A SUPPLEMENT TO

Optician

pull-out supplement

optical milestones of the past millennium the virtual consulting room in search of the ultimate contact lens developments in spectacle lenses the future of laser surgery the frame market of 2020

Vision 2020

Optical milestones
of the past millennium

Spectacles have effectively doubled the working lives of all who read or do close work. **Ronald MacGregor** traces the history of one of the most important inventions of the past 1,000 years

AD 1025: Alhazen was an Arab who wrote the first scientific treatise on optics. He explained the mathematics of optics, light rays and binocular vision. His work was the standard reference for 500 years.
1268: Roger Bacon's treatise *Opus Majus* included the suggestion that convex lenses could be used to obtain magnification or to aid the vision of old people.
1287: Spectacles were invented. The name of the inventor is unknown but he was referred to in a sermon by Giordano da Rivalto less than 20 years later.
1352: The first known visual record of spectacles was painted. It is a fresco by Tommaso da Modena in the Church of the San Nicolo at Treviso in Italy. It shows Cardinal Ugo di Provence using rivet spectacles.
c1480: Nuremberg in Germany became a centre of spectacle making. The craftsmen were later organised under the guild system.
1593: J B Porta's book *Refractione* included the information that lenses of bi-convex, bi-concave, plano-convex and plano-concave forms were available in Venice at that time.
1604: The astronomer Kepler explained the action of spectacle lenses in placing the image exactly on the retina. A few years later he published rules for obtaining the focal lengths of lenses. He also suggested the meniscus form.
1609: J & H Lippershey of Holland are credited with the invention of the telescope which was very quickly taken up and developed by Galileo. It has been claimed that Galileo also adapted the telescope to function as a compound microscope.
1621: Snell worked out the law of refraction. It was expressed in terms of trigonometry by Descartes.
1629: The Worshipful Company of Spectaclemakers received its Charter from King Charles I of England.
1666: Sir Isaac Newton demonstrated the composition of white light using prisms of glass. His book *Opticks* published in 1704 is an all-time classic.
1727: Four hundred years after the invention of spectacles, spectacle-sides (temples) were invented. They were advertised by the optician Edward Scarlett of London.
1758: Achromatic lenses were patented by John Dollond.
1783: The first English patent for spectacles was granted to Addison Smith. It is for spectacles with a top-hinged double front.
1784: Benjamin Franklin invented bifocals but did not bother to patent them.
1801: Thomas Young discovered corneal astigmatism and measured his own.
1810: Tri-focals were suggested by Sir David Brewster, the inventor of the lenticular stereoscope.
1850: The ophthalmoscope was invented by Helmholtz.
1864: The classic work *Refraction and Accommodation* was published by Donders.
Late 19th century: This period saw the invention and introduction of an abundance of new optical apparatus and techniques. Synthetic materials became available for frames. We should mention the keratometer (1855), the perimeter (1857), Snellen's test types (1862), the tonometer (1862), Jaeger's test types (1867), the retinoscope (1871), glass contact lenses (1880), anaesthetic eye-drops (1884), Bjerrum screen (1889), crossed-cylinder test (1894), electric instruments (1898).
20th century: The inventions and discoveries of the 20th century are so numerous that it is difficult to assess their relative importance. Some of those affecting practitioners are the slit lamp (1911), the refractor head (1915), best-form lenses, Crookes' tints, plastics for lenses, lenticulars without cement, Executive bifocals, varifocals, vacuum coatings, aspheric lenses, photochromic lenses, hard coatings, all kinds of non-vitreous contact lenses, non-contact tonometer, television low-vision aids and retinal imaging. We could mention cataract implants, laser surgery and applications of fibre-optics but this takes us into the realm of ophthalmology and that is another story.

