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Intraocular Lens Materials: A Detailed Assessment of Benefits and Drawbacks

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Abstract

Intraocular lenses (IOLs), which are used to repair vision in a large number of patients following cataract surgeries, are potentially the most significant single advancement in ophthalmology. The first IOLs were made by the only biomaterial available for implantation over decay which is a rigid plastic namely, polymethyl methacrylate (PMMA), The main drawback of PMMA is that it necessitates the largest incision in cataract surgery, with the corneal incision is as large as the optics of the IOLs. Because the essential intention of forward-thinking cataract surgery is to make the smallest incision possible, the IOLs must be adaptable and bend. This intention can be accomplished by enhancing the model and matter of IOLs. There are also some characteristics associated with IOLs materials that may have some impact such as (Refractive Index, Water content, Glistening, Etc.), The improvement of the first silicone IOLs used to overcome that problem but it is now rarely used and has been replaced with an Acrylic hydrogel material that provides a good performance; researchers are still evaluating suitable IOLs materials.

Introduction

Intraocular lenses (IOLs) are artificial lenses that are inserted through the human eye instead of the original crystalline lens as part of a typical operation cataract surgery procedure to control refractive errors. The concept of implanting is to first insert IOLs into an appropriated capsular bag to assist in the transplant process, while the IOL's main structure design is composed of two portions central side which is an optical part, and a haptic side which helps to maintain the lens inside.

The first IOLs were implanted in the early 1950s in England, followed by FDA approval for IOLs used in the United States. Before that time, either contact lenses related to the wear and tear of daily application and removal, or thick glasses resulted in remarkable enlargement and distortion of vision in the case of cataract surgery without the required IOLs for the patients (Apple, Escobar-Gomez, Zaugg, Kleinmann, & Borkenstein, 2011).

In terms of lens material and design, cataract surgeries are continuously developing and enhancing fields, where the goal is to achieve the best refractive outcomes with the smallest incision size possible, while also aiming to reduce the response of the host cell as it may cause some effect on posterior capsule opacification (PCO), anterior capsular opacification (ACO) and lens epithelial cell (LEC) proliferation (Rønbeck, Kugelberg, & Surgery, 2014).

IOLs classified into several types based on their optical features and materials. The first (IOLs) implanted were made of rigid polymethyl methacrylate (PMMA) material and were inserted via an extracapsular surgical technique, causing postoperative astigmatism and a large incision (Oner, Gunenc, Ferliel, & Surgery, 2000). Eventually, both the surgical technique and the design improved significantly (Auffarth et al., 2004).

During the 1980s, Epstein took the first step toward improving the IOLs material to make them foldable by replacing PMMA with silicon to make lenses (Apple et al., 1984). This step provides an advantage by inserting the lens into the eye through a small 3 mm incision as compared to a 5-7 mm incision in the case of non-foldable PMMA (Kapoor & Gupta, 2020).

Nowadays, IOLs materials are divided into two categories: acrylic and silicon. Whereas acrylic materials can be divided into different types, foldable lenses are made of hydrophobic acrylic materials, hydrophilic acrylics, and can be rigid (PMMA), with different copolymer acrylic the foldable acrylic lens design is made of (Tandogan et al., 2021). Several factors, such as refractive index, water content, glass transition temperature, and other characteristics, can be used to assess the quality IOLs (Bhattacharjee, Buragohain, Javeri, Das, & Bhattacharjee, 2021).

Firstly, one of the most important features used to evaluate lens performance is the water content percentage (Ryu, Kim, Kim, Paik, & Kim, 2021). Both silicon and hydrophobic materials have a low water content of 3%, but hydrophilic acrylic materials have a higher water content of 38%. Secondly, the refractive index of the material, where the non-foldable rigid (PMMA) has a refractive index of 1.49, and foldable hydrophobic acrylic with 1.47, and 1.46 for hydrophilic acrylic, while 1.41 for silicon.

$$n = \frac{c}{v} \qquad \text{….. (1).}$$

As long as the speed is elevated in a vacuum more than the other medium, as a result, n >1.

