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Ultrastructure of the Common Extensor Tendon in Tennis Elbow

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Summary. In patients with tennis elbow, the common extensor tendon showed a pronounced reactive change consisting of mesenchymal cell proliferation along with aggregates of newly formed vascular channels. When studied ultrastructurally, many of the mesenchymal cells adjacent to the vascular channels were surrounded by a basal lamina, which is not normally seen around tenocytes. The cytoplasm of these cells showed features of both endothelial cells and tenocytes. It thus appeared, that the endothelial cells of the newly formed vascular channels were the source of proliferating mesenchymal cells differentiating toward tenocytes, and together they represented an intrinsic healing mechanism in the tendon.

Key words: Tendon repair – Tennis elbow.

Introduction

It is well known that the majority of patients with tennis elbow recover spontaneously or with conservative treatment (Boyd and McLeod, 1973; Coonrad and Hooper, 1973). However, the cellular aspect of this self-healing mechanism, has never been adequately investigated. This is probably because there is no unanimity of opinion about the pathogenetic mechanism of tennis elbow. Reporting our clinicopathological observations, we proposed that tennis elbow is primarily a tendinopathy, affecting the common extensor tendon (Uhthoff et al., 1978). Indeed, one component of the common extensor, the tendon for extensor carpi radialis brevis, has been found to be the only consistent site of lesion in tennis elbow (Nirschl, 1979).

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The various pathological changes described in relation to tennis elbow include periostitis of the lateral epicondyle (Runge, 1873), tightening of the annular ligament of the radial head (Bosworth, 1955), microruptures of the comon extensor tendon (Coonrad and Hooper, 1973), and chronic inflammation of the subtendinous areolar tissue (Goldie, 1964) or bursa (Osgood, 1922). We believe that structures such as the lateral epicondyle and annular ligament are affected secondarily because of their attachment to the common extensor tendon. According to our observations, inflammatory cell infiltration is never a feature of the pathological alterations in tennis elbow. Rather, degenerative changes such as thinning, fibrillation or microruptures of tendon fascicles are associated with vascular and mesenchymal cell proliferation (Uhthoff et al., 1978). Because of the potential for self-healing in tennis elbow, we assumed that the proliferative changes in the common extensor tendon might represent a reactive state attempting to repair a degenerative process.

The present study was undertaken to elucidate the ultrastructural characteristics of endothelial cells in the newly formed vascular channels and the paravascular mesenchymal cells which together constitute the proliferative component in the common extensor tendon of tennis elbow. We found that many of the ultrastructural features of the mesenchymal cells resembled those of the endothelial cells. This suggested that both types of proliferating cells were interrelated, and that the blood vessels intruding into the substance of disorganized tendon fascicles might be the most likely source of the accompanying mesenchymal cells.

Materials and Methods

For the purpose of the present study, the common extensor tendon from 5 cases of tennis elbow were obtained for electron microscopy. The informations on these 5 cases regarding age, sex, side of arm affected, duration of symptoms and pre-operative cortisone treatment are listed in Table 1. Immediately following surgical removal of fragments from the common extensor tendon, the selected pieces were fixed in half-strength Karnovsky's fixative (Karnovsky, 1965) for 2 h and post-fixed in 1% osmium tetroxide for 1 h. Both the fixatives were buffered with 0.1 m sodium cacodylate, and the fixation was carried out at 4° C. The fragments were then dehydrated in graded ethyl alcohol and finally in propylene oxide. They were embedded in epon, and ultrathin sections for electron microscopic examination were stained with uranyl acetate and lead citrate.

Table 1

Name	Sex	Age (years)	Side of arm	Duration of symptoms	Local corticosteroid injection
R.C.	Female	45	Right	20 months	4 times
M.P.	Male	27	Left	18 months	More than once
L.M.	Male	38	Right	2 years	4 times
M.V.	Female	37	Right	2 years	3 times
A.S.	Male	45	Right	18 months	More than once