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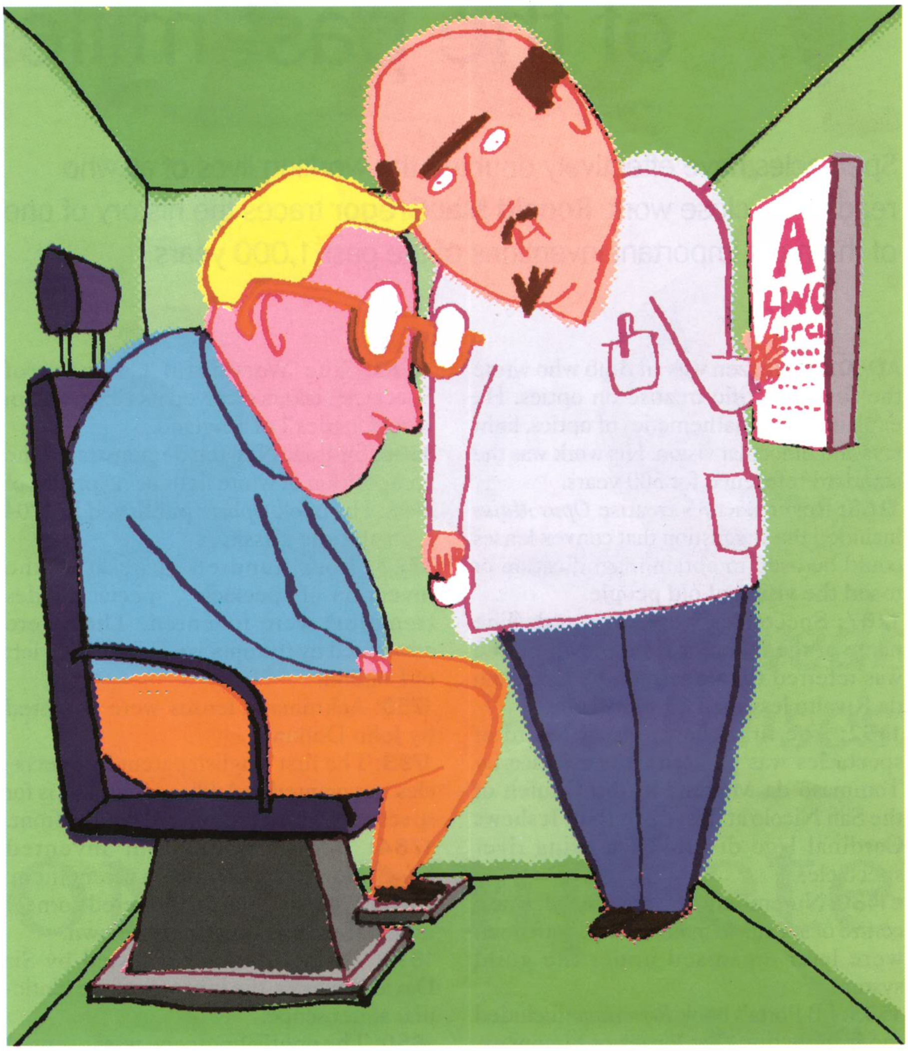
The consulting
of the future



With space at a premium in the practice of the future, manufacturers will be concentrating on hand-held instuments and computer advances such as voice recognition. **Anita Lightstone** switches on

The development of the optometrist's consulting room is largely controlled by two factors: advances in development of the profession; and advances in technology. For example, 30 years ago non-contact tonometry was unknown and visual fields were investigated by use of the Bjerrum screen. Even 15 years ago, the automated visual field screener was still in its infancy and instruments for measuring ocular blood flow and corneal topography were just a twinkle in the researcher's eye. As these technologies advanced, so it became feasible for optometrists to become part of shared-care schemes. Many of the developments that take place in the consulting room will be led by changes in the role of optometrists and also by commercial pressures.

It is likely that one of the increasing commercial pressures on optometrists will be the cost of accommodation. This will be important to practices in urban areas. Consequently, it is probable that the size of the consulting room will decrease. Because of this, manufacturers will be encouraged to reduce equipment size.