Characteristics of IOLs Materials

Refractive Index

The refractive index, which describes the optical properties of the material, is one of the most important optical characteristics. In reality, it is a computation of light speed in the medium (Singh, 2002). While the speed of light in a vacuum, denoted by c is 299 792 458 m/s. Due to the variance in the speed between vacuum and other mediums, therefore the proportion of the light speed in vacuum (c) to the light speed on medium (v) can be expressed as refractive index.

Biocompatibility

The biocompatibility of the substance used to evaluate biotic reaction to an unfamiliar body depends on the scheme and implant matter. The chosen substance must be chemically inoperative, physically steady, can prevent allergic, capable of shaping the necessary model, and have no unusual body reactions (Scales, 1953).

To achieve the best optical system performance, materials used in ophthalmology should have a high refractive index, block the ultraviolet rays, and be optically transparent for as long as possible (Rønbeck, Behndig, Taube, Koivula, & Kugelberg, 2013). By releasing the cells and proteins into the aqueous humor, the blood-aqueous barrier is suspended during cataract surgery (Michelson et al., 2012). Proteins will hold on to the internal surface within the IOL surface, influencing the following cellular response on the IOL(Özyol, Özyol, & Karel, 2017).

Glistening

The aqueous humor depth into the IOL substance results in vacuole evolution in the optics of the IOL. As a result, glistening can be interpreted as fluid-filled formed within the IOL optic when the lens is in an aqueous environment (Werner & Surgery, 2021). It can be easily noticed with hydrophobic acrylic lenses. Several factors, including IOL material, covering, and production, can all have an impact on glistening formation. In some cases, it can be associated with eye glaucoma, which can lead to damage to the blood-aqueous barrier and the use of ocular medications (Von Mohrenfels, Salgado, Khoramnia, Maier, & Lohmann, 2010).

Hydrophobicity

One of the material properties used to evaluate the substance's ability by detached it from water (Ma, Hill, & science, 2006). Using a contact-angle measurement, all materials have their hydrophobicity scale that is graded; it can be scaled from a few levels for a perfect hydrophilic surface to 180° for super-hydrophobic surfaces. Due to H2O bonds in water being extremely polar, this property is primarily determined by the material's chemistry (Cao, Hu, & Gao, 2007).

Hygroscope

Hygroscopic describe the matter's capacity to subsume and maintain water. A high level of hygroscopic matter ejects water through itself (J. Kim, Kim, Ha, Paik, & Kim, 2021). This property explains both the surface and interior of IOLs hydrophobicity in optical field applications. Depending on the interaction of an IOL's surface with water, the hydrophobicity can be evaluated and as apacity of IOLs to draw water into their interior (Cao et al., 2007).

IOLs Materials

Polymethyl Methacrylate

Polymethyl methacrylate (PMMA) is a commonly used polymeric material in the fields of medical industries. It has outstanding properties such as small chromatic dispersion, high transmittance, great hardness, good chemical stability, and good processing performance (Wang, Gao, Li, Fang, & Chen, 2010).

PMMA IOLs are rarely used nowadays due to the large incision with an optic diameter of 5–7 mm and commonly single pieced, as well as having a low water content of 1% and a refractive index of 1.49, because of high rigidity lens cannot pass through a small incision using phacoemulsification (Pérez-Vives, 2018).

Silicone

By designing silicon IOLs with small incisions through the implantation, a new step in ophthalmology was made in 1984. Whereas silicon is a hydrophobic material it has a refractive index ranging from [1.41-1.46], with [5.5-6.5] mm diameter for the optic side (Jiang, Yang, Lv, & Song, 2018).
Because of several factors that have an impact on the silicon lens performance, it has drawbacks such as the ability to be multicolored or to have a slight shade after some time. They open with a snap while unfolding, therefore care must be taken during implantation (Steinert, 2006). Due to their malleability and elasticity, silicon lenses can be accommodated.

