Astigmatism treatment during phacoemulsification: a review of current surgical strategies and their rationale

Tratamento do astigmatismo por ocasião da facoemulsificação: revisão e embasamento das estratégias cirúrgicas atuais

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ABSTRACT

Preexisting corneal astigmatism, present at the time of cataract surgery, is reviewed in detail throughout this article on its most important aspects such as occurrence rates, clinical relevance and current treatment options. Special emphasis is given to the latter aspect. Each method's rationale, advantage and limitation ishigh lightened. Comparisons between treatment options, whenever possible, are also provided.

Keywords: *Astigmatism/surgery; Cataract/complications; Phacoemulsification/methods; Lens implantation, intraocular*

RESUMO

O astigmatismo corneano pré-existente, por ocasião da cirurgia de catarata, é detalhadamente revisado neste artigo sob aspectos tais como: ocorrência, relevância clínica com ênfase nas opções de tratamento atualmente disponíveis. Destacamos o embasamento teórico de cada método, bem como vantagens e limitações foram destacadas. Comparações entre as opções terapêuticas, sempre que possível, são apresentadas.

Descritores: Astigmatismo/cirurgia; Catarata/complicações; Facoemulsificação/métodos; Implantação de lentes intraoculares

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INTRODUCTION

Cataract surgery has evolved over the past few years with new surgical techniques, devices and improvements in the design of intraocular lenses, shifting from traditional spheric-monofocal lenses to aspheric, toric, pseudoaccomodative, accomodative or a combination of these features [1,2]. It is, currently, among the most performed planned surgical procedures worldwide, positively impacting over patients' quality of life [3,4].

Astigmatism is a visually disabling refractive error affecting the general population, especially those with cataracts [2]. With increased patients' expectations, the trend is not only to remove the cataract, but also to address the problem of pre existing astigmatism at the time of phacoemulsification. In addition to being a therapeutic procedure, cataract surgery is currently considered as a surgical approach for refractive errors [5]. The amount of techniques available to correct astigmatism during phacoemulsification suggests that the issue of astigmatism treatment by the time of phacoemulsification is currently under debate [6].

METHODS

PubMed and SciELO were searched on february 22nd 2013 using search words astigmatism and phacoemulsification. Retrieved references with no abstracts were not considered. This initial search retrieved 896 abstracts in english, portuguese or spanish, published from 1993 to 2013. Fifty-eight relevant references, concerning pre existing corneal astigmatism or surgically induced astigmatism, were, thus, obtained and reviewed in detail.

RESULTS

Definition of astigmatism

In an optimal stigmatic (point-like) optical system, a point in the object space is focused as a point image. The shape of the blurred image, for out-of-focus point objects, is always a circle.

An astigmatic optical system is nonpoint-like. In a regular astigmatic optical system an object point is focused as two mutually perpendicular line segments delimiting an intermediate interval, termed Sturm's conoid. No point focus is formed, but the blurred image attains different shapes and directions in Sturm's interval. The focal lines define the orthogonal principal meridians of the conoid. Differential magnification in the principal meridians means that the focal line segments have different lengths. Irregular astigmatism is the non-stigmatic and non-regular astigmatic part of the refractive spectrum. In wave-front analysis, stigmatic and regular astigmatic powers – correctable by spherocylinders– are termed lower-order aberrations. Irregular astigmatic elements are called higher-order aberrations [7].

Prevalence of astigmatism

A significant number of patients having cataract surgery have a degree of pre existing corneal astigmatism [8-11]. Estimates of the incidence of significant, naturally occurring astigmatism vary widely from 7.5% to 75% [11-13]. In a study comprising 4540 eyes in 2415 patients. Figure 1 is a histogram with frequency distribution of corneal astigmatism values for the entire sample showing that 13.2% of eyes did not present corneal astigmatism, 64.6% had corneal astigmatism between 0.25 and 1.25 D, and 22.2% had astigmatism of 1.50 D or higher [9].
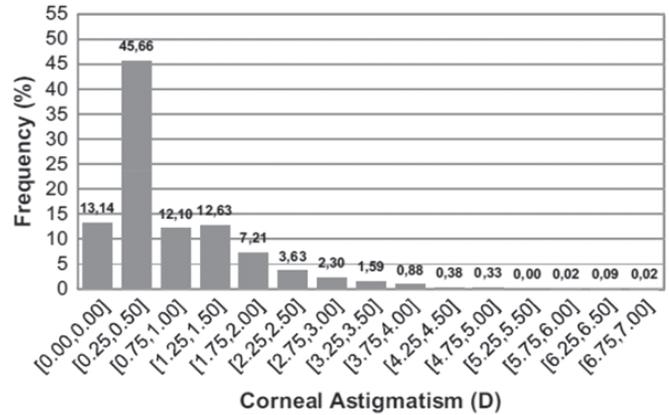

