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Obstruction of trabecular orifices in primary open-angle glaucoma

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SUMMARY

The morphologic and structural changes undergone by the trabecular meshwork have frequently been related to the development of primary open-angle glaucoma, which consists of a sustained increase in intraocular pressure due to the accumulation of aqueous humour in the anterior chamber of the eye.

The aqueous humour leaves the anterior chamber of the eye, passing through the trabecular orifices to Schlemm's canal. Accordingly, the anatomic integrity of the trabecular meshwork is necessary to guarantee correct aqueous drainage and the maintenence of adequate intraocular pressure.

In the present study, the three-dimensional morphology of glaucomatous trabecular meshworks was studied with a view to observing morphological changes possibly related to the development of primary open angle-glaucoma.

Key Words : Trabecular meshwork – Ultrastructure – Scanning electron microscopy – Primary open-angle glaucoma

INTRODUCTION

The drainage of aqueous humour from the anterior chamber of the eye mainly occurs through Schlemm's canal. Before entering this structure, the aqueous humour must first pass through the trabecular meshwork.

The trabecular meshwork is an important anatomic structure located at the iridoscleral-corneal angle of the eye. It consists of several layers of trabecular beams that delimit a complex system of orifices through which the aqueous humour drains from the anterior chamber of the eye to Schlemm's canal. The trabecular meshwork has classically been divided into two parts: an internal, lax uveal meshwork and an external, compact corneoscleral meshwork.

The uveal meshwork consist of 3 or 4 layers of 5 to 12 µm-thick uveal beams, which have a characteristic cylindrical morphology and a rough surface. They are arranged perpendicular to the peripheral limit of the cornea and delimit polygonal uveal orifices that are 20 to 30 µm in diameter. The corneoscleral meshwork is located closer to Schlemm's canal. It consists of 15 to 20 layers of corneoscleral beams, each of them 5 µm-thick. The corneoscleral beams have a smooth and flat shape and are oriented in parallel to the periphery of the cornea. Oval-shaped orifices with a 10 µm-wide maximum axis and a 5 µm-wide minimum axis are delimited by the corneoscleral beams.

The location and morphological features of the trabecular meshwork have led many authors to believe that alterations in their shape and size may alter normal drainage of the aqueous humour. This would lead to an accumulation of the aqueous humour in the anterior chamber of the eye, with a subsequent increase in intraocular pressure. Thus, anomalous trabecular meshworks have consistently been related to different types of glaucoma, the most frequent being the primary open-angle type.

In the present study we compared the morphology of non-glaucomatous and glaucomatous trabecular meshworks in order to observe morphological and structural changes possibly related to the development of primary open-angle glaucoma.

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MATERIALS AND METHODS

Thirty glaucomatous trabecular meshworks and 10 trabecular meshworks with no known disease were used. Non-glaucomatous trabecular meshworks were obtained from sclerocorneal rings remaining after extraction of central corneal buttons for transplantation that were procured by the Hospital Clinic Eye Bank in Barcelona. Donor age ranged from 30 to 60 years.

Glaucomatous trabecular meshworks were obtained from surgical trabeculectomy pieces taken by the same surgeon from patients with a previous diagnosis of primary open-angle glaucoma. All patients selected had an intraocular pressure greater than 21 mmHg and characteristic visual field changes after 1 year under medical treatment. Patient age ranged from 40 to 65. All surgical interventions were performed at the Ophthalmology Service of Hospital Clínic i Provincial in Barcelona.

All specimens were fixed in Karnovsky's solution for a period of time not longer than 24 hours immediately after collection. The specimens were then processed for scanning electronic microscopy using standard preocedures. Observations were made using a Hitachi S2300 scanning electron microscope at the Electron Microscopy Service of our University.

The atomic composition of determined areas of the intracameral surface of some of the specimens included in the study was analyzed using back-dispersed electrons and X-ray energy dispersion microanalysis with a Cambridge Stereoscan 120 microscope.

