The Frequency of Postoperative Complications in Current Types of Hydrophobic and Hydrophilic Intraocular Lenses. A Systematic Review

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SUMMARY

Objective: To compare the incidence of postoperative complications after cataract surgery in current types of acrylic intraocular lenses (IOLs) in relation to the material used to manufacture the implant, published in the scientific literature.
Methodology: Search for publications in the Pubmed database, published in 2015–2024 (inclusive), without language restrictions, featuring the keywords Hydrophobic, Hydrophilic, Intraocular lens. Reviewing all abstracts and excluding publications that do not match the specified topic.
Results: A total of 220 works were published in the last 10 years that met the specified keywords. Of these, 92 publications were dedicated to the comparison of both types of IOLs. These were 4 meta-analyses, 10 reviews and 47 clinical studies, 21 laboratory and experimental studies and 10 studies of a different nature (editorials, considerations, chapters in textbooks).
Conclusion: Current types of soft acrylic intraocular lenses achieve excellent refractive results and high subjective patient satisfaction. This applies to lenses made of both hydrophilic and hydrophobic materials. The main disadvantage of hydrophilic implants is the higher risk of opacification of the posterior capsule of the lens, as well as the risk of opacification of the implant itself. Especially in patients who are expected to undergo subsequent surgery (corneal endothelial dystrophy, retinal pathology), as well as in patients with a higher risk of complications after Nd:YAG laser capsulotomy (patients with myopia, chronic uveitis or glaucoma), the use of hydrophobic material should be considered as a priority.
Key words: hydrophilic, hydrophobic, intraocular lens, cataract

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INTRODUCTION

Cataract surgery with implantation of an artificial intraocular lens (IOL) is one of the most common and successful procedures in human medicine. At present surgeons can use a wide range of various types of IOLs from different manufacturers, made from various materials, with different shapes, designs and optical properties. These implants differ among themselves in their physical and chemical properties, price, and also in their potential adverse side effects. With regard to the high expectations placed on the result of cataract surgery on the part of both the patient and the doctor, it is necessary to carefully follow the development of modern IOLs and to consider their advantages and applicable risks. This is also compounded by the fact that patients of a younger age are also now undergoing lens replacement, sometimes also for refractive reasons. It is therefore of benefit also to monitor late postoperative complications which may appear several years after surgery, sometimes in association with other ocular pathologies.

Posterior capsular opacification (PCO) is the most common late complication after cataract surgery. The incidence of PCO increases with the length of the observation period and is stated in the literature at an average of 11.8% one year after surgery to 28.4% five years after surgery [1]. It is characterized by a proliferation of lens epithelial cells (LECS), their migration around the posterior surface of the lens capsule and blockade of the visual axis. This causes deteriorated visual acuity (VA), reduced contrast sensitivity and complaints with glare. The development of this complication is contributed to by a series of factors such as patient age, ocular comorbidity, surgical technique and also the properties of the IOL [2]. It has been determined that fundamental IOL factors that influence PCO are the shape of the IOL or the design of its edge, and the material from which it is pro-

duced. Studies have demonstrated that lenses with sharp edges inhibit the migration of lens epithelial cells between the optics and the posterior capsule, and thereby reduce the incidence of PCO [3,4]. This principle is now accepted by practically all manufacturers of intraocular lenses. It has also been demonstrated that acrylate lenses, in comparison with other materials such as silicone and hydrogel, have a lower incidence of PCO and frequency of Nd:YAG (neodymium-doped yttrium aluminum garnet) laser capsulotomy. This is caused by the fact that acrylate has a relatively lower tendency to trigger cell proliferation in the lens capsule [5,6]. Both types of acrylate IOLs, i.e. lenses with a higher water content of 18–34% known as hydrophilic lenses, and lenses with a low water content of around 1–5% known as hydrophobic lenses, are currently offered by manufacturers. The aim of this study is to determine and compare the incidence of potential postoperative complications for both types of acrylate IOLs published in the literature in the last 10 years.

METHODOLOGY

We entered the key words hydrophobic, hydrophilic and intraocular lens into a search on the PubMed database (https://pubmed.ncbi.nlm.nih.gov). With respect to the constant technological advance in the development of intraocular lenses, it was our endeavor primarily to search for recent studies published in the last few years. The last 10 years were entered as the time frame, i.e. studies published between 2015 and 2024 inclusive. No limitations, such as language, were stipulated in the search. We reviewed all the abstracts of the published studies. We excluded from our evaluation abstracts that did not correspond to the theme in question, i.e. a comparison of the clinical results of use of IOLs produced from hydrophilic and hydrophobic materials. We also excluded from our review 2 studies relating to the effect of IOL material in pediatric cataract surgery due to the fact that this concerns a highly specific group of patients with a large degree of variability.

According to the principles of evidence based medicine (EBM) we focused primarily on the type of studies with a higher predicative value and capacity to approximate the truth, above all meta-analyses, systemic reviews and randomized clinical trials (RCTs), or other types of clinical trials such as cross-sectional studies, retrospective case control studies, prospective cohort studies and case series. Studies of the type of case reports, expert opinions etc. had little significance for the result of our research.

