The ring of Soemmerring in the rabbit

A scanning electron microscopic study

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Abstract. The scanning ultrastructure of the remnants of the lens left in the eye after extracapsular lens extraction was investigated in the rabbit. Extracapsular lens extraction was performed in 25 eyes and the development of after-cataract followed by biomicroscopic examination. After survival times varying between 1 week and 12 months, the eyes were enucleated and the rings of Soemmerring treated for light microscopy and transmission and scanning electron microscopy. Soemmerring’s ring consisted of the fused remnants of the dissected anterior and posterior lens capsule, enclosing the equatorial part of the former lens, left behind after the operation. The anterior capsule and, to a lesser extent, also the posterior capsule were multilayered and appeared to be thickened. While the remnant of the anterior capsule was lined by a monolayer of epithelial cells, the posterior part of the capsule was only partly lined by irregularly arranged epithelial cells. All epithelial cells were highly vacuolated. In transsection the interior part of the ring consisted of normal fibers, irregularly oriented and irregularly shaped fibers, degenerated fibers, and globular amorphous masses. Many of the normal fibers contained cell nuclei. At the equator and at the posterior side of the fusing anterior and posterior capsule as well, the fiber organization resembled the lens bow region of normal lenses. Frequently, islands of epithelial cells were observed in the center of the ring. The vitreal face of the posterior capsule in the center of the ring (in the optic axis of the eye) seemed to be unchanged and on its pupillary surface, fibers of different size as well as fibroblastlike cells were found. However, clear-cut Elschnig’s pearls were absent. Our results are compared with the observations summarized in the literature. It can be concluded that the epithelial cells in Soemmerring’s ring retain their capacity for division and differentiation. The newly formed fibers seem to be pushed to the center of the ring and to degenerate.

The first descriptions of after-cataract following an extracapsular cataract extraction were by Dietrich in 1824 and Cocteau and Leroy-d’Etiolles in 1827 reviewed by Duke-Elder 1969). After-cataract in man was noticed by Soemmerring (1828), and the remnants of the peripheral parts of the lens have been named after this ophthalmologist from Göttingen: Soemmerring’s ring. Elschnig (1911) performed light-microscopic examinations and offered some case histories on human material. The globular lens remnants on the posterior lens capsule, first described by Hirschberg in 1901, are called Elschnig’s pearls or bladder cells. Duke-Elder (1969) reviewed the light microscopic investigations in after-cataract formation and classified lens remnants in three groups: capsular remains; capsulolenticular remains; pigmented, hemorrhagic, and inflammatory fibrous elements. In a detailed paper, McDonald et al. (1974) have described the formation of after-cataract in the rabbit using transmission electron microscopy and autoradiography. According to the literature, the ring of Soemmerring is formed by the fusion of the anterior and posterior capsule enclosing (within its walls) a variable amount of lens cortex and proliferating and degenerating epithelial cells. This results in a doughnut-shaped capsular structure. The middle of the ring consists of the posterior capsule and it is this capsule, in the axis of the eye, that obstructs vision when it becomes opaque. Unless sector iridectomy has been performed or aniridia is present, or unless the pupil is sufficiently dilated, the ring itself is hidden by the iris.

As part of a study on laser treatment of after-cataract and as an introduction to a study on human material, we investigated the morphology of after-cataract in the rabbit by light microscopy (LM), scanning electron microscopy (SEM), and transmission electron microscopy (TEM). The main purpose of this study was to investigate the scanning ultrastructure of normal and distorted lens fibers in the ring of Soemmerring and the adherent structures on the posterior capsule. In a period of increasing use of the extracapsular cataract-extraction technique in man, reinvestigation of the structure of the retained lens material seems necessary, as we still do not know why the capsule remains clear in some patients, while in others it becomes fibrotic. Some patients never acquire Elschnig’s pearls and others need removal three times a year.

Materials and methods

Adult Dutch pigmented rabbits with clear lenses were used in this study. The lenses of 25 eyes were extracted extracap-
Table 1. Postoperative survival time of rabbits, together with number of eyes examined

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<th>Postoperative survival time</th>
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<td>1 week</td>
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As a whole. From the other eyes Soemmerring’s rings were extracted. The specimens were thoroughly rinsed in cacodylate buffer, dehydrated in a graded series of ethanol and critical point dried with CO₂ (see Willekens and Vrensen 1981). The specimens were glued on SEM specimen mounts with conductive carbon cement and subsequently gold-coated. The specimens were examined in a Phillips SEM 505 scanning electron microscope using a secondary electron detector. After inspection, the specimens were removed and fragmented and the newly exposed faces were gold-coated. Some smaller specimens were mounted on special metal plates and studied in a Philips EM 400 electron microscope using the back-scatter detector.