RESULTS

Scanning electron microscopic observation of non-glaucomatous trabecular meshworks allowed us to observe the cylindricaly-shaped uveal beams running from the iris root to the corneal periphery, and the corneoscleral beams running from the scleral spur to Schwalbe's ring. Both types of beams delimited a large number of trabecular orifices with a highly permeable aspect (Fig. 1).

Study of glaucoamatous trabecular meshworks revealed that in many cases (50%) there was partial or total obstruction of the trabecular orifices. In these specimens, a layer of dense, homogeneous and continuous material covered the intracameral surface, causing the above-mentioned obstruction (Fig. 2). In some cases, this material only covered the anterior portion of the trabecular meshwork while the posterior portion remained permeable (Fig. 3).

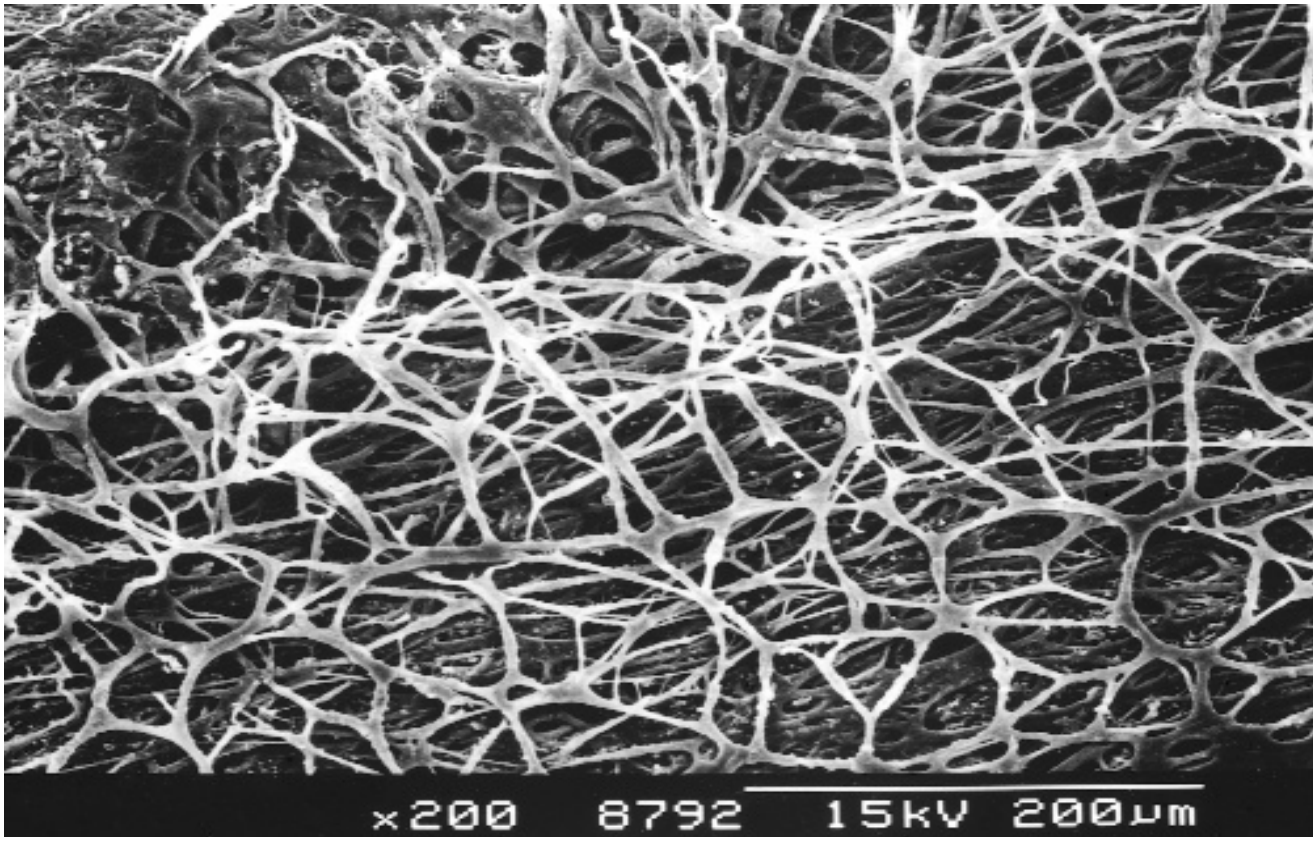

Fig. 1.- Scanning electron microscopy (SEM) (x 200). Intracameral surface of a non-glaucomatous trabecular meshwork. Note the permeability of the trabecular orifices.