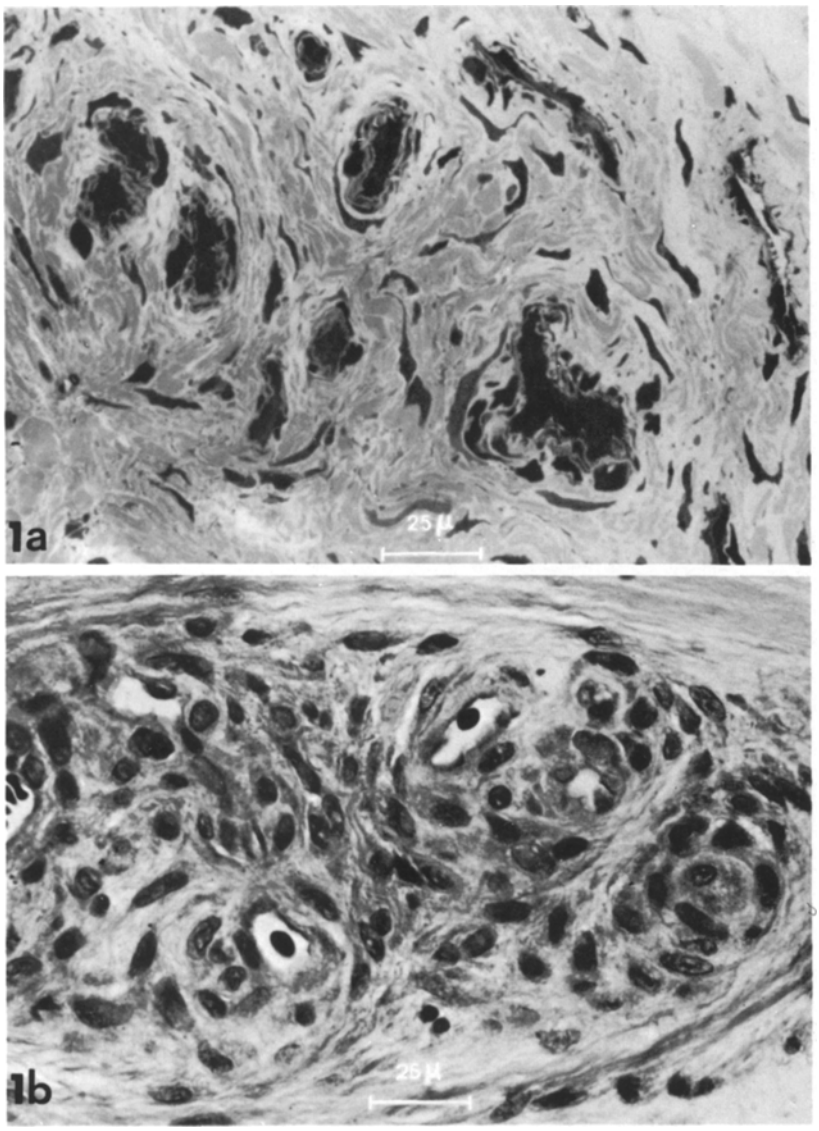

Fig. 1. **a** Section of epon-embedded tissue shows aggregates of vascular channels inside tendon fascicle. Toluidine blue. **b** Section shows the concentric orientation of paravascular mesenchymal cells around vessels. Haematoxylin and eosin

The rest of the tissues were fixed in 10% neutral buffered formalin for light microscopic examination. Section of paraffin-embedded tissues were stained with haematoxylin and eosin, toluidine blue, Masson's trichrome, and by von Kossa's method to identify the presence of calcium.

Results

The vascular channels were with or without a discernible lumen (Fig. 1a, b). When present, the lumena were narrow, sometimes containing structures repre-

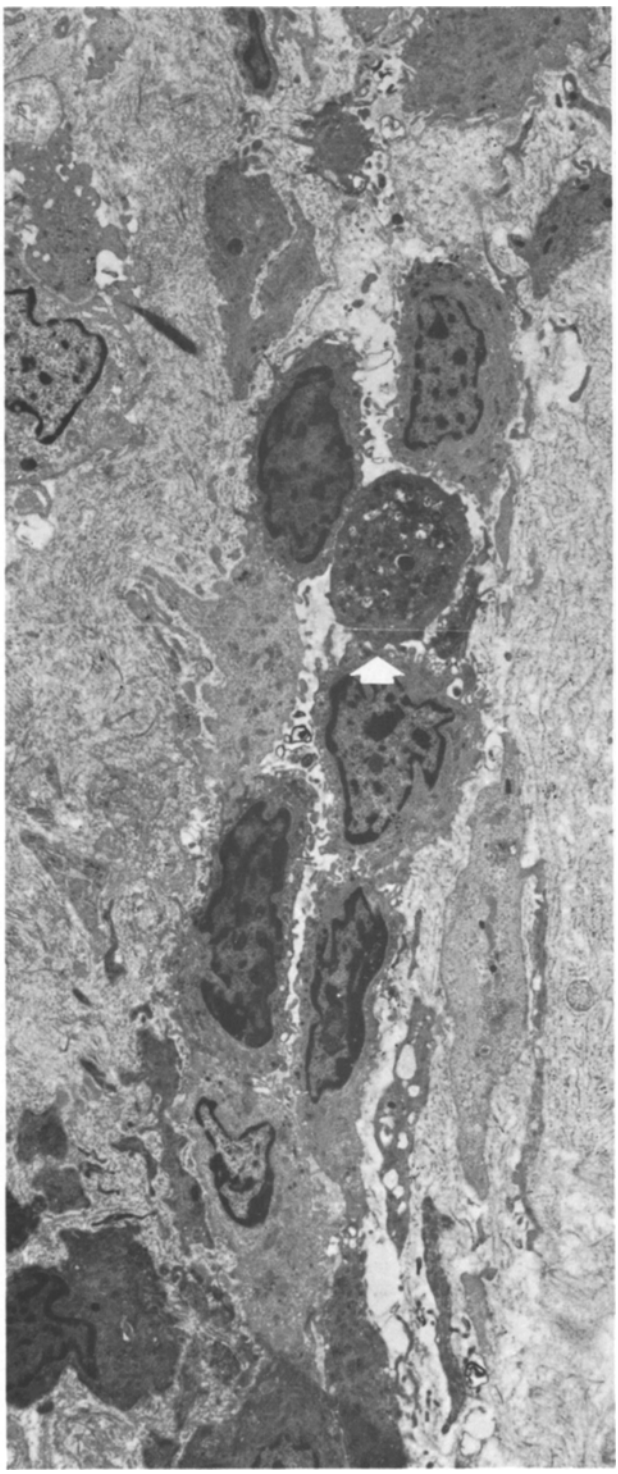

Fig. 2. A vessel shows endothelial cells with varying electron densities and the lumen containing necrotic débris *(arrow)*. Uranyl acetate (*UA*) and lead citrate (*LC*). ×4,850

