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The Hyalo-Capsular Zonula

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Abstract. This paper describes a zonular system between the posterior border of the lens and the anterior hyaloid. It is obviously the anatomical correlate of Wieger's ligament, which previously could not be confirmed anatomically, despite its functional evidence.

Introduction

For the clinician there is no doubt about the existence of a well-defined hyalo-capsular linkage between the posterior lens border and the anterior hyaloid; so it is surprising that the exact anatomical structure of this connection, so evident in both surgery and experiments (Vail 1957; Duke-Elder 1961), could never be demonstrated. The original findings of Wieger in 1883 are lacking since his thesis has been unavailable for many years. However, Salzmann reports Wieger's findings as a firm connection between the anterior hyaloid and posterior lens border, revealed by experiments with injections. He himself correlates a circular fibrillar thickening of the anterior hyaloid closely apposed to the posterior capsule of the lens with the hyalo-capsular linkage. Later, Egger (1924) and Davanger (1975) confirmed the existence of an attachment between the anterior hyaloid and the posterior lens border, but there is no precise anatomical description. Obviously there must be particular technical difficulties in revealing the anatomical base of this attachment.

This paper tries to explain these difficulties with the hypothesis that highly contractile connections are undetectable in their relaxed state, and will become manifest only when stretched. By exerting traction on the lens we find indeed a previously unknown zonular system connecting the lens with the anterior hyaloid 'membrane' (AHM) as a regular feature of human eyes.

Materials and Methods

In our experiments the lens was attached to a crane and then lifted slightly. The contrast of the transparent zonular fibres was increased through immersion in HgS. The capsulo-ciliary zonule was severed surgically whereby the otherwise invisible hyalo-capsular zonule appeared.

A total of 24 unfixed human autopsy eyes were examined. The age of the defuncts was known in 22 cases (mean 50 years, newborn –77 years). In 18 eyes the time between death and enucleation was known exactly (mean 10 h, 1–22 h). The eyes were put in TC medium (TC Medium 199 w/o phenol red) and kept in the refrigerator at 4° C. They were dissected and photographed about 25 h (1–96 h) after enucleation.

The globe was sutured into a ring-shaped holder (Fig. 1) and the cornea and iris removed surgically. A fixation appliance was glued to the dried anterior surface of the lens. This appliance was attached to the lever of a crane, which was variable in altitude and direction of lift. To avoid the effects of surface tension, in 16 eyes the globe was immersed in saline during the procedure. Traction was applied to the lens by the crane to bring in view one zonular layer after the other during dissection. After separation of each layer the zonule was sprinkled again with HgS suspension and the superfluous material flushed away in a gentle stream of pure saline. This method was preferred to proper staining because the apposition of red particles in the interstices between the fibrils makes the zonules visible without altering them chemically.

Stereophotographs were made through the surgical microscope Zeiss OPMI on Ilford 135 at 0.5-s exposure; the aperture was always set at maximum (1:2.0).

Results

After separation of the multilayered zonular fibres connecting the anterior and posterior lens border and the lens equator with the ciliary body (capsulo-ciliary zonule), a single-layered zonular sheet appears that connects the AHM with the ciliary body. It is composed of single radial fibres that are evenly spaced throughout the whole circumference. They are attached near the insertion of the posterior capsulo-ciliary zonular sheet and

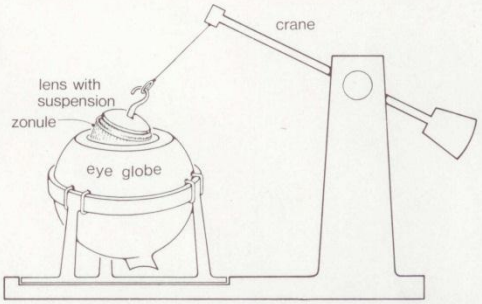

Fig. 1. The globe is fixed within a ring-shaped holder. The lever of the crane can be both lifted and moved on its length axis; the lifting is manipulated by a gear permitting very gentle motions. A thin flexible chain joins the crane lever to a fixation appliance on the lens. This appliance consists of a slightly curved disc of 7 mm diameter, which was cut out of a Ping-Pong ball and glued onto the lens by a rapid adhesive; for working 'under water' a cup formed by a plastic foil is put around the eyeball and eyeball holder and fixed to the base with putty (not shown in the drawing). To drain the rinsing liquid from time to time without producing swirls, there is an aperture in the base that can be opened and closed

