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CLINICAL STUDY

Objective and subjective outcomes in comparing three different aspheric intraocular lens implants with their spherical counterparts

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Abstract

Purpose **To look for objective and subjective differences between three types of aspheric intraocular lens implants and their spherical counterparts.**

Methods **Thirty patients were randomised to receive one of six lens implants including three aspheric lenses and their spherical counterparts. Pre and postoperative testing was carried out including visual acuity, contrast sensitivity and wavefront analysis. All patients were asked to fill in a visual function questionnaire (modification of cataract TyPE) to assess subjective differences in visual quality.**

Results **There was no significant difference between groups for best-corrected visual acuity. Contrast sensitivity testing showed the Tecnis lens to perform better than the Cee-on Edge in all lighting conditions with significant differences at 3 and/or 6 cycles/degree in three out of four lighting conditions. No significant differences in contrast sensitivity were seen between the other lens pairs. All aspheric lenses showed less spherical aberration than their spherical pairs with statistical significance reached in two out of three pairs (the Ceeon Edge *vs* Tecnis, and Acrysof Natural *vs* IQ). The questionnaire revealed no evidence of improved subjective vision with the aspheric lenses compared to the spherical lenses.**

Conclusions **This pilot study concurs with previously published trials in showing decreased spherical aberration and improved contrast sensitivity with aspheric lenses compared to spherical lenses. There was no evidence that the patients implanted with aspheric lenses rate their quality of vision higher than those implanted with spherical lenses. Study numbers were small and larger numbers may be required to demonstrate statistical differences in subjective data.**

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Introduction

As cataract surgery has developed over the years it has become increasingly evident that the goal of 20/20 visual acuity is an oversimplification, and that in the real world we have to consider other measures of vision alongside Snellen acuity. Contrast sensitivity testing, which measures vision under a range of different lighting conditions, is becoming used more frequently to give a more complete picture of visual function. Development of wavefront technology has allowed quantification of higher order aberrations, which have the potential to affect quality of vision, and the use of this technology in refractive surgery has opened up a whole new area to consider when aiming to optimise outcome after cataract surgery.

It is known that contrast sensitivity declines with age, even in the absence of any ocular pathology. This decline has been shown to be due to changes in the aging crystalline lens altering the amount of induced spherical aberration.[1] Spherical aberration occurs when parallel rays of light passing through the peripheral part of a spherical lens are refracted

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more than those passing through the centre of the lens, bringing them to a focus closer to the lens and degrading the image.

The young phakic eye has a minimal amount of total spherical aberration as the inherent positive spherical aberration of the cornea is compensated for by negative lenticular spherical aberration. As the lens ages and its shape changes it induces more positive spherical aberration, leaving the eye with a total positive spherical aberration. Traditionally cataract removal has been followed by insertion of a spherical lens implant, again with a positive spherical aberration, leaving the eye with a similar amount of positive spherical aberration after cataract surgery as before. The recently available aspheric lens implants are designed to reduce this final total positive spherical aberration with the aim of improving quality of vision.

There are now a number of different aspheric lens implants on the market. The original design was a lens to induce a fixed negative amount of spherical aberration to leave the average eye with a final spherical aberration close to zero.[2] Other lenses have been developed along similar lines, but with a smaller amount of negative spherical aberration, to leave the average eye with a small positive amount of spherical aberration. An alternative approach is a lens with no spherical aberration leaving the positive aberration of the cornea unopposed, with the aim of increasing depth of focus.