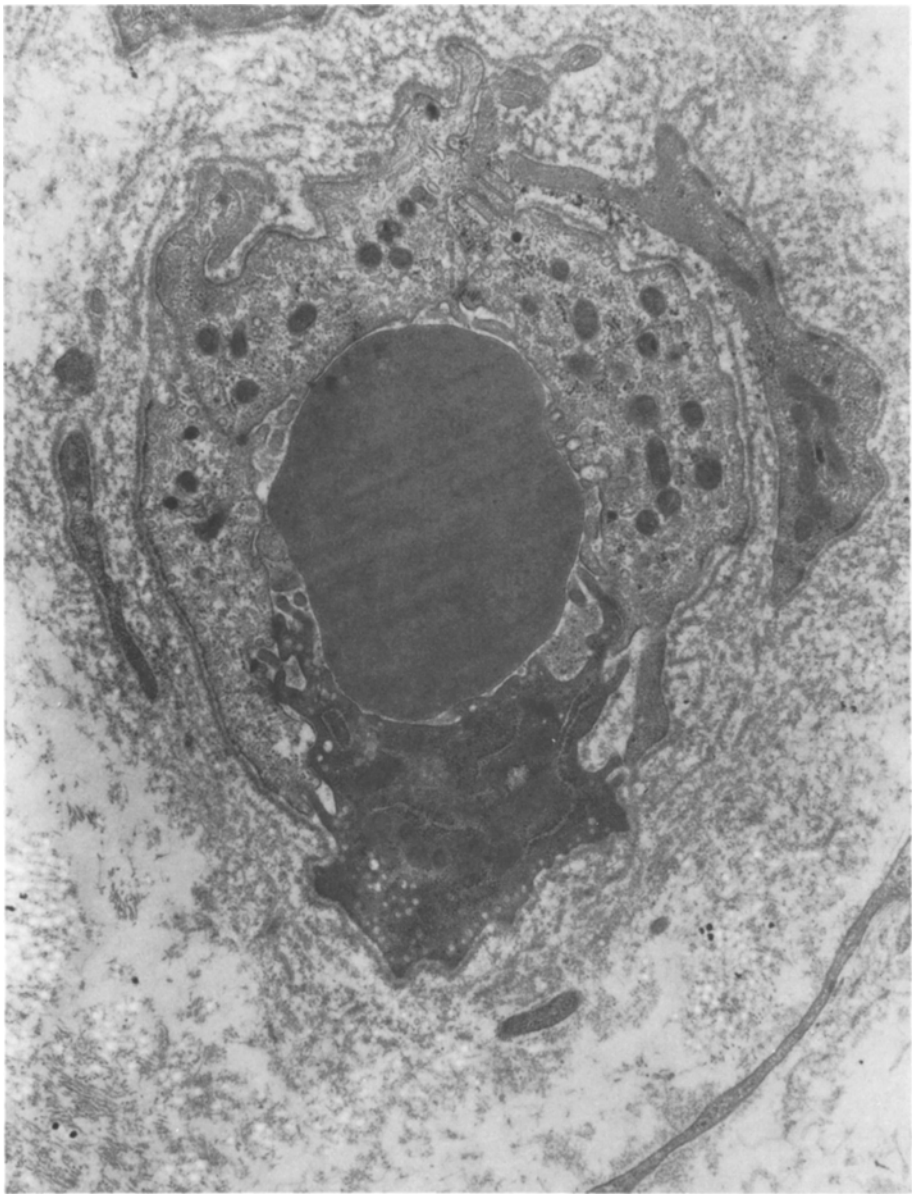

Fig. 3. A vessel containing a red blood cell is invested with multiple layers of basal lamina. UA and LC. ×18,600

senting necrotic débris or red blood cells (Figs. 2, 3). The lining endothelial cells were plump, some being more electron dense than the others. The endothelial cells were occasionally separated by a distinguishable intercellular space, but more often the lateral plasma membranes of neighboring cells were closely apposed. The intercellular junctions were rare even when the plasma membranes