Already test-charts are appearing for use at less than three metres, although the validity of these charts, owing to the effect of proximal convergence, has been questioned. By 2020, the length of the consulting room is likely to be further reduced and visual acuity charts may be displayed to the patient by virtual reality headsets. In addition, measuring vision by asking patients to read letters is likely to be regarded as less than optimal and the objective measurement using visually evoked potentials (VEPs) will become the accepted method of practice.

VIRTUAL REALITY

Virtual reality headsets may also be adapted to allow refraction to be carried out without the use of phoropter (refractor) heads or trial lenses. The microchip inside the computer could be programmed to measure alterations in focusing to give optimum VEP results. Consequently, the optometrist would position the headset on the patient and within seconds the refractive process would have been completed. The same headset could also be programmed to measure other visual functions such as binocular vision, colour vision and visual fields. By 2020, it is possible that the patient's response to stimuli during a visual field examination will be assessed by measuring VEP response.

The age of the average patient will increase as more people live longer. Because of this, the detection of disease will have an increasing priority, particularly for glaucoma and age-related macular degeneration. Methods for measuring intraocular pressure are likely to increase in accuracy as non-contact tonometers use more sensitive measuring devices and improved software. It is probable that more tonometers will become hand-held, making intraocular pressure easier to measure without repositioning the patient and reducing the amount of space required in the consulting room to house the instrument. The hand-held instruments

room

are likely to include ones that can also measure the ocular blood flow, which by 2020 may be regarded as more important than intraocular pressure. In addition, new instruments are likely to be introduced to investigate the nerve fibre layer directly, which is claimed by some to be the ultimate method of detecting glaucoma. Again, these instruments will have to be small and compact.

It is likely that there will be continued development of the use of lasers for investigative techniques. Already lasers are being used to assess the nerve fibre layer of the retina, although the cost of these instruments means that they are only used in hospitals at present. However, the increase in the proportion of the population that is elderly, will produce an incentive for these techniques to be available at primary-care level. For this to happen, not only will the equipment have to be small and reasonably priced, there will also have to be improved methods of payment for shared patient management by the NHS.

Earlier detection of macular degeneration requires improved methods of ophthalmoscopy. These methods will also possibly make more use of laser light sources as this may enable a finer view, with the image details penetrating to the deeper layers of the retina. By using a computer to analyse the images and compare the images to normal fundi, earlier detection should be possible. This instrument gives images that are equivalent to superimposed images of the neural layers of the retinal and the deeper pigment epithelial layer and the choroid. By viewing these layers separately, it should be possible to gain more information.

A likely scenario is that by 2020, today's ophthalmoscopes will be out of date. They will have been replaced by digital imaging, which, using computer systems, will give stereoscopic views of the fundus that extend to the periphery, as well as giving intimate detail of the posterior pole. The new generations of fundus cameras are likely to use lower levels of illumination, possibly with more of them relying on lasers. This will reduce the need for more invasive techniques such as mydriasis and scleral indentation. It is likely that this latter technique, not yet fully accepted by the profession, will become obsolete before ever becoming popular. If the use of artificial intelligence is incorporated into the computer system, predictions of the health of the fundus could be calculated by the computer, leaving the optometrist to carry out a final interpretation, in a similar manner to the way visual fields are investigated today. The need for permanent record of the ophthalmoscopy findings will increase, as the public becomes more litigation minded. Notes and fundus drawings will no longer be regarded as adequate recording of fundus investigation and practitioners will need to record their findings by imaging. However, the instruments to carry this out will need to become very compact, if not hand held, to minimise the space needed for them in the consulting room.

IMAGING THE INTERIOR

It is also possible that by 2020, prototypes of ophthalmoscopes that produce virtual-reality images of the interior of the eye will enable the practitioner to feel as if he or she is entering into the eye. The computer could then be used to home in on any suspect areas and perhaps to project a cross-section of the area, so giving a deeper view, even to the nervous pathways and so showing any nerve damage. This approach to fundus examination is also likely to be expanded and developed into the examination of the anterior segment, with the use of digital video cameras to feed the information to a computer. Again, the use of virtual reality to project an image of the inside of the anterior chamber, allowing the optometrist to inspect the anterior chamber angle and other features easily.

