ETIOLOGY OF POSTOPERATIVE ASTIGMATISM AFTER CATARACT SURGERY

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Abstract

Postoperative astigmatism after cataract surgery depends mainly on its preexisting, on factors that are related to the surgical act and also on the characteristics of the intraocular lens. Over time there have been numerous studies concerning mainly the effects of corneal healing on its curvature and on its refractive stability. An important role in the apparition of this astigmatism has the type of the surgical incision: sutured or not sutured, size, depth and the incision’s location. Nowadays, the not sutured incision, in clear cornea, is the most frequent technique used in the extraction of the cataract with phacoemulsification. The improvements brought lately to cataract surgery follow a good healing and remodeling of the wound, which ensures the refractive stability of the cornea.

Keywords: Postoperative astigmatism, clear corneal incision, refractive stability

Introduction

The major objective of cataract surgery is a good functional result, with an optimal visual acuity, without optic correction.

Donders (1864) was the first who showed that the alteration of the corneal curvature is an unpleasant consequence of cataract surgery [1]. Over time, numerous studies were made concerning postoperative astigmatism after cataract surgery, at first related to the intra capsular extraction and later on to the extra capsular extraction. Since 1982, in the cataract surgery has been the practice of extra capsular extraction with implantation of intraocular artificial lens. The progresses made in this surgical technique further allowed the introduction and utilization on a larger scale of the extraction of cataract through phacoemulsification and of foldable artificial lens implantation.

Surgical induced astigmatism is the astigmatism larger than 1 diopter, with-the-rule or against-the-rule, which is present at 6-8 weeks postoperatively [2]. This form of astigmatism may compromise the postoperative functional results, after the cataract surgery, increasing postoperative astigmatism.

The etiologic factors that can be associated with postoperative astigmatism are: preoperative astigmatism and factors that are related to the surgical procedure.

Preoperative astigmatism

Larger preoperative astigmatism can be associated with increased values of postoperative astigmatism after cataract surgery [3]. Studies showed that nearly 15-29% of the patients who undergo cataract surgery have a preexistent astigmatism larger than 1.5 diop ters [4]. Reducing this type of astigmatism during cataract surgery
may improve the postoperative visual results, especially when a multifocal artificial lens is implanted. So, the correct value of the astigmatism, during cataract surgery must be equal with the sum of the vectors of the preexistent astigmatism and the surgically induced astigmatism [5].

The correction of preexistent astigmatism can be made during cataract surgery through incision techniques, like handling these for the flattening of the most refractive corneal meridian or by implantation of an artificial toric intraocular lens. Both methods can reduce a small to moderate astigmatism [6]. According to other authors, preoperative astigmatism can be corrected during cataract surgery, using different methods that include relaxing peripheral incisions, choosing the incision’s location or implantation of an artificial toric intraocular lens [7,8].

**Surgical induced astigmatism:** can be correlated with a multitude of factors, such as factors related to the incision and factor related to the intraocular artificial lens.

**Factors related to the incision**

**Type of wound, sutured or not sutured.** In case of sutured wound, postoperative astigmatism depends on the length, depth and tightness of the suture [9]. Thus, long sutures, placed near each other, create a tissue compression, leading to a with-the-rule astigmatism. Widely separated sutures, and also less tight sutures, determine an against-the-rule astigmatism. Sutures which are too superficial tend to eliminate themselves spontaneously, leading to against-the-rule astigmatism. In sutured wounds, as long as the stitches are in place, the postoperative astigmatism remains constant, and after their removal this astigmatism induced by sutures removes itself [10].

On the other hand, studies have shown that on the same cornea, the healing of sutured and suture less wounds is different [11]. Thus, sutured wounds initially heal more slowly, but over time, obtain a pseudolamellar continuity. In contrast, not sutured wounds are characterized by an early healing, almost lamellar, but may be followed by an inefficient regeneration of the scar.

**Degree of suture tightening.** This is another factor identified to be responsible for postoperative astigmatism. A large suture allows the cornea to become flat, reducing the curvature in the vertical meridian and against-the-rule astigmatism. If the suture is too tight, it stretches the cornea vertically, increasing the curvature in the meridian and causing with-the-rule astigmatism [12].