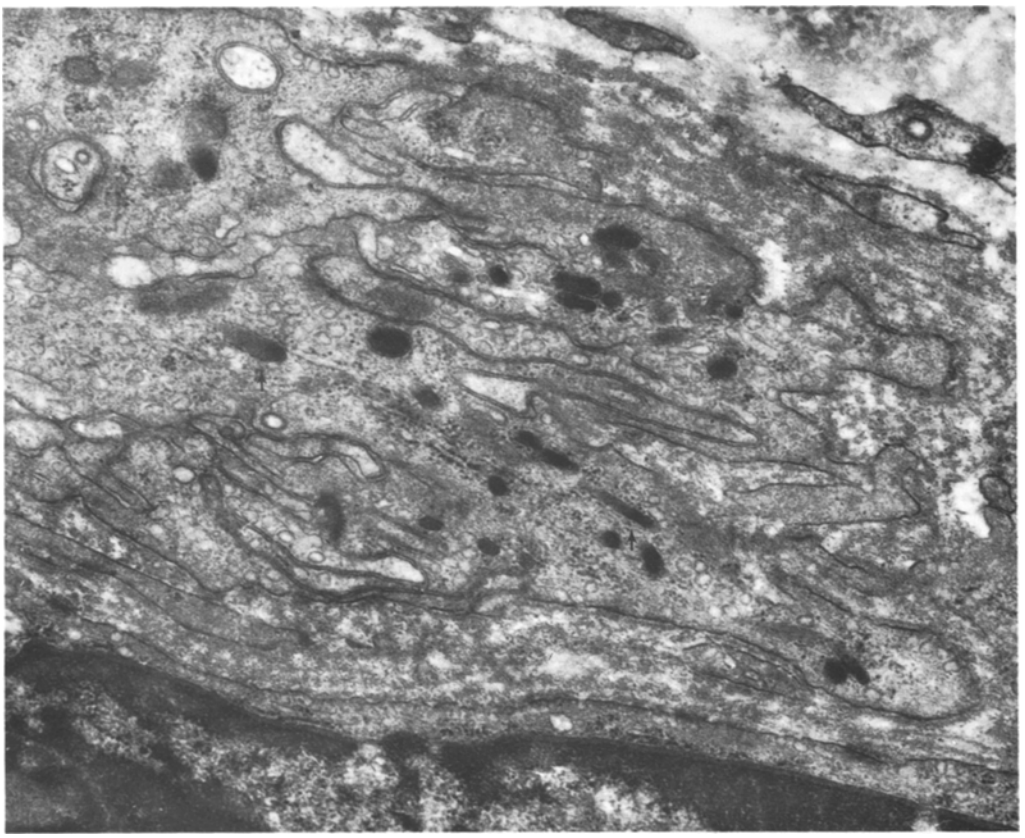

Fig. 4. Closely apposed cells with interdigitating plasma membranes contain Weibel-Palade bodies *(arrows)*. UA and LC. ×32,000

interdigitated. The cellular margin was convoluted and often had slender projections on the luminal aspect. Surface-connected caveolae and cytoplasmic vesicles were prominent at both the liminal and abluminal sides. Both free and attached ribosomes as well as mitochondria were moderate. The golgi apparatus was seldom conspicuous. Isolated Weibel-Palade bodies were present in several cells. The cytoplasm contained a considerable number of filaments, both in parallel and in random arrangements. Several microtubules were frequently found in association with the filaments. The nuclear margin was irregular, sometimes showing indentations.

Some of the vascular channels appeared as a closely packed cluster of cells surrounded by basal lamina (Fig. 4). The endothelial nature of these cells was suggested by the presence of Weibel-Palade bodies.

The vascular channels were invested with multiple wavy layers of basal lamina of slightly varying thickness (Fig. 3). These layers were frequently fragmented and enclosed elongated cell processes which partially encircled the en-

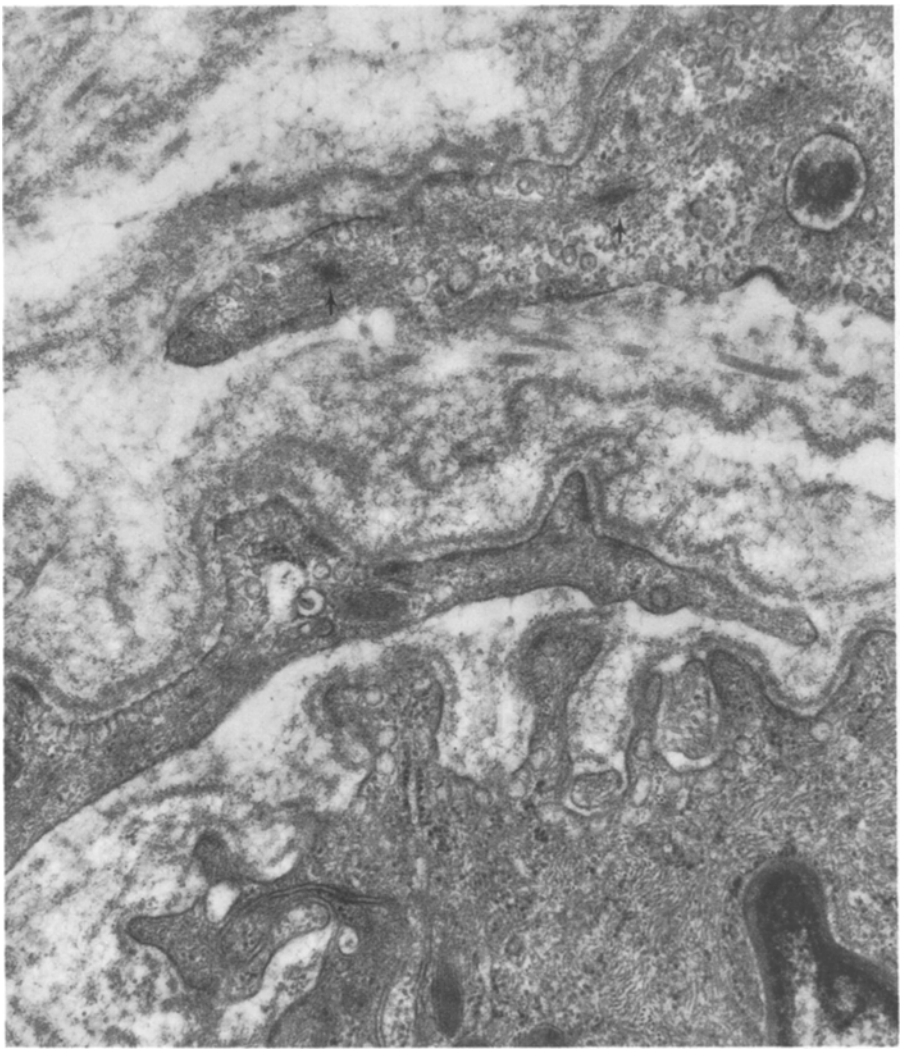

Fig. 5. A pericyte shows aggregates of microfilaments with dense bodies *(arrows)*. UA and LC. ×36,400

dothelial-lined channels. In their position and orientation these cell processes appeared to represent pericytes. Their cytoplasmic characteristics were similar to that of the endothelial cells; but in some, the filamentous arrays showed dense bodies and there were even sub plasmalemmal attachment sites (Fig. 5).

