The great accommodation debate

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The mechanism of accommodation and its relevance to presbyopia has been debated since Victorian times, and the arguments are still surprisingly vehement. Are new data bringing us any closer to a resolution?

Sir Arthur Conan Doyle, author of the Sherlock Holmes books, also wrote a book called *The Lost World*, dominated by a brilliant and insufferably arrogant scientist, Prof Challenger. After an expedition to the lost world – a remote and inaccessible plateau in South America, where dinosaurs still roam – Challenger returns to London to present his findings to a public meeting of the Royal Society. A ferocious argument erupts, which is only resolved when the professor lets loose a pterodactyl, which flaps slowly around the Natural History Museum, before escaping through a window.

Science doesn't usually arouse such high passions these days, though we still rely on data – if a pterodactyl can be regarded as a datum – to support any conclusions. *The Lost World* was written in 1912, more than half a century after Helmholtz started another long-running and at times equally acrimonious debate, now 150 years old, on the mechanism of accommodation. Despite the release of a whole pack of pterodactyls, or at least data, the debate still retains a Victorian sense of melodrama and personality, and indeed some protagonists do occasionally come alarmingly close to blows.

In essence, Helmholtz argued that constriction of the ciliary muscle releases the tension on the zonules, leading to a relaxation and rounding of the lens, so increasing its power. Some 40 years later, Tscherning argued more or less the opposite: that ciliary-muscle contraction increases the tension on the zonules, thereby altering the shape of the lens without changing its thickness. Another prominent theory, originally postulated by Mueller around 1854, and given modern form by Coleman, is that accommodation is achieved through anterior movement of the lens, under pressure from the vitreous. But it was the resurrection of Tscherning's conception by Schachar in the 1990s that re-injected the sense of Victorian melodrama into the debate.

"People get very resolute in their beliefs," Dr Spencer Thornton MD, University of Tennessee Health Science Center, Memphis, told *EuroTimes*. "There's been a big resistance to anything beyond Helmholtz. I don't doubt that increased lens sphericity contributes to accommodation, but in my view there are at least six mechanisms that all contribute partially including anterior lens movement, the belt action of the iris, and indeed gestalt, the brain's ability to interpret."

The flip side of the coin is presbyopia. The Helmholtzian view posits sclerosis of the lens, by which he is usually taken to have meant a loss of elasticity, preventing the rounding necessary for accommodation. The hypothesis doesn't predict changes in the zonules, the ciliary muscle, lens movement, vitreous phase or lens growth, all of which are modified to some extent as we age, though not necessarily at the same rate as the progression of presbyopia.

In contrast, a gradual loss of tension on the zonules with age is central to the Schachar theory of presbyopia. Continuous lens equatorial growth throughout life is posited to lower zonular tension, thereby rendering the zonules unable to pull the lens into the correct shape to accommodate. To its great credit, the theory makes a number of testable predictions, many of which are the polar opposites of the Helmholtzian view.

In particular, the equatorial diameter of the lens should increase with age, lowering zonular tension. Anything that can restore zonular tension, such as scleral expansion/spacing, should in principle restore accommodation (assuming that the lens has not become too sclerotic in the interim). In contrast, if presbyopia is caused by hardening alone there is no reason whatsoever why scleral spacing should work. If it does work, then Helmholtz must have been wrong about the cause of presbyopia, and by extension, about the mechanism of accommodation too.

Scleral spacing and the mechanism of accommodation

The latest round of results of the scleral spacing procedure were presented in Barcelona, this November, at the first congress of the International Presbyopia Society by Barrie Soloway MD, of the New York Eye and Ear infirmary.

"The fact is it works," Dr Soloway told *EuroTimes* "though frankly I've given up worrying about exactly how. It could be supporting the Schachar theory, but it's also compatible with the Coleman theory of anterior lens movement," he said.