There is mounting evidence that aspheric lenses do reduce spherical aberration and in some cases improve contrast sensitivity without any detrimental effect on visual acuity.[3–19] What is less clear is whether the patients are aware of any difference in quality of vision between the aspheric and spherical lenses. A few studies have attempted to address this question. In 2005 Caspirini *et al*[20] compared the Tecnis Z9000 and four different spherical lenses, asking patients to complete a questionnaire on the incidence of subjective photic phenomena. He noted no difference between the Tecnis Z9000 and three of the spherical lenses, although the fourth spherical lens showed a greater incidence of these phenomena. In his comparison of the Tecnis Z9000 and AR40e, Franchini[21] included a questionnaire evaluating subjective perception of haloes and glare, noting no difference between the groups. Earlier this year Denoyer *et al*[22] compared the Tecnis Z9000 and Ceeon Edge with an Activities of Daily Vision score (ADVS). There was no difference between the groups in global ADVS, but the quality of distance vision scored significantly better in the Tecnis group. A similar study by the same author reported a few months later showed that patients implanted with aspheric lenses felt they had better quality of vision, particularly near vision.[23] Other studies have not found any difference in patient satisfaction comparing aspheric and spherical lenses.[24,25] Only one published study to date has compared different types of aspheric lenses. Johansson looked at the Tecnis Z9000 and Akreos AO lenses. He reported lower spherical aberration in the Tecnis group, but better depth of focus in the AO group. Patients reported better visual quality and fewer visual disturbances with the AO lens.[26]

We were interested to know whether the claimed improvements in spherical aberration and contrast sensitivity with these lenses really do translate into a perceivable improvement in quality of vision in our patients in everyday life. We also wondered if there was any difference between the different aspheric designs and lens types in their effect on quality of vision. We designed a randomised controlled trial to look at three of the aspheric lens types comparing them to their spherical counterparts. These paired lenses were identical in both material and design with the exception of the aspheric modification. We included both objective (visual acuity, contrast sensitivity, wavefront analysis) and subjective (visual function questionnaire) outcomes. We present here the results of the pilot study.

Methods

Ethical approval was obtained from Mid and South Buckinghamshire LREC (ref 06/Q1607/2). Patients were recruited from cataract preassessment clinics, and informed consent obtained. Any person over the age of 18 able to understand English and to give informed consent was eligible for inclusion in the trial. Exclusion criteria included coexistent ocular pathology, cylinder greater than 2 dioptres, complicated surgery and wheelchair bound patients.

Patients were randomised to receive one of six different intraocular lens implants. Three of these were aspheric lens implants, and each of these was paired with the spherical lens implants that was its equivalent in material and design, with the only difference being the aspheric modification. The lens implants selected were the Tecnis Z9000, which was paired with the Cee-on Edge (AMO), the Acrysof IQ paired with the Acrysof Natural (Alcon) and the Akreos AO paired with the Akreos Adapt (Bausch and Lomb).

After recruitment, each patient underwent assessments preoperatively, and at 2 weeks and 3 months postoperatively. Randomisation to a particular lens implant was carried out on the day of surgery. All surgery was carried out by one surgeon (LB), and the two observers carrying out the pre and postoperative assessments (FC and SD) were masked as to which lens the patient had received.

Parameters measured at each of the three assessments included best corrected visual acuity under standard

photopic lighting conditions, contrast sensitivity under mesopic (6 cd/m^2) and photopic (85 cd/m^2) conditions with and without glare (CST 1800 digital with Ginsberg Box, Vision Sciences Research Corporation), pupillometry (Colvard pupillometer, Oasis), autorefraction and topography. Following dilation capsulorrhexis size was measured at the slit lamp at the postoperative assessments, and all patients had wavefront analysis carried out (Zywave, Bausch and Lomb). Wavefront analysis produced a measurement for spherical aberration at a maximally dilated pupil size, and also calculated the predicted phoropter refraction, which gives a measure of change in refraction with differing pupil sizes (corresponding to different functional light levels). A visual function questionnaire (modification of cataract TyPE[27]) was completed at each of the three assessments by all patients. Those patients undergoing second eye surgery were matched for the lens type they had received in the first eye and were asked to complete a further visual function questionnaire after second eye surgery.

Statistical analysis was carried out using GraphPad Prism 4 software. To compare the visual and questionnaire data for the lens pairs, unpaired *t*-tests (one-tailed and two-tailed respectively) were used, and to compare the three aspheric lens types with each other, a one-way ANOVA (analysis of variance) was used with post-test Tukey.

Results

Thirty-one patients (13 male and 18 female) were recruited to the trial. The mean age was 75 years with a range of 51–87 years. Twenty-eight of these were undergoing first eye cataract surgery and two second eye surgery. In terms of complications, one patient developed endophthalmitis and was removed from the trial, being replaced (after re-randomisation) by another individual. There was one anterior capsular rim tear and one posterior capsule tear without vitreous loss. For the purposes of analysis of results, each of the six lens groups contained five patients.