In areas close to vascular aggregations, there were cells which were surrounded by a basal lamina (Figs. 6, 7), scattered singly in the paravascular mesenchymal tissue. Their cytoplasmic and nuclear characteristics were closely similar to those of the endothelial cells. Sub-plasmalemmal vesicles were often

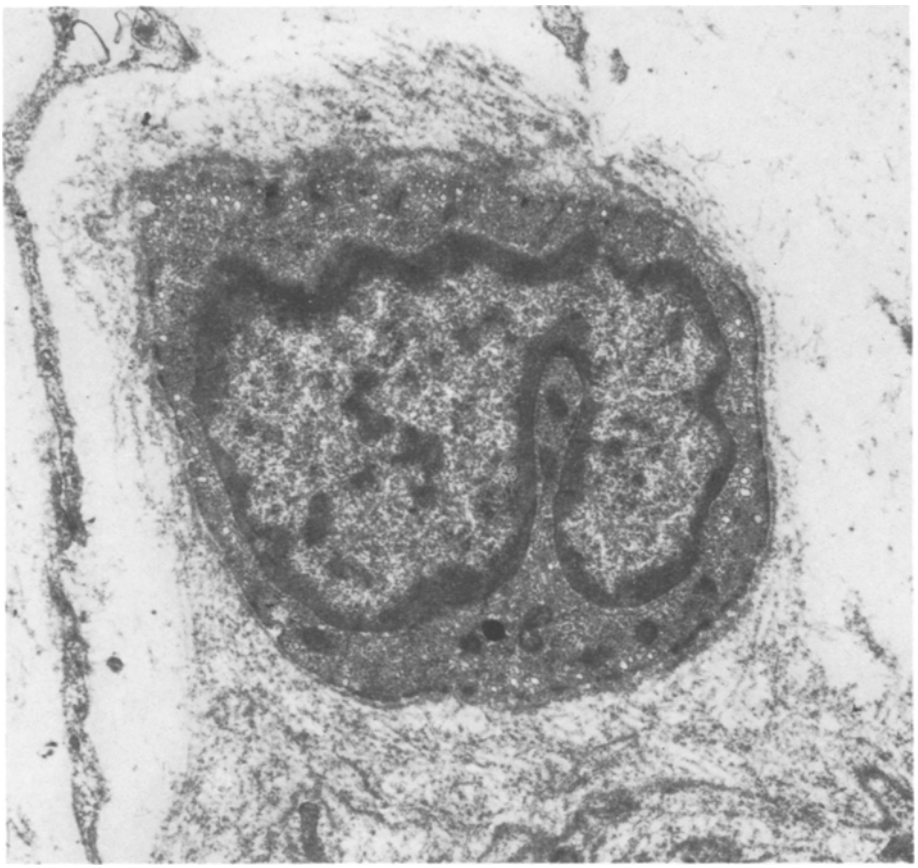

Fig. 6. A paravascular mesenchymal cell with small cytoplasmic volume, sparse organelles and subplasmalemmal microvesicles, is surrounded by a basal lamina. UA and LC. ×14,000

conspicuous in these cells. Some of the basal lamina-bound cells had small cisternae of rough endoplasmic reticulum scattered in the cytoplasm (Fig. 8).

The tenocytes showed a wide variation in size and shape. In areas where tendon fascicles were still intact, the tenocytes were slender and elongated. In contrast, the cells were plump and polygonal where fascicles were fragmented or in disarray (Figs. 9, 10). These cells, when compared with the attenuated tenocytes, indicated a marked hypertrophy and represented tenoblasts (Dyer and Enna, 1976). The cell surface frequently showed long or short focal projections. The voluminous cytoplasm contained both free and attached ribosomes. There were several mitochondria with condensed matrix. The golgi apparatus was conspicuous and centrioles were present occasionally (Fig. 10). Randomly distributed microfilaments with a few microtubules were abundant in the cytoplasm. There were membrane-bound lysosomal bodies in some of the cells, and an occasional cell would contain lipofuscin pigments. The nuclear contour was irregular with indentations. Infrequently, a hypertrophied tenocyte would