In October, the FDA phase III trial had recruited a total of 135 patients and 32 controls. In the treatment group, visual acuity had improved from 20/63 or worse at entry to 20/50 or better in 87 per cent of patients; 20/40 or better in 76 per cent of patients; 20/30 or better in 46 per cent of patients; and to 20/25 or better in 18 per cent of patients.

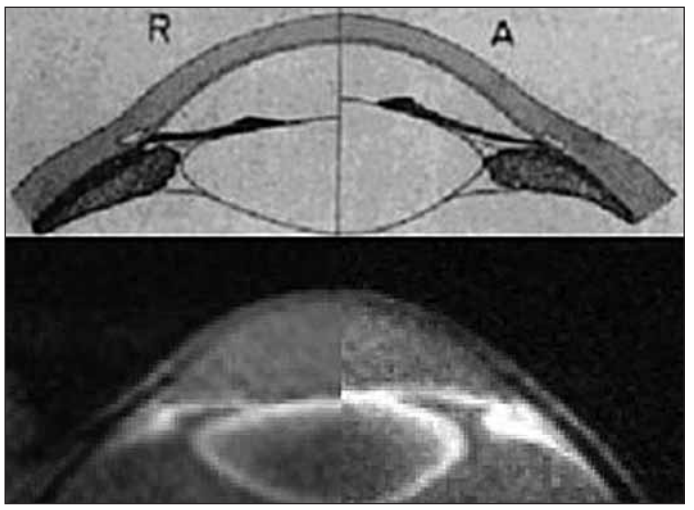
These results were achieved without any loss of distance acuity, over a minimum six-month period. Follow-up is planned for two years. The difference with the control group (in whom VA remained unchanged) was statistically significant, and Dr Soloway is quick to point out that measures of near vision like the Landolt C test at 40cm are objective endpoints: "Either you can see where the square is missing from the circle, or you can't," he said.

There have been relatively few complications compared with earlier prototype scleral spacing implants, and in particular almost no cases of anterior segment ischemia, conjunctival erosion, irritation or inflammation.

Despite improvements in the implants, the most common complication was still subluxation; Dr Soloway noted a total of eight cases. In a sense, however, subluxation provided a proof of concept: "Visual acuity deteriorated during subluxation, in some cases to 20/80 or worse, and was restored to 20/40 or better when we corrected the subluxation."

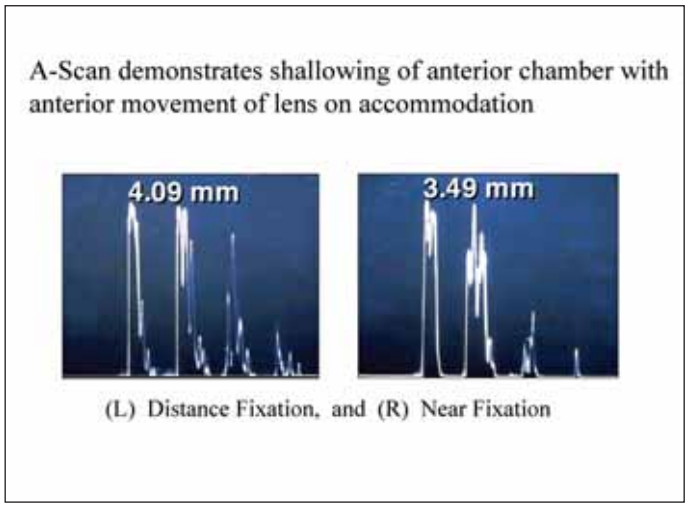
Dr Thornton sees the results as vindication for his own technique of ciliary sclerotomy, which he argues is safer and more effective, utilising as it does four radial incisions to the ciliary body, rather than the transverse incisions of scleral spacing; but in both cases the intention is to expand the globe, increasing the space and freedom of movement in the anterior segment – freeing the lens from 'crowding', as Dr Thornton puts it.

