An Ultrastructural Study of Elschnig’s Pearls in the Pseudophakic Eye


In two pseudophakic human eyes, obtained post mortem, Elschnig’s pearls were visible biomicroscopically. One eye contained a medallion lens and the other an iridocapsular lens (implanted for 53 months and 39 months, respectively). The medallion lens was fixed to the iris but was not attached to the Soemmering’s ring. Elschnig’s pearls and star-shaped cells were found on the posterior capsule in the pupillary space. One loop of the iridocapsular lens was encased in the Soemmering’s ring whereas the other was located between the iris and the lens remnants. The Elschnig’s pearls were on the anterior side of the ring; only a few were in the pupillary space.

Two other pseudophakic eyes with clear posterior capsules also contained small numbers of Elschnig’s pearls on or just near the peripheral lens remnants.

Extracapsular cataract extraction can produce a great variety of complications. One of the more common long-term complications is the opacification of the posterior capsule. In adults, the incidence is approximately 50% after three to five years and children and young adults seem to be even more susceptible to this complication. Opacification of the posterior capsule is also termed secondary membrane or after-cataract.

After-cataract may cause visual obstruction and is therefore a clinically important phenomenon. The formation of after-cataract is often associated with Elschnig’s pearls, also termed globular or bladder cells. Few studies have been devoted to these transparent, globular structures, which vary in size and frequency. Visual acuity may be affected by the pearls, depending on their protrusions into the pupillary space. Morphologic investigations disclose that they protrude from the space between the intact posterior capsule and the anterior capsular flap which is left behind after extracapsular cataract extraction.

Elschnig’s pearls appear to stain homogeneously with hematoxylin and Congo red and some are nucleated. Each pearl represents one cell; hence, they are also referred to as giant cells. Elschnig’s pearls are regarded as representing aberrant attempts of the lenticular epithelium to form new fibers. The globular shape of the structure is thought to result from the absence of the normal internal lenticular pressure so that the growing epithelial cells develop into an abnormal spherical shape. We studied the overall morphologic, light microscopic, and ultrastructural features of Elschnig’s pearls in pseudophakic human eyes obtained post mortem. We paid special attention to the possible role of the loop of the intraocular lens in the formation of Elschnig’s pearls.

Material and Methods

In this study two human pseudophakic eyes, obtained post mortem and containing Elschnig’s pearls, were investigated by biomicroscopy, light microscopy, scanning electron microscopy, and transmission electron microscopy. We also examined two pseudophakic eyes containing no biomicroscopically visible Elschnig’s pearls and with clear posterior capsules by biomicroscopy and scanning electron microscopy. The Table summarizes the clinical data for these four eyes.

After enucleation the eyes were inspected biomicroscopically and fixed in a cacodylate-
TABLE
SUMMARY OF CLINICAL DATA

<table>
<thead>
<tr>
<th>EYE</th>
<th>TYPE OF INTRAOCULAR LENS</th>
<th>LENGTH OF IMPLANTATION (MOS)</th>
<th>AGE OF PATIENT (YRS)</th>
<th>CLINICAL SYMPTOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Medallion (transiridectomy-fixated)</td>
<td>53</td>
<td>80</td>
<td>Elschnig's pearls</td>
</tr>
<tr>
<td>B</td>
<td>Binkhorst four-loop (iris clip)</td>
<td>39</td>
<td>72</td>
<td>Elschnig's pearls</td>
</tr>
<tr>
<td>C</td>
<td>Binkhorst four-loop (iris clip)</td>
<td>48</td>
<td>67</td>
<td>Clear posterior capsule</td>
</tr>
<tr>
<td>D</td>
<td>Binkhorst four-loop (iris clip)</td>
<td>44</td>
<td>87</td>
<td>Clear posterior capsule</td>
</tr>
</tbody>
</table>

buffered mixture of paraformaldehyde 1% and glutaraldehyde 1.25% (pH, 7.4; total osmolarity, 530 mOsm). Fixation time varied between five and ten days. The cornea and the posterior halves of the globes were dissected after fixation. The anterior segments of eyes A, C, and D and a part of the anterior segment of eye B were processed for scanning electron microscopy by dehydration in an ascending series of ethanols and critical-point dried with carbon dioxide. The dried specimens were glued in toto to aluminum specimen mounts with conductive carbon cement, gold-coated, and viewed in a scanning electron microscope.