For transmission electron microscopy, the specimens were postfixed in OsO₄ and, after dehydration in ethanol, embedded in Epon 812. Semithin and ultrathin sections were cut and stained with toluidine blue and uranyl acetate lead citrate, respectively. The ultrathin sections were studied in a Philips EM 201 electron microscope.

For light microscopy several specimens were rinsed and dehydrated in a graded series of ethanol for 2 weeks and embedded in nitrocellulose.

**Results**

Table 1 shows the postoperative survival time together with the number of eyes examined. We operated on 16 rabbits, mostly one eye at a time. The animal with 1-week survival time suddenly died of unknown causes; the results of the study on this specimen were therefore not taken into account.

Soemmerring’s ring was found in all dissected eyes (Fig. 1a, b). No clear-cut Elschnig’s pearls were observed. In most cases remnants of pigment-containing cells were found on the outside of the anterior capsule of the ring, probably derived from the pigment epithelium of the iris (Fig. 2a ar.d b). In different places in the anterior chamber of the eye (e.g., on the anterior side of the iris), light microscopy showed parts of the dissected anterior capsule, enclosing small amounts of acidophilic material. These so-called lentoids of Thiel will not be discussed, as they are beyond the scope of this article.

Three weeks after the operation, the equatorial part of the lens remnants was still rather flat but definitely a ringlike structure had been formed. In the center of the ring the posterior lens capsule was sometimes covered with fibrinlike material (Fig. 1a). In transection, the walls of the ring consisted of the posterior and anterior capsules, the anterior capsule being thicker than the posterior ones (Fig. 3). The material enclosed between the capsules predominantly consisted of lenticular fibers oriented in a regular pattern. The equatorial cap of nucleated fibers showed the configuration of a normal lens bow, i.e., an arrangement of fiber nuclei in a bowlike pattern. (In Figs. 3 and 11a, its site is indicated by an arrow.)

Between 3 weeks and 4 months’ survival time after the

![Fig. 1. a, b Low-power scan of Soemmerring’s ring in the rabbit a 3 weeks and b 6 months after extracapsular lens extraction. Both pictures illustrate the doughnut-shaped encapsulated lenticular remains in the periphery and the retained posterior capsule in the center. a shows the more flattened aspect and central depression of fibrin at short survival time. Inset: Medium-power scan of the fibrin](image)

![Fig. 2. a, b. Medium-power scan a and transmission b picture of posterior synechiae on the anterior capsule of Soemmerring’s ring. In the transmission picture pigment granules are indicated by arrows: the cell membrane is lost, probably due to a preparation artifact. In the scan, numerous globular cells (arrows) and fibroblasticlike cells are adherent to the capsule c](image)
operation, the ring increased in size on cross section. The central part of the ring, formed by the posterior capsule, proved to be smooth on its vitreous surface. The pupillary surface showed various adherent structures: parts of the dissected anterior capsule, fibroblastlike structures, various fibrillar materials (Fig. 4a and b), and peripherally also the curled-up attachment of the anterior and posterior capsule (Fig. 11b, asterisk). In transsection, the anterior and posterior capsule of the ring did not show much difference compared with the capsules after 3 weeks' survival time. At its inner face the capsule was lined by a monolayer of epithelial cells. The inner face of the posterior capsule was not lined by epithelium except for an accumulation of epithelial cells near the site of fusion between the anterior and posterior capsules. The main difference between Soemmerring's ring at 3 weeks and 4 months was the increasing loss of regularity in the fiber organization of the latter. The equatorial cap of nucleated fibers was still there but the more central fibers in the ring showed various degrees of degeneration. Normal fibers are hexagonal and are anchored by various cell membrane specializations like interlocking protrusions, ball and socket junctions, undulations, folds, and bends. Most fibers in the center of Soemmerring's ring became irregular or sometimes square or triangular. The anchoring elements were changed in various ways: often great undulations and distorted interlocking protrusions were found. Sometimes fibers seemed degenerated to such an extent that only a skeleton remained. Some of these normal and abnormal lenticular fibers are shown in Figs. 5–8. Besides the lenticular fibers, also globular amorphous masses were observed at a more central position in the ring. (In Fig. 9, a transitional zone is depicted.) Between 4 and 12 months' survival time, no significant changes in the shape or size of the ring were noted. The rings were 5–7 mm wide and the maximum thickness of the ring was 2.5 mm. The organization of the zonular fibers of a specimen after 8 months' survival time was studied. Macroscopically and biomicroscopically, the zonular fibers looked normal and scanning electron microscope also revealed no alterations (Fig. 10). The central part of the capsule showed no difference compared to the specimen with a shorter survival time. In transsection, the anterior capsule was thicker than the posterior capsule and was multilayered. This multilayering is shown in Fig. 12. Maximal thickness was found at the side where the anterior was approaching the curved site of fusion with the posterior capsule (Fig. 11). The capsule itself had a granular appearance (Fig. 12).