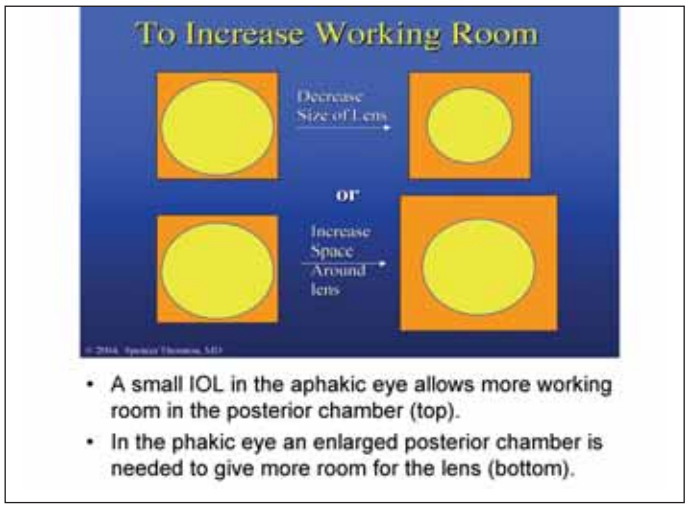
The clinical trial of ciliary sclerotomy will start recruiting patients in early 2007.



Courtesy of Lawrence Strenk PhD

Composite image of relaxed accommodation and accommodation compared to Helmholtz's classic drawing





Courtesy of Spencer Thornton MD

But the positive scleral spacing results have not gone unchallenged. While not disputing the measured benefits to near vision, Prof Jane Koretz, PhD, at the Rensselaer Polytechnic Institute, Troy, New York, contests their relevance to accommodation.

"The real difficulty is that measuring visual acuity does not give an indication of whether accommodation is occurring. There might be some advantages of the technique, but these could just as easily be artefacts caused by alterations to the cornea," she told *EuroTimes*.

Adrian Glasser, PhD, at the University of Houston, is equally sceptical.

"I'm afraid I just don't accept that this study has demonstrated accommodation, only perhaps at best multifocality, or changes in the depth of field of the eye," Dr Glasser told *EuroTimes*.

A number of patients treated with scleral spacing have been referred to Dr Glasser, Dr Steven Mathews, PhD, Texas Tech University, Lubbock, and Prof Jay Pepose MD, PhD, of the Pepose Vision Institute, St Louis, Missouri, to measure accommodation directly using either a dynamic infrared optometer or an objective Hartinger and a Grand-Seiko refractometer (which the phase III trial did not do).

Dr Glasser is plain: "There hasn't been any evidence of improved accommodation in any case out of the 10 patients that have been measured directly, objectively, so far."

While all applaud any technique that brings about direct benefits to visual acuity, at present it is only fair to conclude that scleral spacing procedures have not yet proved anything one way or the other about the mechanism of either accommodation or presbyopia.

Hiding behind the iris

Such controversies over measurement have bedevilled the whole field for a long time.

"Much of the disagreement stems from the difficulties in seeing the ciliary body and zonules behind the iris," Prof Koretz told *EuroTimes*. But there have been a handful of cases of aniridia and albinism, where the whole lens can be observed with retroillumination. "These have always supported the Helmholtz mechanism," she said.

Probably the most compelling findings have come from high-resolution MRI imaging, in work done by Dr Susan Strenk, PhD and Dr Lawrence Strenk, PhD, at the University of Medicine and Dentistry, New Jersey, Piscataway, in collaboration with Prof Koretz.

The studies show unequivocally that the lens rounds during accommodation, the equatorial diameter decreasing by about seven per cent. This finding is not compatible with the Schachar model, which posits an increase in the equatorial diameter during accommodation, under greater tension from the zonules.

Dr Glasser's group have reported very similar findings in rhesus monkeys to the MRI studies. Other researchers report similar findings in patients with aniridia (Fincham, 1937). They too report a decrease in the equatorial diameter of about six to seven per cent.

"Not a single study has ever shown an increase in equatorial diameter with accommodation; the concept is pure conjecture," Dr Glasser told *EuroTimes*.

