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Review Article

Pathological Changes of the Anterior Lens Capsule

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The anterior lens capsule (ALC), as the thickest basement membrane in the body, is an acellular, soft, smooth, transparent membrane secreted by lens epithelial cells. The ALC has its unique biomechanical properties to serve as a barrier and separate the lens from infectious viruses and bacteria together with the posterior capsule and pericapsular membrane. However, the biomechanical and ultrastructural properties of the ALC can be changed under certain conditions. Here, we provide a brief review of the pathological changes of the ALC in several eye disorders, including cataract, aniridia, climatic droplet keratopathy, exfoliation syndrome, true exfoliation syndrome, Alport syndrome, and silicone oil tamponade.

1. Introduction

The anterior lens capsule (ALC), as the thickest basement membrane in the body, encapsulates the crystalline lens and acts as a barrier and separates the lens from infectious viruses and bacteria together with the posterior capsule and pericapsular membrane. The ALC is an acellular, soft, smooth, transparent basement membrane secreted by lens epithelial cells (LECs). The ALC with the accompanying monolayer subcapsular epithelium represents the most important metabolic element of the crystalline lens. Recently, the biomechanical properties and biomedical engineering perspectives of the ALC were reviewed by us [1]. Also, here, we provide a brief review of the pathological changes of the ALC in several eye disorders, which were never mentioned previously.

2. Pathological Changes

2.1. Cataract. Cataract is most simply defined as opacification of the crystalline lens inside the eye, which is the commonest cause of vision loss worldwide [2, 3]. Under normal physiological conditions, the ALC with the lens epithelium represents a major site of ion transport and fluid transport, which plays a vital role in maintaining lens homeostasis and transparency by providing the driving force for the ionic gradients and the fluid circulation [4, 5]. Therefore, any factor disturbing the transport processes, components or biomechanical characteristics of the ALC, and morphology or biochemistry of the lens epithelium will lead to water accumulation in the lens and the subsequent unbalance of lens homeostasis, thus resulting in cataract formation [6]. Using AFM, Choi et al. [7] found that the cataract group showed significantly lower surface roughness in the anterior side of the ALC and higher surface roughness in their posterior side than the noncataract control group. They also found lower Young's modulus in the cataract group compared to the control group, regardless of the ALC side. Compared to nuclear cataracts, intumescent white cataracts do not have a significant difference in ALC thickness but differ in ultrastructure morphology, including extrusions at the basement membrane epithelial border, lamellation, rarefication, and filaments in the basement membrane [8].

In eyes with mature cataracts, poor fundus red reflex and poor visibility of the capsule makes surgery more

challenging. Therefore, capsule staining is often performed to enable the round edges of the capsulorhexis visible and facilitate the continuous curvilinear capsulorhexis (CCC) procedure. Several studies have verified that biomechanical properties of the ALC would change after vital dyes staining, including trypan blue, brilliant blue, and indocyanine green [9–13]. The darker and longer capsule staining that trypan blue provides is particularly advantageous, making it preferable to other agents for dye-aided cataract surgery. It has been reported that the stained capsules in human led to a decrease in elasticity and an increase in stiffness, especially in diabetic patients [13]. This effect is probably a light-dependent process and resulted from the photosensitizing action of trypan blue and light-induced collagen crosslinking of the capsule collagen because no biomechanical changes were found in porcine capsules with trypan blue staining in the absence of light or after a short illumination time of 30 seconds [12]. However, it is also reported that trypan blue application had no effect on capsule elasticity and stiffness [14]. By using a mechanized tensile strength model, Jaber et al. [15] found that there was no difference in CCC strength between trypan-blue-stained capsules and control capsules, indicating staining with trypan blue did not reduce CCC tear resistance.

2.2. Aniridia. Aniridia is characterized by underdeveloped iris and accompanied by abnormalities of the cornea, anterior chamber angle, lens, retina, and optic nerve [16, 17]. It has been discovered that the ALC from some aniridic patients is thinner and more fragile, making the capsulorhexis more challenging [17, 18]. Degenerative changes (degeneration, necrosis, and loss) and proliferative changes (proliferation and double layer) of the lens epithelium were also reported in familiar aniridia with cataract [19]. The exact cause of the thin, friable ALC in aniridia is unknown; one possibility is the absence of or diminished content in one or more of the ALC constituents.