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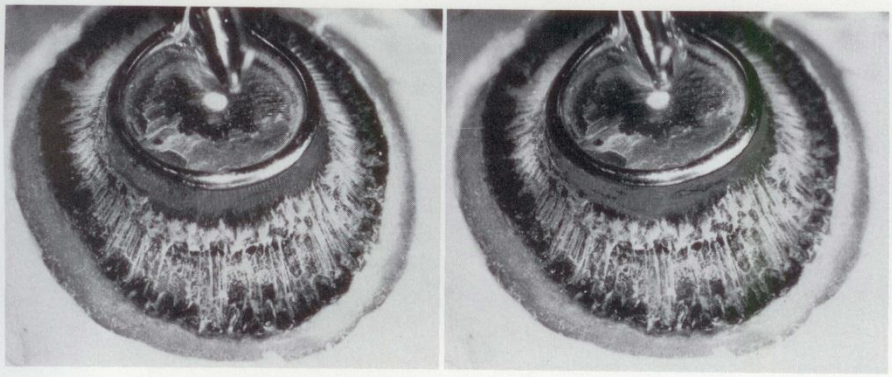
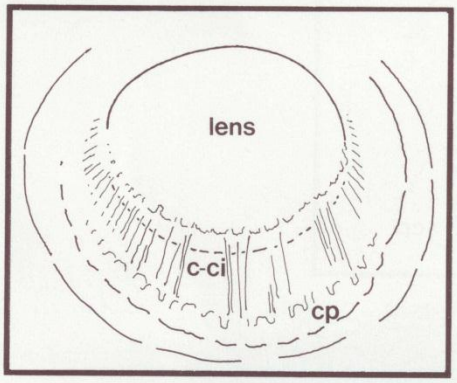
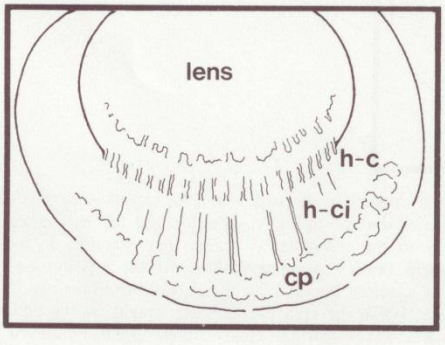




a



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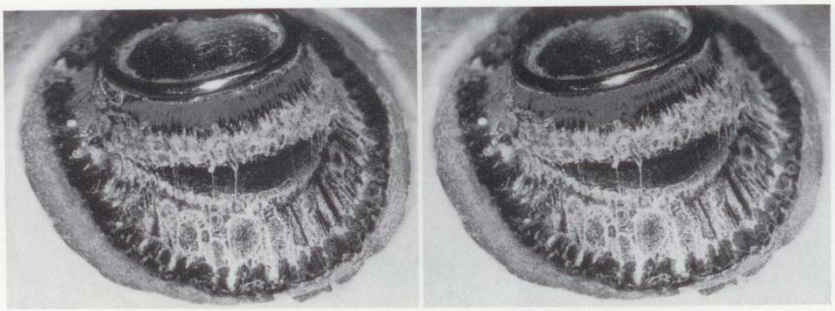

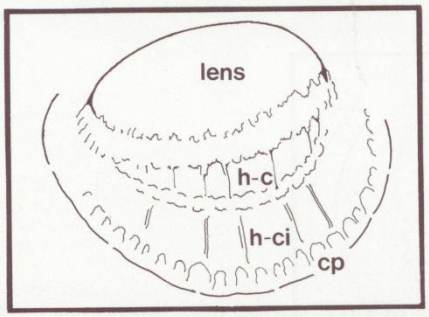

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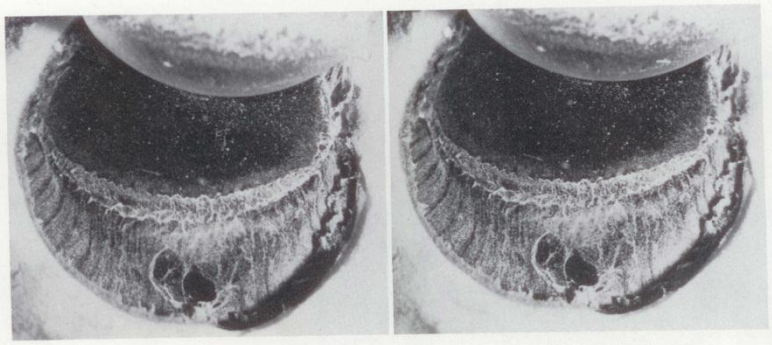
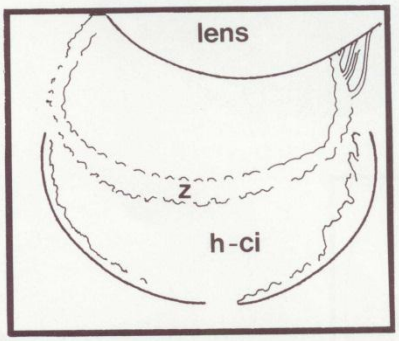
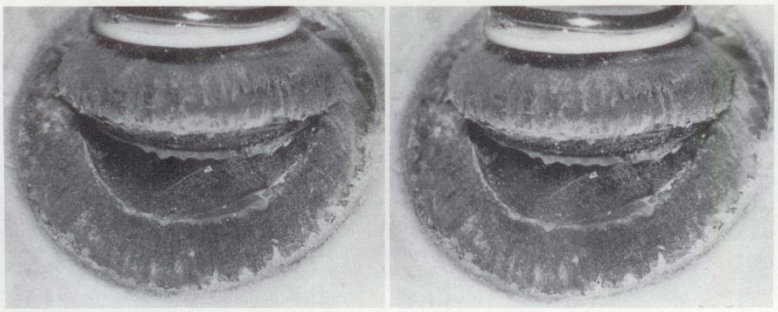