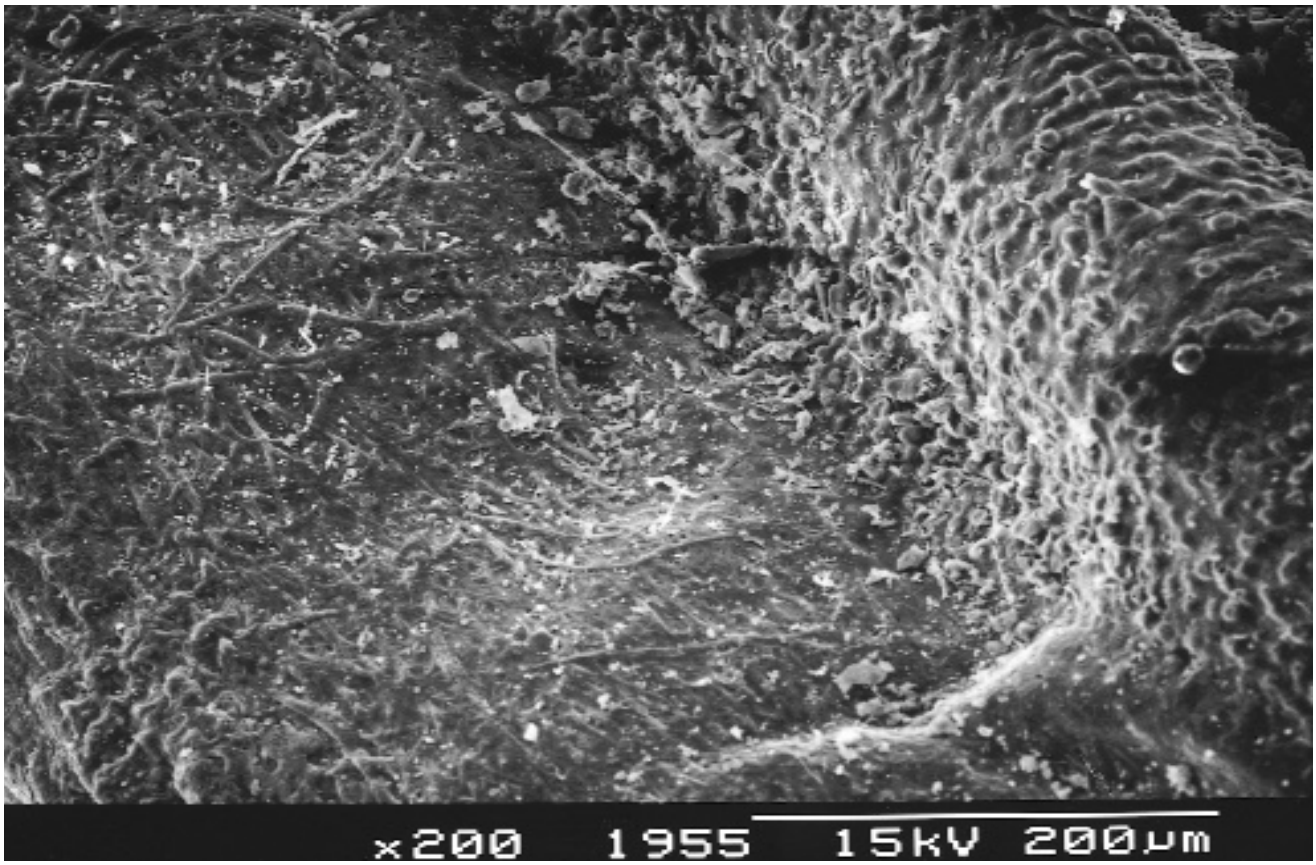

Fig. 2.- SEM (x 200). Detail of the intracameral surface of a glaucomatous trabecular meshwork with trabecular orifices completely obstructed by a layer of dense and homogenous material.