2.3. Climatic Droplet Keratopathy. Climatic droplet keratopathy (CDK) is a corneal degeneration disease and characterized by a band-shaped pattern of subepithelial opacities and golden-yellow spherules [20, 21]. There is a strong association between changes of the ALC and presence of CDK. The capsule changes are usually confined to the central pupillary area, which includes a white opalescence, an elevation in front of the contour of the rest of the lens to form a plateau, and a "bag" or herniation of the lens capsule through the pupil. These ALC changes might be caused by excessive ultraviolet light exposure, which is also the main cause of CDK [22].

2.4. Exfoliation Syndrome. Exfoliation syndrome (XFS) or pseudoexfoliation syndrome is an age-related disease in which abnormal fibrillar extracellular material is produced and accumulates in many ocular tissues, mainly the ALC and the pupillary margin. The typical distribution of ALC deposits consists of three zones: a granular, often layered, peripheral zone; a central disc, and a clear area between them. Several studies confirmed fibrils accumulation above or in the basement membrane of the ALC in XFS eyes [23–28], and another unknown, electron-dense, microgranular, unbound material was also observed by transmission electron microscopy beneath the lens epithelium in XFS patients [29]. By immunofluorescence and electron microscopic immunogold techniques, heparan sulfate and chondroitin sulfate proteoglycans, laminin, entactin/nidogen, fibronectin, and amyloid P protein were shown to be an integral constituent of XFS material [30]. The ALC thickness was reported to vary greatly measured by light microscopy, and there was no statistical difference between XFS lenses and controls [31], while with high-resolution anterior segment optical coherence tomography, the ALC was found to be thicker in XFS patients than normal people [32]. The ALC ultrastructural abnormalities (diffuse intracellular and extracelluar edema, transparent vacuoles, apoptotic cells, and destroyed epithelial cells) were also found to be more extended and more frequently observed in XFS patients than cataract controls [33]. XFS can be unilateral or bilateral, but exfoliation material can also be found in the unaffected eyes of patients with clinically unilateral XFS [34, 35]. If capsule staining (i.e., trypan blue) is needed, lower concentration and/or exposure is recommended because the ALC has more affinity to trypan blue in XFS patients [36].

2.5. True Exfoliation Syndrome. True exfoliation syndrome (TEX) is a rare disorder in which characteristic lamellar separation of the ALC occurs. The pathogenesis of TEX is not clear; although intense infrared radiation is thought to be the main causative factor, most cases are idiopathic. Histologically, a thickened delaminated structure, perpendicular fibrils and vesicular degeneration in the capsule, and degenerative lens epithelium have been documented [37]. Recently, double delamination and pigment deposition on the detached membrane are reported to be new findings in TEX patients [38].

2.6. Alport Syndrome. Alport syndrome is a rare disorder of the basement membrane characterized clinically by progressive hereditary nephritis, sensorineural hearing loss, and ocular abnormalities. Genetically, Alport syndrome is due to mutations involving the coding for type IV collagen resulting in a defective synthesis of type IV collagen [39]. Clinically, the typical ocular manifestations of Alport syndrome are a flecked retinopathy and bilateral anterior lenticonus, which is resulted from the conical protrusion of the lens anteriorly through the thinnest and weakest part of the capsule [39]. Several electron microscopic studies have demonstrated the marked thinning and vertical dehiscence of ALC in Alport syndrome [40–43]. Spontaneous rupture of the ALC was also reported, which is suggestive of defective capsular strength [44, 45]. By using the lens capsule of wild-type and Alport syndrome mice as a model, the osmotic swelling experiments from the work of Gyoneva et al. [46] revealed direction-dependent changes. They found Alport lenses strained significantly more than wild-type lenses in

Table 1: Pathological changes of the ALC in different diseases.

Disease	Main changes
Cataract	Lower surface roughness in the anterior side of the ALC and higher surface roughness in their posterior side Lower Young's modulus Ultrastructure morphology changes in intumescent white cataracts
Trypan blue staining	Decrease in elasticity and an increase in stiffness No difference in CCC strength Thinner and more fragile
Aniridia	Degenerative changes (degeneration, necrosis, and loss) and proliferative changes (proliferation and double layer) of the lens epithelium
Climatic droplet keratopathy	Plateau or "bag" or herniation-like of the lens capsule
Exfoliation syndrome	Abnormal fibrillar extracellular material deposition Diffuse intracellular and extracelluar edema, transparent vacuoles, apoptotic cells, and destroyed epithelial cells More affinity to trypan blue
True exfoliation syndrome	Thickened delaminated structure, perpendicular fibrils, and vesicular degeneration in the ALC Double delamination and pigment deposition on the detached membrane
Alport syndrome	Marked thinning and vertical dehiscence of the ALC Spontaneous rupture of the ALC
Silicone oil tamponade	Surface irregularities, pits, and depressions in the posterior surface of the ALC LECs with apoptotic changes and cytoplasmic vacuoles Increased mechanical resistance of the ALC

ALC: anterior lens capsule; CCC: continuous curvilinear capsulorhexis; LECs: lens epithelium cells.

the anterior-posterior direction, which is consistent with clinical data: Alport patients develop conical protrusions on the anterior and posterior lenticular poles.