At its inner surface the anterior capsule was lined by one layer of epithelium; in some specimens, however, multilayered epithelium was found in some places. The inner face of the posterior capsule rarely had an epithelial lining except near the fusion site of the anterior and posterior capsule (Fig. 11a, open arrow), as had been found already in an earlier postoperative stage. Epithelial cells at this place were present in groups, separated by strands of capsular material. These cells were highly vacuolated, as could be demonstrated by transmission electron microscopy. Two types of epithelial cells could be distinguished (Fig. 13a and b). One type had a lobulated nucleus, containing a lot of marginal, darkly staining heterochromatin. The cytoplasm contained numerous clear vacuoles, large cisterns of endoplasmic reticulum, and few mitochondria. The other type of cell contained a smaller nucleus with one or two small nucleoli without associated chromatin. Its cytoplasm had a fine granular aspect and only a few vacuoles and cell organelles could be observed. The second type was especially common in and near the site of fusion of the anterior and posterior capsule, but in some places the two types could be found adjacent to each other.

Sometimes transitional forms were found. In transsection, the content of the ring was extremely variable, from nearly normal fibers to amorphous, globular masses. Superficially in the equatorial region, the ring was made up by nearly normal fibers, closely packed (Fig. 5a) and with a normal set of anchoring devices, such as ball and sockets and interlocking protrusions (Fig. 5b). Sometimes irregularities in the pattern were obvious. In addition, folds and bends of the fiber surface were regularly observed in this region (Fig. 6). The numerous lens fiber nuclei were generally oval-shaped and contained lightly staining chromatin and up to three small nucleoli free of associated chromatin, thus resembling the nucleus of the second type of epithelial cell (Fig. 14). In transsection of the ring as a whole, these nucleated fibers were arranged near the equator in a bowlike pattern, the lens bow. A second lens bow was also observed posteriorly from the fusion site of anterior and posterior capsule (Fig. 11a, arrows).

In deeper parts, the fibers became more irregular, often with a flattened outline and more complicated interlocking protrusions (Fig. 8). In some instances, the outer aspect of the lens fibers was degenerated, in some places leading to the formation of large empty holes (Fig. 7). These structures probably represent Morganian globules. The amorphous structures that may fill a large part of the ring are illustrated in Fig. 9.

Discussion

Since the first description of after-cataract in rabbits by Dietrich in 1824 and somewhat later in man by Soemmerring in 1828, (reviewed by Duke Elder, 1969) many investi-

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Fig. 3. Medium-power scan of a transsection of Soemmerring's ring (3 weeks' survival time). The walls of the ring are formed by anterior and posterior capsule, which are fused centrally. The curled-up adhesion of the anterior capsule to the posterior capsule is indicated by an asterisk. The equatorial cap of nucleated fibers is indicated by an arrow

Fig. 4. a Fibrillar material and fibroblastlike cells are seen on the pupillary surface of the posterior capsule in the center of Soemmerring's ring. In b, capsular remains are observed

Fig. 5. a, b. High-resolution picture of normal lenticular fibers found in Soemmerring's ring: a illustrates the regular pattern of the fibers; b the ball and socket junctions (asterisks); the interlocking protrusions (arrows)

