

## Morphological assessment of lens capsule after different techniques of cataract extraction

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**Aim** — to evaluate morphological changes in the posterior lens capsule (LC) after different techniques of cataract extraction.

**Material and methods.** Eight pseudophakic human autopsy eyes were divided into two groups by the technique used for cataract extraction. Group 1 included 4 eyes following extracapsular cataract extraction (ECCE) and rigid IOL implantation. Group 2 included 4 eyes after minimally invasive cataract surgery (MICS) that involves the use of ultrasound energy. Semithin LC sections were polychromatically stained, visually examined, and imaged for further analysis. **Results.** There were certain common features in clinical and morphological appearances of lens capsules from either group, including fibrous metaplasia of epithelial cells and/or pseudoregenerative Elschnig-Adamuk pearls on their inner surfaces, more significant in the ECCE group. MICS group, however, demonstrated many distinct and previously undescribed changes. In particular, post-MICS LCs looked swollen, flabby, and even amorphous, their architectonics was disturbed and fibers separated forming micro slit-like spaces, which could be a result of acoustic cavitation caused by ultrasound exposure. We have named this morphological type of secondary cataract 'hyaloid-like'.

**Conclusion.** Clinical and morphological type of postoperative LC opacification as well as its severity depends, to a certain extent, on the technique used for cataract extraction. Hyaloid-like opacifications are typical of minimally invasive surgery involving the use of ultrasound and often show no 'classic' changes (fibroproliferative and pseudoregenerative). The latter is explained by the fact that the posterior LC, which has lost its biomechanical properties, can no longer be a substrate for proliferating cells.

**Keywords:** secondary cataract, posterior capsule opacification, minimally invasive cataract surgery, ultrasonic phacoemulsification, extracapsular cataract extraction, histopathological changes of the lens capsule.

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Postoperative opacification of the posterior lens capsule (PLC), or secondary cataract (SC), is commonly divided into two clinical and morphological forms: regenerative and fibrous [1]. The process largely involves anterior epithelial proliferation with further migration of the newly formed cells along the inner surface of the capsular bag toward its optical center where they undergo conversion into myofibroblasts [2-4]. As a result, the bag, its posterior portion in particular, either assumes the appearance of an opacified film whose surface is uneven due to clusters of swollen Elschnig-Adamuk pearls, or resembles a white-grey smooth membrane.

As shown by results of previous studies [5], minimally invasive cataract surgery (MICS) that involves the use of ultrasound is often associated with nonspecific PLC changes. Not only the capsule gets opacified on biomicroscopy, but also thickens. Homogeneity of the opacification has raised doubts regarding its influence on visual acuity and the necessity of laser treatment. Nevertheless, in the absence of other causes, it is laser discission of the posterior capsule that restores vision in these patients. Noteworthy is that capsular fragments created during the procedure are usually described as a viscous, jelly-like bands slowly sinking down into the vitreous cavity, which means that the opacified capsule is soft and flabby. Judging from the literature, this type of secondary cataracts has not been studied morphologically so far.

The aim of this study was to evaluate morphological changes in the PLC after different techniques of cataract extraction.

### Material and methods

Eight pseudophakic human autopsy eyes primarily considered as a possible donor material for keratoplasty were divided into two groups by the technique used for cataract extraction. For that, the following parameters were assessed: corneal scar type and mechanical properties (rigidity/elasticity) of the intraocular lens (IOL). Group 1 included 4 eyes following extracapsular cataract extraction (ECCE) and rigid IOL implantation. Group 2 included 4 eyes after minimally invasive surgery, in which ultrasound was most likely applied. Donor age averaged 70 years in Group 1 and 74 years in Group 2. After removal of the cornea, the eyes were soaked in 2.5% cooled glutaraldehyde and washed in phosphate-buffered saline. The IOL and the capsular bag or its fragments were carefully retrieved and additionally fixed in 1% osmic acid solution. Washed samples were then dehydrated in spirits and acetone, embedded in a mixture of epoxy resins (*epon-araldite*), and thermostated at 60°C for polymerization. Semithin 1- $\mu$ m thick sections were prepared on an LKB-IV Ultratome (Sweden) and polychromatically stained with methylene blue and basic fuchsin. Slides thus obtained were examined under a Leica DM2500 light microscope (Germany) and imaged with a Leica

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DFC320 digital camera. For morphometric analysis of the images ImageScope Color software was used.