Figure 1: Histogram of the corneal astigmatism distribution in the entire sample (4540 eyes) [9]

Classification of corneal astigmatism magnitudes

Corneal astigmatism power may be considered as mild up to 1.00 D. Moderate, for magnitudes between 1.0 D and 2.00 D, or highly astigmatic if equals to, or greater than the upper limit of 2.00 D [14].

Astigmatism analysis

Meaningful analysis of astigmatic data is essential to understanding the results of refractive and cataract surgical procedures. Certain elements of astigmatic analysis are simple and straightforward, but other aspects can be extraordinarily complex. Several investigators have developed elaborate methods of further describing and characterizing astigmatic change. Such methods may exhibit marked differences among each other [15]:

Alpins and coworkers [16-19] use vector analysis to generate various indices to more fully describe astigmatic outcomes. Many of these indices, such as difference vector, index of success and coefficient of adjustment, provide remarkably useful and intuitive means of understanding the effects of the surgery.

Thibos and coworkers [20-21] take another approach to analyzing astigmatic data. This method separates refractive data into 3 power vectors: spherical equivalent and 2 Jackson crossed cylinders separated by 45 degrees. With these, they can demonstrate analysis of the data with useful graphic depictions. Thibos also calculates the blur strength, which is another index that can be used to characterize the effect on vision of the spherical and astigmatic components of the residual refractive errors.

Naeser and Hjortdal use polar analysis, as an alternative to vectorial analisys, in which they characterize any astigmatic value by 2 polar values that are separated by 45 degrees. In a subsequent work, Naeser and Hjortdal extended their methodology to trivariate analysis, which provides a 3-dimensional depiction that displays both polar values and the spherical equivalent [15].

Optical and physiological effects of ocular astigmatism

Optical effects of ocular astigmatism are blur and distortion [7]. Astigmatism of as little as 0.75 D may leave a patient symptomatic [12-13]. Blur is the lack of point focus and altered shape of the retinal image caused by the astigmatism. Distortion is the altered shape of objects caused by unequal magnification of the retinal image in the various meridians [7].

Treatment options

Perhaps the most challenging aspect of astigmatism surgery involves the determination of the quantity and exact loca-

tion of the cylinder that is to be corrected [12,22,23]. Unfortunately, preoperative measurements (keratometry, refraction, and corneal topography) do not always correlate. Lenticular astigmatism may account for some of this disparity, particularly in cases where there is a wide variance between refraction and corneal measurements; however, some discrepancies are likely caused by the inherent shortcomings of traditional measurements of astigmatism. Standard keratometry, for example, measures only two points in each meridian at a single optical zone of approximately 3mm. Corneal topography can be very helpful when refraction and keratometry do not agree, and it is increasingly becoming the overall guiding measurement on which the surgical plans are based [12].

Posterior corneal astigmatism contribution to total corneal astigmatism is gaining interest, in recent years, due to increasing number of cases of unintended astigmatism under or overcorrections [24-25].

a) Incisional approach

Incisional surgery creates gaping of the wound, addition of tissue in the incision, and elongation of the radius of curvature with subsequent flattening of the central cornea along the surgical meridian. Surgically induced astigmatism following tangential and arcuate incisions is characterized by coupling, by which an astigmatic change in one meridian is followed by a similar change in the orthogonal meridian with no net change in spherical equivalent refraction. Tight sutures will flatten the tissue around the incision with an initial steepening of the central cornea. Sutures have no long-time effect on astigmatism and an initial with-the-rule astigmatism is followed by against-the-rule decay after superior sutured cataract incisions. Surgically induced astigmatism after incisional surgery is predominantly influenced by wound length and placement, while patient age, preoperative astigmatism, and intraocular pressure play minor roles. Ablational laser surgery does not generate a coupling effect, and the spherical effect of ablation for astigmatism must be taken into account [7].