2.7. Silicone Oil Tamponade. Silicone oil is an intraocular tamponade after vitrectomy surgery, which is used for the treatment of complicated retinal detachment [47]. However, intravitreal silicone oil can lead to several complications including cataract, glaucoma, band keratopathy, oil emulsification [48, 49], and ALC changes.

In Citirik et al.'s study, by electron microscopy, silicone oil was detected on the posterior surface of the ALC in 50% cases and surface irregularities, pits, and depressions were present in the posterior surface of the ALC in all the ten silicone oil tamponade cases [50]. Ultrastructural effects of silicone oil on the ALC of the clear crystalline lens of myopic eyes were also studied [51]. Light microscopic examination showed relatively more flat cells with irregular outline of LECs with wide intercellular spaces, deeply stained nuclei, and multiple intracytoplasmic vacuoles. Collagenous surfaces filled with multiple pits, depressions, and abnormal deposits were found under scanning electron microscopy, while transmission electron microscopy revealed LECs with apoptotic changes, cytoplasmic vacuoles, and filopodia-like protrusions between LECs and the capsule [51]. In the ALC of rabbit eyes with silicone oil tamponade, many vacuoles amid matrix accumulation were present on the posterior surface, suggesting the deposition of emulsified silicone oil droplets [52], which is similar to the histopathological findings of human eyes [53].

Clinically, rigidity of the ALC is frequently encountered during cataract surgery in silicone-oil-filled eyes [54], which increases the mechanical difficulties of anterior capsulorrhexis. The anterior subcapsular tissue plaque resulted from silicone oil tamponade may be responsible for the increased mechanical resistance of the ALC [55].

The different pathological changes of the ALC in different diseases are summarized in Table 1.

3. Conclusions

The ALC, as structural support for the lens within the eye, plays an important role on normal lens growth and metabolism. However, the biomechanical properties of the ALC may change in several ocular diseases, including cataract, aniridia, climatic droplet keratopathy, exfoliation syndrome, true exfoliation syndrome, Alport syndrome, and silicone oil tamponade. These pathological changes vary from biomechanical alterations (surface roughness, Young's modulus, elasticity, stiffness, rigidity, fragility, etc.) to ultrastructural abnormalities (increase or decrease in thickness, abnormal material accumulation, lamellar separation, vesicular degeneration, ALC dehiscence, surface irregularities, cytoplasmic vacuoles, etc.) in different ocular diseases. If cataract surgery is scheduled for these eyes, the surgery procedure, especially the capsulorhexis, would be challenging. Therefore, attention should be raised when performing cataract surgery for these patients.

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare to have no potential conflicts of interest.

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References

[1] D. Huang, C. Xu, R. Guo, J. Ji, and W. Liu, "Anterior lens capsule: biomechanical properties and biomedical engineering perspectives," *Acta Ophthalmologica*, 2020.

[2] J. Thompson and N. Lakhani, "Cataracts," *Primary Care: Clinics in Office Practice*, vol. 42, no. 3, pp. 409–423, 2015.

[3] P. Asbell, I. Dualan, J. Mindel, D. Brocks, M. Ahmad, and S. Epstein, "Age-related cataract," *The Lancet*, vol. 365, no. 9459, pp. 599–609, 2005.

[4] J. Fischbarg, F. P. J. Diecke, K. Kuang et al., "Transport of fluid by lens epithelium," *American Journal of Physiology-Cell Physiology*, vol. 276, no. 3, pp. C548–C557, 1999.

[5] J. F. Hejtmancik, S. A. Riazuddin, R. McGreal, W. Liu, A. Cvekl, and A. Shiels, "Lens biology and biochemistry," *Progress in Molecular Biology and Translational Science*, vol. 134, pp. 169–201, 2015.

[6] Q. Yan, J. I. Clark, T. N. Wight, and E. H. Sage, "Alterations in the lens capsule contribute to cataractogenesis in SPARC-null mice," *Journal of Cell Science*, vol. 115, no. 13, pp. 2747–2756, 2002.

