Compared optical performances of multifocal and monofocal intraocular lenses (contrast sensitivity and dynamic visual acuity)

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The functional results (contrast sensitivity and dynamic visual acuity) of 19 multifocal (3M design) and 14 all polymethylmethacrylate biconvex monofocal intraocular lenses (IOLs), 6 mm in optical diameter were compared. Best corrected visual acuity was ≥8/10 (Monoyer chart) Parinaud 2 in all cases. Major differences of functional performance in favour of monofocal IOLs were found outside standard conditions of vision (low contrast and illumination levels). A significant difference in contrast sensitivity was found for each spatial frequency in favour of multifocal IOLs (0·0016<p<0·05). Mesopic vision was statistically higher in the monofocal IOL group (p=0·0015). Moreover, dynamic visual acuity allowed accurate evaluation of the difference in performance between these two models of implant. In view of these results multifocal IOLs should be reserved for patients with normal psychosensitive adaptation; an ocular pathology that could alter contrast sensitivity or mesopic vision is a contraindication for multifocal IOLs.

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Multifocal (diffractive) and bifocal (refractive) intraocular lenses (IOLs) are an alternative to monofocal IOLs with a presbiopic correction. The first studies in patients with these IOLs have shown greater patient comfort for near vision without additional extraocular correction. Such optical systems, however, induce aberrations. Some psychophysical tests, such as contrast sensitivity and dynamic visual acuity, make it possible to study these problems.

The aim of this study was to assess these optical aberrations by comparing the functional results (contrast sensitivity and dynamic visual acuity) of monofocal and multifocal IOLs.

Materials and methods

MATERIALS (TABLE 1)

The study was based on 33 extracapsular cataract operated eyes (manual or phacoemulsification techniques) performed by the same surgeon at the Department of Ophthalmology at the Centre Jean Abadie in Bordeaux (France). Nineteen of these eyes received a 3M type multifocal IOL and 14 had an all polymethylmethacrylate biconvex monofocal IOL, 6 mm in diameter. All were fitted within the capsular bag. The patients had no other associated ocular pathology.

Group 1 (multifocal IOLs) included 19 eyes from 14 women and four men whose mean age was 73 (range 48–86) years. The time between the operation and the psychophysical tests was 19·5 (range 9–27) months. Thirteen eyes were operated with the manual cataract extracapsular extraction technique and six with the phacoemulsification procedure.

Group 2 (monofocal IOLs) included 14 eyes from five women and five men whose mean age was 73 (range 62–83) years. The time between the surgical intervention and the tests was 19 (range 6–43) months. Ten eyes were operated with the manual cataract extracapsular extraction technique and four with the phacoemulsification technique.

No capsulotomy was performed in any patients during the follow up period.

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Methods

The postoperative functional tests included the following.

Visual acuity (VA)

We measured the best corrected distant VA (Monoyer's visual acuity chart at 5 metres). The near vision (Parinaud visual acuity chart at 33 centimetres) was measured with and without additional correction.

Contrast sensitivity (CS)

Contrast sensitivity measures the spatial and contrast power of discrimination of the visual system. The apparatus used was a videotest (BVAT II SG, Mentor, LCA). It was composed

Table 1 Clinical data of eyes in groups 1 (multifocal IOLs) and 2 (monofocal IOLs)

	Group 1 (multifocal)	*Group 2 (monofocal)*
Number of eyes	19	14
Sex (F/M)	14/4	5/5
Age (years)		
Mean	73	73
Range	(48–86)	(62–83)
Time between operation and tests (months)		
Mean	19·5	19
Range	(9–27)	(6–43)
Surgical techniques		
Manual CEE	13	10
Phaco	6	4
Power of the lens (dioptre)	18 to 21·5	14 to 22·5
Postoperative astigmatism (dioptre)		
Mean	1·2	1·2
Range	(0–3)	(0·25–3)

CEE=cataract extracapsular extraction
Phaco=phacoemulsification

of a graphic processor generating a sinusoidal pattern on a screen. The monitor, measuring 26×26 centimetres representing a visual angle of 4·25°, was placed 3·5 metres away from the patient. The contrast thresholds were recorded by the forced choice method. The patient indicated the pattern orientation, thus validating his answer.

The contrast was diminished progressively until the perception threshold was reached. Five spatial frequencies were tested – 1·5, 3, 6, 12, 20 cycles per degree. The mean luminance of the screen was kept unchanged at 85 cd/m².

The results were plotted on comparative curves.