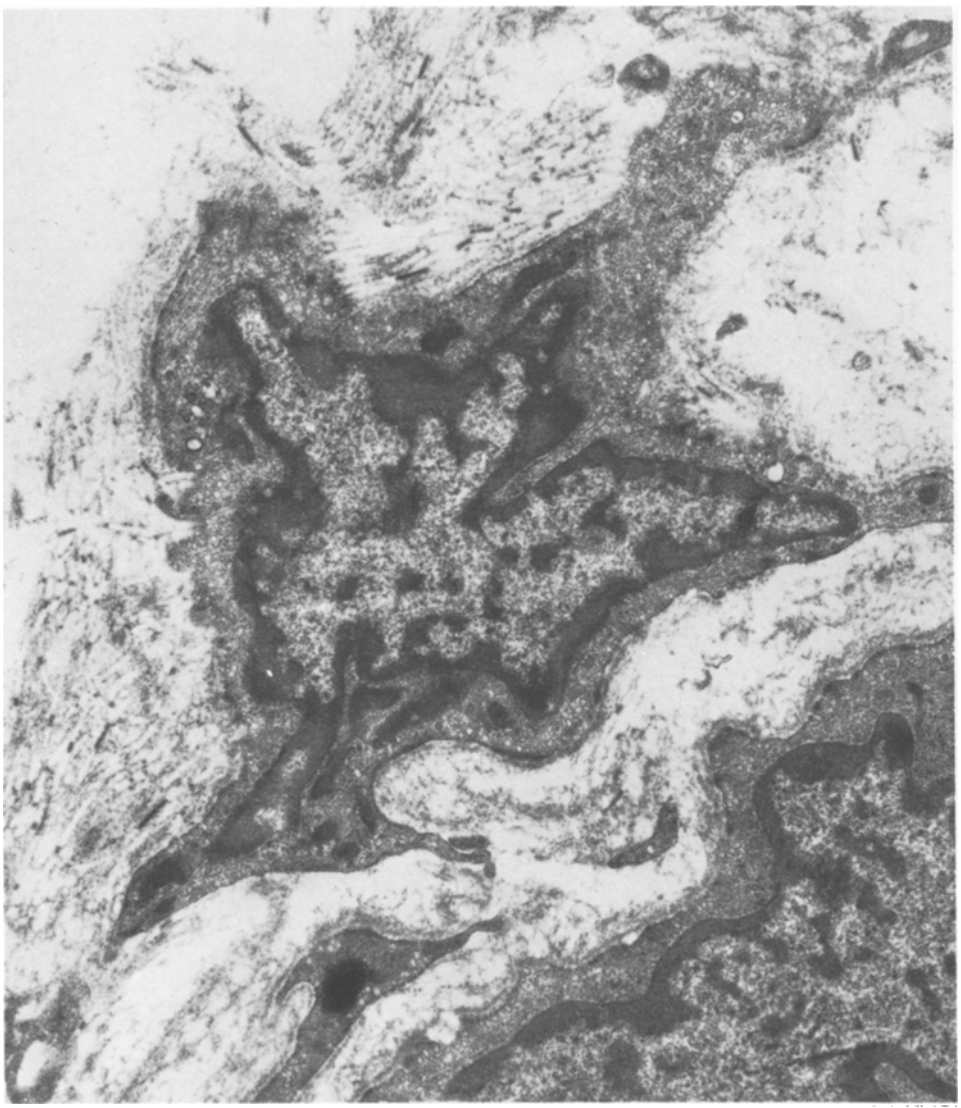

Fig. 7. Subplasmalemmal vesicles are conspicuous in a basal lamina-bound mesenchymal cell. UA and LC. ×16,600

show partial investment by a membrane-like structure closely resembling a basal lamina (Fig. 11).

Beside the hypertrophic tenocytes, a number of small cells had dilated cisternae of rough endoplasmic reticulum, swollen mitochondria and nuclei with dense chromatin. Their appearance suggested that they were undergoing an early stage of degenerative changes. Truncated cell processes, non-specific membrane-bound structures and amorphous débris were commonly found in the adjacent collagenous tissue.

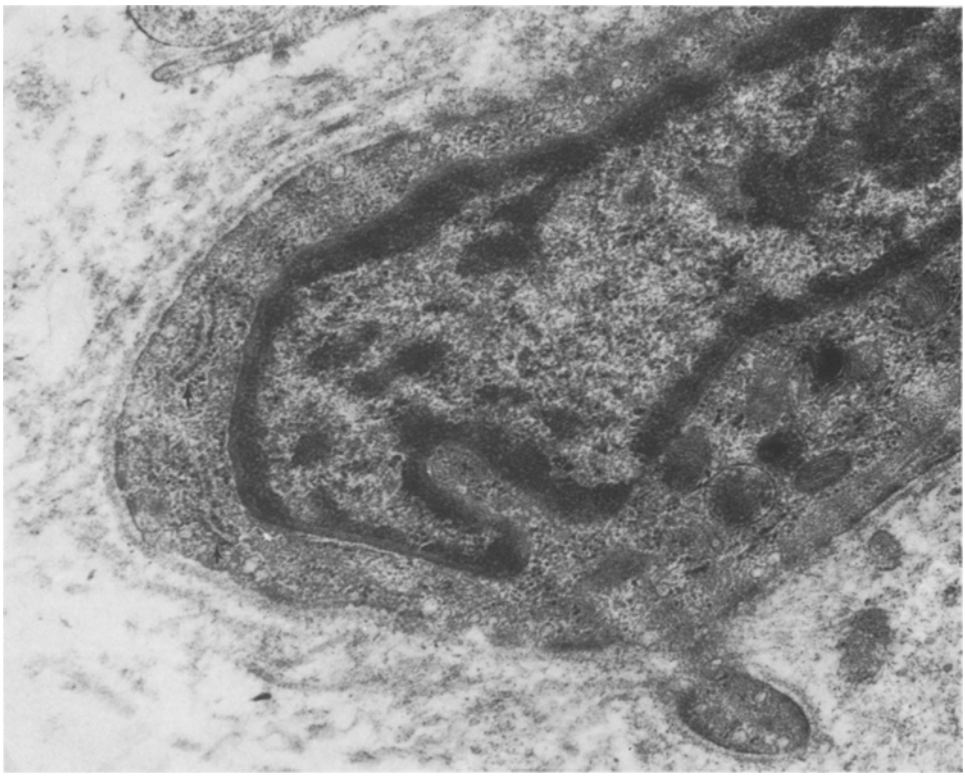

Fig. 8. Small cisternae of rough endoplasmic reticulum *(arrows)* in a paravascular mesenchymal cell which retains a basal lamina. UA and LC. ×35,700

Discussion

The normal tendon is composed of longitudinally arrayed fascicles of dense collagen fibers with slender, elongated fibroblastic cells, commonly known as tenocytes, arranged along the same axis. There are a series of thin-walled vascular channels which are found in the interfascicular connective tissue, running parallel to the collagen bundles and forming frequent cross anastomosis (Edwards, 1946; Field, 1971), while the fascicles themselves are devoid of any vascular structures. This demarcation was lost in the common extensor tendon of tennis elbow where the newly-formed aggregates of vessels along with irregularly distributed mesenchymal cells appeared to intrude into the substance of disarrayed and fragmented fascicles.