It is hard to imagine changes to the current slit lamp, but by 2020, it is possible that the present design may have become just a small hand-held ball that is held in front of the eye and programmed to take a selection of images. These images could include not only various views of the anterior chamber and the cornea, but also the structure of the tear-film layer, as desired by the practitioner. It is also possible that, with the use of laser, the investigation of the anterior chamber angle without the use gonioscopy lenses may be feasible, again with results being digitally recorded and advice being supplied by the computer as to whether the chamber angle is narrow. However, this would probably be regarded as inferior to the use of virtual reality.

Generally, the computer will have a much higher profile in the consulting room than it does today. With advances in voice recognition technology, it is likely that examination results, when these are not automatically entered into the computer from another instrument, will be entered by the optometrist speaking to the computer. The instruments within the consulting rooms are all likely to be computer controlled and by 2020, it should have become mandatory that the information produced from these instruments will be in compatible format, so that computers from different systems will be able to talk to each other. All information will be fed back to a central computer that will then reach a provisional recommended. diagnosis and treatment for each patient. The role of the optometrist will be to review the patient's symptoms, signs and history and so conclude appropriateness of treatment. The optometrist will then follow or override the advice as necessary. It is possible that the hospital eye service or the College of Optometrists will provide for the optometrist an on-line facility for advice and assistance in diagnosis, if required.

Email is likely to be the standard form of communication not only to other professionals, but also directly to patients. With the increasing rights of patients to see their records it is probable that all referral letters and reports will be copied to the patient. In many cases, the patient will not need to visit the consultant, but images will be transmitted and the consultant will then decide whether the patient should be seen.

The use of three-dimensional, virtual-reality images could eventually replace the need for patients to attend the consultant for diagnosis; visits would only be needed for treatment. This should reduce waiting lists and also reduce NHS costs.

THE INTERPRETING OPTOMETRIST

By 2020 most of the examination techniques may require much less skill to carry out than they do today and will be less invasive; the optometrist's skill will be in interpreting results and taking appropriate action. It is possible that the modern optometrist of 2020 will employ technicians to carry out or investigative procedures. This will mean that optometrists will have more time to devote to their specialities within the profession, such as the examination of people with specific learning difficulties or orthokeratometry or they may become involved in other areas such as fluorescein angiography.

One day the optometrist may be able to conduct an eye examination using a palm-top computer while playing a round of golf with the local ophthalmologist. The round of golf may even be played on the virtual reality headset while the optometrist is working in his/her consulting room.

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In search of the ultimate CLs

Professors Brien Holden and **Deborah Sweeney** consider the future for extended-wear lenses and look forward to a time when contact lenses will be available for the full spectrum of refractive errors

The eye care industry has seen enormous growth over the past 20 years in response to research developments and new lens designs. In 1970 there were around 2 million contact lens wearers worldwide; in 1986 there were 25 million, and today there are 80 million.[1] However, when compared to more than 2 billion spectacle wearers, contact lenses are yet to come of age.

Despite contact lens improvements, patients are still searching for the ultimate vision correction. The keys to patient satisfaction with methods of vision correction have always been simplicity and convenience, ocular comfort, good vision and safety. Practitioners are also looking to further developments to improve the performance of contact lenses, to reduce the rate of adverse responses, and improve patient satisfaction. The future of contact lenses will depend on the ability of science and industry to meet these demands.

EXTENDED WEAR

Most patients want a long-term or permanent correction for their vision problems. While daily disposable lenses provide one of the most convenient and safest means of wearing contact lenses, up to 15 per cent of patients sleep in these lenses, predisposing themselves to adverse responses.[2] Many patients are now contemplating laser surgery to provide permanent vision correction.