## Results and discussion

Capsule changes after ECCE were found to be inhomogeneous. In all SC types, the process was staged. Morphologically, post-ECCE cataracts were notable for relative preservation of the equatorial epithelium, which implies that epithelial cells in the so called germinative, or growth, zone were still able to proliferate. Mitotic activity of the epitheliocytes, on the one hand, and the presence of a proper substrate, i.e. the lens capsule, on the other, should be considered necessary conditions for realizing cell migration potential across the inner surface of the capsule (**Fig. 1, a**). As the capsule is being colonized (proliferative stage of cataract development), its structural transformation continues. In particular, the epitheliocytes heterotopically convert into fibroblasts and myoblasts-like cells that are able to produce fibrous extracellular matrix (**Fig. 1, b**). It is myofibroblasts that are responsible for PLC contraction and folding (**Fig. 1, c**). The next stage (fibroplastic) is associated with a decrease in the number of cells on the inner surface of the LC due to their gradual atrophy with further replacement for a more dense fibrous component (fibrous SC) (**Fig. 1, d**). In our experience, the latter was sometimes twice as thick as the lens capsule or thicker.

Apart from proliferation, the epitheliocytes in the ECCE group have also demonstrated a trend towards hypertrophy and development of Elschnig-Adamuk pearls arranged in multi-layered clusters across the inner surface of the PLC and throughout the intercapsular space (**Fig. 1, e**). Morphologically speaking, the term 'regenerative' (widely used in previous classifications to describe this particular type of secondary cataract) is inaccurate, as it implies restoration of lost structure. However, in our case, lens epithelial cells proliferate, increase in size, and migrate across the inner surface of the PLC toward a highly uncharacteristic location. Perhaps, a better term would be 'proliferative-hypertrophic' or 'pseudoregenerative' SC. The latter seems the most appropriate, as it emphasizes the attempted restoration of the lens by means of untypical cell structures on the PLC. The process can be combined, i.e. signs of both fibrous and pseudoregenerative SCs can be present (mixed SC) (**Fig. 1, f**).

Note that in our study the said changes never involved the capsule itself. Despite slightly reduced transparency, it only served as a substrate for cells that either migrated, or proliferated and underwent fibroplastic transformation.

Post-MICS lens capsules were also morphologically disturbed. It is possible that ultrasound exposure causes lens epitheliocytes to lose their proliferative activity. Thus, the samples we have studied carried signs of aberrant proliferation as well as incomplete cell differentiation and dissociation (**Fig. 2, a**). Fibroplasia was accom-

panied by morphological changes similar to those after ECCE, i.e. fibrous acellular tissue formation along the inner surface of the capsule (**Fig. 2, b**). Given older patient ages in Group 2 (74 years on average), we assume that reduced thickness and density of the newly formed tissue as compared to the ECCE group is partially due to the age-related decrease in mitotic activity of the epitheliocytes, which is a well-known phenomenon [4].

Hypertrophy of anterior epithelial cells after MICS promoted the development of Elschnig-Adamuk pearls (blister-like cells arranged in multi-layered clusters) across the inner surface of the capsule from its equator to the posterior optic zone and throughout the intercapsular space (**Fig. 2, c**). These pseudoregenerative morphological changes greatly resembled those after ECCE, except for relative fewness of the hypertrophied cellular structures.