Hydrophobic Foldable Acrylic

It is one of the most recent materials to be used in ophthalmology. This material is made of a substance with a molecular structure composed of many similar units bonded together (S. M. Kim & Choi, 2008). Characterized with little amount content of water with a percentage of about 1% and n=1.55, depending on the temperature of the solidity.

Acrylic lenses have the thinnest thickness of any lens material due to their high refractive index. To facilitate folding, the lens must be warmed and seem like PMMA. When wet these lenses can bend and overlap and can be controlled, but at high temperature, it becomes sticky, and unfolding becomes difficult (Lee, Sun, Choi, Park, & Surgery, 2009).

Hydrophilic Foldable Acrylic

It is an acrylic material composed of a gel with water as the liquid component, which is commonly used in optical field applications (Hazra, Palui, & Vemuganti, 2012). Polyhydroxyethylmethacrylate (PolyHema) is used, with [18-30] % present in the water percentage with n=1.47. These types have more tendency to bend and overlap than the previous type, also capable of being directed more than the silicone type. Due to the high water percentage, the lens is required to be controlled and remain hydrated until they are implanted. Different designs are available for the hydrophilic acrylic (hydrogel), designed with 6 mm optic which is suspended to the optics of PMMA also multi pieces are available (Kohnen & Klaproth, 2010). Where table 1, shows the refractive Index of Selected Intraocular Lenses [23].

Table 1. Refractive Index of Selected Intraocular Lenses [23].

Lens	Refractive Index
Hydrophobic acrylic	
Tecnis acrylic	1.47
PMMA	1.49
Envisat	1.54

Lens	Refractive Index
AcrySof	1.55
iSymm AF-1	1.55
Hydrophilic acrylic	
Softec HD	1.43
ACR6D	1.44
Collamer	1.45
Hydroview	1.47
Akreos AO	1.60
Silicone	
Staar Elastic Lens	1.41
Staar Elastimide Lens	1.41
Tecnis silicone	1.46

Advance IOLs Design

Toric IOLs

Toric IOLs mean lens implantation to treat astigmatism, which is used at the time of cataract surgery to decrease postoperative astigmatism. Because of their rotational symmetry, most IOLs are designed to treat spherical refractive errors of the human eye (Solomon, Sandoval, Potvin, & Surgery, 2019).

IOLs are used to correct the cylinder error because their power varies with different meridians. The most important requirement in IOLs designs is the alignment and fixation of the lens so that the IOLs axis must be aligned with the cylinder error (Lu et al., 2019). Any post-surgical rotation of the lens would decrease correction and can even present extra cylinder error if the rotation was large. Several factors, such as corneal astigmatism, IOL selection, and marking techniques, may affect the performance after the toric IOL (Vickers, 2017).

Multifocal IOLs

Multifocal IOLs lenses aim to provide good distance and near vision. Multifocal IOLs are used. Different designs have been attempted to achieve this multifocal; however, the designs are classified into two sections: Refractive multifocal and diffracting multifocal (Argal & Research, 2013).

Diffractive Multifocal IOLs

Diffraction is caused by small, nearly distant, annular grooves cut into the lens surface. An unlimited number of focal points is caused by diffraction. To have a suitable multifocal lens, the optical properties can be adjusted of the diffracting IOL. The diffracting IOL produce two distinct focal points, one for distance and one for near, the clarity of vision is excellent at both of these distance (Hayashi, Yoshida, Hirata, Yoshimura, & Surgery, 2018).