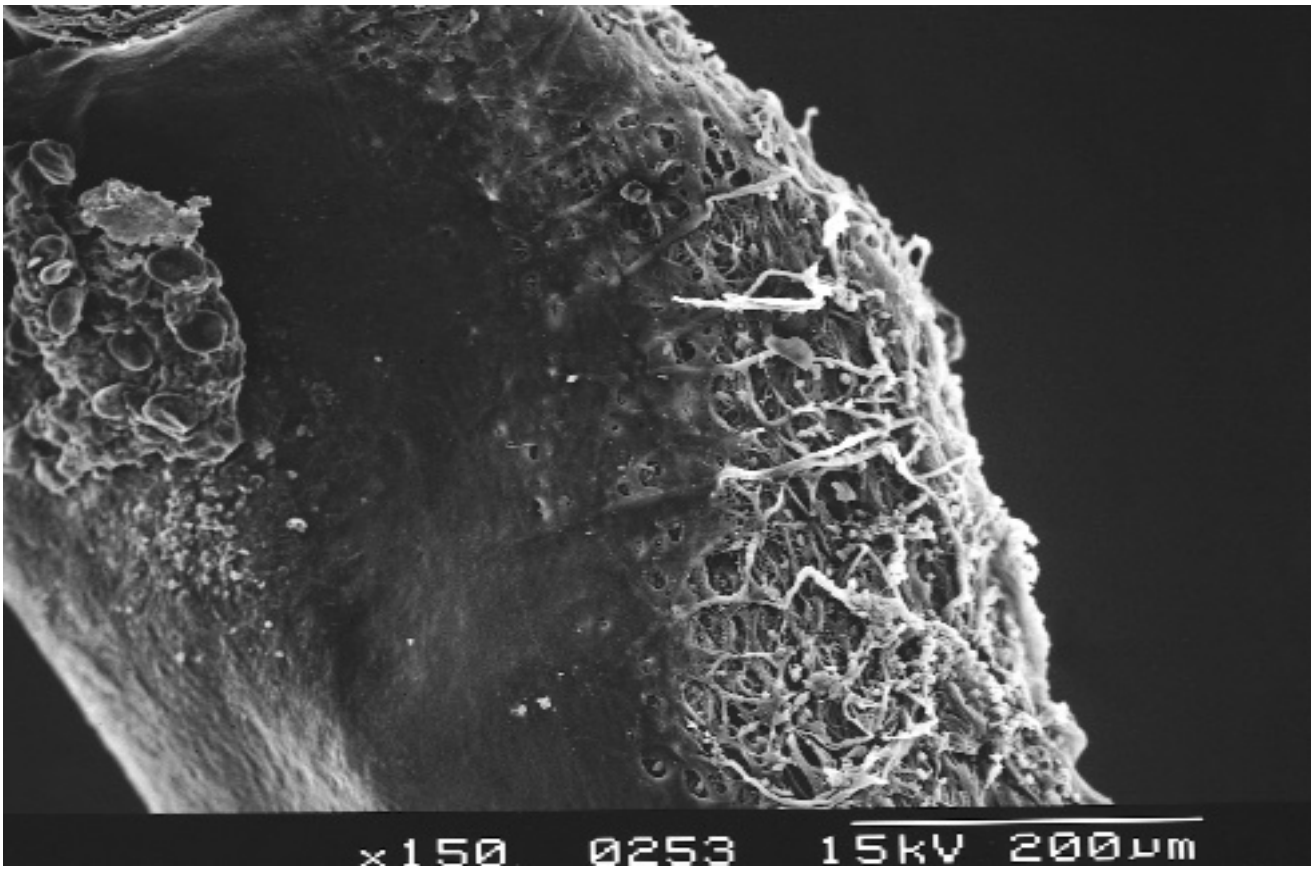

Fig. 3.- SEM (x 150). Glaucomatous trabecular meshwork with obstruction of the anterior-most trabecular orifices and permeable posterior orifices.