Looking at mean best-corrected visual acuity for each lens group, there was no significant difference seen between the pairs of lenses preoperatively or postoperatively, or in the change in acuity from the first to last visit. Similarly no difference was seen between the three aspheric lens types postoperatively.

In terms of topography and refraction, there was no significant difference seen between lens pairs in the average K value for each group preoperatively or postoperatively, or in the change in K value over the time of surgery. No difference was seen for the mean K values postoperatively between the three aspheric lens types.

With refraction there was no difference between the mean postoperative spherical equivalent between the lens pairs or the three aspheric lenses. The average deviation of spherical aberration from predicted values for all lenses was −0.35 dioptres, with no significant difference between groups.

Contrast sensitivity (CS) was measured at each of five different spatial frequencies under four lighting conditions; mesopic with and without glare, and photopic with and without glare. The mean CS values for each lens group were plotted against spatial frequency for each light condition. Means were compared for the paired lens groups and for the three aspheric lenses. The most interesting results were seen comparing the Cee-on Edge to the Tecnis lens. Under mesopic lighting conditions without glare, there was a trend towards improved contrast sensitivity at the mid-range spatial frequencies (3 and 6 cycles/degree) in the Tecnis group compared to the Cee-on Edge, but this did not reach statistical significance. Under mesopic lighting conditions with glare, however, a significant difference was noted at 6 cycles/degree, and under photopic conditions with and without glare, a significant difference was noted at both 3 and 6 cycles/degree (Figure 1). No significant differences were seen under any lighting conditions between the Acrysof Natural and the Acrysof IQ. Comparing the Akreos Adapt and Akreos AO showed a significant difference under mesopic conditions with glare, with the spherical Adapt unexpectedly performing better than the aspheric AO at 12 cycles/degree. This difference was reflected when the results for all the spherical lenses were compared to all the aspherics (Table 1). When the mean contrast sensitivity results were compared for the three different aspheric lenses, there was a trend towards the Tecnis performing better than each of the other two lenses under all lighting conditions, with significant differences at 3 cycles/degree under mesopic conditions with glare, and 6 cycles/degree under photopic conditions with and without glare (Figure 2).

The postoperative spherical aberration measured at maximal pupil diameter (after dilation) showed a trend to be reduced in all the aspheric lenses compared to their spherical counterparts. Significant differences were seen for the Tecnis *vs* the Cee-on Edge, the Acrysof IQ *vs* the Acrysof Natural and the group of all aspheric lenses *vs* all spherical lenses (Figure 3).

The values for the predicted phoropter refraction showed more stable refractions over different pupil sizes for the aspheric lenses compared to the spherical lenses. Again there were statistically significant differences for the Tecnis *vs* Cee-on Edge, Acrysof IQ *vs* Acrysof Natural and the group of all aspheric lenses *vs* all spherical lenses (Figure 4).