The changes to the lens that lead to presbyopia are more equivocal, however, and resonate with Dr Thornton's long-standing argument that crowding in the anterior segment plays a critical role in presbyopia.

The high-resolution MRI images leave little doubt that the lens continues to grow with age. Better evidence for continued growth of the lens comes from measurements of the wet weight of lenses extracted from human eye bank eyes, which has been reported in many studies. Interestingly, at least in the case of humans, only the anterior portion continues to grow; the equatorial diameter of the lens remains remarkably constant with age, as does the position of the posterior surface (this is not true of rhesus monkeys, whose lens grows in both anterior and posterior portions, fixing the lens in a posterior position).

The anterior growth of the human lens causes an increase in sphericity with age, which drags the ciliary body forwards, restricting the possibility of further anterior movement. A recent high-resolution MRI-imaging study by Dr Strenk's group (J Cataract Refractive Surgery 32: 1792-98; November 2006) shows that, although the lens equatorial diameter does not change with age, the diameter of the ciliary muscle ring certainly does decrease, which might lower zonular tension "ultimately to zero in the non-accommodated state."

"It is far more likely that the ciliary muscle ring is being pulled inward by the zonules. As the lens grows, and its axial thickness increases, this would tend to pull inward on the zonular fibres. In fact, there is substantial evidence that the lens does not become loose with increasing age. A loose lens would result in microfluctuations in the refraction of the eye in older individuals. There is a substantial body of literature on the so-called 'microfluctuations of accommodation' indicating that these are absent in older individuals and that the presbyopic lens is not loose," Dr Glasser noted.

Some have suggested that intracapsular IOL implantation enables the ciliary muscle to revert to a more youthful posterior position. But it is not the IOL implantation per se that accomplishes this, but rather the emptying of the capsular bag of the phakic lens. This in fact suggests that it is the phakic lens and zonular fibres that are pulling the ciliary body inward. After cataract surgery, once the capsule is empty and the capsular bag is flaccid, this allows the release of zonular tension so the ciliary body reverts to its more youthful position, he explained.

This reversion in ciliary muscle position may facilitate anterior IOL movement documented using real-time A-scan ultrasonography by Dr Thornton and others – the basis of the Eyeonics Crystalens IOL.

In this regard, Dr Strenk cautions: "Lens softening or refilling strategies that don't reduce lens volume or equatorial diameter will not increase circumlental space or restore zonular tension, without which an accommodative lens response is unlikely regardless of the amount of ciliary muscle contraction."

Whether ciliary sclerotomy also increases the diameter of the ciliary muscle ring, restoring zonular tension, and to some degree anterior lens movement, has not yet been examined or proved.

The greater sphericity of the lens with age raises a paradox, known as Brown's Paradox, after Dr Nicholas Brown, MD, Oxford Eye Hospital, UK, who resurrected the use of Scheimpflug photography for studying accommodation and presbyopia in the early 1970s. Using this technique, Dr Brown documented an increase in lens sphericity with age as long ago as 1972.

Greater lens sphericity, in which the disaccommodated state gradually edges towards the accommodated state with age, should obviously lead to myopia rather than presbyopia. The fact is that it doesn't mean there must be compensatory changes in the refractive index of the lens itself; and such changes have indeed been measured, according to Prof Koretz.

"There is an issue of cause-and-effect that has not yet been resolved," Prof Koretz told *EuroTimes*. "I suspect that the changes in refractive index are secondary to changes in lens growth and sphericity, in other words it's basically atrophy; but that's by no means proved."

All in all, new data, especially high-resolution MRI imaging, seem to confirm the Helmholtz mechanism of accommodation, but there is still plenty of ambivalence about the mechanism of presbyopia. That the lens becomes more spherical with age is beyond doubt; but the role of crowding, zonular tension, anterior IOL movement and the cause of refractive index changes still offer rich veins of enquiry.