After removal from the mount, the specimens were fractured. Some pieces were gold-coated for inspection of the fracture planes by scanning electron microscopy while other pieces were postfixed in osmium tetroxide 1% and embedded in Epon 812. For light microscopy, we stained semithin sections (1 μm) of this osmified material with toluidine blue. Ultrathin sections were stained with uranyl acetate and lead citrate and examined in a transmission electron microscope.

The anterior segment of eye B was used partly for scanning electron microscopy and partly for transmission electron microscopy, using the procedures described for the other specimens.

Results

Biomicroscopic examination of eyes A and B disclosed wrinkled posterior capsules with groups of transparent globular structures extending from the periphery into the pupillary space. In eye A many star-shaped cells were present in the center of the posterior capsule (Fig. 1). After the dissection procedures, the posterior view of the anterior segment showed ring-shaped peripheral lens remnants (a Soemmerring’s ring). The Elschnig’s pearls in both specimens seemed to originate in this ring

Fig. 1 (Kappelhof and associates). In eye A, Elschnig’s pearls extend from the pupillary margin into the pupillary space (arrow). More centrally, star-shaped cells can be seen (arrowheads) (×20).
structure. Some of the ciliary processes in eye A (medallion lens) showed distortion and elongation. This intraocular lens was not encapsulated in peripheral lens material. One of the loops of the iridocapsular lens in eye B was encased in the Soemmerring’s ring whereas the other was located between the iris and the lens remnants without adhesions. Our ultrastructural observations were focused on the Elschnig’s pearls and on their relationship with the lens remnants and the intraocular lens.

Scanning electron microscopy confirmed the biomicroscopic observations. In eye A the medallion lens proved to be free of the Soemmerring’s ring but was fixed to the iris (Fig. 2). After removal of the intraocular lens, the Elschnig’s pearls and the star-shaped cells were found on the posterior capsule in the pupillary space (Fig. 3). In eye B many of the Elschnig’s pearls were on the anterior side of the Soemmerring’s ring and only a few protruded into the pupillary space. The Elschnig’s pearls ap-

Fig. 2 (Kappelhof and associates). Anterior aspect of eye A with the medallion intraocular lens in situ. The cornea is dissected. I, iris; S, sclera (×16).

Fig. 3 (Kappelhof and associates). Elschnig’s pearls in eye A extend from the pupillary margin into the pupillary space (same area shown in Figure 1). The star-shaped cells are also visible (arrowhead). The partially visible cut loop of the intraocular lens is indicated by an arrow (×125).
peared as globular structures, piled up and ranging in diameter from 5 to 120 μm. At higher magnification the elongated form of the basal part of the Elschnig’s pearls was clearly visible (Fig. 4).

In both specimens the surface structure of the Elschnig’s pearls varied. Some of the membranes were almost smooth whereas others were covered with microvilli (Fig. 5). The star-shaped cells on the anterior side of the posterior capsule of eye A were uniform in size. They were located in the center and their protrusions approached the Elschnig’s pearls. In some parts their processes were in close contact with each other and formed a cellular network. The surface structure of these cells was not smooth but did not have the filamentous aspect found in the Elschnig’s pearls (Fig. 6). The Elschnig’s pearls bulged from the gap between the intact posterior capsule and the anterior capsular flap. These capsular remains enclosed the equatorial part of the lens, left behind after extracapsular cataract extraction. Inspection of the fractured Soemmerring’s ring in eye A showed that these capsules had failed to adhere in some places or had opened again (Fig. 7). In eye B one of the loops of the intraocular lens separated the anterior and posterior capsule, leaving a space where cellular elements bulged out (Fig. 8).

