregation of the fibrils.

The arrangement of the oxytalan-like microfibrils (precursors of elastic tissue; Montes, 1992) parallel to the thin collagen fibrils suggest their neoformation.

The present investigation demonstrates that during elongation of the palmar fascia the tissue is reorganized. Therefore, the morphology of the connective tissue may be determined not only by the pathological process, but also by the operating stretching force. This raises the possibility that some of the histopathological changes described in many studies are due to changing loads on the hand. This additional variable might contribute to the difficulties in identifying the specific circumstances generating Dupuytren's disease.

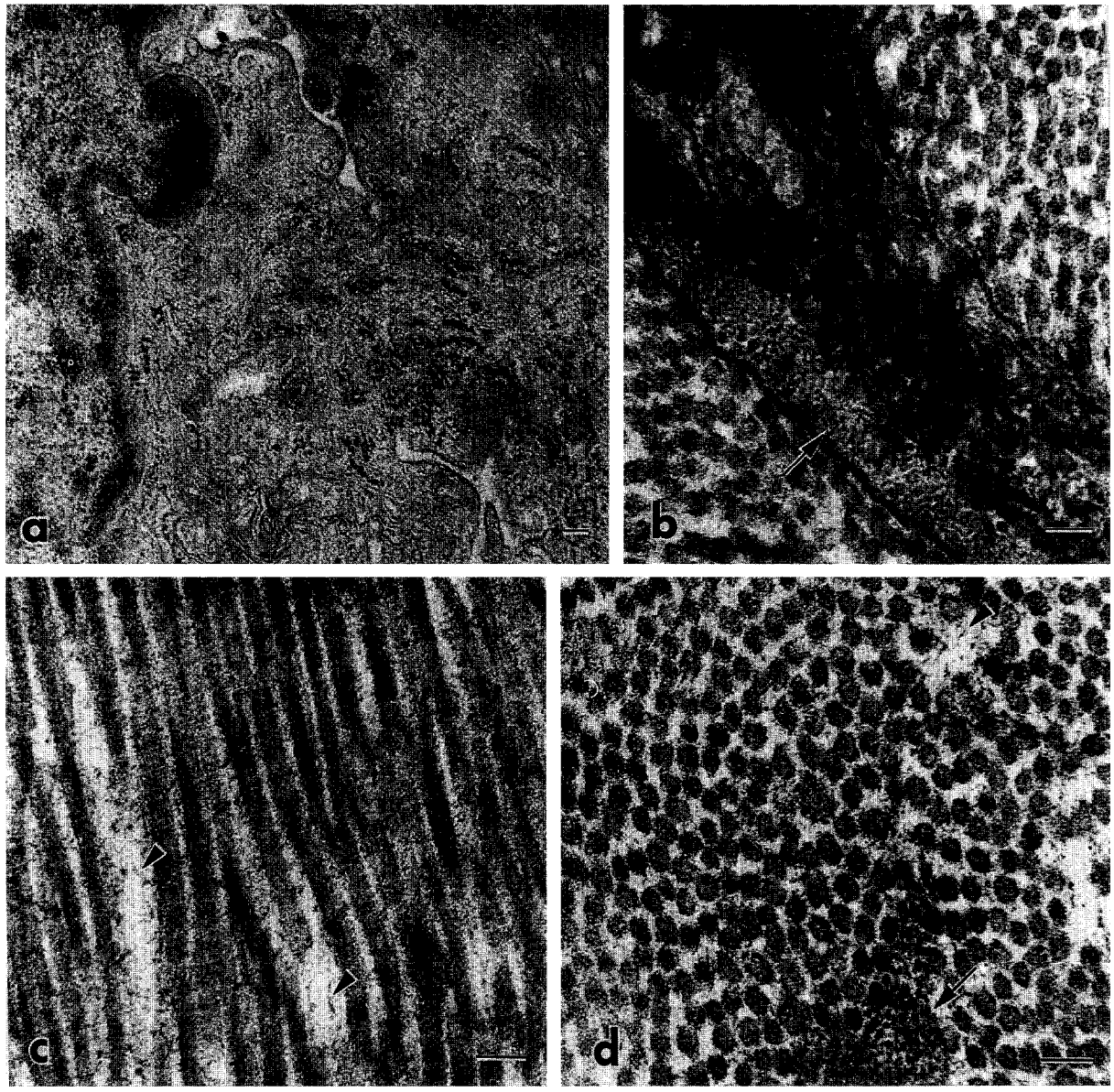

Fig 4 Palmar fascia treated by continuous extension. (a) A myofibroblast showing a large amount of rough endoplasmic reticulum and a well-developed cytoskeleton consisting of microfilaments and intermediate filaments. (b) The bundle of microfilaments inside the cell process (arrow) is orientated in the same direction as the surrounding collagen fibrils. (c) Longitudinal and (d) cross section of the parallel arranged collagen fibrils; fine filaments (arrowheads) and oxytalan-like microfibrils (arrow in d) are in between. (a) × 40,000; (b), (c), (d) × 80,000; bar = 0.1 μm.

In the four cases examined here, the tissue contained myofibroblasts. In Dupuytren's disease these cells exist before the dramatic contracture of the fascia appears (Luck, 1959; Chiu and McFarlane, 1978). They are responsible for the active shortening of the palmar fascia by contraction (Gabbiani and Majno, 1972; Schürch et al, 1992). The extracellular matrix will be removed and substituted by tissue of reduced length (Brickley-Parsons et al, 1981; Flint et al, 1982; Badalamente et al, 1983; Tomasek et al, 1986; 1987). Since some myofibroblasts of the nodule show a euchromatic nucleus, extensive rough-surfaced endoplasmic reticulum and a well-developed Golgi complex, this