**Suture material used.** Changes in corneal curvature after cataract surgery, in case of operated sutured wounds, differ depending on the suture material used, resorbable or nonresorbable. According to Jaffe and Clayman [13], the main factors responsible for these changes are wound dehiscence which occurs in cases of sutures with absorbable sutures and wound compression which appears in cases with sutures with non-absorbable sutures. Comparative studies were performed on eyes operated of cataract with monofilament sutures and with sutures with natural silk threads, taking into consideration the importance of the relations between changes in the corneal curvature after the removal of the monofilament and after the biodegradability of the silk thread [14]. Thus, in cases of monofilament sutures, the power and the cylinder axis were constant as long as the sutures remained in place. After their removal, postoperative astigmatism was significantly reduced due to the decreasing of tension produced by monofilament sutures, in the wound. In case of absorbable sutures, the value of the cylinder axis varied, and the healing was associated with a local inflammatory reaction.

**Depth of wound.** The process of corneal wound healing involves epithelial cells and fibroblasts in the anterior segment and endothelial cells in the posterior segment [15]. Through studies on humans and monkeys, in case of unsutured wounds, it was observed that the morphology of the scar tissue differs depending on wound depth [11]. Thus, in the anterior regions it was found an early restoration, almost anatomical, pseudolamellar, while in the posterior regions they were disorganized. These regional differences of healing are supposed to be due to local mechanical factors, such as removing the fibrin plug or due to intrinsic properties of different healing between stromal layers.

**Location of the incision in relation to the limbus.** The incisions in cataract surgery can be: scleral, limbic or corneal [16].

The scleral incision it is also called a scleral tunnel. Because it is located posterior, it minimizes the corneal deformation which is stabilized by the limbic ring, with a minimum postoperative astigmatism. Another advantage is that it’s watertight, it’s self-sealing, thus not requiring suturing, but when is less efficient it determines a postoperative astigmatism. The more scleral the incision the lower is the value of the astigmatism.

The limbic incision can be done in the anterior part of the limbus across the cornea, in the middle or at the posterior part, along the sclera. Incisions located in the anterior part heal slower, while the incisions situated in the posterior part require sutures, with postoperative astigmatism.

The corneal incision it is done without involving the conjunctiva or the sclera, and it is also called clear cornea incision. This causes a minimal inflammatory reaction, does not require diathermy, thus avoiding the coagulation of collagen fibers. When it is small (about 3 mm), the postoperative astigmatism is minimal, the...
healing and recovery time is short. In this respect, the literature data show that the incision of 2.8 mm in clear cornea induces small refractive changes, at least in the eyes with small preoperative corneal astigmatism, regardless of the incision's location [17]. This type of incision is recommended only in case of foldable artificial lens implantation. It is not recommended in cases of rigid intraocular lens implantations, when the surgical wound must be equal to or greater than 5 mm, because the postoperative astigmatism is difficult to prevent. Comparative studies were performed on postoperative astigmatism through clear corneal incision and posterior limbic incision [18], noticing that for the same size incision, 2.2 mm, the posterior limbic location induces astigmatism significantly lower and less variable (0.25±0.14) compared with the clear corneal incision (0.69±0.49). A more corneal incision determines a more important with-the-rule astigmatism and a scleral incision determines a smaller against-the-rule astigmatism [19]. Although studies have shown that limbic incisions and scleral incisions induce less astigmatism than the ones in clear cornea, in the case of small incisions the effect of the locations is less important [17]. Due this fact, nowadays, the most common incisions made in cataract surgery through phacoemulsification are the ones in clear cornea, thus replacing the scleral tunnel and the limbic incision.

**Type of incision.** In terms of plans in which the incision is made, this can be of three types [16]: in a singular plan, in two plans and in three plans.

The single plan incision can be a perpendicular incision on limbus and is generally made on the anterior limbus. This type of incision is healing slowly and requires suturing. Another procedure of it, is the ab-exerno oblique limbal incision - was used a lot over the past decades for extracapsular cataract extraction. It is generally made in the middle region of the limbus, the plane of the incision is at 110° from the plane of the cornea. The disadvantage of these two types of incisions is the need for suturing, with the emergence of high postoperative astigmatism [20].