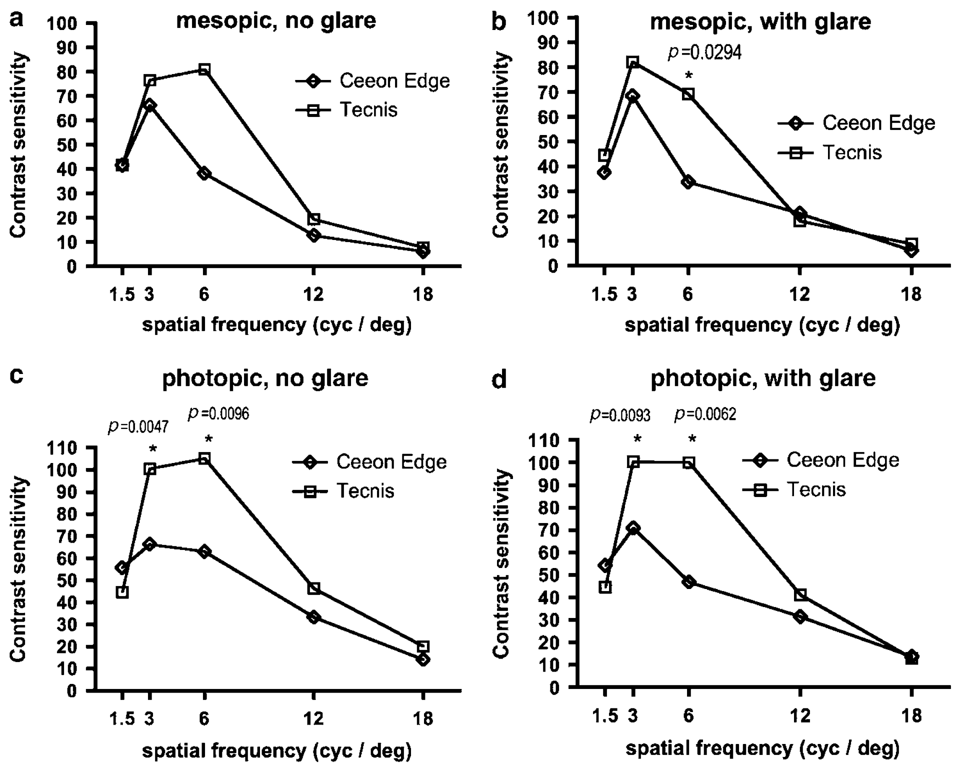

Figure 1 Contrast sensitivity results comparing the Ceeon Edge and Tecnis lens groups under a range of lighting conditions. Points marked * indicate a statistically significant difference between the groups. 1a: mesopic conditions without glare, 1b: mesopic conditions with glare, 1c: photopic conditions without glare, 1d: photopic conditions with glare.

Table 1 Summary of significant differences in contrast sensitivity between lens groups under all lighting conditions

	Tecnis vs Cee-on Edge	*Acrysof IQ vs Acrysof Natural*	*Akreos Adapt vs Akreos AO*	*All spherical vs all aspheric*
Mesopic without glare	No significant difference	No significant difference	No significant difference	No significant difference
Mesopic with glare	Tecnis better at 6 cyc/deg	No significant difference	Adapt better at 12 cyc/deg	All spherical better at 12 cyc/deg
Photopic without glare	Tecnis better at 3 and 6 cyc/deg	No significant difference	No significant difference	No significant difference
Photopic with glare	Tecnis better at 3 and 6 cyc/deg	No significant difference	No significant difference	No significant difference

cyc/deg = cycles per degree.

In looking at the results for the questionnaire, scores for each question were looked at separately, with each lens being compared to its spherical counterpart, all aspheric lenses to all spherical lenses, and each of the three aspheric lenses with each other. For Tecnis *vs* Cee-on Edge, Acrysof IQ *vs* Acrysof Natural and all aspherics *vs* all spherical lenses, no statistically significant differences were seen between each of the pairs of groups. Comparing the Akreos AO to the Akreos Adapt, the patients rated their vision with the spherical Adapt better than the aspheric AO for two questions: 'how would you rate your vision?' and 'how much does your vision hinder you reading price labels in shops and supermarkets?'. For the remainder of the questions no difference was seen between any of the paired lens groups. In all 13 of the 30 patients who elected to undergo second eye surgery returned completed questionnaires. Numbers in each group were too small to allow comparison of the individual lens pairs or the three aspheric lenses, but analysis could be performed comparing all spherical lenses to all aspheric lenses. No significant differences were seen in all but one question. For the question relating to daytime driving, the grouped aspheric lenses scored significantly better than the grouped spherical lenses ($P = 0.035$).