In surveys conducted by the Cornea and Contact Lens Research Unit (CCLRU) at the University of New South Wales, patients have overwhelmingly indicated their desire for 'permanent' vision correction. In one survey, 97 per cent of prospective patients expressed the desire to be able to wear lenses continuously for at least six nights per week.[3] In recent surveys of the patients attending the CCLRU clinic,[4] the most important features in determining patients' choice of a contact lens were initial comfort and quality of vision. However, 85 per cent of patients believed that extended wear (EW) was also an essential feature in determining their choice of contact lens.[5]

Extended wear aims to fulfil the desire of patients for immediate comfort, good vision, convenience and safety, while at the same time meeting practitioners' expectations of a contact lens that can provide unaltered corneal physiology, patient comfort and safety as well as excellent vision.

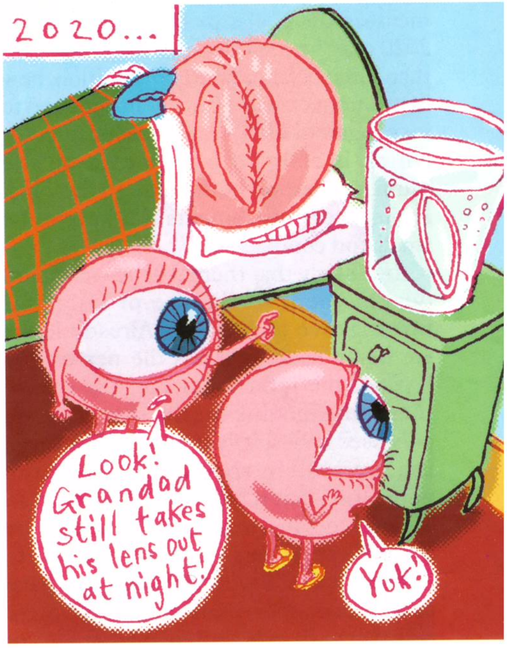
With the development of new highly oxygen-permeable silicone hydrogel materials, the alleviation of hypoxia and its side-effects has been largely overcome. The new extended-wear lenses made of such materials are capable of supporting up to 30 nights of continuous contact lens wear for the vast majority of patients. The first generation of a new range of EW products is now being launched by the major corporations. The new EW lenses have achieved:

- ◆ high oxygen transmissibility to avoid physiological changes;
- ◆ lens performance and comfort similar to conventional lenses;
- ◆ convenience for patients; and
- ◆ possible reduced infections, due to the elimination of hypoxia.

THE ULTIMATE LENS

While patients and practitioners come to grips with the new extended-wear lenses, researchers are already working on the next generation of products.

In the survey of patient satisfaction at CCLRU, the disadvantages of the high-Dk silicone hydrogel lenses were also rated by EW patients. Approximately 10 per cent of the group surveyed listed deposits as a disadvantage of their current lenses and 30-night schedule. Problems with deposits, which can interfere with the quality of vision and require the lenses to be removed and cleaned, need to be overcome. Adverse responses also need to be avoided. Problems with discomfort (8 per cent) and dryness (38 per cent) persisted, and discomfort and dryness remained the main reasons patients dropped out of lens wear. Importantly, 18 per cent of the patients wanted to wear their lenses for longer than one month. These results indicate the need for further development in biocompatibility with the ocular environment,[6] in order to develop



the 'ultimate contact lens'. To achieve this objective requires a surface biocompatibility that is nearly as good as the cornea itself.

Adverse responses also still occur with the highly oxygen-permeable lenses, although it is hypothesised that the improvement in corneal health achieved with these lenses may reduce the rate or severity of adverse responses, and the threat of sight-threatening microbial keratitis. However, not until the new lenses are used in large numbers will the effects of elimination of hypoxia on corneal infection rates be known.

So there are a number of issues that remain to be solved with extended-wear lenses. These include:

- ◆ further increases in wear time, as long as several months at a time;
- ◆ reduction in dryness symptoms and improved comfort (the ultimate lens should make the eye feel better than no lens); and
- ◆ elimination of adverse responses.