RESULTS

After entering the key words into the search of the PubMed database we found 220 published studies. Of these, 128 studies related to a different theme, as a rule they did not compare both types of IOLs against one another or focused on a different issue. A total of 92 publications were used for further analysis. In these studies full texts were obtained, and the studies were analyzed further. They included 4 meta-analyses, 10 reviews and 47 clinical trials. Of these trials 14 were RCTs, 6 prevalence studies, 9 retrospective case studies and controls, 12 cohort studies and 6 case series. Two studies relating to the effect of the material of the IOL in pediatric cataract surgery in the published review are not presented here. The reason for this is that it concerns a highly specific group of patients with a large degree of variability and potential further factors influencing the result of the operation [7,8]. The results of all the other studies are incorporated into the evaluation in our review. With respect to the lower scientific value of the other studies, i.e. 21 laboratory and experimental studies and 10 studies of a different character (case report, editorial, consideration, technique, chapter in textbook), we did not include them in the resulting evaluation, in certain cases the information from them is used in the discussion.

Meta-analyses

In 2017 Zhao et al. published the results of a meta-analysis dealing with the frequency of posterior capsular opacification in the case of hydrophobic and hydrophilic IOLs. They analyzed studies published up to 2016, and included a total of 11 RCTs in their review. A total of 889 eyes were included in the meta-analysis. It was determined that hydrophobic IOLs had an overall lower PCO score and were associated with a lower frequency of Nd:YAG laser capsulotomy, the odds ratio (OR) was 0.38, 95% the confidence interval (CI) was 0.16–0.91, $p = 0.029$); this meant that laser capsulotomy in the case of hydrophilic IOLs was approximately 2.6x more frequent than in the case of hydrophobic IOLs. VA in both groups was comparable [9].

A similar meta-analysis was published by Wu in 2022. The authors incorporated a total of 13 RCTs in their evaluation, covering the results of 939 patients (1262 eyes). In this study also the authors determined a lower incidence of PCO in the case of use of a hydrophobic IOL in comparison with a hydrophilic IOL (the standardized median difference was -1.80; 95% CI: -2.62 to -0.98). Patients with hydrophobic IOLs also had a significantly lower frequency of Nd:YAG laser capsulotomy, and the result was similar as in the previous study [10].

Another meta-analysis from 2019 conducted by Thom et al. focused on the influence of AcrySof (Alcon Laboratories, Inc.) IOLs on the incidence of Nd:YAG laser capsulotomy in comparison with other types of multifocal IOLs (hydrophobic, hydrophilic, silicone and PMMA). In total the authors incorporated the results from 59 RCTs published in 67 professional articles. In their conclusion the authors stated the lowest risk of performance of Nd:YAG capsulotomy in the case of AcrySof IOLs. In comparison with this IOL, the hazard ration (HR) was highest in the case of acrylate hydrophilic IOLs (HR: 7.54; 95% CI: 4.24–4.06; $p < 0.001$), followed by PMMA IOLs (HR: 3.64, 95% CI: 1.87–6.33; $p < 0.001$), other hydrophobic IOLs (HR: 2.68; 95% CI: 1.41–4.77; $p < 0.01$) and silicone IOLs (HR: 1.13; 95% CI: 0.59–1.91; $p < 0.1$). It is therefore possible to state that in this meta-analysis hydrophilic IOLs carried a 7.5x greater risk of performance of Nd:YAG capsulotomy in comparison with AcrySof IOLs [2].

The last meta-analysis so far on this subject was published in 2024 and focused on the incidence of anterior capsular contraction syndrome following cataract surgery, comparing different materials and designs of IOLs. In total the authors incorporated 5 RCTs and three cohort studies covering a total of 1221 eyes. Although a shrinkage of the surface of the opening of anterior capsulorhexis occurred in the case of IOLs manufactured from both types of material, the contraction was statistically significantly greater in the case of hydrophilic IOLs in comparison with hydrophobic IOLs, both one month and one year after the performed surgery. The standardized median difference was -0.73 and -1.33 respectively. Above all for patients with a higher risk of anterior capsular contraction (high myopia, pseudoexfoliation syndrome, retinitis pigmentosa), it is recommended that surgeons choose hydrophobic IOLs [11].

Systematic review

We can define the total of 15 studies we found as a review. Nonetheless, 5 of these relate to a different subject. We therefore incorporated the 10 remaining studies into our review.

Grzybowski et al. summarize the advantages and disadvantages of hydrophilic and hydrophobic IOLs. The main advantages of hydrophilic IOLs are above all good handling, greater resistance to damage, higher uveal biocompatibility and also reduced chromatic aberration. By contrast, hydrophobic IOLs demonstrate better prevention of PCO than hydrophilic IOLs, and according to the authors should be preferred for highly myopic eyes in which Nd:YAG capsulotomy could increase the risk of retinal detachment. As regards the material of toric IOLs, comparable rotational stability has been demonstrated in both types of materials. In the case of hydrophilic IOLs it is also necessary to take into consideration the risk of calcification. Although the mechanism remains unclear, a risk factor may be breach of the blood-ocular barrier. Studies have also demonstrated a significant negative influence of intraocular injection of exogenous air or gas during lamellar endothelial transplantation or pars plana vitrectomy, increasing the risk of opacification of the hydrophilic IOL [12,13].