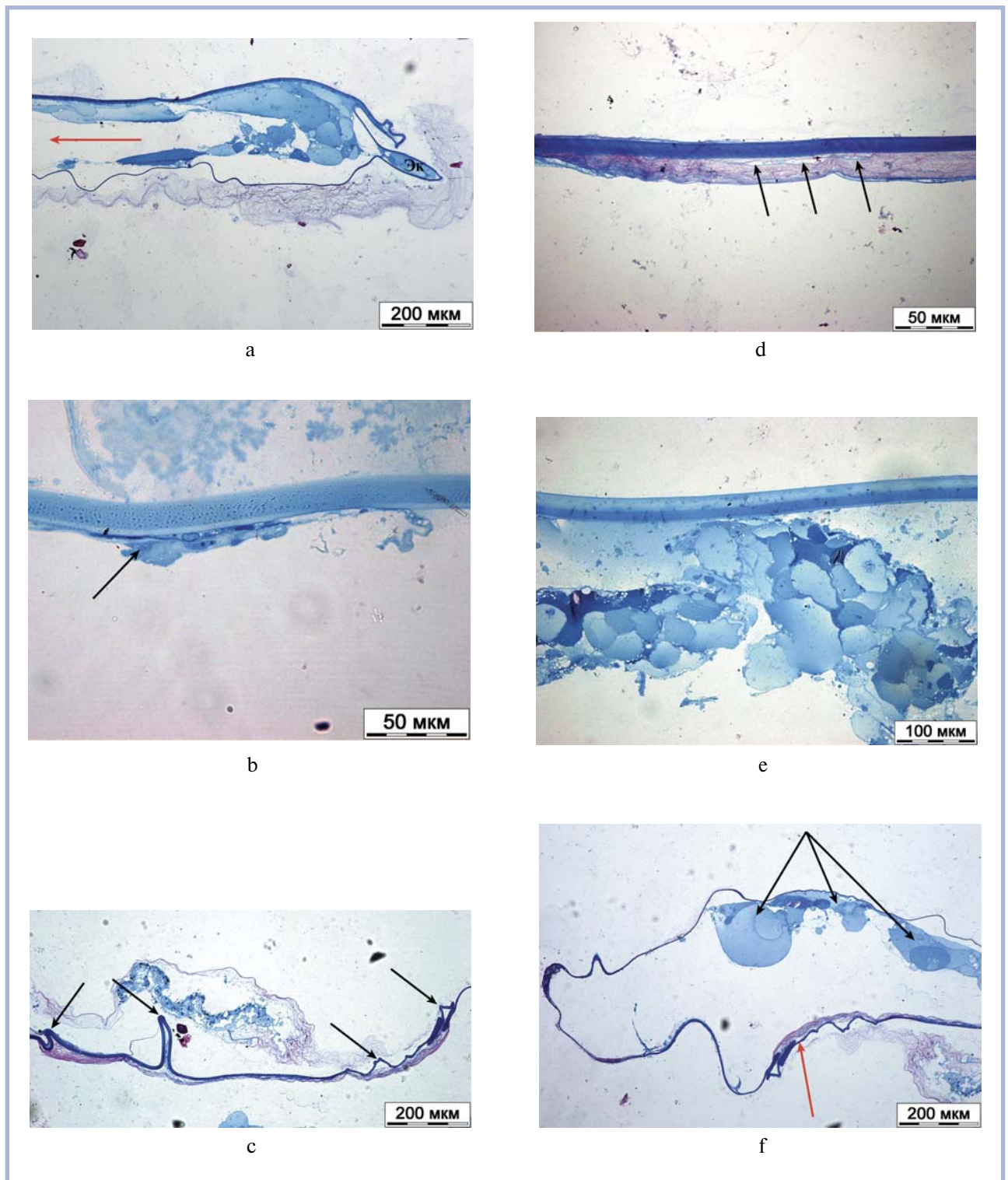
There was one more morphological variant of LC changes in the MICS group, of which we found no description in the literature. Capsule periphery appeared generally intact but its inner surface was covered with a thin band of fibrocellular tissue. Toward the center, capsule edges got gradually less clear and its structure loosened until the architectonics was severely disturbed and the edges could not at all be defined (**Fig. 2, d**). Individual fibers separated forming micro slit-like spaces, which could be a result of acoustic cavitation due to ultrasound exposure. The surface of the altered capsule could no longer be the substrate for cell migration and, thus, carried no cellular and/or fibrillar elements. To some extent, the vulnerability of the central posterior capsule to structural change may be due to its peculiar anatomy (lesser thickness within a  $\varnothing$  2.5 mm zone) as well as age-related thinning.

It should be emphasized that the capsule morphology we have described agrees with other studies on MICS effects mentioned in the beginning of this article [5]. The absence of 'classic' changes (listed above) and a jelly-like appearance of the tissue that slightly resembled the vitreous made us define this type of secondary cataract as 'hyaloid-like'. In our opinion, its development may be conditioned by technical parameters of MICS, particularly, the need for higher intensity of ultrasound that may sometimes arise during the procedure.

Possible scenarios and stages of clinical and morphological changes in the lens capsule after cataract extraction are presented schematically in **Figure 3**.