The two planes incision can be an angled limbic incision - it can be made at any level of the limbus, either corneal or scleral. The incision is made in two planes, one perpendicular and another one at 110° from the surface of the cornea. Usually, the incision perpendicular to the average depth is the first one, followed by the oblique one, which opens the anterior chamber. It requires sutures, with the possibility of postoperative astigmatism. Another way for this procedure is the inverse corneal incision - it is made in the transparent cornea, 1-2 mm in front of the limbus, having the form of flute's mouthpiece and has a significant leak. The wound is small, so postoperative astigmatism is minimal [20].

The three planes incision refers to the scleral tunnel. In this approach, first it is made a perpendicular incision in the scleral area, afterwards the intralamellar space is then dissected horizontally, and finally the anterior chamber is penetrated by an oblique incision. This incision is usually used in the phacoemulsification technique. Its advantage is a good tightness and self-sealing, especially in the case of small wounds. These features ensure a better control over postoperative astigmatism.

**Dimension of the incision.** Lately, reducing the size of the incision has been a major concern for many cataract surgeons. However, larger scale use of phacoemulsification and foldable intraocular lens development allowed smaller and smaller incisions in cataract surgery. Nowadays, the standard technique for cataract surgery, in the industrialized countries, is made through an incision of about 3 mm.

Reducing incision size induces a smaller astigmatism after cataract surgery. On this respect, it was proved that a smaller incision can manipulate the cornea softer and with minimal stress concerning the adjacent tissue, providing better optic results [21,22]. Decreasing the incision's dimension from over 3 mm to less than 2 mm determined the reducing of the induced astigmatism and the corneal aberrations [21,22].

Referring to the locations of the incisions in relation to limbus, the studies show that there are not significant differences in the magnitude of the postoperative astigmatism, if they are made in clear cornea or sclera, when it comes to small incisions. Thus, an Italian study has compared clear corneal incisions of the same length made in the temporal area and the tunnel incisions made in the superior area at 12 o'clock. The degree of astigmatism was similar, but there were different meridians [23].

As mentioned before, nowadays, small unsutured corneal incision is preferred by most cataract surgeons. It is known that the anterior surface of the cornea is the main refractive, element of the eye, contributing to more than 2/3 of its refractive power [24]. So, it is important to eliminate the corneal incision's effect over its optic properties. Lately, the tendency to corneal micro-incisions (about 2 mm), which provide a well anatomical restoration and refractive stability of the cornea, characterized the evolution of cataract surgery. Comparatively with standard incisions, the microincision's advantages are a smaller postoperative astigmatism and less corneal irregularities, with better
implications over the postoperative functional result and earlier rehabilitation. In this respect it has been shown that the mini-incision of 2.2 mm and micro-incision 1.8 mm used in cataract surgery by phacoemulsification are neutral in terms of astigmatism [21]. It seems that the 2 mm clear corneal incision is optimal for the induction of insignificant optical changes in the human cornea, after surgery [25].

**Location of the incision by meridian.** Postoperative astigmatism in cataract surgery may also vary depending on the meridian on which the incision is placed. The literature data show that small superior incisions, affect more the corneal curvature than similar incisions, placed in the temporal area [26]. Several explanations have been given for this purpose. It is known that the human cornea is about 1 mm wider than higher [27]. Thus, an upper incision can be easily closer to the corneal apex than a temporal incision, with more pronounced effects on the curvature of the corneal center. The temporal incision is further from the visual axis and any flattening due to any wound is less likely to affect corneal curvature and visual axis [28]. On the other hand, in a superior incision, the gravity factor and the blinking tend to create traction on it. These forces are neutralized better in temporal locations, because the incisions are parallel with the vectors of the forces.

Different effects of the incisions, in terms of induced astigmatism, depending on their location, have been reported by many other authors. Kohnen et al. [29] reported a statistically significant difference in induced astigmatism after unsutured tunnel limbic incision, temporal and nasal. Guirao et al. [30] showed that temporal incision induces fewer aberrations than the nasal one.