The ultimate contact lens, therefore, is one which offers excellent vision; true biocompatibility, to allow the lens to be left in the eye indefinitely and eliminates adverse responses; and true comfort, eliminating dryness and feeling 'better than no lens'. Such a lens would meet the needs of both patients and practitioners. The convenience of such lenses would mean that they finally challenge spectacles as the choice of vision correction.

OTHER LENS TARGETS

Along with the ultimate biocompatible contact lens, there are a number of other areas to be addressed. Lenses must be developed that can correct the full spectrum of refractive errors, thus widening the patient base and bringing the convenience of lenses into the hands of more people needing vision correction. This includes the development of lens designs suitable for presbyopes and astigmats, in materials that will also provide high-oxygen permeability and biocompatibility.

Presbyopia, in particular, is a growing problem in the world's ageing population, and significant efforts in design and understanding of visual function will be required to develop products that will lure presbyopes to contact lens wear. Monovision, for example, should not be ignored as studies by Back[7] have shown that the modality can be successful. For the astigmat, a revolution is happening. Contact lens companies are offering toric lenses as daily disposables, with tints, and they will also soon be available in the new silicone hydrogel materials.

IMPLANTABLE CONTACT LENSES

Contact lenses may soon be joined by more permanent methods of vision correction. As mentioned previously, most patients who require some form of vision correction are looking for a permanent means of correcting this disability. As a result they are willing to undergo refractive surgery, which permanently affects their corneas, in the hope of gaining a permanent end to wearing spectacles or contact lenses. A corneal onlay, or implantable contact lens, would provide an alternative to laser surgery. It would provide a treatment for moderate and high refractive errors attributable to high myopia or to aphakia as a consequence of cataract surgery. It would also be applicable to a partial thickness replacement of scarred or diseased corneal tissue.

The implantable contact lens should offer many advantages over refractive surgery, including:

- a reversible procedure, which would allow modification if vision changes were required;
- an in-office procedure that would be relatively simple (and require less surgical skill than other refractive procedures);
- less inconvenience for the patient; and
- stable refractive correction, as it does not involve a stromal wound healing response.

The onlay would be a synthetic polymer that would be placed on the corneal surface after debridement of the central area of epithelium. The epithelium would then grow over and attach to the synthetic lenticule, holding it in place.

Many ophthalmic surgeons have indicated that they believe such a device, suitable for the correction of high refractive errors as a result of either myopia or aphakia, is one of the most desirable procedures to be developed, given its permanent yet reversible outcomes.

The device could also be used as a replacement for scarred or diseased corneal tissue. Corneal transplants, which are the current method of corneal tissue replacement, are in limited supply and also have associated concerns regarding tissue rejection and viral infection.

The issues which need to be overcome in the development of the onlay are movement of water and nutrients through the implant, which is necessary for ocular health; and epithelium migration, proliferation and adherence over the synthetic implant. Currently, porous polymers are under investigation as the most promising materials to achieve these aims.

CONCLUSION

The future of contact lenses is based on a marriage between the patient's need for convenience, comfort and vision, and the eye's requirements for health. The union of these two elements will bring about safe, comfortable and effective vision correction for many millions of people in this new century.

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Lenses for the new millenni

The rapid rate of technological change in spectacle lenses shows no sign of slowing down in the new millennium, writes **Colin Fowler**

Trying to guess what will be the spectacle lens of the future is no easy task. As someone once said: 'If I knew what was really going to be the lens of the future, I would not be telling you about it, I would be patenting the idea.'

Perhaps a good point at which to start is to look back at what was being used at the beginning of this century. A page from the J&H Taylor catalogue, dated c1910 illustrates a wide range of fused, solid, cement and split-bifocal designs. A varifocal lens had been patented (but not produced commercially) by Owen Aves[1] in 1907 and a high-index aspheric post-cataract lens designed by Moritz von Rohr[2] had been patented on behalf of the Zeiss company in 1909. A wide range of tinted lenses could be obtained, but of course, all in glass.