d

Figs. 2a–d. a Situs at the onset of the experiment: slight traction applied to the lens while the capsulo-ciliary zonule is still intact. **b** After separation of the multilayered zonular fibres connecting the anterior and posterior lens border and the lens equator with the ciliary body, a single-layered zonular sheet appears that connects the AHM with the ciliary body. Under light traction on the lens, another meshwork of radial fibres situated between the AHM and the posterior lens border becomes visible. **c** If the traction on the lens is enhanced the hyalo-capsular fibres will rupture, and the junction will open like a velcro band. **d** On the AHM the fibres are inserted on a circular line, which in some eyes appears as a slightly grayish and dentate line. While the HgS particles are caught by the peripheral part of the AHM, they can be rinsed off easily from the patellar part. *cp* ciliary processus; *c-ci* capsulo-ciliary fibres; *h-ci* hyalo-ciliary fibres; *h-c* hyalo-capsular fibres; *z* zone of insertion of the hyalo-capsular fibres on the AHM

For stereoscopic visualisation, use near-distance correction (25 cm) with 10 prism diopters base-out on both sides



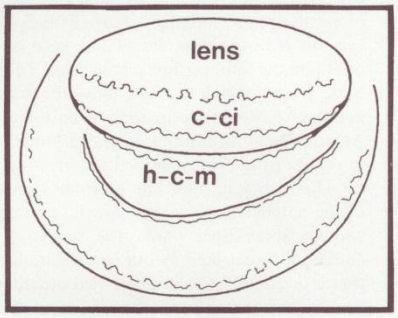
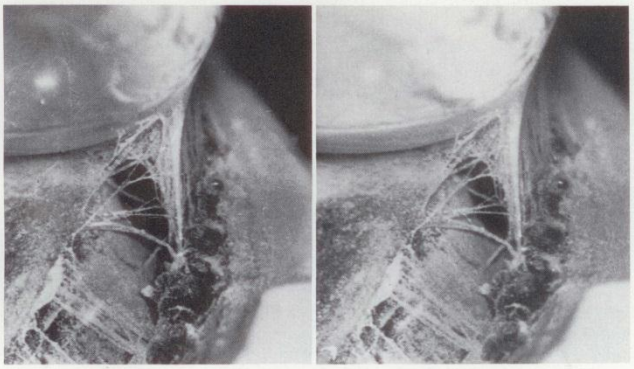


Fig. 3. After separation of the hyalo-capsular meshwork a membrane-like structure between the AHM and the posterior lens border appears in some eyes. Increasing traction on the lens results in a break of this sheet, which retains its shape, forming a flounce on either side of the gap. *c-ci* rest of the capsulo-ciliary fibres; *h-c-m* hyalo-capsular membrane-like structure



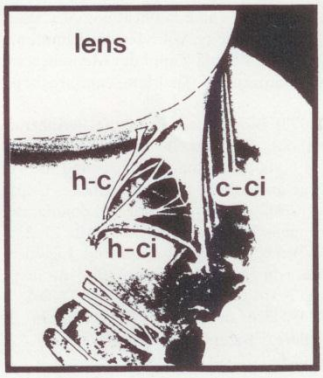


Fig. 4. The construction principle of the three different systems of zonular fibres *c-ci* capsulo-ciliary zonule; *h-ci* hyalo-ciliary zonule; *h-c* hyalo-capsular zonule