Dynamic visual acuity (DVA)[2]

DVA measures visual acuity at different levels of brightness, taking into consideration the time needed for test perception. The luminance level ranged from superior scotopic (5·8 logarithmic unit picostilb (LU psb)) to inferior photopic (8·1 LU psb), so covering the whole mesopic zone where the early photopic deficits were recorded. Measurements were recorded with a modified Goldmann Weeckers adaptometer to which a 25 dioptre negative lens was added, thereby reproducing visual acuities at different levels of luminance. After a 3 minute dark adaptation period, the patient was then preadapted for 5 minutes at 8·5 LU psb. Using a correction for near vision, he was asked to read the tests corresponding to different degrees of visual acuity with a progressively increasing luminance level ranging from 5·8 to 8·1 LU psb.

The results were recorded as follows:

- visual acuity (Monoyer's visual acuity chart) as a function of luminance level.
- index I=E×D×A
  - E = illumination level (LU psb=logarithmic unit picostilb; 10^8 picostilb= 1 cd/m²).
  - D = response delay (in centimal minutes).
  - A = angular visual acuity (in centimal minutes of visual acuity angle).
- curves
- for statistical data analysis, the Fisher probability test was used. This test is suitable for small populations (significant if p≤0·05).

Table 2 Comparative functional results of multifocal and monofocal IOLs

	Group 1 (multifocal)	*Group 2 (monofocal)*
Best corrected visual acuity	Distant 0·8 to 1·2 near: without addition P1·5 1 case P2 10 cases P3 5 cases P4 2 cases	Distant 0·8 to 1·2 near: with addition +3 or +3·50 P1·5 4 cases P2 10 cases
P2 with addition (−050±1·25) 7 cases		
Dynamic visual acuity		
Photopic visual acuity		
Mean	1	1
Range	(0·5–1·2)	(0·8–1)
Mesopic visual acuity		
Mean	0·3	0·5
Range	(0·2–0·6)	(0·2–0·8)
Index		
Mean	200·7	89·75
Range	(140·48–280)	(39–200·8)

Table 3 Contrast sensitivity: contrast threshold (SD) at different spatial frequencies

Spatial frequency (cycles/degree)	*Contrast threshold (CT1) group 1*	*Contrast threshold (CT2) group 2*	*Ratio CT2/CT1 (%)*
1·5	3·1 (1·6–6·3)	2·4 (1–4)	77
3	2·2 (1–4)	1·3 (0·63–1·6)	60
6	2·7 (0·63–10)	1 (0·63–1·6)	37
12	6·8 (1·6–20)	3·1 (1–6·3)	45
20	26·2 (6·3–63)	9·5 (2·5–20)	36

Results

No significant difference was noted between the two age groups, the time period between the surgical procedure and examination, the mean astigmatism, and the surgical technique (Table 2).

VISUAL ACUITY

All selected patients had a best corrected visual acuity ≥8/10 Parinaud 2.

No significant difference was found for distant visual acuity between the two groups (p=0·12). For near vision, a significant difference in favour of monofocal IOLs was noted (p=0·001) when monofocal IOLs with near vision correction and multifocal IOLs without near vision correction were compared. No significant difference was noted between the two groups with near vision correction.

In seven cases, a correction ranging from +0·50 to +1·25 dioptres was needed to improve near vision in group 1 (multifocal).

CONTRAST SENSITIVITY

A statistical comparison between the two groups was made for each spatial frequency (SF) (Table 3). For each SF, a significant difference was noted:

SF: 1·5 cycles/degree p=0·05; 3 cycles/degree p=0·001; 6 cycles/degree p=0·001; 12 cycles/degree p=0·002; 20 cycles/degree p=0·0016.

The difference was progressively more significant for 1·5, 12, 20, 3, and 6 cycles/degree, respectively. This may be seen on the comparative curves of contrast sensitivity (Fig 1).

DYNAMIC VISUAL ACUITY

No significant difference was noted in photopic visual acuity (>8·1 LU psb) between the two groups. On the other hand, a significant difference was found for mesopic visual acuity (>5·8 – <8 LU, psb) between both groups (p=0·0015).

The index (I=E×D×A) study showed a highly significant difference between both groups ($p<10^{-6}$). The mean index I is 37 for young people and 54 at 45 years. It was 200·7 in the multifocal group and 89·75 in the monofocal group (Table 2).