Light microscopy showed the inner structure of the Elschnig’s pearls. Their cytoplasm stained homogenously with toluidine blue and some showed a nucleus. Serial sections of eye A showed that almost all the pearls were nucleated with the nucleus sometimes located within the basal, slender part of the cell. The nuclei were sometimes round or oval but more often they appeared to be lobulated. In some sections this indentation gave the impression that the pearls were multinucleated (Fig. 9). We carefully examined the area at which the anterior capsular flap approached the posterior capsule and observed that the two were not closely appositioned (Fig. 10). At this point cellular material could be found between the two capsules. These cellular elements were indistinguishable from Elschnig’s pearls. The anterior capsular flap was subcapsularly lined with a single layer of epithelium. This epithelium also
covered the outside of the Soemmerring's ring (Fig. 11).

Transmission electron microscopy disclosed a homogenous cytoplasm with a fine granular aspect and almost no cell organelles. A rare vesicular body or vacuole could be found apart from the nucleus. The nuclei contained one or two nucleoli free of associated chromatin. The complex indentations of the nuclear envelope were obvious. In many places membranes of adjacent Elschnig's pearls showed interdigitations with gap junctions and structures resembling desmosomes (Fig. 12). The membranes of the most superficial Elschnig's pearls exhibited the microvillous surface observed on scanning electron microscopy (Fig. 13). The posterior lens capsule had an amorphous structure with a thickness of about 5 μm. There was a space between the posterior capsule and the Elschnig's pearls measuring 0.3 to 2 μm wide. This

---

Fig. 5 (Kappelhof and associates). Surface of the Elschnig's pearls in eye B. Two smaller, smooth-surfaced pearls can be seen on the microvillous surface of a bigger one (arrows) (×3,800).

Fig. 6 (Kappelhof and associates). Star-shaped cells on the posterior capsule in eye A. Nuclei are indicated by arrows (×2,000).
Fig. 7 (Kappelhof and associates). Fractured Soemmerring’s ring in eye A, showing the place of adherence between the anterior capsular flap and the posterior capsule on transection. A gap between the capsules permits cellular material to escape from the ring (arrows). Arrowheads, anterior capsule; stars, posterior capsule (×270).

Fig. 8 (Kappelhof and associates). Intraocular lens loop (arrowheads) enmeshed in the Soemmerring’s ring in eye B. The capsules are separated, leaving a gap, in which globular elements protrude (arrows). The posterior capsule, indicated by a star, is torn as a result of the preparation (×75).
Fig. 9 (Kappelhof and associates). Elschnig's pearls on the posterior capsule in eye A. The lobulated nuclei (with nucleoli) are clearly visible (arrows). The membranes are partly stained heterogenously (toluidine blue. ×600).

Fig. 10 (Kappelhof and associates). Soemmerring's ring in eye A with Elschnig's pearls on the posterior capsule (arrowheads) and on top of the Soemmerring's ring (arrows). The center of Soemmerring's ring has an amorphous structure (star); the gap between the anterior capsule (AC) and the posterior capsule (PC) is filled by cellular elements (toluidine blue, ×60).
space was electron-lucent and the capsule near this space demonstrated fibrillar elements (Fig. 14).

Eyes C and D had smooth posterior capsules without adhering cellular material. In eye C both loops of the intraocular lens were encased between the anterior capsular flap and the intact posterior capsule. In eye D one loop was in the same position whereas the other was free of adhesions. In neither specimen was a gap between anterior capsular flap and the posterior capsule apparent. As in the fractured specimen, both capsules had adhered tightly (Fig. 15). More careful examination, however, dis-
closed globular elements in both eyes C and D. In eye C the Elschning’s pearls were hidden behind the iris and were detected only after dissection. They protruded from the site of fusion of the two capsules just near the place where one of the loops was enmeshed (Fig. 16). In eye D few globular elements were detected by scanning electron microscopy. They were located in groups on the anterior side of the Soemmerring’s ring where there appeared to be breaks in the capsule (Fig. 17).

**Discussion**

In 1901 Hirschberg was the first to describe in humans what came to be called Elschning’s pearls. In 1911 Elschning provided a detailed description of his light microscopic investigations concerning this phenomenon in after-cataract formation. Elschning’s pearls were described as semiglobular and globular structures piled on the posterior capsule. Elschning’s pearls were thought to be caused by the opening in the capsule. Originating from the space between the posterior capsule and the anterior capsular flap, Elschning’s pearls extended into the pupillary space. Elschning himself regarded them as lens epithelium which had escaped from the Soemmerring’s ring and grown into aberrant fibers because of the lack of normal internal pressure from the intact lens. Since then only a few morphologic studies concerning Elschning’s pearls have been published. Recent articles concerning after-cataract changes, however, have dealt with the ultrastructure of epithelial cells found on the posterior capsule after extracapsular cataract extraction.