In 1941, William Swaine wrote a review of ophthalmic lens development for the 50th anniversary issue of *The Optician*, and concentrated on the advances in 'best form' lenses, the adoption of the dioptric notation, and standardisation trial case lenses as significant advances in the first part of the century. Interestingly, Swaine ignored developments in plastic spectacle lenses, which had been developed (but not widely produced) prior to the outbreak of war in 1939.

MATERIAL DEVELOPMENTS

If we look at the currently available ophthalmic lenses, and how they have developed over the past few years, there are two over-riding impressions. First is the rapid development of plastic lens materials, and the second is the extensive use of complex lens surfaces. Twenty years ago, the readily available lens materials in plastic were acrylic, CR39 and polycarbonate. In the UK, of course, most lenses supplied then were glass, as a result of the restrictions imposed by the National Health Service on lens choice.

Now all that has changed. Plastic lenses account for more than 95 per cent of the UK market, with refractive indices available up to 1.71, and with much improved photochromic versions, surface coatings and lens forms, so that glass has been relegated to a specialist market.

Unfortunately, we still have the paradox that, although higher refractive indices make lenses in plastic thinner, the materials still have poor chromatic dispersion properties. This inevitably means that the wearer of a high prescription (>10.00D) is able to obtain a thin lens, but the visual acuity through the edge of the lens will be compromised by transverse chromatic aberration resulting from the inevitably poor constringence values of current high-index materials in plastic.

This problem was partially solved by Pilkington for glass with the 'Slimline 50' material, but plastic lens materials still have a long way to go in this respect. Perhaps this is one area where material developers could make big improvements in the 21st century.

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POLYCARBONATE PROMOTION

The next few years will also undoubtedly see polycarbonate lenses being heavily promoted, possibly in response to consumer concerns about eye protection and also practitioners having increasing worries about legal action arising from eye injuries.

Although modern photochromic materials (both plastic and glass) are a great improvement on the first commercial products of the 1960s, they still do not always give the wearer the required tint. As is inevitable from a photochemical process, the density of tint is dependent not only on UV light intensity, but also on temperature.

The next few years should hopefully see the development of a reasonably priced wearer-controlled tint. Devices using a pair of polarisers in front of each eye, which vary in tint density when one lens is rotated relative to the other, are not ideal, as the lens never reaches a clear state, but are still the subject of patents.[3] Some years ago Nikon demonstrated at Optrafair a wearer-controllable tint based on an electrochromic device.[4] This consisted of a thin multi-layer coating on glass, which could be tinted by the application of an electrical current from a small battery built into the spectacle frame.

One of the frame hinge joints incorporated a switch which made the lens progressively darker as long as it was pressed. As soon as pressure was released from this switch, the tint stayed at that density. The other hinge joint incorporated a switch which, when pressed, gave subjectively a very rapid clearance back to the clear state. At the time (1989) excessive cost was given as the reason for not mass-producing these items, but one could imagine a ready market if they could be manufactured at a reasonable price.

ASPHERICS AND ACCURACY

One of the features of current single-vision spectacle lenses is the large number of designs made in aspheric form. Originally aspheric surface lenses were only used for the high positive power range, where there was a significant demand from aphakic patients. This was because non-aspheric designs could not give the optical quality in this power range. Aspheric surfaces were also difficult to manufacture accurately, and it was not until the advent of CR39 plastic moulding techniques that these lenses could be produced at reasonable cost.

However, it was Jalie[5] who pointed out the cosmetic advantages of using aspheric surface lenses for low powers so that nearly flat forms could be used with acceptable optical properties, particularly in positive powers. But this development would not have been possible without an accompanying improvement in manufacturing methods for aspheric surfaces. Modern computer controlled (CNC) machine tools have enabled complex surfaces to be accurately manufactured at a much lower cost than previously.