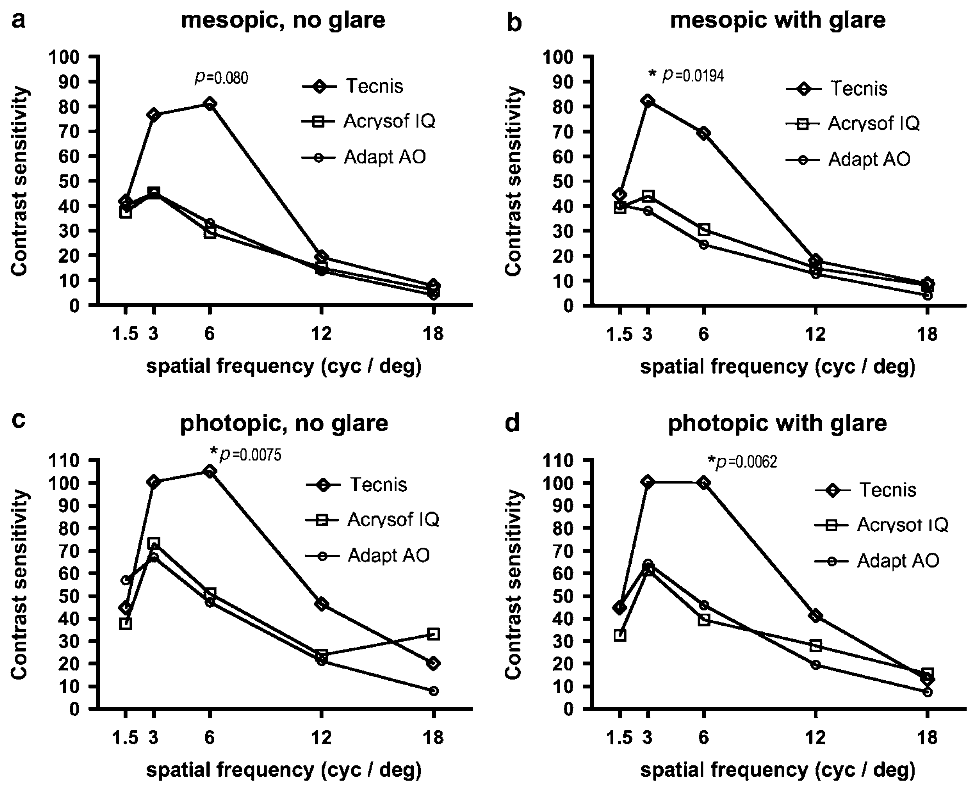

Figure 2 Comparison between contrast sensitivity results of three aspheric lenses under mesopic conditions (1a), mesopic conditions with glare (1b), photopic conditions (1c) and photopic conditions with glare (1d). Significant differences between lens groups are marked with an asterisk.

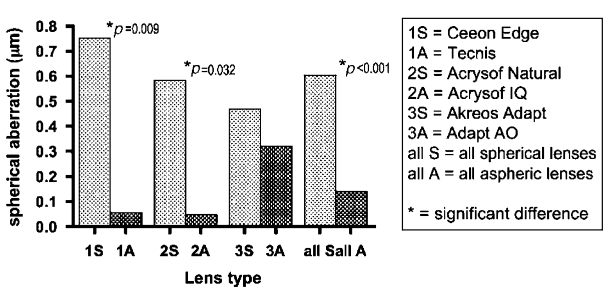

Figure 3 Comparison of postoperative spherical aberration between lens groups.

Discussion

This is a small study, intended as a pilot for a larger study, but the results that we are seeing are consistent with those of previously published studies. We expected no differences between groups in best-corrected visual acuity, topography and refraction, and this has held true.

Those previous publications that have reported improved contrast sensitivity with aspheric lenses compared to spherical lenses tend to have noted greatest significance in the low to mid spatial frequencies. Frequencies around 3–6 cycles/degree have the most relevance to day-to-day visual tasks. We found a trend for the aspheric Tecnis lens to outperform the spherical Cee-on Edge in the 3–6 cycles/degree range in all lighting conditions, with significant differences at one or both of these frequencies in three out of the four lighting conditions. No such differences were evident in the performance of the Acrysof IQ compared to the Acrysof Natural, or the Akreos AO compared to the Akreos Adapt. The finding that the Tecnis performed significantly better than the other two aspheric lenses at 3 and 6 cycles/degree would be consistent with this.