A viable and relatively simple way to decrease astigmatism is to manipulate the cataract incision to impact favorably pre existing astigmatism. This may be accomplished by first centering the incision on the steep corneal meridian (hence to be termed "on axis" technique) and then by varying its size and design, to affect a desired amount of wound flattening, and hence a decrease in cylinder. Such an approach, however, presents logistical challenges including movement around the surgical table, often producing awkward hand positions [12,26-28].

Opposite clear corneal incisions may also be used to address pre existing astigmatism [12,29]. In this technique, a second opposite penetrating clear corneal incision is placed over the steep meridian 180 degrees away from the main incision. This approach is technically simple and requires no additional instrumentation; however, a second substantial penetrating incision is now present, possibly increasing the risk of wound leak or even infection. In addition, single-plane beveled incisions are known to be less effective, for a given arc length, at flattening the cornea as compared with traditional perpendicular relaxing incisions [12].

For the reasons mentioned above, both on axis and opposite clear corneal incisions techniques have largely been supplanted by the use of a consistent and astigmatically neutral phacoincision, typically placed temporally, for stability, and then adding supplemental limbal relaxing incisions (LRI) [12,30]. Such an approach has become the most popular way to manage astigmatism at the time of cataract surgery [12,31-39]. The use of LRI offer several advantages over astigmatic incisions placed within the cornea, at smaller optical zones, including less chance of caus-

ing a shift in the resultant cylinder axis and a lesser tendency to cause irregular corneal flattening with irregular astigmatism. Technically, LRI are easier to perform and more forgiving than shorter and more central corneal astigmatic incisions [12,31]. Another important advantage gained by moving out to the limbus involves the coupling ratio, which describes the amount of flattening that occurs in the incised meridian relative to the amount of steepening that results 90 degrees away; paired LRIs (when kept at or under 90 degrees of arc length) exhibit a very consistent 1:1 ratio, and elicit no change in spherical equivalent refraction, obviating the need to make any change in implant power. Admittedly, these more peripheral incisions are less powerful, but are still capable of correcting up to 3.50 D of astigmatism in the cataract-aged population. One must keep in mind that the goal is to reduce the patient's cylinder, without overcorrecting or shifting the resultant axis. Their stability may well be caused by the proximity of well-vascularized limbal tissue. Nonetheless, as with any surgical technique, potential complications exist, the most likely to be encountered is the placement of incisions on the wrong axis. When this occurs, it typically takes the form of a 90-degree error with positioning on the opposite, flat meridian. This results in an increase and likely doubling of the patient's pre existing cylinder [12].

b) Non-incisional approach

A recent advance in cataract surgery was the introduction of toric intraocular lenses (IOL) for the correction of pre existing corneal astigmatism [40,46]. The use of toric IOL have been reported to be an effective method of reducing postoperative refractive astigmatism and spectacle dependence following cataract surgery [47]. Rotational stability of toric IOL is an issue of major concern, once proper alignment is critical for compensating corneal cylinder, resulting in good uncorrected vision. Each degree of rotation causes an average loss of cylinder power of approximately 3%; thus, when an IOL rotates 30 degrees there is no astigmatic correction, although there is a change of axis [44,46-55]. Articles comparing the use of toric IOL to other astigmatism reducing techniques, such as opposed clear corneal incisions [56] or LRI [57], are still scanty in number on literature. Slightly advantageous outcomes, favoring toric IOL have been reported [56,57], but debate on which technique unequivocally offers better results is just at the beginning. Toric IOL may also be employed in conjunction to such techniques aiming further refractive improvements [38].

Correction of unintentional residual ametropia may be achieved by excimer laser enhancement procedures. Such an approach exploits the advanced technology and exquisite accuracy of the excimer lasers [12,58]. Phacoemulsification wound healing, along with a stable refractive error, must be confirmed prior to enhancement procedures. Custom wavefront-guided ablations are particularly well suited in the scenario of a pseudophakic eye, because the dynamic lens component no longer exists. For a few cataract surgeons, excimer laser enhancements have become part of the routine preoperative discussion with patients [12].

CONCLUSION

Due to the prevalence of pre existing corneal astigmatism among cataract patients and its effects on final visual acuity, it is demanding for the cataract surgeon to address astigmatism, by the time of phacoemulsifcation, effectively as possible. Although several astigmatism reducing techniques exist, LRI and toric IOL are the most often used methods. Both strategies show limitations, advantages and drawbacks inherent to their use.

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