The Future of IOLs Materials

In conclusion, this review manuscript provided a detailed overview of the enhancement and improvement in the ophthalmology field, demonstrating the progression from the initial IOLs materials used. Whereas IOL implantation is one of the most common surgeries performed worldwide, with the technology constantly improving, some patients experience unfavorable side effects after the implantation. The advancement in technology predicts some changes in the shape of IOLs, IOL materials, design, and new implantation options. To ensure better performance and results, the aim of future work should focus on developing current materials. And predict creative, advanced, and alternative branches in the IOLs models and refractive ophthalmology.

Acknowledgments

This manuscript aims to provide a certain study in the optical field, especially in manufacturing the lenses. Starting by explaining how these lenses are made and how this field has been developed over decay and showing the side effect of each level of progress in this field till find the most suitable material that could be used in the intraocular lens branch.

References

Apple, D. J., Escobar-Gomez, M., Zaugg, B., Kleinmann, G., & Borkenstein, A. F. (2011). Modern cataract surgery: unfinished business and unanswered questions. *Survey of ophthalmology, 56*(6), S3-S53.

Apple, D. J., Mamalis, N., Loftfield, K., Googe, J. M., Novak, L. C., Kavka-Van Norman, D., . . . Olson, R. J. J. S. o. o. (1984). Complications of intraocular lenses. *A historical and histopathological review, 29*(1), 1-54.

Argal, S. (2013). Newer intraocular lens materials and design. *Journal of Clinical Ophthalmology and Research, 1*(2), 113.

Auffarth, G., Brezin, A., Caporossi, A., Lafuma, A., Mendicute, J., Berdeaux, G., & Smith, A. (2004). Comparison of Nd: YAG capsulotomy rates following phacoemulsification with implantation of PMMA, silicone, or acrylic intra-ocular lenses in four European countries. *Ophthalmic Epidemiology, 11*(4), 319-329.

Bhattacharjee, H., Buragohain, S., Javeri, H., Das, D., & Bhattacharjee, K. (2021). Delayed postoperative opacification of three hydrophobic acrylic intraocular lens: A scanning electron microscopic and energy dispersive spectroscopic study. *Indian Journal of Ophthalmology, 69*(5), 1103.

Cao, L., Hu, H. H., & Gao, D. (2007). Design and fabrication of micro-textures for inducing a superhydrophobic behavior on hydrophilic materials. *Langmuir, 23*(8), 4310-4314.

Hayashi, K., Yoshida, M., Hirata, A., & Yoshimura, K. (2018). Changes in shape and astigmatism of total, anterior, and posterior cornea after long versus short clear corneal incision cataract surgery. *Journal of Cataract & Refractive Surgery, 44*(1), 39-49.

Hazra, S., Palui, H., & Vemuganti, G. K. (2012). Comparison of design of intraocular lens versus the material for PCO prevention. *International journal of ophthalmology, 5*(1), 59.

Jiang, B., Yang, J., Lv, Z., & Song, H. (2018). Wearable vision assistance system based on binocular sensors for visually impaired users. *IEEE Internet of Things Journal, 6*(2), 1375-1383.

Kapoor, S., & Gupta, S. (2020). Basic Science of Intraocular Lens Materials. In *Intraocular Lens* (pp. 3): IntechOpen.

Kim, J., Kim, M. K., Ha, Y., Paik, H. J., & Kim, D. H. (2021). Improved accuracy of intraocular lens power calculation by preoperative management of dry eye disease. *BMC ophthalmology, 21*(1), 1-7.

Kim, S. M., & Choi, S. (2008). Clinical efficacy and complications of intraocular lens exchange for opacified intraocular lenses. *Korean Journal of Ophthalmology, 22*(4), 228-235.

Kohnen, T., & Klaproth, O.K. (2010). Intraocular lenses for microincisional cataract surgery. *The Ophthalmologist*, *107*, 127-135.

Lee, S. J., Sun, H. J., Choi, K. S., & Park, S. H. (2009). Intraocular lens exchange with removal of the optic only. *Journal of Cataract & Refractive Surgery, 35*(3), 514-518.