Fig. 6. High-resolution scan of normal lenticular fibers found in Soemmerring's ring. These fibers exhibit two more types of membrane specializations: undulations and folds and bends. These fibers are found in control rabbit lenses in the lens bow region
gators have described the so-called ring of Soemmerring (Werneck 1833; Textor 1842; Wessely 1910; Poos 1931; Cowan and Fry 1937; Binder et al. 1961; Smith et al. 1982), using mostly biomicroscopic and light microscopic methods. More recently, McDonald et al. (1974) have studied the development of after-cataract in the rabbit using transmission electron microscopy and 3H-thymidin autoradiography as well. In addition to the formation of the Soemmerring's ring, several have observed partial or complete regeneration of lenses after extracapsular extraction in the rabbit and other species (Cocteau and Leroy d'Etiolle 1827; Gonin 1896; Stone 1938). Binder et al. (1961) have carried out a detailed study on this subject, concluding that the degree of regeneration depends on the extensiveness of the adhesions between the anterior and posterior capsule during wound healing. Fibrin is thought to play a role in this process. A consistent observation in human after-cataract is the presence of so-called Elschng's pearls. They have been described in detail by Cowan and Fry (1937), Hiles and Johnson (1980), and by McDonnell et al. (1983) in man. Roy and Hanna (1975) mention their formation in the rabbit.

In the present study, we consistently found the formation of Soemmerring's rings. On only one occasion did we observe a partially intact lens. At enucleation after 4 months' survival time, half of the lens was present, either due to regeneration or incomplete extraction. The other part of the lens was occluded by extensive adhesion of the lens remnants with the iris. The low incidence of regeneration in our study contrasts with the observation of Binder et al. (1961). However, they did not remove the anterior capsule, whereas in our study a large part of the anterior capsule was dissected, as is also common practice in human extracapsular cataract extraction.

In rabbit, constant dilation of the pupil is not easily obtained and, therefore, complete removal of the anterior capsule is not as easy as in man. However, as much anterior capsule as possible was removed in this experiment. This procedure may induce adhesions between the posterior capsule and the remnants of the anterior capsule. Moreover, anterior capsule removal may induce more abundant wound healing and fibrin deposition, which seems to arrest regeneration (Binder et al. 1961).

Regarding the formation of Elschng's pearls, on biomicroscopy only one eye showed these pearls on the pupillary face of the posterior capsule. However, postmortem inspection did not substantiate this observation. According to Duke-Elder (1969), Elschng's pearls are derived from subcapsular epithelial cells that escape from the ring and are aberrantly deposited on the posterior capsule. Their absence in our study, and the fact that they are found in rabbit in one study only (Roy and Hanna 1974), may indicate that in this species the adhesion between the anterior and the posterior capsule is rather firm, leaving little space for escaping epithelial cells. The common observation of Elschng's pearls in man probably indicates that the adhesion of the capsules is less firm in man.

The fibrillar and cellular debris on the pupillary face of the posterior capsule, as found in the present study, confirms the observations of others (Duke-Elder 1969; Smith et al. 1982). In contrast with the capsule of the intact lens, the capsule of the ring of Soemmerring is multilayered, as has also been noticed by McDonald et al. (1974). These authors explained this layering by assuming that the metabolism of the underlying epithelial cell changes after lens extraction, most likely by a shift in synthesis of the relative amount of collagen and mucopolysaccharides, the main constituents of the capsule. The ring capsule also seems to be much thicker than normal in some areas, especially in the anterior capsule near the equator (McDonald et al. 1984; this paper).

Prince (1964) has investigated the thickness of the lens capsule in control rabbits and reported that the anterior capsule is much thicker (10–25 μm) than the posterior capsule (4–6 μm). A maximal anterior thickness of 25 μm was found near the equator, which gradually decreased to 10 μm in the anterior pole and to 4 μm in the posterior pole. Prince made these observations in young rabbits. In the adult rabbit the posterior capsule has about the same thickness, but during its lifetime the anterior capsule can increase in thickness by a factor of three. This local variation in thickness of the capsule and its increase with time makes it difficult to interpret the changes in thickness of the remnants of the anterior capsule. Also, the posterior capsule seemed to have increased in thickness—at least where it was covered at its inner side by epithelial cells. The presence of capsule-producing epithelial cells in this region, as can be deduced from the layered aspect of the capsule, supports this conclusion.

In transection of Soemmerring's ring, an epithelial lining all along the anterior face was observed at the inner side of the capsule. This fully confirms previous observations.

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**Fig. 7.** Medium-power scan of degenerated fibers found in Soemmerring's ring. Besides skeletal fibers (arrows) large empty globular structures were observed. These structures probably represent the SEM analogs of Morgagnian globules as seen in light microscopy.

**Fig. 8.** High-resolution scan of lenticular fibers with exuberant large and irregular interlocking protrusions found in Soemmerring's ring. Groups of these fibers were found showing various degrees of deterioration.

**Fig. 9.** Medium-power scan of the center of a transection of Soemmerring's ring. The upper part of the picture shows the more peripheral lenticular fibers (F); the lower part exhibits amorphous structures (A).