The three aspheric lenses that were chosen are each designed to induce a different amount of spherical aberration. The Tecnis and the Acrysof IQ both induce negative spherical aberration of different amounts; the Tecnis of the order of $-0.27\,\mu$m, aiming to neutralise the positive aberration of the average cornea[2], and the IQ $-0.20\,\mu$m. The Akreos AO induces no spherical aberration at all, which would leave the positive corneal aberration unopposed. There is an argument for leaving a small amount of positive spherical aberration at the end of surgery to maintain some depth of focus. Studies looking at eyes with natural super-vision and those of pilots have found an average overall positive spherical aberration of around $0.10\,\mu$m.[28,29] In laboratory tests,

Franchini reported that the Tecnis offers the best compromise between minimising spherical aberration and maintaining depth of focus.[30]

Our spherical aberration results fit with what one might expect knowing the intrinsic amounts of spherical aberration in each of the lenses. Patients receiving the Tecnis and Acrysof IQ lenses were left with the least residual spherical aberration, and the Akreos AO groups with slightly more positive aberration. Interestingly the study also showed that each of our spherical lenses induced a different amount of spherical aberration, with the Cee-on Edge coming out most positive followed by the Acrysof Natural and then the Akreos Adapt. This may have contributed to the lack of significance in the results for spherical aberration for the Akreos lenses. As contrast sensitivity is related to spherical aberration it could be argued that this may also have had an effect on the contrast sensitivity results.

The value for the predicted phoropter refraction for a particular pupil size gives the wavefront analyser's prediction for the refraction at that pupil size. We found that the change in refraction with differing pupil size varied in a similar pattern to the spherical aberration (Figures 3 and 4) suggesting that this is a function of spherical aberration. This increasing myopia in dim light can be a real problem for some patients, and is an area in which aspheric lenses may well be helpful.

One of the outcomes of the study we were most interested in was whether the patients were actually aware of any differences in the perceived quality of vision with the different lenses. The questionnaire responses revealed very little in terms of noticeable differences. The two questions that produced a significant difference between groups actually suggested that the spherical lenses outperformed the aspheric lenses. The Akreos Adapt group rated their vision better than the Akreos AO group when asked about their overall vision and how much they were hindered by their vision when reading price labels in shops. It is interesting that this lens was the spherical lens with the least positive amount of aberration. One possible explanation is that retaining a moderate amount of positive spherical aberration as opposed to a small amount is helpful, but it is difficult to commit to a conclusion such as this with small numbers. It is interesting that following second eye surgery the grouped aspheric lenses were rated better for daytime driving than the grouped spherical lenses, but ideally we would like to repeat these analyses with larger numbers.

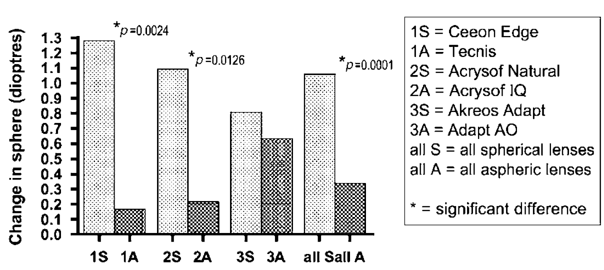

Figure 4 Predicted phoropter refraction values for each lens pair postoperatively. This value indicates the mean change in refraction over a range of pupil sizes for each lens type. An asterisk indicates a statistically significant difference between the two groups.

This study concurs with previously published comparisons that aspheric lenses do seem to reduce total spherical aberration and improve contrast sensitivity. We do not feel we yet have any convincing evidence in our patient population that the patient's visual experience with an aspheric lens is better than with a spherical lens. Our study does, however, have limitations due to its size. In light of the small numbers involved, it is perhaps not surprising that statistical significance was not reached. The study design was found to be workable, well tolerated by the patients and when scaled up would hopefully provide better statistical significance. In addition, it might be expected that customising the amount of spherical aberration correction for each patient may lead to more predictable results. The wavefront aberrometer gives a total of the higher order aberrations of the eye. By separating the lenticular from the corneal aberration it may be possible to calculate which aspheric IOL would give the 'best' residual spherical aberration for a particular eye, and hence personalise the aspheric correction for each patient. Under these circumstances better subjective visual outcome data with aspheric lenses might be expected more commonly.

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