

# Tilt and Decentration of Intraocular Lenses-a Brief Review

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## Abstract

Eyes need a flexible, clear and refractively suited lens to provide the retina with sharp images in far and near distance. But even given an optimal lens, the resulting image would be blurred without proper lens positioning, observable in some cases of Marfan syndrome or after ocular trauma with lens dislocation. In contrast, as seen in routine ophthalmologic slit lamp examination, healthy eyes do not suffer from coarse lens misalignment.

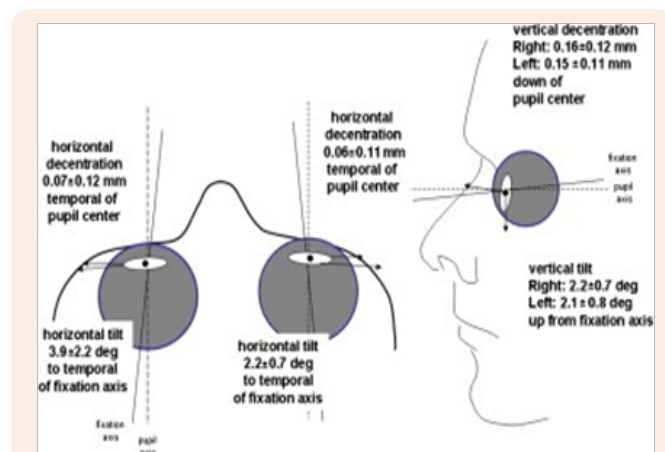
**Keywords:** Artificial lenses IOL; Tilt and decentration

**Abbreviations:** IOL: Artificial Lenses; CCC: Continuous Curvilinear Capsulorhexis; HOA: Higher Order Aberrations; AIOLs: Aspheric IOLs; SA: Spherical Aberration

## Introduction

**In depth evaluations of lens tilt and decentration are carried out using mainly two devices:**

A Purkinje-meter [1] or a Scheimpflug imaging based system, where the latter is commercial available for advanced ophthalmologic diagnostics. Both methods deliver comparable results, as shown in a cross-validation study [2]. Using these methods, it has been found that even in normal eyes with good visual acuity, a small amount of lens misalignment relative to the optic axis exists (Figure 1) [3] therefore; a small amount of lens misalignment seems to be physiological.



**Figure 1:** Mean values and standard deviation of tilt and decentration in normal eyes.

Tilt and decentration plays an important role especially when artificial lenses (IOL) are implanted. Therefore, IOL position was studied since the early years of cataract surgery [4]. Severe dislocation of the implanted IOL optic was found to decrease the retinal image quality while losing 11% of effective optical zone when a 6 mm optic is decentered by 0.5 mm [4] and optic

tilting of more than 5 degrees lowers optical quality [5]. Despite the introduction of the continuous curvilinear capsulorhexis (CCC) later on in cataract surgery development lowering tilt and decentration of IOL implants, investigators unexpectedly found the resulting optical quality in pseudophakic patients to be worse than in normal subjects [6]. It has been concluded that an ideal substitute for the natural lens has to compensate for higher order aberrations (HOA) of the cornea to yield physiological results.

Additionally, the spheric shape of the IOL optic itself was shown to lead to unwanted aberrations reducing retinal image quality [7]. Furthermore, it has been found that especially IOL tilt induces coma-like HOAs [8].

Given these results and the growing acceptance of refractive surgery, visual quality after cataract surgery was a growing subject of clinical research in ophthalmology [9] and highly sophisticated diagnostics to assess HOA have been introduced into our daily clinical practice [10].

Spherical aberration is the HOA of greatest clinical significance [11]. The human cornea exerts a positive SA, +0.27  $\mu\text{m}$  at a 6.0-mm optical zone, respectively, stable over age [11-13]. The SA of the crystalline lens, however, changes with aging: in younger eyes, a negative spherical aberration of the natural lens can be observed [14,15] compensating corneal positive SA [16-18]. In elderly eyes on the other hand, this lens exerted negative spherical aberration becomes more and more positive, therefore reducing image quality and contrast sensitivity [12,16,18-20].

Therefore, some of today's IOLs address the problem of spherical aberrations using several design concepts [21-23] where either an aberration neutral IOL or, moreover, an spherical aberration correcting IOL is targeted where the latter ones are often referred to as aspheric IOLs (AIOLs). AIOLs not only offer the correction of sphere and astigmatism but additionally the lowering of total spherical aberration (SA) by dampening the SA exerted by the cornea to improve contrast sensitivity [24-27]. In these implants, tilt and decentration is a very critical factor.

This was shown in laboratory studies [28-30] where it was found that outside certain limits of tilt and decentration, AIOLs not only fail to dampen corneal SA but even pronounce total HOAs compared to standard IOLs [31,32]. Many studies were performed

to assess IOL tilt and decentration *in vivo*, using either Purkinje meters [33-37] or Scheimpflug imaging [38,39]. To assess tilt and decentration in relation to HOAs after implantation of an aspheric IOL in patients, clinical studies were conducted [40, 41] and it was shown that the limits for tilt and decentration for proper functioning of AIOLs found in laboratory studies were respected after AIOL implantation *in vivo*, resulting in a reduction of total SA.

As these studies dealt with capsular bag implantation as the standard locus for IOL implantation, the question was raised whether other loci e.g. the ciliary sulcus can be equally suited for the implantation of aberration correcting IOLs. To address this problem, a study was conducted to evaluate tilt and decentration of IOLs implanted in the ciliary sulcus [42]. This study found more misalignment after sulcus implantation than in standard capsular bag implantation. Therefore, the ciliary sulcus seemed not best suited for AIOL implantation and, in order to avoid optical quality reduction in already more complicated eyes, implantation of standard, non-aspheric optics was recommended in this situation.

As IOL design advances and more specialized IOLs are developed, e.g. IOLs with Galilean telescope like optics, tilt and decentration will certainly continue to be an important factor in IOL technology [43] to achieve best postoperative image quality.

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