The newly formed vascular channels in tennis elbow showed several ultrastructural peculiarities. The multiplication of the basal lamina into several layers around each of the vessels probably indicated a rapid turnover of the endothelial cells, which are believed to manufacture their own basal lamina (Vracko and Benditt, 1972). In the present study, the endothelial cells themselves did not exhibit the usual flattened appearance; rather, the cells were plump with varying

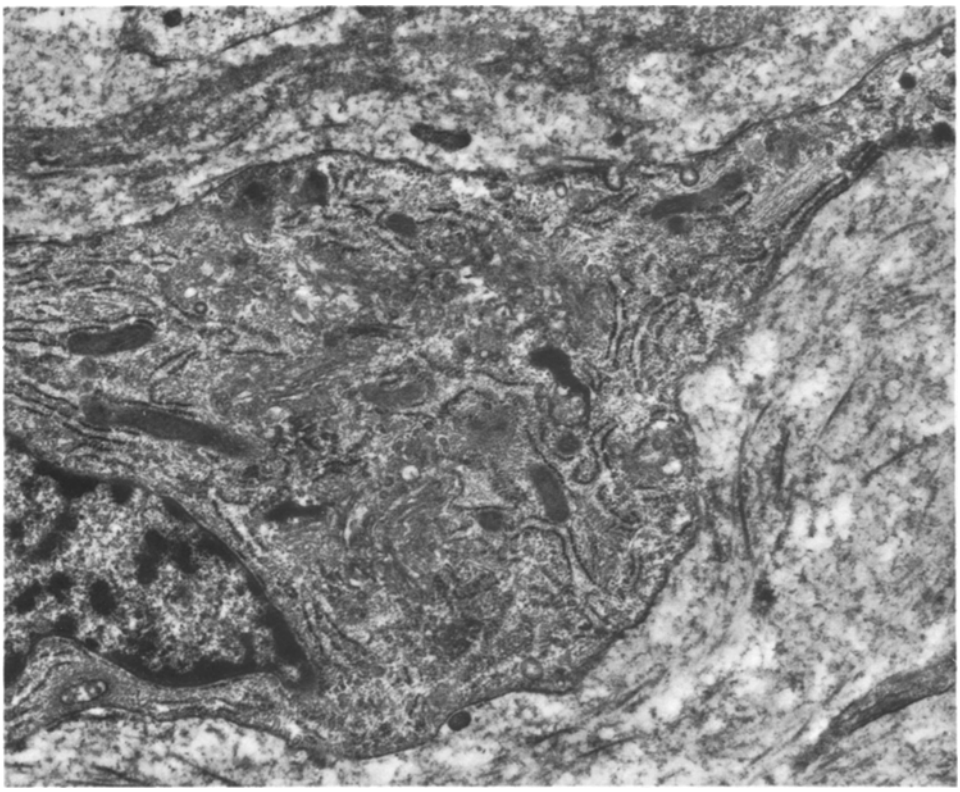

Fig. 9. A tenoblast contains a prominent golgi apparatus, a moderate number of mitochondria and numerous microfilaments in the cytoplasm. UA and LC. ×31,550

shapes. Intractyoplasmic filaments were markedly increased in these cells. Although a certain number of filaments can be found normally, their number increases greatly in the vessels of healing wounds (Cliff, 1963) and of granulation tissues (Gabbiani and Majno, 1977).

We found that there were a large number of pericytes within the replicated basal lamina layers of each of the vascular channels. These pericytes had abundant microfilaments which sometimes showed dense bodies suggesting a smooth muscle differentiation. Filamentous structures may be present in normal pericytes which share structural features of both smooth muscle and endothelium (Majno, 1965). In our study, while the pericytes were densely packed with filaments, the vascular channels seldom demonstrated a smooth muscle layer in the wall.

It has been postulated that pericytes may represent a source of undifferentiated mesenchymal cells which can participate in repair processes (Cliff, 1976). In the present study, many of the isolated cells in the connective tissue adjacent to the vascular congeries were surrounded by a single layer of basal lamina, which is not normally seen around fibroblastic cells or tenocytes. Some of these cells resembled endothelial cells in the sparsity of cytoplasmic contents