Discussion

For seven of the 19 eyes with multifocal IOLs, an additional correction was needed to reach a near visual acuity ≥Parinaud 2. This indicates that a partial loss of multifocal property was found in a high percentage (36·8%). Moreover, the multi-

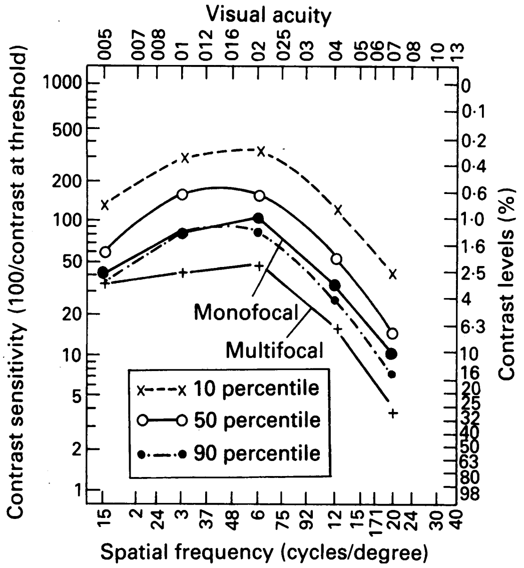

Figure 1 Comparative curves of monofocal and multifocal intraocular lenses. The zone between the 10 percentile curve and the 90 percentile curve indicates the range for a normal population. The 10 percentile, 50 percentile, and the 90 percentile curves represent the contrast sensitivity values for the 10 percentile, 50 percentile, and 90 percentile of a normal population, respectively.

focal property was associated with a low contrast sensitivity.

The results of this study show the limitation of multifocal IOLs outside the standard condition of vision and confirm the concept of 'visual noise' mentioned by Nordmann.[3] Olsen and Corydon's study[4] (13 eyes) and the European multicentric study (EMS) (56 eyes) did not find any difference in contrast sensitivity levels between the two types of IOLs.[5]

On the contrary, Nowack[6] using the Ocutrast technique reported a significant loss of contrast sensitivity in the multifocal group compared with a monofocal group.

Bonnet *et al*,[7] using the Pelli-Robson[8] and the Regan[9] tests, also found a significant difference.

Concerning DVA, to our knowledge no study with multifocal IOLs has been performed. On the other hand, our results confirm those of Bonnet *et al*[7] who showed a change for distant and near visual acuity, as well as a lower contrast sensitivity with multifocal IOLs under low luminance.

DVA with index I measures visual performance under low illumination. As was stated earlier, this index depends on the adaptation time. The index was significantly higher in the multifocal IOLs group indicating that the adaptation time in dim luminance was superior and the visual performances under low luminance were lower in the multifocal group.

In other words, a person with a multifocal IOL would take longer to detect an object in a dim room, or would not detect it at all if a weak contrast existed between the object and the background.

HOW CAN THE DIFFERENCES IN PERFORMANCE BETWEEN MONOFOCAL AND MULTIFOCAL IOLS BE EXPLAINED?

The incident light crossing a multifocal IOL is divided into two beams, and only one of them is projected on to the retina. For diffractive IOLs, the division of light does not depend on pupil size, but 18% of the incident light is diffused away and is not focused on any focal plane.[10]

Multifocal IOLs are very sensitive to variations in astigmatism and once the stabilisation of this factor occurs, there is a retinocortical adaptive benefit in low contrast sensitivity.[11]

The decentration of the IOL plays a role in functional results and an 'in the bag' implantation is necessary.[12]

To benefit from the multifocal property, perfect biometric measurements are advisable, given that the slightest error during this procedure will alter the functional outcome.

Conclusion

Our comparison of multifocal/monofocal IOLs confirms the results of the most important studies for contrast sensitivity, particularly the clinical evaluation by the Food and Drug Administration of the 3M diffractive multifocal IOL in 671 patients with 1 year follow up.[13] For dynamic visual acuity, index I gave a numbered value of the deterioration of visual function under low illumination, and confirmed the clinical impression published elsewhere. These data must be considered when selecting patients; multifocal IOLs should be reserved for patients with normal psychosensitive adaptation, particularly in the elderly. Moreover, the FDA requires the makers of multifocal IOLs to provide information on the following[14]:
static and dynamic acuity
perception of angular movement
movement in depth
visual field
fixation
glare sensitivity
colour vision
contrast sensitivity
adaptation
scotopic/mesopic vision

Finally, the presence of an ocular pathology (macular or other) that could alter contrast sensitivity or vision under low illumination, is a contraindication for multifocal IOLs.

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