Lu, W., Miao, Y., Li, Y., Hu, X., Hu, Q., & Huang, J. (2019). Comparison of multicolored spot reflection topographer and Scheimpflug-Placido system in corneal power and astigmatism measurements with normal and post-refractive patients. *Journal of Refractive Surgery, 35*(6), 370-376.

Ma, M., & Hill, R. M. (2006). Superhydrophobic surfaces. *Current opinion in colloid & interface science, 11*(4), 193-202.

Michelson, J., Werner, L., Ollerton, A., Leishman, L., & Bodnar, Z. (2012). Light scattering and light transmittance in intraocular lenses explanted because of optic opacification. *Journal of Cataract & Refractive Surgery, 38*(8), 1476-1485.

Oner, F. H., Gunenc, Ü., & Ferliel, S. T. (2000). Posterior capsule opacification after phacoemulsification: foldable acrylic versus poly (methyl methacrylate) intraocular lenses. *Journal of Cataract & Refractive Surgery, 26*(5), 722-726.

Özyol, P., Özyol, E., & Karel, F. (2017). Biocompatibility of intraocular lenses. *Turkish journal of ophthalmology, 47*(4), 221.

Pérez-Vives, C. (2018). Biomaterial influence on intraocular lens performance: an overview. *Journal of Ophthalmology*, 2018.

Rønbeck, M., Behndig, A., Taube, M., Koivula, A., & Kugelberg, M. (2013). Comparison of glistenings in intraocular lenses with three different materials: 12-year follow-up. *Acta ophthalmologica, 91*(1), 66-70.

Rønbeck, M., & Kugelberg, M. (2014). Posterior capsule opacification with 3 intraocular lenses: 12-year prospective study. *Journal of Cataract & Refractive Surgery, 40*(1), 70-76.

Ryu, K. J., Kim, S., Kim, M. K., Paik, H. J., & Kim, D. H. (2021). Short-term therapeutic effects of topical corticosteroids on refractory dry eye disease: clinical usefulness of matrix metalloproteinase 9 testing as a response prediction marker. *Clinical Ophthalmology,* 759-767.

Scales, J. T. (1953). Tissue reactions to synthetic materials. *Proceedings of the Royal Society of Medicine, 46*(8), 647-652.

Singh, S. (2002). Refractive index measurement and its applications. *Physica Scripta, 65*(2), 167.

Solomon, K. D., Sandoval, H. P., & Potvin, R. (2019). Correcting astigmatism at the time of cataract surgery: toric IOLs and corneal relaxing incisions planned with an image-guidance system and intraoperative aberrometer versus manual planning and surgery. *Journal of Cataract & Refractive Surgery, 45*(5), 569-575.

Steinert, R. F. (2006). Vision function versus vision testing. *Ophthalmology, 113*(8), 1255-1256.

Tandogan, T., Auffarth, G. U., Son, H. S., Merz, P., Choi, C. Y., & Khoramnia, R. (2021). In-vitro glistening formation in six different foldable hydrophobic intraocular lenses. *BMC ophthalmology, 21*, 1-6.

Vickers, N. J. (2017). Animal communication: when i'm calling you, will you answer too?. Current biology, 27(14), R713-R715.

Von Mohrenfels, C. W., Salgado, J., Khoramnia, R., Maier, M., & Lohmann, C. P. (2010). Clinical results with the light adjustable intraocular lens after cataract surgery. Journal of Refractive Surgery, 26(5), 314-320.

Wang, N., Gao, N., Li, H., Fang, Q., & Chen, E. J. A. C. S. (2010). Influence of Different Structural Particles on the Properties of PMMA Composites [J]. *Acta Chimica Sinica*, *68*(8), 827-832.

Werner, L. (2021). Intraocular lens evolution in the past 25 years as told by the Journal of Cataract & Refractive Surgery. *Journal of Cataract & Refractive Surgery*, *47*(2), 147-149.

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