The study by Fizia-Orlicz et al. also confirms that hydrophobic IOLs have a lower incidence of posterior capsular opacification, though on the other hand they are more prone to glistening (formation of small vacuoles in the lens material) [14].

Özyol in his review differentiates between uveal biocompatibility on the basis of an inflammatory reaction of the eye to an implant as a foreign body, and capsular biocompatibility determined by the relationship of the IOL to the residual lens epithelium. Insufficient capsular biocompatibility of IOL materials may cause a growth of the epithelial cells of the lens, and both anterior and posterior capsular opacification. Sharp edges of the IOL and a hydrophobic surface are important for capsular biocompatibility, whereas for uveal biocompatibility a hydrophilic anterior surface is important. However, because uveal biocompatibility of current soft IOLs is not a particular problem even for eyes with a higher risk of inflammation, according to the authors it appears clinically more expedient to prioritize capsular biocompatibility, and therefore hydrophobic IOLs [15].

Labuz et al. summarized the results of 10 studies describing the incidence of straylight (light dispersion) type dysphotopsias in the case of 9 types of multifocal IOLs. Hydrophilic IOLs demonstrated a statistically lower incidence of this phenomenon in comparison with hydrophobic IOLs. In addition, IOLs with a yellow filter had a lower incidence of this phenomenon, but in this case the difference was not statistically significant [16].

The remaining 6 review studies focus on IOL opacification. Khoramnia states that in the case of current types of IOL the main type of opacification is calcification in the case of hydrophilic and glistening in the case of hydrophobic materials. These opacifications have a variable influence on the passing of light through the material in question, and generally lead to an increased dispersion of light. In the case of subjective complaints, the only option for solution is replacement of the IOL [17,18]. Although in most cases glistening and subsurface nanoglistening of hydrophobic IOLs do not cause a deterioration of VA or require replacement of the IOL, these phenomena may induce light dispersion and thereby reduce comfort and quality of vision [19]. Glistening and subsurface nanoglistenings are manifested as microvacuoles with a size ranging from 1.0 to more than 25.0 µm. Calcification deposits in the case of hydrophilic IOLs appear on or below the surface of the IOL, and can be stained in vitro with 1% alizarin red solution or using the von Kossa method [20].

The study conducted by Tezt demonstrates that the main problem of hydrophobic IOLs, i.e. glistening, is eliminated to a substantial extent in the case of new materials. In case of the latest types of hydrophobic IOLs with a slightly higher water content (approx. 4–5%), glistening no longer occurs [21].

Clinical trials

In the period in question we found a total of 47 clinical trials. Specifically these included 14 RCTs, 6 prevalence studies, 9 retrospective case studies and controls, 12 cohort studies and 6 case series. For the sake of clarity we have presented the results of the trials according to the dominant theme the individual trials focused on.

1. Visual acuity

Practically all the studies that describe VA, either corrected or uncorrected, present entirely comparable results in the case of hydrophilic and hydrophobic IOLs, as well as the frequency of refractive surprise and subjective patient satisfaction [22]. In addition, multifocal IOLs of the same design but manufactured either from hydrophilic or hydrophobic material produced the same results in the trials. In total 4 RCTs and 3 further studies focused on this issue. However, the authors did not compare the incidence of postoperative complications in any of these studies [23–28].

2. PCO and frequency of Nd:YAG capsulotomy

A large proportion of studies compared the incidence of PCO or the frequency of Nd:YAG laser capsulotomy in the case of hydrophilic and hydrophobic IOLs. In the majority of large cohorts this incidence is significantly higher in the case of hydrophilic materials.

Chang and Kugelberg published the results of an RCT in which they assessed the incidence of PCO in photography in retro-illumination 9 years after surgery, and the result was analyzed with the aid of computer software. The authors compared these results in two groups, with a hydrophilic (BL 27) and hydrophobic (AcrySof SA60AT) IOL, both with sharp edges. The selection of IOLs was randomized, and a total of 120 eyes of 120 patients were incorporated in the study. The nine-year observation period was completed by 78 patients. Patients with a hydrophilic IOL had a significantly higher incidence of PCO (average surface 100% versus 13.4%). The number of patients with Nd:YAG laser capsulotomy was also significantly higher in the group with a hydrophilic IOL (95% v 47%) [29]. In another study the same authors also published the incidence of glistening in this observed group. By contrast, this was statistically significantly higher in the case of hydrophobic IOLs. The development of glistening had no relation to the dioptric power of the IOL and did not influence contrast sensitivity or VA [30].