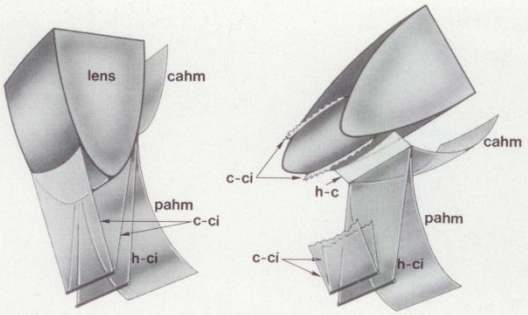


Fig. 5. The hyalo-ciliary and the hyalo-capsular system become visible only after dissection of the capsulo-ciliary system and under traction on the lens. *Left side:* before dissection of the capsulo-ciliary fibres; no traction on the lens, fibres not stretched. *Right side:* after dissection of the capsulo-ciliary fibres; lens under traction, fibres stretched. *c-ci* capsulo-ciliary zonule; *h-ci* hyalo-ciliary zonule; *h-c* hyalo-capsular zonule; *pahm* peripheral part of the AHM; *cahm* central part of the AHM

are closely apposed to the latter in their course towards the ciliary body (Fig. 2a). If this hyalo-ciliary zonule is subsequently sectioned surgically, the AHM neither changes its shape nor position – at least not on a noticeable scale – but remains attached to the lens.

The cause for the persisting fixation becomes apparent if traction on the lens is increased: there is another meshwork of radial fibres that extends between the AHM and the posterior lens border (hyalo-capsular zonule). This hyalo-capsular zonule is a single layer with evenly spaced fibres of about the same thickness as those of the other zonular systems when elongated by tension to about the same length (Fig. 2b).

The insertion of the fibres on the posterior lens border appears to be at the same site as the hyalo-ciliary zonule, but details cannot be clarified with the method described. On the anterior hyaloid the fibres are inserted on a circular line that in some eyes shows no particularities once the hyalo-capsular zonule is ruptured; in others, however, it appears as a slightly grayish and dentate line. If the traction on the lens is enhanced, some of the hyalo-capsular fibres will rupture, and the juncture will open like a velcro band. Now the patellar fossa lies free (Fig. 2c and d).

There are individual variations as to the thickness, density and spacing of the hyalo-capsular fibres, but no correlation with patient age or the time between death and examination could be ascertained in the eyes examined.

There is one important variation, though: Whereas in 14 eyes the anterior hyaloid was entirely free after separation of the hyalo-capsular zonule – indicating the zonular fixation is the only fixation system – in 10 eyes it remained attached to the lens. After sprinkling with HgS, a membrane-like structure between the anterior hyaloid and the lens appeared. Increasing traction on the lens resulted in a break of this rather stiff sheet, which retained its shape, forming a flounce on either side of the gap (Fig. 3). After rupture of this 'membrane', the anterior hyaloid appeared intact and detached from the lens.

Discussion

In the unfixed eye, with a staining procedure that does not affect the chemical structure of tissue, three different systems of zonular fibres can be revealed (Figs. 4 and 5):

1. The capsulo-ciliary system, which is a broad zone of zonular fibres connecting the lens margin with the ciliary body;

2. The hyalo-ciliary system, which is a single layer and connects the border of the patellar fossa with the ciliary body;

3. The hyalo-capsular system, first described here, connecting the posterior lens border with the border of the patellar fossa.

The hyalo-ciliary zonule is undistinguishable in the untouched eye since its fibres are closely apposed to the posterior leaf of the capsulo-ciliary zonule. Only after dissection of the latter in experiments, or after cataract extraction in the living eye, the hyalo-ciliary zonule becomes apparent (Eisner 1973).

Normally the hyalo-capsular zonule is completely invisible. The contracted fibres escape detection in both light microscopy and electron microscopy. Only when stretched does the hyalo-capsular zonule become recognizable as a circular single row of evenly spaced radially arranged fibres (Fig. 2b). In the living eye this is rarely seen, but it has been observed in some cases of traumatic subluxation of the lens. There is little doubt that these fibres, which are the only attachment between the lens and the AHM, are the anatomical correlate of Wieger's ligament. An additional membranaceous fixation structure that was found in some of the eyes examined requires further investigation.

The hyalo-capsular zonule inserts on the AHM at the rim of the patellar fossa, a site known to contain a band of circular zonular fibres (Spee 1902). The direct relationship to this band could not be clarified by our investigations, but one may assume that it is similar to that at the two other circular zonular bands, the median and the coronary ligament (posterior, and anterior orbicular band of Daicker). The AHM is thus fixed on the neighbourhood by three girdles of circular zonular bands, giving off radial fibres to the middle of the pars plana, to the posterior third of the ciliary processes, and to the posterior border of the lens.

The zonular nature of the hyalo-capsular juncture is not unexpected for the clinician. It explains the parallelism with the capsulo-ciliary system. It weakens with age, a well-known fact in cataract extraction. It also explains the effectiveness of alphachymotrypsin in dissolving the juncture.

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