Fibrillary lines of the cornea

A clinical sign in keratoconus

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In the course of studying keratoconus patients, fibrillar structures lying immediately inside Fleischer's ring have been observed. Their arrangement is thought to be characteristic of this condition. They lie at the level of the subepithelium and are identical in form but not in arrangement to similar structures in the normal cornea. These are described in the preceding paper (Bron, 1975). The present paper describes the distribution of fibrillary lines in keratoconus and how they differ from those in normal eyes.

Material and methods

Observations were made in the Keratoconus Clinic of Moorfields Eye Hospital. Clinical findings were docu-

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mented on a proforma which recorded clinical history, vision, refraction, ocular pressure, keratometry, and biomicroscopical and ophthalmoscopical findings. Photo-slit photographs were taken of all subjects and macrophotographs (Brown, 1970) were taken in some cases. Drawings were made of the corneal changes. The dimensions of the fibrillary structures observed were gauged by measurements from selected macrophotographs. The findings in 77 newly referred patients are presented in this paper.

Clinical findings

The fibrillary lines of keratoconus are fine, white, curved, and slightly wavy, and lie in concentric bundles at the internal margin of Fleischer's ring (Fig. 1). They are not visible in all patients with keratoconus and are most readily seen when

FIG. 1 *Keratoconus. Arrangement of fibrils internal to Fleischer's ring*

FIG. 2 *Macrophotograph of fibril in keratoconus (arrowed)*

FIG. 3 *Concentric bundles of fibrils in keratoconus (Macrophotograph $\times 70$). Note communications between adjacent fibrils reminiscent of inosculating nerves (arrowed)*

Fleischer's ring is dense and fully developed. The fibrils are seen to lie just deep to the epithelium when examined in the slit section (Fig. 2). They are more readily visible than the majority seen in normal eyes.

The fibrils are best demonstrated with the broad oblique focal illumination of the slit lamp, though they may occasionally also be faintly visible on retro-illumination against the fundus or iris. Individual fibrils are about $8\ \mu$ in diameter (range 6.1 – 10.2 : 21 fibrils measured in six patients) and are separated from neighbouring fibrils by a variable interval of some 50 to $100\ \mu$. Here and there communications between adjacent fibrils may be seen (Fig. 3). The number of fibrils found internal to Fleischer's ring is

not constant, and often a solitary fibril is present which appears to run for a considerable distance around the ring.

In a proportion of corneae further groups of fibrils are found concentric to those bordering Fleischer's ring (Fig. 3).

Fig. 4 shows the distribution of fibrils in a number of keratoconus corneae. In some corneae showing definite but early signs of keratoconus the fibrils exhibit the vertical or radiating distribution found in the normal cornea (Fig. 4a). Other keratoconus corneae exhibit both the vertical or radiating pattern of the normal cornea, and the circular pattern typical of keratoconus (Fig. 4b). Transitional forms are also

FIG. 4 Variation of corneal fibril pattern in patients with keratoconus.

(a) Normal pattern, similar to that seen in non-keratoconus corneae

(b) Combined pattern. Separate circular fibrils plus the radiating form of normal corneae

(c) Transitional pattern

(d) Vertical fibrils extending above the gap in Fleischer's ring

(e) "Wheatsheaf" pattern

(f) Fibrils bridging across the horizontal gap in a Fleischer's ring

found where the circular pattern runs into the vertical, invariably above (Fig. 4c).

Fibrils are predominantly found within the confines of Fleischer's ring. However, bundles of fibrils may extend above the gap in the upper portion of an incompletely developed Fleischer's ring (4d) and, rarely, may run across the ring itself in this location. Vertically-aligned fibrils in this region may show a constriction which gives the bundle of fibrils an S-shape or a "wheatsheaf" configuration (Fig. 4e). At this stage of development the fibril pattern is more like an inverted V than the upright V-pattern of the normal cornea.

Although the circular bundles of fibrils in keratoconus are customarily associated with the visible Fleischer's ring, the fibrils can also be seen bridging across the gap which is often present in the horizontal meridian when the ring is developing. These bundles continue in the same arc as the visible ring (Fig. 4f).

No particular relationship between the visibility of the stromal nerves and the visibility or extent of the fibrillary changes has been noted. However, as in normal corneae, connections between deeper stromal nerves and the fibrils have been observed.

Table I gives details of the fibril incidence in the 77 keratoconus patients examined in this study: 54 men (mean age 31.2 yrs; range 11 to 39 yrs) and 23 women (mean age 24.3 yrs, range 12 to 65 yrs). Only those fibrillar patterns thought to be characteristic of keratoconus, e.g. circularly arranged bundles, whether immediately within or more central to Fleischer's ring, wheatsheaf patterns, etc., were included in the Table. It will be seen that fibrils of keratoconus type

Table I Incidence of fibrils* in keratoconus

Incidence of fibrils	Sex	No. of patients		No. of eyes	
Total examined	M	54	77	108	154
	F	23		46	
Fibrils present	M	17	31	29	51
	F	14		22	
Bilateral fibrils	M	12	20	24	40
	F	8		16	

* Fibrils with a distribution typical of keratoconus.

were present in about a third of the eyes examined. Fibrils were present bilaterally in twenty patients.