Ursell also published similar results of his multicentric, retrospective analysis, in which he evaluated the incidence of PCO and the frequency of performance of Nd:YAG capsulotomy in 3 groups – patients with a hydrophobic AcrySof IOL – 13 329 eyes, patients with another hydrophobic IOL 19 025 and patients with a hydrophilic IOL 19 808. The incidence of Nd:YAG capsulotomy 3 years after surgery in these groups was 2.4%, 4.4% and 10.9% respectively [31]. Similar results were recorded by the authors also in terms of the incidence of PCO: 4.7%, 6.3% and 14.8% respectively. Similar differences between IOLs were recorded by the same authors also 5 years after surgery, only with increased values of the frequency of capsulotomy (5.8–19.3%) and PCO (7.1–22.6%) [32].

Another large cohort of patients was described by Iliescu, who retrospectively determined the incidence of PCO and performed Nd:YAG capsulotomy in 4805 eyes depending on the used IOL material (2560 hydrophilic, 2245 hydrophobic lenses), in which the average follow-up observation period was 40 ±6.15 months (27–54 months). In the case of hydrophilic IOLs the incidence of PCO and the number of Nd:YAG procedures was statistically significantly higher (18% v 4% and 14% v 2% respectively) [33].

A series of other authors have evaluated the influence of IOL material on the frequency of Nd:YAG laser capsulotomy.

Eggermont et al. published the incidence of Nd:YAG laser capsulotomy one year after cataract surgery at a number of different centers in the Netherlands in the years 2016 and 2017. The data were obtained from the national database. The difference between centers fluctuated between 1.2% and 26.0 %, and 0.9% and 22.7% respectively. The authors determined that at centers with a higher incidence of laser capsulotomy the surgeons more frequently did not perform routine polishing of the posterior capsule, and used coaxial irrigation/aspiration, and used hydrophilic IOLs more frequently. [34].

Lee also retrospectively evaluated the results of 2866 eyes 5 years after cataract surgery. The authors evaluated the incidence of Nd:YAG capsulotomy for various different IOLs (four types in total, three hydrophobic – SN60WF, ZCB00 and MX60, and one hydrophilic – MI60). The frequency of performance of capsulotomy was significantly higher in the case of the IOL made from hydrophilic material, specifically 7.9%, 10.1%, and 10.6% versus 31.7% [35].

Similarly, Dvali et al. monitored the incidence of POC depending on IOL material in a smaller cohort of 164 eyes. Both types of IOL had the same design. There was no statistically significant difference between the groups at 3, 6 and 12 months after surgery, but at 18 months after surgery the difference in the incidence of PCO were now statistically significant. In the group of hydrophilic IOLs the incidence of PCO was in 10.8% of eyes, in the group of hydrophobic IOLs only 5.8% [36].

Sharon retrospectively evaluated the average interval between initial cataract surgery and subsequently performed Nd:YAG capsulotomy in 255 eyes. In the case of IOLs made of hydrophilic material this time was significantly shorter (23 ±13 months) in comparison with hydrophobic IOLs (28 ±13 months) [37].

Duman observed the frequency of performance of Nd:YAG laser capsulotomy of the posterior capsule in a cohort of 4970 eyes (performed on 153 eyes – 3.1%). The median observation period was 84 months. The percentage of capsulotomy in the case of hydrophilic IOLs was statistically higher in comparison with hydrophobic IOLs [38].

Kossack retrospectively determined the influence of IOL material on the frequency of performed Nd:YAG capsulotomy in a total of 3025 patients. Four years after surgery this was significantly lower in patients with hydrophobic IOLs (31.6% out of 2078 patients) in comparison with hydrophilic IOLs (56.6% out of 947 patients). The authors also estimated the difference in the financial costs for postoperative care (in Germany) in the case of hydrophobic and hydrophilic IOLs, which was 50 € v 88 €, precisely due to the necessity to perform subsequent Nd:YAG capsulotomy [39].

Tokko determined the risk factors for the performance of Nd:YAG capsulotomy. He selected 300 eyes at random from a cohort of patients on whom capsulotomy had been performed up to 3 years after cataract surgery, and compared them with a randomly selected group of patients who had not undergone capsulotomy within 3 years of surgery. The risk factors he determined were younger age, male sex and hydrophilic IOL material. The average age of the patients who had undergone capsulotomy was 65.8 ±11.3 (versus 70.1 ±10.6 years, $P < 0.001$ in the group without capsulotomy), in the group who had undergone capsulotomy 42.7% were men (in comparison with only 34.7% in the group without capsulotomy, $P = 0.04$), and a hydrophilic IOL was present in 74.7% of eyes with capsulotomy (in

comparison with 47.0% in the group without capsulotomy, P < 0.001). The time between primary cataract surgery and capsulotomy was shorter for patients with a medical history of uveitis (95% CI, 5.10 v 9.70 months; P = 0.02) and in patients with an implanted hydrophilic IOL (95% CI, 18.67 v 21.57 months; P < 0.001) [40].