[7] S. Choi, H.-J. Lee, Y. Cheong et al., "AFM study for morphological characteristics and biomechanical properties of human cataract anterior lens capsules," *Scanning*, vol. 34, no. 4, pp. 247–256, 2012.

[8] M. Hawlina, S. Stunf, and A. Hvala, "Ultrastructure of anterior lens capsule of intumescent white cataract," *Acta Ophthalmologica*, vol. 89, no. 4, pp. e367–e370, 2011.

[9] C. Simsek and O. Gokmen, "The effects of vıtal dyes on mechanıcal propertıes of the human anterıor lens capsule," *Indian Journal of Ophthalmology*, vol. 68, no. 1, pp. 66–70, 2020.

[10] C. Haritoglou, S. Mauell, R. G. Schumann et al., "Increase in lens capsule stiffness caused by vital dyes," *Journal of Cataract and Refractive Surgery*, vol. 39, no. 11, pp. 1749–1752, 2013.

[11] G. Wollensak and E. Spoerl, "Influence of indocyanine green staining on the biomechanical properties of porcine anterior lens capsule," *Current Eye Research*, vol. 29, no. 6, pp. 413–417, 2004.

[12] G. Wollensak, E. Spörl, and D.-T. Pham, "Biomechanical changes in the anterior lens capsule after trypan blue staining," *Journal of Cataract and Refractive Surgery*, vol. 30, no. 7, pp. 1526–1530, 2004.

[13] B. H. Dick, S. E. Aliyeva, and F. Hengerer, "Effect of trypan blue on the elasticity of the human anterior lens capsule," *Journal of Cataract and Refractive Surgery*, vol. 34, no. 8, pp. 1367–1373, 2008.

[14] C. Simsek, S. Oto, G. Yilmaz, D. D. Altinors, A. Akman, and S. G. Gungor, "Comparison of the mechanical properties of the anterior lens capsule in senile cataract, senile cataract with trypan blue application, and pseudoexfoliation syndrome," *Journal of Cataract and Refractive Surgery*, vol. 43, no. 8, pp. 1054–1061, 2017.

[15] R. Jaber, L. Werner, S. Fuller et al., "Comparison of capsulorhexis resistance to tearing with and without trypan blue dye using a mechanized tensile strength model," *Journal of Cataract and Refractive Surgery*, vol. 38, no. 3, pp. 507–512, 2012.

[16] I. Ivanov, A. Shuper, M. Shohat, M. Snir, and R. Weitz, "Aniridia: recent achievements in paediatric practice," *European Journal of Pediatrics*, vol. 154, no. 10, pp. 795–800, 1995.

[17] H. Lee, R. Khan, and M. O'Keefe, "Aniridia: current pathology and management," *Acta Ophthalmologica*, vol. 86, no. 7, pp. 708–715, 2008.

[18] S. Schneider, R. H. Osher, S. E. Burk, T. B. Lutz, and R. Montione, "Thinning of the anterior capsule associated with congenital aniridia," *Journal of Cataract and Refractive Surgery*, vol. 29, no. 3, pp. 523–525, 2003.

[19] Z. Q. Hou, Y. S. Hao, W. Wang, Z. Z. Ma, Y. F. Zhong, and S. J. Song, "Clinical pathological study of the anterior lens capsule abnormalities in familial congenital aniridia with cataract," *Beijing Da Xue Xue Bao Yi Xue Ban*, vol. 37, no. 5, pp. 494–497, 2005.

[20] C. S. Matta, K. F. Tabbara, J. A. Cameron, A. A. Hidayat, and A. A. al-Rajhi, "Climatic droplet keratopathy with corneal amyloidosis," *Ophthalmology*, vol. 98, no. 2, pp. 192–195, 1991.

[21] R. H. Gray, G. J. Johnson, and A. Freedman, "Climatic droplet keratopathy," *Survey of Ophthalmology*, vol. 36, no. 4, pp. 241–253, 1992.

[22] G. Johnson, D. Minassian, and S. Franken, "Alterations of the anterior lens capsule associated with climatic keratopathy," *British Journal of Ophthalmology*, vol. 73, no. 3, pp. 229–234, 1989.

[23] K. N. Sorkou, M. E. Manthou, S. Meditskou, N. Ziakas, and I. T. Tsinopoulos, "Exfoliation fibrils within the basement membrane of anterior lens capsule: a transmission electron microscopy study," *Current Eye Research*, vol. 44, no. 8, pp. 882–886, 2019.