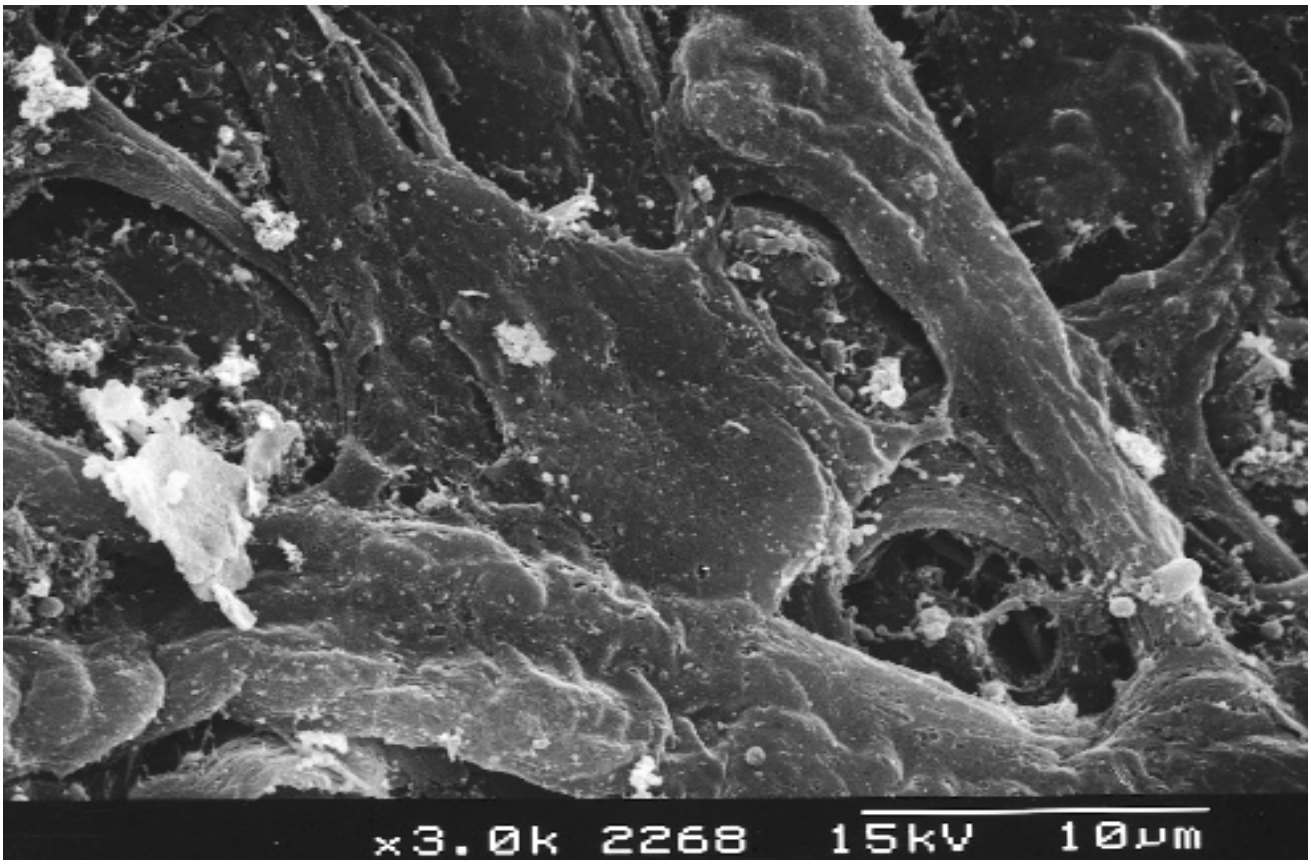

Fig. 4.- SEM (x 3000). Detail of a flat cell located on the dense and homogeneous material obstructing a trabecular orifice of a glaucomatous trabecular meshwork.