Only a small number of studies state a comparable incidence of PCO and Nd:YAG capsulotomy for both types of IOL. One RCT compared the hydrophilic IOL Superflex (Rayner Surgical, Worthing, UK) and a hydrophobic IOL (Alcon, Fort Worth, TX, USA). It evaluated posterior capsular opacification one month and two years after surgery in a total of 80 eyes of 80 patients. In both groups the frequency was relatively low, and in both groups it was comparable [41]. Bai compared the incidence of PCO for both types of IOL (hydrophilic v hydrophobic material) in 60 eyes of patients with diabetes mellitus. The incidence was comparable in both groups 2 years after surgery. Also comparable were postoperative VA, contrast sensitivity and the frequency of performed Nd:YAG capsulotomies (10.3 v 11.5%) [42].

3. PCO in the case of a pre-existing posterior lens capsular opacification

Joshi observed the influence of the lens material on the behavior of a pre-existing peripheral posterior lens capsular opacification (total 80 eyes). It was necessary to perform Nd:YAG laser capsulotomy on 22.5% of patients with an implanted hydrophilic IOL, and on 7.5% of patients with a hydrophobic IOL [43].

4. PCO and Nd:YAG capsulotomy in micro-incision IOLs

In two published RCTs the authors determined relatively high values of PCO in groups with both an implanted hydrophilic and a hydrophobic IOL. The frequency of Nd:YAG capsulotomy 3 years after surgery in the first study was 34% v 49%. In the second study, conducted 4 years after surgery, this frequency was as high as 50% and 77% respectively. Nonetheless, in all cases this concerned lenses designated for micro-incision cataract surgery with an incision size of less than 1.8 mm. For this reason the authors are considering the advantages of using these types of IOLs in comparison with standard types of IOLs [44,45].

5. PCO and posterior capsular folds

Joshi observed the incidence of PCO and posterior capsular folds (striae) in a cohort of 1247 eyes. In patients with an implanted hydrophilic IOL this phenomenon occurred in 31.4% of cases, and in only 7.6% of patients with a hydrophobic IOL. The PCO score was 0.6% in the hydrophilic group and 0.1% in the hydrophobic group [46].

6. PCO and buckling

In his observational study Rajesh not only monitored the incidence of secondary cataract, but also the stability of the IOL in the lens sac and deformation of the haptics ("buckling") in a total of 444 eyes of 317 patients. Of these eyes, 254 had a hydrophilic IOL and 190 a hydrophobic IOL. Secondary cataract occurred in 11% of cases of hydrophilic IOLs and in 1.1% of hydrophobic IOLs. Deformation of haptics was determined in a total of 8.3% of eyes, occurring in 13.9% of eyes with hydrophilic IOLs and 1.6% of eyes with hydrophobic IOLs. Buckling in the case of hydrophilic IOLs was associated with change of refractive state of the eye. The main subjective complaints in these patients were blurred and deteriorated vision [47].

7. PCO and the incidence of macrophages in patients with Fuchs uveitis syndrome

Özdamar determined the influence of the material (hydrophobic, hydrophilic) on the incidence of PCO and macrophages in patients with Fuchs uveitis syndrome. The cohort comprised a total of 56 eyes. In this specific group of patients the authors did not determine a statistically significant difference in the size of PCO, the time of origin of PCO, the frequency of Nd:YAG capsulotomy or the incidence of macrophages on the IOL [48].

8. Anterior capsular contraction

Wang determined the influence of IOL material on postoperative contraction of anterior capsulorhexis of identical diameter performed with the aid of FLACS (femtosecond laser-assisted cataract surgery) in 320 eyes. Hydrophobic IOLs triggered statistically lower contraction in comparison with hydrophilic IOLs, measured 1 month, 3 months and 1 year after surgery [49].

9. Negative dsyphotopsias

Several studies have focused on the potential influence of IOL material on the incidence of negative dysphotopsias in patients following cataract surgery.

On study followed the incidence of negative dysphotopsias and assessed the potential impact of the material (hydrophobic – AcrySof SA60AT manufactured by Alcon and hydrophilic – CT Asphina 603 P manufactured by Carl Zeiss) and hydration of the main temporal incision. In total the authors registered this phenomenon (negative dysphotopsias) in 9.1% of patients, although in 83% of cases this concerned only transitory complaints. The authors determined a significant influence of hydration of the incision on the onset of this complication, but no influence of the material on the frequency of negative dysphotopsias was demonstrated [50]. Bhogal-Bhamra in a smaller cohort of 32 patients observed the incidence of secondary optic phenomena objectively (with the aid of an Aston Halometer) and subjectively, depending on the material of the implanted lens. No differences were determined either in VA or in the frequency or severity of these phenomena [51].

Sezgin Asena compared the results of two diffractive trifocal lenses, hydrophilic (AT lisa tri 839 MP) and hydrophobic (AcrySof PanOptix) in a total of 238 eyes of 119 patients. Both lenses demonstrated good and comparable visual and refractive results. The frequency and

severity of complaints of halo effect was significantly higher in the hydrophilic group [52].

By contrast Serdiuk described a statistically higher incidence of dysphotopsias in patients with a trifocal hydrophobic lens in comparison with another two trifocal lenses made of hydrophilic material. The other assessed parameters, primarily VA at various distances, were comparable [53].