[24] T. T. Kivelä, "Histopathology of exfoliation syndrome," *Journal of Glaucoma*, vol. 27, no. 1, pp. S38–s43, 2018.

[25] J. C. Morrison and W. R. Green, "Light microscopy of the exfoliation syndrome," *Acta Ophthalmologica*, vol. 66, no. 184, pp. 5–27, 1988.

[26] Z. Sbeity, P. M. Palmiero, C. Tello, J. M. Liebmann, and R. Ritch, "Noncontact in vivo confocal laser scanning microscopy of exfoliation syndrome," *Transactions of the American Ophthalmological Society*, vol. 106, pp. 46–55, 2008.

[27] R. Ritch, "Ocular findings in exfoliation syndrome," *Journal of Glaucoma*, vol. 27, no. 1, pp. S67–s71, 2018.

[28] J. H. Seland, "The ultrastructural changes in the exfoliation syndrome," *Acta Ophthalmologica*, vol. 66, no. 184, pp. 28–34, 1988.

[29] K. N. Sorkou, M.-E. Manthou, K. T. Tsaousis, P. Brazitikos, and I. T. Tsinopoulos, "Transmission electron microscopy study of undescribed material at the anterior lens capsule in exfoliation syndrome," *Graefe's Archive for Clinical and Experimental Ophthalmology*, vol. 256, no. 9, pp. 1631–1637, 2018.

[30] U. Schlötzer-Schrehardt, S. Dörfler, and G. O. H. Naumann, "Immunohistochemical localization of basement membrane components in pseudoexfoliation material of the lens capsule," *Current Eye Research*, vol. 11, no. 4, pp. 343–355, 1992.

[31] J. Ruotsalainen and A. Tarkkanen, "Capsule thickness of cataractous lenses with and without exfoliation syndrome," *Acta Ophthalmologica*, vol. 65, no. 4, pp. 444–449, 1987.

[32] M. Batur, E. Seven, S. Tekin, and T. Yasar, "Anterior lens capsule and Iris thicknesses in pseudoexfoliation syndrome," *Current Eye Research*, vol. 42, no. 11, pp. 1445–1449, 2017.

[33] K. Sorkou, M. E. Manthou, N. Ziakas, K. T. Tsaousis, and I. T. Tsinopoulos, "Severe abnormalities of lens epithelial cells in exfoliation syndrome: a transmission electron microscopy study of patients with age-related cataract," *Medicina (Kaunas)*, vol. 55, no. 6, p. 235, 2019.

[34] Z. Sbeity, P.-M. Palmiero, C. Tello, J. M. Liebmann, and R. Ritch, "Non-contact in vivo confocal scanning laser microscopy in exfoliation syndrome, exfoliation syndrome suspect and normal eyes," *Acta Ophthalmologica*, vol. 89, no. 3, pp. 241–247, 2011.

[35] P. Parekh, W. R. Green, W. J. Stark, and E. K. Akpek, "Electron microscopic investigation of the lens capsule and conjunctival tissues in individuals with clinically unilateral pseudoexfoliation syndrome," *Ophthalmology*, vol. 115, no. 4, pp. 614–619, 2008.

[36] H. Hosseini, M. H. Nowroozzadeh, M. R. Razeghinejad, H. Ashraf, R. Salouti, and M. J. Ashraf, "Anterior lens capsule has more affinity to trypan blue in patients with pseudoexfoliation," *Eye*, vol. 25, no. 9, pp. 1245-1246, 2011.

[37] C. Teekhasaenee, "Current concepts in true exfoliation syndrome," *Journal of Glaucoma*, vol. 27, no. 1, pp. S105–s110, 2018.

[38] C. Teekhasaenee, Y. Suwan, W. Supakontanasan, W. Tulvatana, and R. Ritch, "The clinical spectrum and a new theory of pathogenesis of true exfoliation syndrome," *Ophthalmology*, vol. 123, no. 11, pp. 2328–2337, 2016.

[39] J. Savige, S. Sheth, A. Leys, A. Nicholson, H. G. Mack, and D. Colville, "Ocular features in Alport syndrome: pathogenesis and clinical significance," *Clinical Journal of the American Society of Nephrology*, vol. 10, no. 4, pp. 703–709, 2015.

[40] S. Sonarkhan, M. Ramappa, S. Chaurasia, and K. Mulay, "Bilateral anterior lenticonus in a case of Alport syndrome: a clinical and histopathological correlation after successful clear lens extraction," *BMJ Case Reports*, vol. 2014, 2014.