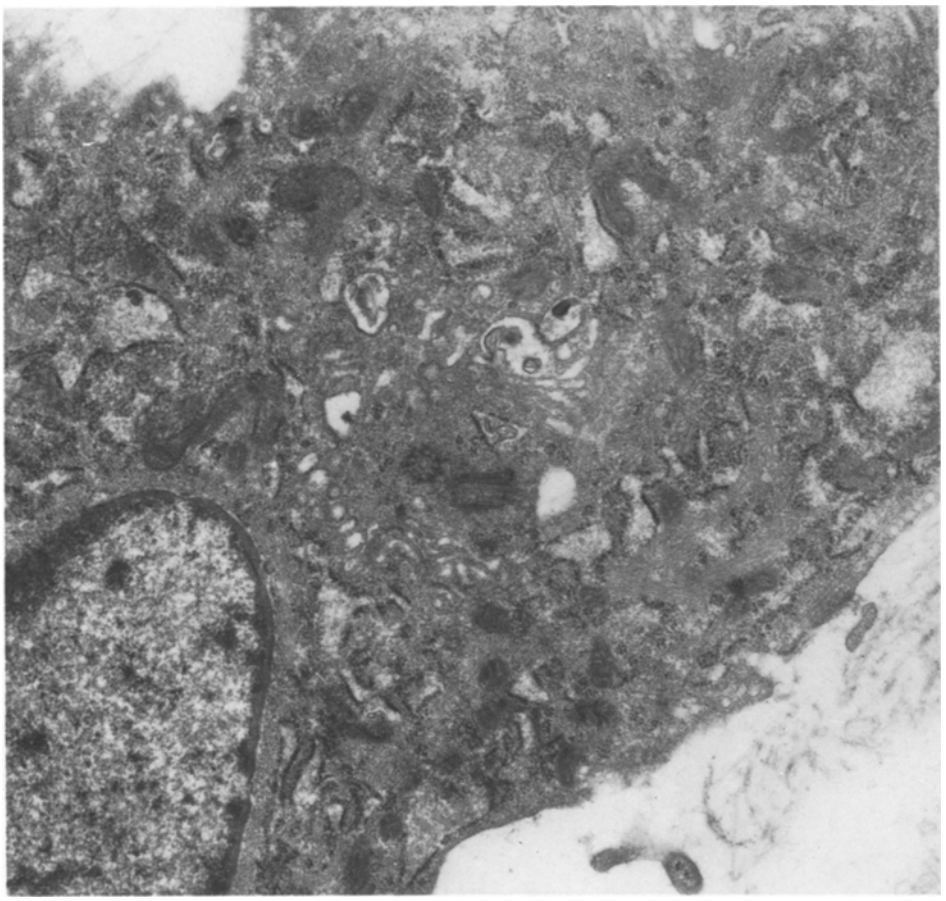

Fig. 10. Two centrioles are present along with other organelles in a tenoblast. UA and LC. × 37,700

and the presence of sub-plasmalemmal microvesicles (Fig. 6). In some cells where the basal lamina appeared to be partially present, cytoplasmic characteristics were similar to that of a metabolically active tenoblast (Fig. 11). Because of this wide spectrum of ultrastructural features seen in the cells which retained a basal lamina, it appeared that the paravascular mesenchymal cells were probably of endothelial origin, differentiating towards tenocytes.

The intrinsic healing capacity of the tendon is now generally accepted (Lundborg, 1976; Van der Meulen and Leistikow, 1977). It is believed that with adequate stimulus resting tenocytes can be activated into tenoblasts producing new collagen for repair (Matthews and Richards, 1974). Furthermore, myofibroblasts which contain properties of both smooth muscle and fibroblasts appear at the site of healing (Postacchini et al., 1977). In the present study, tenoblasts were numerous in the disarrayed fascicles indicating an ongoing process of repair. Those which were partially surrounded by a basal lamina were more likely to have originated from the newly forming blood vessels than from resting

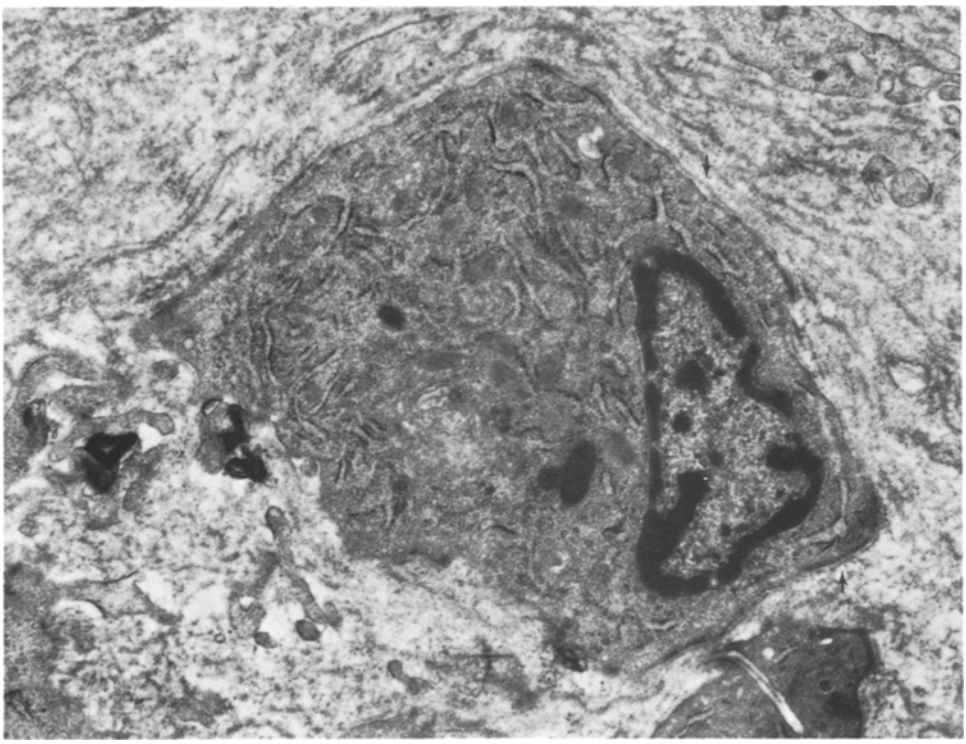

Fig. 11. A tenoblast is partially invested by basal laminalike structure *(arrows)*. UA and LC. ×16,600

tenocytes. Cells showing the typical features of myofibroblasts were seldom seen.

In conclusion, we believe that vascular and cellular proliferation forms as much a part of the morphological alterations in common extensor tendon in tennis elbow as the degenerative changes. The proliferative change represents an intrinsic healing mechanism. The cells involved in the process, both endothelial and mesenchymal, appear to be interrelated because of considerable similarities in their ultrastructural features.

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