10. Straylight (scattered light)

Tang et al. determined straylight in pseudophakic patients with the aid of the C-Quant instrument, 3–4 weeks after performed surgery. The authors generally registered an increase of straylight upon pupil dilation. In the case of dilation straylight was greater with aspherical IOLs (in comparison with spherical IOLs), while no difference was recorded with regard to the material. In the case of normal pupil size straylight was greater with hydrophobic IOLs in comparison with hydrophilic IOLs [54]. A similar conclusion was also reached by Lapid-Gortzak et al., who measured straylight by the same method and compared two types of diffractive multifocal IOLs, one made of hydrophilic material (84 eyes) and the other made of hydrophobic material (79 eyes) [55].

11. Higher order aberrations

Jafarzadehpur et al. observed the value of higher order aberrations (HOA) with the aid of an OPD Scan III (Nidek) in the case of two types of spherical monofocal IOLs, hydrophobic and hydrophilic. VA, total coma, total trefoil and the overall value of HOA were comparable in both groups [56].

12. Chromatic aberrations

Vinas determined a higher longitudinal aberration by 0.16 D (or 0.15 D according to the method of measurement) in the case of a hydrophobic IOL in comparison with an IOL of the same design manufactured from hydrophilic material [57].

13. Rotational stability of toric IOL

Haripriya retrospectively observed the number of necessary additional rotations in the case of two types of toric intraocular IOLs, hydrophilic Auroflex (4603 eyes) and hydrophobic AcrySof (926 eyes). Surgical repositioning was performed in the case of rotation by 15 or more degrees. The authors did not determine a statistically significant difference in the frequency of additional rotation in both types of IOL (2.5% v 1.9%). A generally higher frequency of additional rotation was determined in younger patients, in preoperatively higher astigmatisms and in with-the-rule astigmatisms [58].

Draschl also determined the stability of IOLs depending on the material. A hydrophilic IOL was implanted in one eye of 40 patients with bilateral corneal astigmatism of less than 1.75 D (measured with the aid of the instrument IOL Master 500), and a hydrophobic IOL of the same design was implanted in the other eye, in both cases non-toric variants. Three months after surgery rotational stability was monitored with the aid of retroillumination photography, the IOL was rotated on average by 2.4 ±1.85 degrees in the hydrophilic group and 1.6 ±1.61 degrees in the hydrophobic group. The difference was statistically significant [59].

14. Cystoid macular edema (CME)

Dvali observed the influence of material on central retinal thickness (CRT) and any applicable incidence of CME on a smaller cohort of 48 eyes with the aid of OCT (optical coherence tomography) examination. The authors determined a comparable increase of CRT by 30 ±0.1 μm 5–7 days after surgery in both groups, but did not identify a single case of CME [60].

15. IOL opacification

A relatively rare but very severe complication in connection with IOL material is its subsequent opacification.

Wang et al. retrospectively evaluated postoperative incidence of IOL opacification in 42545 eyes following cataract surgery. In 66% of the cohort this concerned hydrophilic material, in 27.9% hydrophobic, and in 6.1% a hydrophilic IOL with a hydrophobic surface. In total the authors determined the incidence of opacification in 14 different types of implants, of which this concerned permanent lens opacification in 10 IOLs. In 7 cases these were hydrophilic IOLs and in 3 cases hydrophilic-hydrophobic IOLs. The median interval between surgery and diagnosis of IOL opacification was 34.4 ±8.4 months (within the range of 12–59 months) [61].

Neuhann et al. analyzed the reasons for explanting of a total of 200 IOLs. The main cause was IOL opacification – 153 cases (76.8%), the next most common reason was IOL subluxation – 27 cases (13.5 %). A total of 167 explanted IOLs were manufactured from hydrophilic material or hydrophilic with a hydrophobic surface. An analysis of opacifications demonstrated surface and subsurface deposits of calcium phosphate in the majority of opacified IOLs (152 out of 153). Overall this concerned products from 22 different manufacturers, although one manufacturer was represented markedly more frequently (119 lenses, 59.5 %) [62].

Lorenza Blanco et al. retrospectively determined the incidence of IOL opacification following corneal endothelial transplantation in a cohort of 372 artephakic eyes. The average follow-up observation period was 856 days. A total of 128 implanted IOLs were hydrophilic, 120 were hydrophobic and in 124 the material was not determined. In total IOL opacification occurred in 12.9% of cases, in 10 eyes replacement was required. A significantly higher risk was manifested by hydrophilic IOLs, and the authors recommend that these lenses are not used in the case of risk of planned endothelial keratoplasty. By contrast, no influence was determined in the case of types of lamellar transplantation, frequency of rebubbling or used tamponade [63].

Moura-Coelho et al. retrospectively evaluated a cohort of 232 patients following DMEK. They analyzed cases of IOL opacification – total 21 eyes (9.1%). The main risk factors were higher water content in the lens (odds

ratio 65.5) and rebubbling (odds ratio 9.51). They also analyzed cases in which it was necessary to explant the IOL due to opacification. This concerned 4 IOLs, in two cases made of hydrophilic material, in 2 cases hydrophilic with a hydrophobic surface [64].