## Conclusion

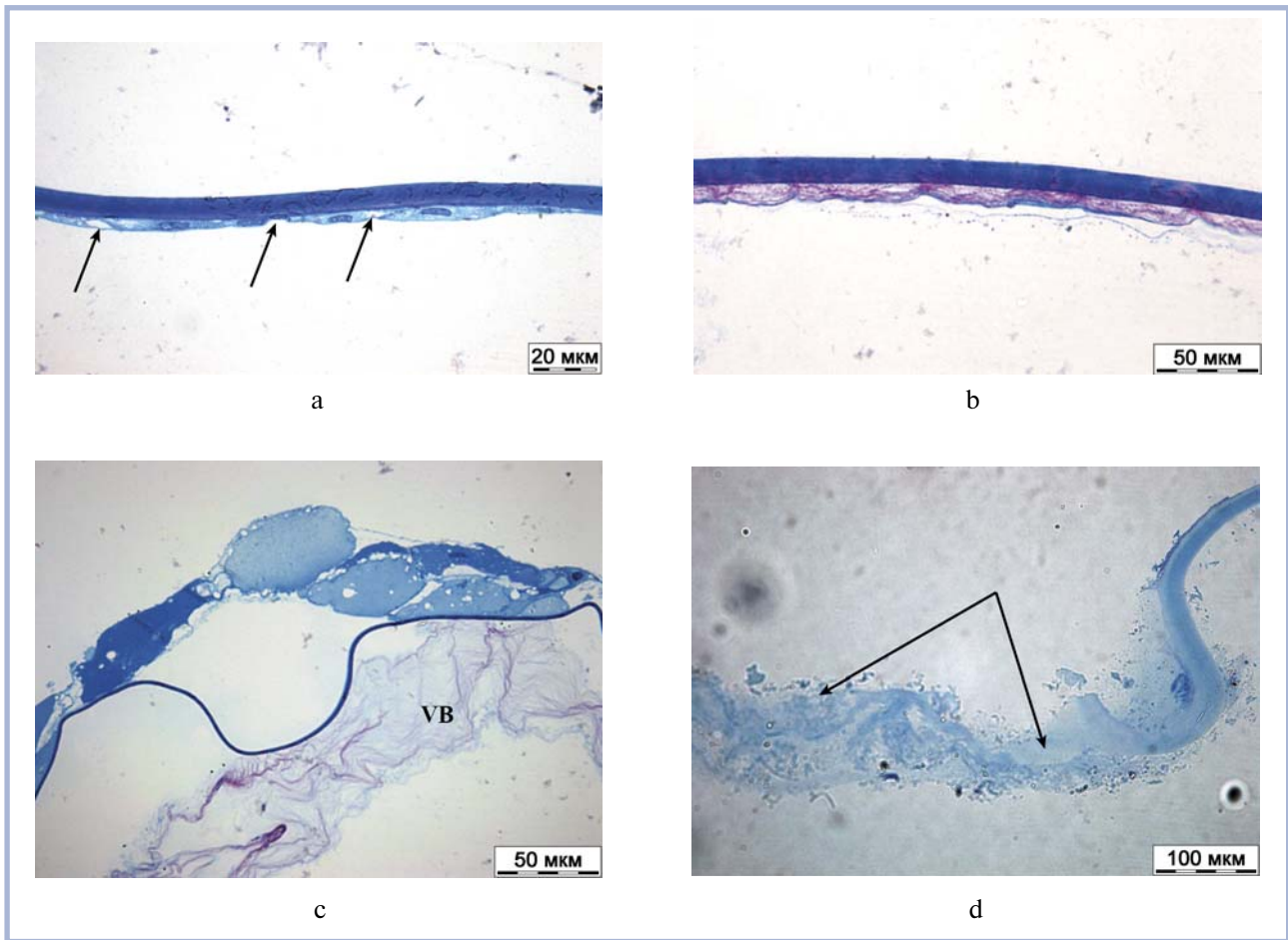
Distinctive features and severity of postoperative changes in LC morphology to a certain extent depend on the technique of cataract extraction. Classic secondary cataracts after either ECCE, or ultrasound MICS bear many similarities, such as fibrous metaplasia on the inner surface of the capsule with development of so called pseudoregenerative Elschnig-Adamuk pearls (in our experience, more pronounced in the ECCE group).