**Fig. 10.** Medium-power scan of the zonular fiber organization of Soemmerring's ring. The ruptured fibers are artifactual. c: capsule of the ring; cp: ciliary process.

**Fig. 11.** a, b. Soemmerring's ring in transection (7 months' survival time). a Illustrates the thickness of the anterior capsule in light microscopy. The black arrows indicate nucleated fibers arranged in a configuration resembling a lens bow. These configurations are seen at the equator and posteriorly from the fusion site of the anterior capsule to the posterior capsule. The open arrow indicates the place where epithelium was found under the posterior capsule. b Illustrates the curved fusion site of the capsules in a medium-power scan. The asterisk indicates the fusion site of anterior and posterior capsule.
Fig. 12. High-resolution scan of the anterior capsule after 8 months' survival time. The multilayering is clearly demonstrated. In this picture the subcapsular epithelium is seen from above. The arrows indicate the protruding nuclei.

Fig. 13. a, b. Transmission picture of the two types of subcapsular epithelial cells. a Illustrates the cell type with numerous vacuoles (V), large cisterns of endoplasmic reticulum (asterisk) and a lobulated nucleus (N) with marginal heterochromatin. b Illustrates the cell type with a fine granular cytoplasm (C), fewer and smaller vacuoles (V) and a smaller nucleus with nucleolus (N).

Fig. 14. Transmission picture of one of the nucleated lens fibers. The nucleus is oval-shaped and contains lightly stained chromatin with two nucleoli (n) without associated chromatin, thus resembling the nucleus of the second type of epithelial cell.

given in the literature by various authors. At its inner side, the posterior face had an irregular epithelial lining, mainly along the medial half. Epithelial cells on the outer side of the anterior capsule, as mentioned by Cowan (1937) in man, were not found in our rabbits. Light microscopic observations using 5–10 μm sections showed that at the equator and also near the fusion site of the anterior and posterior capsule, nucleated fibers were arranged in a configuration resembling a lens bow. This confirms the observations of Wessely (1910) in man.

Ultrastructurally, two cell types could be distinguished. The first type was characterized by an indented nucleus with numerous patches of chromatin, large cisterns of endoplasmic reticulum, numerous clear vacuoles, and a normal set of cell organelles (Fig. 13a). A second cell type was characterized by a round-to-oval nucleus that was indented less, with unfolded chromatin and a clear-cut nucleolus, few cytoplasmic organelles, and a homogenous cytoplasmic matrix (Fig. 13b).

Transitional forms occurred between the first and second epithelial cell type. Some of the cells of the second type strongly resembled the young lens fibers seen in the lens bow region of intact lenses. These two distinct cell types, with comparable structural characteristics, have also been observed in McDonald (1974). This distinction between two cell types, one of which sometimes resembled newly formed fibers, indicated that the epithelial cells left behind after the extracapsular extraction were able to differentiate. From the fact that they are also able to divide and synthesize capsular material (McDonald 1974), it can be concluded that the epithelial cells retain their vital functions after the extracapsular lens extraction. A new observation in the present paper is that the superficial fibers in the ring of Soemmerring bordering the equatorial region were relatively normal and exhibited, in an orderly fashion, the mutual anchoring devices. These anchoring devices have been described in detail in control rabbits (Willekens and Vrenson 1981). More to the center in Soemmerring's ring appeared the ultrastructure of degenerated fibers and globular amorphous structures. The disturbed structures were mostly present in the center of the transsected ring or away from the differentiating, newly formed lens fibers. This probably indicates that normal lens fibers, when they are pushed to the center due to the addition of new fibers, become disturbed and degenerate (for an illustration of this phenomenon see Fig. 9).

Extracapsular extraction of lenses in the rabbit leads to the formation of rings of Soemmerring, which gradually increase in thickness during the first 3 postoperative months. The epithelial lining of the capsule seems to consist of vital cells, as can be deduced from the fact that they are able to divide, to lay down new capsular material (McDonald 1974), and to differentiate into relatively normal fibers, with mutual interconnections, as in normal control lenses (this study). The normal continuous outgrowth of the newly formed fibers is obstructed, most likely due to adhesions of the anterior and posterior capsule at the inferior margin of the ring. These results in degeneration of these originally normal fibers, and finally, to the formation of amorphous masses and Morgagnian granules. The absence of clear-cut Elschinig's pearls on the pupillary face of the posterior capsule may indicate that the marginal adhesion of anterior and posterior capsule is stronger in rabbits than in man.

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