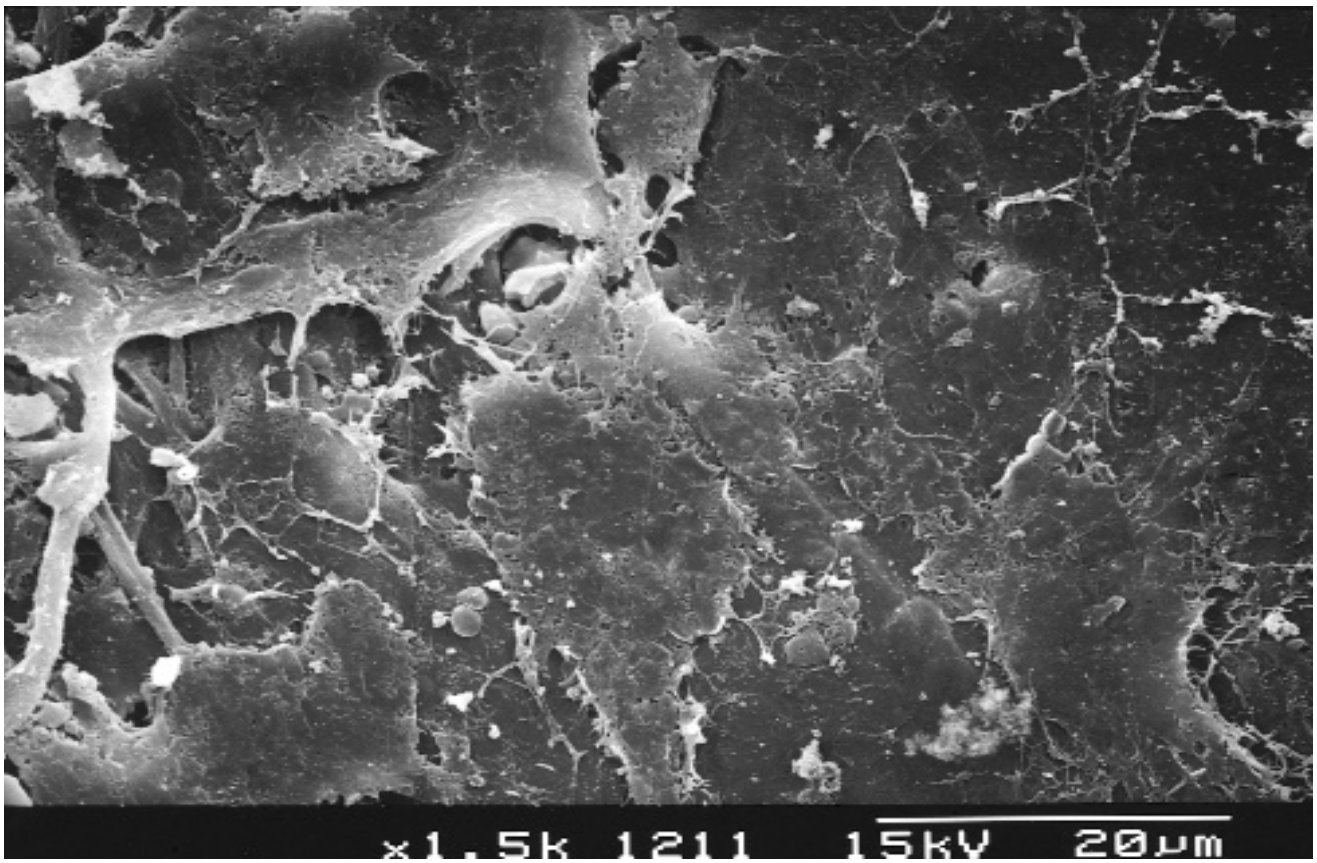

Fig. 5.- SEM (x 1500). A flat cell with an irregular contour can be identified above the homogeneous material obstructing the trabecular orifices.

In some of the specimens cell-like structures were observed superficially to the material covering the intracameral surface of the glaucomatous trabecular meshwork (Fig. 4). These cell-like structures had a flat morphology, with irregular contours and diameters ranging from 15 to 20 µm (Fig. 5). They also emitted cytoplasmatic expansions in varying numbers and morphology that contacted one another or contacted the endothelial cells of neighbouring trabecular beams.

Three trabecular meshworks that were completely obstructed with the previously described deposit material were observed with scanning electron microscopy using back-dispersed electrons. The purpose in studying these cases was to see whether this material had originated as a contaminant from the silver adhesive used in scanning electron microscopy to fix the specimens to the stubs. The images obtained revealed the absence of silver at the intracameral surface of the obstructed areas (Fig. 6). In addition, X-ray energy dispersion microanalysis performed on the obstructed areas of these specimens revealed the existence of two peaks originating from the gold coating of the specimens. No peak corresponding to the silver used in the adhesive was observed (Fig. 7).

DISCUSSION

Our findings point to the existence of significant morphological and structural changes in the trabecular meshwork in primary open-angle glaucoma that may be directly related to this pathology. Obstruction of the trabecular orifices is a mechanical handicap for the correct drainage of the aqueous humour from the anterior chamber to Schlemm's canal. This may cause aqueous retention in the anterior chamber, with a subsequent increase in intraocular pressure.

The observation of a dense and homogeneous deposit material obstructing the orifices of some glaucomatous trabecular meshworks has previously been reported by Chaudry et al. (1979), Dueker (1980) and Vinuesa et al. (1982). These authors reported similar changes to those observed in the present study, but failed to offer any possible explanation for the composition and origin of this material.

On the other hand, the studies of Quigley and Addicks (1980), Maglio et al. (1980) and Gieser et al. (1981) rule out the obstruction of trabecular orifices as a possible mechanism in the development of primary open-angle glaucoma since the permeability of these orifices was complete in all the trabecular meshworks observed by

Fig. 6.- SEM with back-dispersed electrons (x 129). The image shows that the material obstructing the trabecular orifices does not consist of silver from the adhesive, which is concentrated at the base of the sample.