The detailed arrangements are noted in Table II. The various combinations of patterns are not necessarily mutually exclusive.

Table II *Particular arrangements of fibrils in keratoconus*

<i>Clinical feature</i>	<i>No. of eyes</i>	<i>Patients Bilateral fibrils</i>
Gap fibrils	5	1
Gap + ring fibrils	11	2
Fibrils concentric to ring fibrils	2	—
Ring fibrils joining oblique and vertical fibrils	9	2
Ring fibrils distinct from oblique and vertical fibrils	16	4

Discussion

The fibrils described here are individually identical to those seen in the normal cornea both in situation at a subepithelial level and in their biomicroscopical characteristics. Those in keratoconus differ only in their grouping and distribution in the cornea. In the normal and in keratoconus corneae, communication between the subepithelial fibrils and nerve fibres in the stroma may be found, so that it is reasonable to suppose that in both situations the fibrils represent subepithelial nerve arborizations known to exist in the human eye (Zander and Weddell, 1951).

The difference in the fibril pattern between the normal and keratoconus eye is quite distinct. In the normal eye a well-developed pattern may appear to radiate upwards from the region of the inflexion point of a Hudson–Staehli line. If the Hudson–Staehli line is dense then it may send up secondary spokes which register exactly over the radiating fibrils. This suggests that an identical process may determine both the arrangements of the fibrils and the Hudson–Staehli line (Bron, 1975). The characteristic fibril arrangement in keratoconus is their occurrence immediately inside the internal edge of Fleischer's ring. This is intriguing, since the Hudson–Staehli and Fleischer lines are related. They are both iron lines of the cornea, marking the site of visible intraepithelial iron accumulation (Gass, 1964). It appears that they are interdependent, since the lower arc of Fleischer's ring seems to evolve from a Hudson–Staehli line in some cases and they are not seen as separate entities in the same cornea, except in the sense that a Fleischer ring may show horizontal extensions to the limbus,

most of which seem to represent the Hudson–Staehli line (Gass, 1964; Bron, 1973). It has been suggested recently that inward migration of epithelium from the limbus may play an important part in determining the configuration of the Hudson–Staehli line and Fleischer's ring (Davanger and Evensen, 1971; Bron, 1973). In the same way it may be suggested that the arrangement of the fibrils is related to the pattern of organization of the overlying epithelial cells. The occurrence of the fibrils immediately internal to Fleischer's ring in keratoconus and more centrally and concentric to it, would imply a change in this epithelial organization between epithelium lying central and peripheral to the site of the ring. The ring is said to occur at the base of the cone, *i.e.* at the site of a distinct curvature change, and it is possible that factors such as lid contact over the cone influence the disposition of the epithelium. The occurrence of 'gap' fibrils bridging between an upper and lower arc of Fleischer's ring does not influence this. The visible iron pigment lines are

FIG. 5 *Macrophotograph of "wheatsheaf" fibril pattern below the gap in the upper arc of Fleischer's ring*

probably preceded by a stage where histochemically demonstrable iron is present within epithelial cells and no line is visible clinically (Gass, 1964).

It is felt by the authors that the fibril pattern of keratoconus results from a modification of the fibril pattern of the normal cornea. This is presumably due to the ectasia and curvature changes as they affect the anterior cornea. Although it is easy to imagine a transition from a radiating to a circular pattern over some areas of the cornea (Fig. 4c), it is not easy to envisage the forces acting to produce the compressed bundle of fibrils which give rise to the "wheatsheaf" figure (Fig. 5) found usually in the upper cornea, usually below or within a gap in Fleischer's ring. Perhaps this relates to the common placement of the apex of the cone over the lower cornea. Ectasia presumably affects the upper cornea later. Any effect of ectasia on epithelial growth would be expected to be asymmetrical.

The continuity above, between fibrils running round Fleischer's ring and vertically disposed central fibrils (Fig. 1), is not explained simply as the result of a physical distraction of those fibrils already present. Some new fibril connections must have developed or been emphasized during the evolution of this configuration. If these are indeed neural structures, then questions are raised about the plasticity of the relationship between the subepithelial nerve plexus, its terminal twigs, and the epithelium. In the cornea and other parts of the body, such terminals are generally regarded as being in a state of morphological instability (Lele and Weddell, 1956).

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Although the exact nature of the fibrils and the factors influencing their formation must be regarded as speculative, studies are in progress to establish their neural structure and to determine their relationship to the epithelium. The suggestion that the fibril pattern characteristic of keratoconus develops as a modification of the pattern in the normal eye rests on morphological comparisons between patients and the identification of supposed transitional forms. Long-term follow-up of the cases under study should permit the evolution of the fibril patterns in question to be determined more precisely.

Summary

Fibrillary lines, whether in the normal cornea or in keratoconus, are faint structures which must be searched for diligently with the appropriate bio-microscopical settings, using a high magnification and oblique focal illumination of high intensity. They are unlikely to be confused with other superficial linear changes in the cornea, such as mare's tail epithelial lines, fingerprint lines and their variants, ring lines, and so on. A detailed description of these and other entities is given elsewhere (Brown and Bron, in preparation).

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