[41] A. K. Junk, F. H. Stefani, and K. Ludwig, "Bilateral anterior lenticonus: scheimpflug imaging system documentation and ultrastructural confirmation of Alport syndrome in the lens capsule," *Archives of Ophthalmology (Chicago, III: 1960)*, vol. 118, no. 7, pp. 895–897, 2000.

[42] M. Citirik, C. Batman, G. Men, M. Tuncel, and O. Zilelioglu, "Electron microscopic examination of the anterior lens capsule in a case of Alport's syndrome," *Clinical & Experimental Optometry*, vol. 90, no. 5, pp. 367–370, 2007.

[43] J. H. Choi, K. S. Na, S. H. Bae, and G. H. Roh, "Anterior lens capsule abnormalities in Alport syndrome," *Korean Journal of Ophthalmology*, vol. 19, no. 1, pp. 84–89, 2005.

[44] K. Trifonova, G. Jordanoff, V. Stoyanov, and K. Slaveykov, "Spontaneous anterior lens capsule rupture of a patient with Alport syndrome—a case report," *Open Access Macedonian Journal of Medical Sciences*, vol. 5, no. 7, pp. 974–977, 2017.

[45] M. Lohchab and R. Arora, "Bilateral spontaneous lens capsule rupture in Alport's syndrome," *Indian Journal of Ophthalmology*, vol. 67, no. 3, p. 406, 2019.

[46] L. Gyoneva, Y. Segal, K. D. Dorfman, and V. H. Barocas, "Mechanical response of wild-type and Alport murine lens capsules during osmotic swelling," *Experimental Eye Research*, vol. 113, pp. 87–91, 2013.

[47] H. H. Ghoraba, A. G. Zaky, H. M. Abd Al Fatah, E. E. D. M. El Gemai, and M. A. Heikal, "Sticky silicone oil," *Retina*, vol. 37, no. 8, pp. 1599–1606, 2017.

[48] S. Baillif and P. Gastaud, "Complications of silicone oil tamponade," *Journal Français d'Ophtalmologie*, vol. 37, no. 3, pp. 259–265, 2014.

[49] K. G. Riedel, V.-P. Gabel, L. Neubauer, A. Kampik, and O.-E. Lund, "Intravitreal silicone oil injection: complications and treatment of 415 consecutive patients," *Graefe's Archive for Clinical and Experimental Ophthalmology*, vol. 228, no. 1, pp. 19–23, 1990.

[50] M. Citirik, M. F. Sargon, S. Has, and S. Bilgin, "Alterations of the anterior lens capsule in vitrectomized eyes with silicone oil tamponade," *Ophthalmic Surgery, Lasers and Imaging Retina*, vol. 43, no. 5, pp. 388–394, 2012.

[51] W. Soliman, M. Sharaf, K. Abdelazeem, D. El-Gamal, and A. Nafady, "Ultrastructural effects of silicone oil on the clear crystalline lens of the human eye," *European Journal of Ophthalmology*, vol. 28, no. 5, pp. 566–572, 2018.

[52] T. Miyamoto, S. Saika, A. Yamanaka, Y. Okada, and Y. Ohnishi, "Deposition of silicone oil droplets in the residual anterior lens capsule after vitrectomy and lensectomy in rabbits," *British Journal of Ophthalmology*, vol. 88, no. 5, pp. 703–707, 2004.

[53] S. Saika, T. Miyamoto, T. Tanaka, Y. Ohnishi, A. Ooshima, and W. Kimura, "Histopathology of anterior lens capsules in vitrectomized eyes with tamponade by silicone oil," *Journal of Cataract and Refractive Surgery*, vol. 28, no. 2, pp. 376–378, 2002.

[54] C.-W. Yung, A. Oliver, J. M. Bonnin, and H. Gao, "Modified anterior capsulotomy technique and histopathology of the anterior capsule in cataracts after prolonged exposure to intravitreal silicone oil," *Journal of Cataract and Refractive Surgery*, vol. 34, no. 12, pp. 2020–2023, 2008.

[55] F. H. J. Koch, A. Cusumano, P. Seifert, M. Mougharbel, and A. J. Augustin, "Ultrastructure of the anterior lens capsule after vitrectomy with silicone oil injection. correlation of clinical and morphological features," *Documenta Ophthalmologica*, vol. 91, no. 3, pp. 233–242, 1995.