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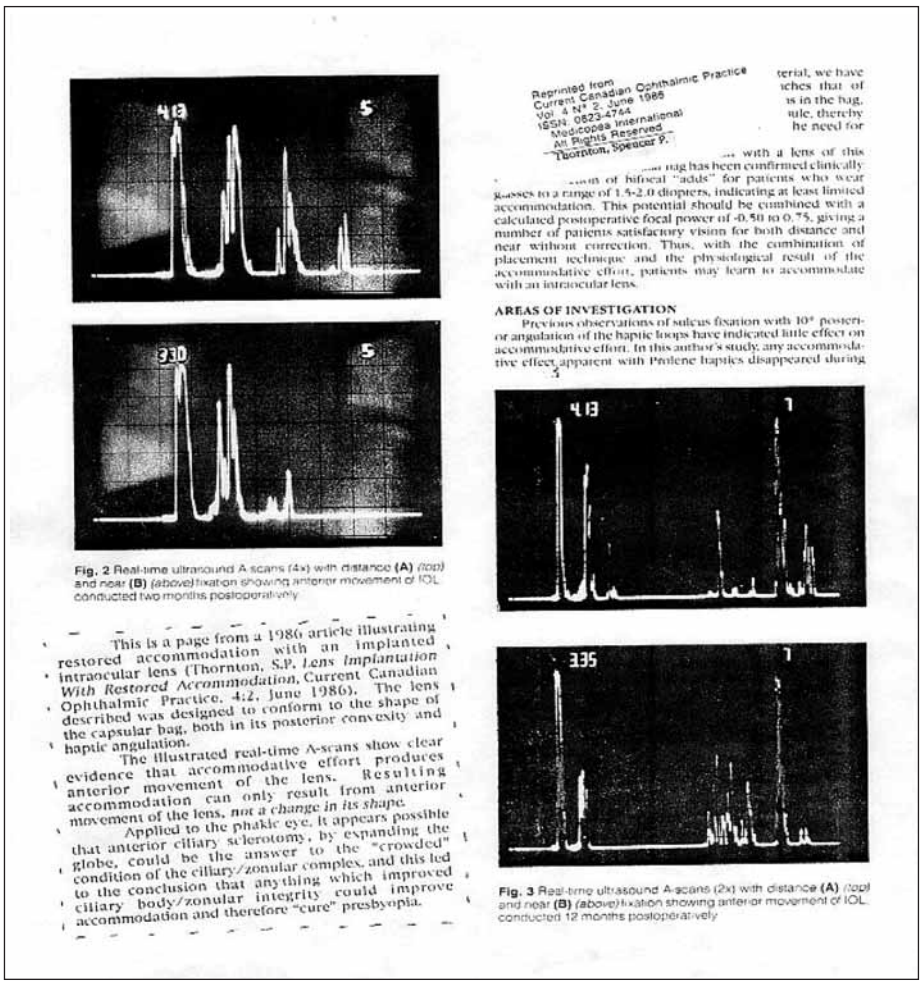

Fig. 2 Real-time ultrasound A-scans (4x) with distance **(A)** *(top)* and near **(B)** *(above)* fixation showing anterior movement of IOL conducted two months postoperatively

This is a page from a 1986 article illustrating restored accommodation with an implanted intraocular lens (Thornton, S.P. *Lens Implantation With Restored Accommodation*, Current Canadian Ophthalmic Practice, 4:2, June 1986). The lens described was designed to conform to the shape of the capsular bag, both in its posterior convexity and haptic angulation.

The illustrated real-time A-scans show clear evidence that accommodative effort produces anterior movement of the lens. Resulting accommodation can only result from anterior movement of the lens, *not a change in its shape*.

Applied to the phakic eye, it appears possible that anterior ciliary sclerotomy, by expanding the globe, could be the answer to the "crowded" condition of the ciliary/zonular complex, and this led to the conclusion that anything which improved ciliary body/zonular integrity could improve accommodation and therefore "cure" presbyopia.

Fig. 3 Real-time ultrasound A-scans (2x) with distance **(A)** *(top)* and near **(B)** *(above)* fixation showing anterior movement of IOL conducted 12 months postoperatively