In animal models (cats and rabbits) it has been demonstrated that the anterior lens epithelium proliferated on the posterior capsule, forming multiple layers. In cats Elschning’s pearls are rounded or oval, perfectly transparent structures occasionally covered with anterior capsule. In rabbits Elschning’s pearls are uncommon, although posterior capsule opacification after extracapsular cataract extraction is prominent.

In humans, epithelial cells of the anterior lens capsule together with iris stromal cells form opaque membranes. The intraocular lens is thought to act as a scaffold for proliferating cells. McDonnell, Zarbin, and Green found that the fibrous membranes in posterior capsule opacification consisted of hyperplastic lens epithelium that had apparently undergone fibrous metaplasia. These cellular aggregates always originated at the site of apposition between the anterior capsular flap and the posterior capsule. They considered the epithelial nature of the cellular material to be proven by the formation of a basement membrane and the presence of interdigitating cytoplasmic processes and desmosomes.

In our study, Elschning’s pearls exhibited some characteristics of epithelial cells (for example, interdigitating processes and structures resembling desmosomes between adjacent cells and microvilli on the free surface). We could not demonstrate the formation of a basement membrane by Elschning’s pearls. The fine granular cytoplasm, the gap junctions, and the lack of cell organelles on transmission electron microscopy suggested that Elschning’s pearls are lens epithelial cells differentiating into lenticular fibers. This confirmed previous sugges-
Fig. 15 (Kappelhof and associates). Section of Soemmerring's ring in eye C. The area of fusion between the anterior capsule and the posterior capsule is indicated by the arrow (×84).

Fig. 16 (Kappelhof and associates). Elschnig's pearls in eye C, situated on the Soemmerring's ring just near the place where one of the loops of the intraocular lens (arrow) was enmeshed. The Elschnig's pearls are indicated by arrowheads. PC, posterior capsule; AC, anterior capsule (×110).
All Elschnig’s pearls in eye A may have possessed a nucleus because of unfinished differentiation or because of abnormal differentiation. Eyes B, C, and D did not undergo serial sectioning.

Although Elschnig’s pearls have been described as globular, our study showed they can exhibit long and slender shapes on scanning electron microscopy and, therefore, that the spherical form is only one variety of the cell (Fig. 4). The gap between the anterior and posterior capsule of the Soemmerring’s ring is thought to be a primary causative factor.\textsuperscript{9,11,32}

The intraocular lens loops in a pseudophakic eye can act as a mechanical element to initiate separation of the capsules, as Hiles and Johnson\textsuperscript{12} suggested. Although our results seem to be in accordance with this idea, further substantiation is needed before broad conclusions can be drawn.

The origin of the star-shaped cells found centrally on the posterior capsule of eye A remains unclear. Their shape showed some resemblance to the pigmented star cells which are a frequent congenital anomaly.\textsuperscript{30} Because of their fibroblast-like appearance on scanning electron microscopy, it seems likely that they were derived from the iris stroma.

Study of eyes C and D, in which no obvious Elschnig’s pearls were found after biomicroscopic inspection, disclosed a small number of globular elements (Elschnig’s pearls) either at the junction of the anterior and posterior capsule or at breaks in the anterior part of Soemmerring’s ring. In the latter case we observed that although the anterior and posterior capsule adhered tightly all along the inner side of Soemmerring’s ring, there were breaks on the anterior side of the capsule. Epithelial cells grow through these breaks; this was also found by Hiles and Johnson\textsuperscript{12} in the rabbit.

Proliferation of epithelial cells outside the ring of Soemmerring is much more frequent than biomicroscopic examination suggests. However, this phenomenon is only clinically relevant if the proliferating epithelial cells extend into the pupillary space. A complete suppression of this phenomenon might be obtained if all epithelial cells located in the lens bow region were removed during extracapsular cataract extraction but it is doubtful whether this will ever be achieved.

References