**Fig.1. Morphological appearance of the LC after ECCE.**

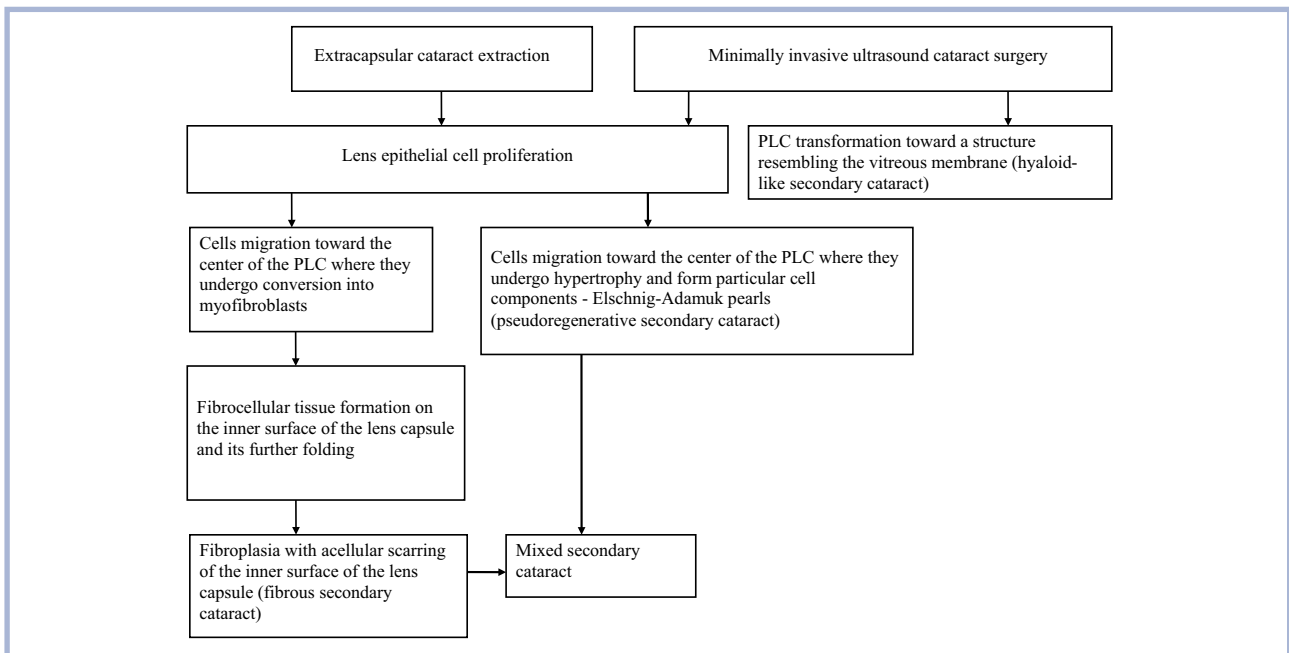
a — epithelial cells proliferation at the equator (Eq) of the capsular bag and their migration across the inner surface of the capsule toward its optical centre (the direction is indicated by an arrow). Here and in b-f: a semithin section. Methylene blue and basic fuchsin staining; b — a cell multilayer consisting of altered lenticular cells that are now proliferating on the inner surface of the LC (arrow); c — some fibroblasts from the fibrocellular tissue convert into myofibroblasts; the latter contract and cause the LC to fold (arrows); d — fibrous tissue that is formed on the inner surface of the PLC as a considerable number of fibroblasts undergo atrophy (arrows); e — numerous hypertrophied cells — Elschnig-Adamuk pearls — arranged in clusters across the inner surface of the PLC; f — mixed type capsule opacification. Elschnig-Adamuk pearls on the inner surface of the PLC (black arrows). Fibrous tissue on the inner surface of the anterior LC (red arrow) is more than twice as thick as the capsule itself.





**Fig. 2. Morphological appearance of the LC after MICS.**

a — dissociation of lens epithelial cells (arrows) that migrate along the inner surface of the anterior LC. Signs of a decreased proliferative activity of the epitheliocytes after ultrasound exposure. Here and in b—d: a semithin section. Methylene blue and basic fuchsin staining; b — a thin band of acellular fibrous tissue on the inner surface of the capsule; c — Elschnig-Adamuk pearls on the inner surface of the PLC. VB — vitreous body; d — central PLC looks swollen, flabby, and amorphous, its fibers separated forming micro slit-like spaces (arrows). The poorly demarcated PLC is steeped in the glycoprotein matrix. Similarity of appearance with the vitreous.



**Fig. 3. Possible scenarios and stages of clinical and morphological changes in the lens capsule after different techniques of cataract extraction (scheme).**

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Hyaloid-like opacification has been found to be typical of ultrasound MICS. It is associated with swollen jelly-like appearance of the LC, unclarity of its edges, and formation of slit-like microcavities. Relative rarity of classic SCs (fibroproliferative and pseudoregenerative) in this group is likely to have two reasons, namely, 1) specific biomechanical properties of the lens capsule that reflect its peculiar anatomy and age-related changes and 2) a decreased proliferative activity of the epitheliocytes due to cavitation effect of ultrasound.

**Author contributions:**

Study conception and design — S.A., A.G.  
Acquisition and handling of data — A.G., A.F., V.R.  
Statistical analysis of data — A.G.  
Drafting of manuscript — A.G., A.F.  
Critical revision — S.A.

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