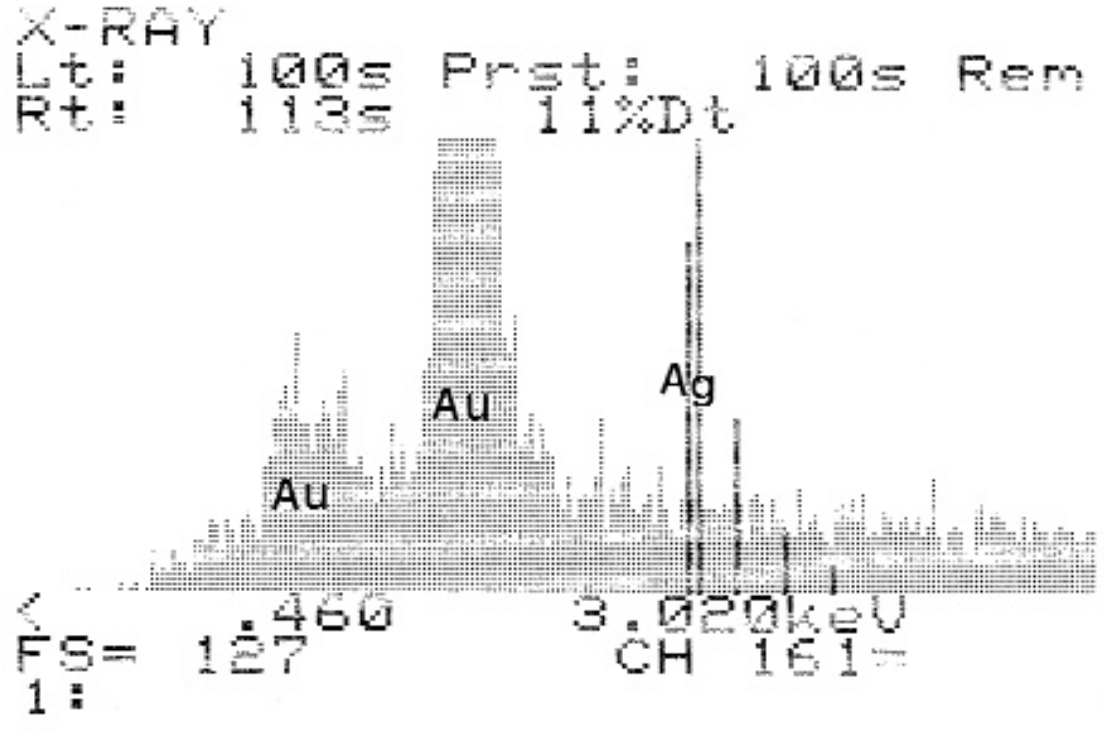

Fig. 7.- X-ray energy dispersion microanalysis of the homogeneous material obstructing the trabecular orifices. No silver is detected in its atomic composition. Both gold peaks are generated by the coating of the sample.

them. Maglio et al. (1980) suggested that the deposits obstructing the trabecular orifices observed by Chaudry et al. (1979) may have been due to contamination of the specimen's surface with the silver adhesive used to fix the sample to the stub. We discarded this possibility by observing obstructed trabecular meshworks under scanning electron microscopy with back-dispersed electrons and by performing X-ray energy dispersion microanalysis on the obstructed areas. Both techniques ruled out the presence of silver in the material analyzed.

The observation of cell-like structures in the layer of deposit material may explain how this latter originates. In our opinion, these cells may be endothelial cells from trabecular beams undergoing a process of migration. For different reasons, such as increased phagocytosis of pigment granules and other deposit materials, trabecular endothelial cells may become activated and start a migration process that leads them to leave the trabecular beam on which they lie. As these cells move, they use the underlying layers of beams as a substrate on which they deposit an extracellular matrix that forms the homogeneous and dense material that finally obstructs the trabecular orifices. The migration stops when an endothelial cell contacts another endothelial cell of a neighbouring beam through its cytoplasmic expansions and the two cells finally fuse together. Through this mechanism, the layer of material extends and progressively obstructs the more superficial trabecular orifices.

The theory relating endothelial cell activation to the obstruction of trabecular orifices is supported by the work of different authors such as Sherwood and Richardson (1988) or Johnson et al. (1989), who demonstrated that trabecular endothelial cells can become activated and migrate after the phagocytosis of different types of particles, among them pigment granules. On the other hand, authors such as Buller et al. (1990) and Zagórski et al. (1990) have reported that postphagocytic migration of human trabecular endothelial cells is either very limited or does not occur.

The observation in some specimens of more pronounced changes in the anterior portion of the trabecular meshwork can be explained in terms of the participation of Descemet's membrane and corneal endothelial cells in a process similar to that previously described, which covers the trabecular meshwork backwards from the front. This observation is based on the fact that both endothelial cell types, trabecular and corneal, have a common embryonic origin and can therefore become activated in response to similar stimuli and behave similarly, as reported by Tripathi and Tripathi (1989) and Foets et al. (1992).

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