cell type is probably responsible for rebuilding a new extracellular matrix in the fascia in Dupuytren's disease (Brandes and Reale, 1993). This is in agreement with clinical studies showing that these cells are an important factor in the progression of the disease (Rombouts et al, 1989). Therefore, the persistence of myofibroblasts after elongation justifies the supposition that the fascia will be reduced in length again after removal of the extension-device. Indeed, clinical observations report a recurrence of the contrac-

ture within 10 days in about 60% of the patients treated (Messina and Messina, 1993).

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References

BADALAMENTE, M. A., STERN, L. and HURST, L. C. (1983). The pathogenesis of Dupuytren's contracture: Contractile mechanisms of the myofibroblasts. Journal of Hand Surgery, 8: 3: 235–243.

BAILEY, A. J., TARLTON, J. F., VAN STAPPEN, J., SIMS, T. J. and MESSINA, A. (1994). The continuous elongation technique for severe Dupuytren's disease; a biochemical mechanism. Journal of Hand Surgery 19B 4: 522–527.

BRANDES, G., KÖRNER, T., BRENNER, P. and REALE, E. (1991). Histochemical localization of glycoconjugates in the palmar aponeurosis of Dupuytren's patients. Journal of Submicroscopic Cytology and Pathology, 23: 4: 551–558.

BRANDES, G. and REALE, E. (1993). Morphology of the cells in different stages of Dupuytren's disease. European Journal of Cell Biology, 60: Suppl 37: 95.

BRANDES, G. and REALE, E. (1994). Proteoglycans of rat articular cartilage: Their distribution and interactions. Histochemical Journal: submitted.

BRICKLEY-PARSONS, D., GLIMCHER, M. J., SMITH, R. J., ALBIN, R. and ADAMS, J. P. (1981). Biochemical changes in the collagen of the palmar fascia in patients with Dupuytren's disease. Journal of Bone and Joint Surgery, 63A: 5: 787–797.

CHIU, H. F. and McFARLANE, R. M. (1978). Pathogenesis of Dupuytren's contracture: A correlative clinical-pathological study. Journal of Hand Surgery, 3: 1: 1 10.