By contrast Schrittenlocher, who retrospectively evaluated a total of 564 consecutive patients following DMEK surgery, did not determine the influence of the type of IOL material (hydrophilic v hydrophobic) or the type of tamponade (SF6 v air). In total in their cohort they determined IOL opacification in 14 cases (2.5%) [65].

DISCUSSION

Both types of soft acrylate IOLs, namely hydrophilic and hydrophobic, are currently widely used in ophthalmology. The advantages of hydrophilic IOLs are above all good handling and easy implantation [66], greater resistance to damage [67], including random damage by laser treatment during Nd:YAG capsulotomy [68,69], higher uveal biocompatibility and also lower chromatic dispersion [70]. The main disadvantage is the higher frequency of PCO and subsequent need for Nd:YAG laser capsulotomy. Wang explains the lower incidence of PCO in the case of hydrophobic lenses with reference to the biological effect of the IOL material on adhesion, migration, morphology and epithelial-mesenchymal transition (EMT) of human lens epithelial cells [71].

The performance of laser capsulotomy itself also carries certain risks, and may increase the incidence of certain complications, above all elevation of intraocular pressure, cystoid macular edema and retinal detachment. The incidence of these complications is stated in summary at approximately 13%. In certain groups of patients, such as patients with diabetes mellitus, uveitis, high myopia etc., the risk of complications following YAG capsulotomy is even higher [72,73].

Some manufacturers have attempted to adapt the surface of the existing materials in order to attain better biocompatibility of the IOL. For example, in experiments they have used plasma, ionizing radiation, ozone or the technique of progressive layering. The materials which have been successfully incorporated into the lens surface using these procedures include e.g. PEG, polyhedral oligomeric silsesquioxane, 2-methacryloyloxyethyl phosphorylcholine, heparin, F-heparin, titan, TiO2, titanium nitride, vinylpyrrolidone and cytokine inhibitors. Using these procedures it is possible to make the IOL more hydrophobic (or hydrophilic), or to create an IOL with a hydrophilic anterior and hydrophobic posterior surface [74]. Nevertheless, at present the majority of IOLs adapted in this manner are not available for clinical use, and for example the clinical results of hydrophilic IOLs with a hydrophobic surface have not yet convincingly demonstrated greater resistance to the incidence of PCO [75].

Probably the most serious (and fortunately quite rare) postoperative complication is IOL opacification. A series of authors have presented cases of opacification of hydrophilic intraocular lens or hydrophilic IOLs with a hydrophobic surface. Specifically one type of intraocular lens, namely Lentis LS-502-1 (Oculentis GmbH, Berlin, Germany) demonstrated a very high (9.9–53 %) frequency of opacification [76,77]. It was determined by laboratory analysis that this concerned a subsurface deposit of calcium phosphate [78]. The cause of IOL opacification may be material properties, contamination in connection with manufacture and individual factors of patients such as changing concentrations of intraocular ions, age, arterial hypertension, hypercholesterolemia or diabetes mellitus [77,79]. For example, in an experiment Buhl demonstrated a higher risk of IOL calcification in the case of a higher concentration of phosphates, as is the case in the chamber fluid of diabetic patients. Concentrations (10 mM and 14 mM Na2HPO4) which caused opacification in hydrophilic IOLs did not have an influence on the transparency of the material in the case of hydrophobic IOLs [80].

Opacifications have also been described in isolated cases of other types and manufacturers of IOLs. Mackert analyzed 75 explanted opacified IOLs and assessed the type of opacification. In 68 cases this concerned a single-piece hydrophilic acrylic IOL, in one case a 3-piece hydrophilic acrylic IOL and in 6 cases a 3-piece hydrophobic acrylic IOL. In 67 cases this concerned fine granular opacities and in 8 cases crust-like opacifications. In 62 cases it concerned a primary type of opacification (i.e. on the basis of production and packaging), in 13 cases a secondary type of opacification of unclear etiology. The anterior surface was affected in all 75 lenses, the posterior surface only in 23 cases [81]. Calcification of hydrophobic IOLs was observed very rarely in comparison with hydrophilic IOLs, nevertheless such cases were also described [82,83].

The risk of IOL opacification probably increases significantly in association with certain other intraocular procedures, above all in connection with insufflation of gas or air into the vitreous cavity or the anterior chamber of the eye [13]. Bopp described a case of 14 explanted opacified IOLs following pars plana vitrectomy (PPV). The procedure used varied, in 8 eyes hexafluoroethane C2F6 was used for endotamponade, in one eye perfluoropropane C3F8 was used, in two cases air and in 3 cases silicone oil. The average interval between the operation and registration of IOL opacification was 20.5 ±18.6 months. In 6 cases this concerned an IOL made from hydrophilic material, in 7 cases from hydrophilic material with a hydrophobic surface, and in one case it was not possible to determine the lens material [84]. Markovich described 11 cases of an opacified hydrophilic IOL (total 6 manufacturers) following performance of PPV with gas tamponade. Opacification was recorded 1 month to 6 years after surgery. Eight lenses were explanted and subsequently analyzed, a granular deposit was identified containing calcium and phosphorus [85]. Werner analyzed 7 opacified and subsequently explanted IOLs following DSAEK. In 6 cases this concerned hydrophilic material from a total of 6 manufacturers. Laboratory tests determined surface/subsurface deposits of calcium, central circular distribution in the region bordered by anterior capsulorhexis or the pupils [86].