From the structural point of view it is known the fact that the incision in the cataract surgery can induce a flattening effect when it is performed near or on the steepest meridian of the cornea [19]. Thus, placing the incision on the steepest corneal meridian in the cataract surgery through phacoemulsification, corrects lower values of the pre-existing astigmatism and it is sufficient for most eyes operated of cataract [8]. A temporal incision of 2.8 mm is recommended for patients with negligible preexistent astigmatism, while the upper and nasal incision should be used also for the correction of low-grade astigmatism when steepest axes are located at 180° and 90° [31].

**Factors which depend on intraocular lenses**

The surgeon’s decision to choose a particular type of artificial lens implant to a specific patient is difficult nowadays because of the existence on the market of a wide range of such implants. This requirement can be fulfilled by choosing a foldable artificial lens, which can be implanted through a corneal artificial micro-incision, with a minimum postoperative astigmatism.

Factors that may induce postoperative astigmatism and are related to the artificial intraocular lenses are: the position of the posterior chamber artificial intraocular lens, the materials from which are made the artificial intraocular lenses, the size of the optic segment, the form and size of the haptics and also the design of the artificial intraocular lens.

**The position of the intraocular lens in the posterior chamber.** Intraocular lens implantation in the capsular bag is the optimal method in most cases of cataract surgery [32]. The position of the intraocular lens in the capsular bag can affect postoperative astigmatism in cataract surgery. The refractive changes induced by the rotation of the intraocular lens and its longitudinal displacement, are well known [4]. Posterior misalignment is the most common one and has multiple causes: haptic alteration, zonular dialysis, posterior capsule rupture, asymmetric capsulorhexis, asymmetric haptic placing, one in the sulcus and one in the capsular bag. Late spontaneous dislocation in the bag is associated with zonular insufficiency, like that of the exfoliated syndrome [34].

Examinations performed on cadaver eyes with posterior chamber intraocular lenses showed that asymmetric setting (bag-sulcus) is a cause of descentration [35,36]. The descentration degree was 0.8 mm for the case of bag-sulcus fixation and only 0.4 mm for bag-bag fixation [37].

**Materials used for artificial intraocular lenses.** Before the artificial intraocular lenses era, the most common used were the ones made of polymethylmethacrylate (PMMA). In this respect, it is known that PMMA implants may be associated with an inflammatory reaction greater than the ones with hydrophilic acrylic and with a higher rate of posterior capsule opacification [38]. It is unclear whether this effect is directly related to the implant material or to the greater size of the wound required for rigid implants. Currently, artificial crystalline lens implants are made of either silicone or acrylic polymers. On the other hand, these materials can be generally classified after their hydrophilic or hydrophobic nature. Hydrophilic materials are considered generally to have a better uveal biocompatibility compared with hydrophobic materials, but the latter, with their current design may have greater performances in the prevention of posterior capsule opacification [39,40]. Such a complication requires YAG capsulotomy, which later can cause a misalignment of the artificial lens [41].
Optical part size. It may be responsible for the occurrence of postoperative astigmatism and it is due to more frequent use of small diameter artificial lens, which are more difficult to center. Artificial intraocular lenses with larger optical parts (6 mm), are better, because they are less dependent on centering and have a lower rate of posterior capsule opacification [42]. On the other hand, a larger diameter may require a larger incision, thus increasing the risk of postoperative astigmatism.

Shape and size of haptics. They have an important role in the misalignment of the intraocular lens with the possibility of apparition of the postoperative astigmatism. Haptics with the J form come into contact with the posterior capsule on a portion with 25% lower than the ones with the C loop [43]. On the other hand, a total diameter of 12.0 to 12.5 mm is sufficient for a better centering of the intraocular lens. A larger diameter can stretch the capsule in the direction of the lens, becoming oval, and the misalignment of the intraocular lens thus being possible.

The design of the artificial intraocular lens. The intraocular lens dislocation has been reported in both of the designs, single piece or multi piece [44]. This complication is more common when the artificial implant is not placed symmetrically in the capsular bag.

Conclusions

Postoperative astigmatism of greater value may compromise functional outcome after cataract surgery. The causes of this type of astigmatism are multiple, but the characteristics of the surgical incision are the most important. Small incision in clear cornea reduces the risk of corneal damage, providing an early anatomical and functional rehabilitation after cataract surgery.

Bibliography