COLTOFF-SCHILLER, B. and GOLDFISCHER, S. (1981). Glycosaminoglycans in the rat aorta: Ultrastructural localization with Toluidine blue O and osmium-ferrocyanide procedures. American Journal of Pathology, 105: 232–240.

FLINT, M. H., GILLARD, G. C. and REILLY, H. C. (1982). The glycosaminoglycans of Dupuytren's disease. Connective Tissue Research, 9: 173–179.

GABBIANI, G. and MAJNO, G. (1972). Dupuytren's contracture: Fibroblast contraction? An ultrastructural study. American Journal of Pathology, 66: 131–146.

KARNOVSKY, M. J. (1971). Use of ferrocyanide-reduced osmium tetroxide in electron microscopy. American Society of Cell Biology Abstracts, 11: 146.

LUCK, J. V. (1959). Dupuytren's contracture: A new concept of the pathogenesis correlated with surgical management. Journal of Bone and Joint Surgery, 41A: 4: 635–664.

McFARLANE, R. M., McGROUTHER, D. A. and FLINT, M. H. *Dupuytren's Disease: Biology and Treatment.* Edinburgh, Churchill Livingstone, 1990.

MESSINA, A. and MESSINA, J. (1991). The TEC treatment (continuous extension technique) for severe Dupuytren's contracture of the fingers. Annals of Hand Surgery, 10: 3: 247–250.

MESSINA, A. and MESSINA, J. (1993). The continuous elongation treatment by the TEC device for severe Dupuytren's contracture of the fingers. Plastic and Reconstructive Surgery, 92: 1: 84–90.

MONTES, G. S. (1992). Distribution of oxytalan, elaunin and elastic fibres in tissues. Journal of the Brazilian Association for the Advancement of Science, 44: 4: 224–233.

NÉZELOF, C. Histological Aspects of Dupuytren's Contracture. In: Hueston, J. T. and Tubiana, R. (Eds.) *Dupuytren's Disease.* Edinburgh, Churchill Livingstone, 1974: 25–27.

REALE, E. (1986). The ground substance of the human articular cartilage after postfixation in ferrocyanide-reduced osmium tetroxide. Journal of Clinical Chemistry and Clinical Biochemistry, 24: 11: 918–920.

ROMBOUTS, J.-J., NOËL, H., LEGRAIN, Y. and MUNTING, E. (1989). Prediction of recurrence in the treatment of Dupuytren's disease: Evaluation of a histologic classification. Journal of Hand Surgery, 14A: 4: 644–652.

SCHÜRCH, W., SEEMAYER, T. A. and GABBIANI, G. (1992). Myofibroblast. In: Sternberg, S. S. (Ed.) *Histology for Pathologists.* New York, Raven Press, 1992: 109–144.

SCOTT, J. E. (1991). Proteoglycan:collagen interactions in connective tissues. Ultrastructural, biochemical, functional and evolutionary aspects. International Journal of Biological Macromolecules, 13: 157–161.

TOMASEK, J. J., SCHULTZ, R. J., EPISALLA, C. W. and NEWMAN, S. A. (1986). The cytoskeleton and extracellular matrix of the Dupuytren's disease "myofibroblast": An immunofluorescence study of a nonmuscle cell type. Journal of Hand Surgery, 11A: 3: 365–371.

TOMASEK, J. J., SCHULTZ, R. J. and HAAKSMA, C. J. (1987). Extracellular matrix-cytoskeletal connections at the surface of the specialized contractile fibroblast (myofibroblast) in Dupuytren disease. Journal of Bone and Joint Surgery, 69A: 9: 1400–1407.

TUNN, S., GURR, E., DELBRÜCK, A., BUHR, T. and FLORY, J. (1988). The distribution of unsulphated and sulphated glycosaminoglycans in palmar fascia from patients with Dupuytren's disease and healthy subjects. Journal of Clinical Chemistry and Clinical Biochemistry, 26: 7–14.

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