As already stated, (unlike hydrophilic IOLs) opacification of hydrophobic IOLs occurs extremely rarely. On the other hand, the main observable change in the material of hyd-

rophobic IOLs is glistening – the formation of microvacuoles filled with water which may cause straylight. As a rule they do not cause patients greater complaints, but cases have been described in which it was necessary to explant an IOL due to adverse secondary optic phenomena. Under laboratory conditions Yildirim examined the resistance of a total of 5 hydrophobic IOLs to the formation of glistening. These were the IOLs 800C (Rayner, Worthing, UK), AcrySof SN60WF (Alcon, Fort Worth, USA), Tecnis ZCB00 (Johnson & Johnson Vision, Santa Ana, USA), Vivinex XY1 (Hoya, Tokyo, Japan) and CT Lucia 611P (Zeiss, Oberkochen, Germany). The authors assessed the number of microvacuoles per mm2 (mVs/mm). The largest measured values were in the case of the IOL SN60WF (66.0 ±45.5) mVs/mm2 and the IOL 611P (30.7 ±8.4) mVs/mm2. By contrast, in the case of the IOLs 800C, XY1 and ZCB00 the measured values were very low (2.0 ±3.6, 2.7 ±2.4 and 0.9 ±0.6 mVs/mm2). The study also demonstrated that resistance to the formation of glistening depends on the composition of the copolymer of the relevant acrylate [87].

Another interesting question in the choice of implant at individual centers is its price. Ting published data based on the national cataract register of the United Kingdom for the years of 2015–2020. The register contained a total of 907 052 operations. It compared the number of implanted hydrophilic and hydrophobic IOLs in facilities with a different financing mechanism. At centers financed by the "block contract" system – i.e. payment of an agreed amount in advance regardless of the specific performed procedures, implantation of a hydrophobic IOL was prioritized (96.5% v 3.5%). At these centers a role was most probably played by the endeavor to ensure the lowest possible number of complications that could subsequently increase the burden of costs. By contrast, at centers where cataract surgery was financed by the "payment by results" system, hydrophobic IOLs were implanted in only 65.7% of cases (hydrophilic in 34.3%). Here a role may have been played by the fact that the center is paid for the subsequent resolution of complications such as Nd:YAG capsulotomy. The authors state that the selection of IOL is therefore somewhat unetheically influenced by the type of payment and price, despite the fact that the average price difference between both IOLs was not large [88]. Within our environment, as a rule this fact is addressed on the part of payers through a system of different package payments for the implantation of a hydrophilic or hydrophobic IOL. However, this does not relate to centers financed according to payment decrees or other contracts.

CONCLUSION

Current types of soft acrylic intraocular lenses achieve excellent refractive results and a high level of subjective patient satisfaction. This applies to lenses made of both hydrophilic and hydrophobic materials. Also some other properties such as rotational stability, influence on postoperative retinal thickness, frequency of refractive surprises and higher order aberrations are entirely comparable. Hydrophilic IOLs demonstrate slightly better results in terms of the frequency of dysphotopsias, have lower chromatic dispersion, greater resistance to mechanical damage and are very well implanted. They do not result in the phenomenon of glistening, which appears exclusively in the case of hydrophobic IOLs. However, the main disadvantage of hydrophilic implants is unequivocally the higher risk of opacification of the posterior capsule of the lens, as well as the risk of opacification of the implant itself. This phenomenon occurs more frequently in the case of subsequent intraocular operations, primarily PPV and corneal endothelial transplantation. In patients who are at risk of undergoing such subsequent surgery (corneal endothelial dystrophy, retinal pathology), as well as in patients with a higher risk of complications after Nd:YAG laser capsulotomy (patients with myopia, chronic uveitis or glaucoma), the use of hydrophobic material should be considered a priority.

We still do not have an entirely optimal and universal type of material for the production of IOLs. In general an optimal material should have excellent optical properties and thereby enable perfect VA, it should be biocompatible, prevent posterior capsular opacification and also enable change of the refractive index for the creation of dioptric power specific to the individual patient. An IOL made of such material should be implanted by a small incision in order to ensure that the entire procedure is maximally sparing for the patient. A certain role is naturally also played by the price of the resulting material. At present materials considered to be highly promising are hybrid polymers such as PEG-PEA/Styrene (polyethylene glycol, polyethylene adipate), 2-HEMA and EOEMA copolymers (poly 2-hydroxyethyl methacrylate, poly 2-ethyloxyethyl methacrylate), or a combination of a number of different materials with different refractive indexes, known as GRIN (GRadient INdex), which both anatomically and functionally could be very similar to a natural lens [89].

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