SHIFT IN SUPPLY PATTERNS

Not only axially symmetric aspheric surfaces, but also aspheric toroidal surfaces are becoming increasingly common, after first being used commercially in the Essel 'Atoral' lens. If this trend continues, it may bring about a fundamental shift in the pattern of lens supply. An aspheric toroidal surface cannot be produced on the traditional types of lens generator as used by prescription laboratories for many years. Thus it is an increasing trend for the more complex surface lenses to be only available from the source manufacturer, and not from a prescription laboratory using semi-finished lens forms. It may be that lower cost CNC generators, together with the smoothing and polishing equipment required for these surfaces may come within reach of small laboratories. But if it does not, then we shall see a two-tier system of lens supply – premium design lenses only available from the original manufacturer, with smaller prescription laboratories restricted to semi-finished lens forms of less sophisticated design.

In the field of presbyopic correction, new designs of progressive addition lenses (PAL) continue to be produced, adding to the already bewildering choice available to optometrists and opticians. Indeed, a review of the US patent literature shows that progressive lenses were the subject of 10 patents in 1999. It is difficult to see how much more improvement can be extracted from the traditional type of PAL, while still retaining the concept of having one progressive surface, a second surface worked to prescription, and a single homogenous lens material. Current approaches include the refinement of the design by using an aspheric toroidal surface to give better optical quality in cylindrical prescriptions (for example by Rodenstock). Even more technically demanding is the new Seiko technique (as used in the 'Genius Grand' lens) for combining the progression and the prescription cylinder into a complex aspheric rear surface, the front surface being made spherical. This means that each lens must be made individually to prescription, and cannot be generated from a semi-finished stock. If this process proves successful, it opens up the possibility of much more individual design of a lens to an individual's requirements. But this then begs the question of how you decide what exactly are the optimum parameters for an individual wearer?

The next century will undoubtedly bring some alternative methods for coping with the problems of presbyopia. The past 150 years have seen many suggestions using alternative technologies, such as lens systems, hydraulically deformable lenses, gradient refractive index lens materials and diffractive optics. All these have so far failed to become a commercial success because of mechanical complexity, compromises in optical quality, cost of manufacture, or just poor cosmetic appearance. In addition, mention must be made of lenses using a liquid crystal element for changing power, which are the subject of much intensive development, particularly in Japan. A recent example of such a design is the 1998 patent from the Citizen Watch Company.[6] If this technology can be made to work into a low cost, cosmetically attractive and durable lens, then it could revolutionise the presbyopic correction market.

So a new millennium brings the prospect of exciting new developments in spectacle lenses. Despite the advances in disposable contact lenses, spectacle lenses remain the means of choice for the vast majority to obtain the optimum visual acuity. The rate of technological change shows no sign of slowing down, so that the next 20 years could be the most fruitful era in the history of lens development.

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The future of surgical correction

Shehzad Naroo looks to a future where refined lasers produce smooth ablations in the cornea and anti-ageing drugs can halt the onset of presbyopia

In the year 2020 the popularity of surgical correction of refractive errors will increase. Techniques will become more established as accuracy increases and equipment becomes more refined.

To obtain a better picture of the future for refractive surgery a quick glance backwards is worthwhile. Twenty years ago, the idea of mixing argon gas with fluorine to create an ultraviolet laser with vaporising capabilities on the cornea had not been conceived. In 1981, it was suggested that lasers could be used to change the corneal shape. In 1983 Stephen Trokel *et al*[1] ablated bovine corneas with an argon fluoride excimer laser. The first procedure on a sighted eye was performed in 1988 and the first private laser clinic in the UK opened its doors in 1991.

During the past 10 years we have seen a rapid rise in the number of patients having excimer laser photorefractive keratectomy (PRK) and more recently laser-assisted *in-situ* keratomileusis (Lasik) successfully.[2] It is important to acknowledge the advent of these two techniques in particular; had they been outright failures, then the public and the medico-ophthalmic professions would have lost all faith in refractive surgery and the whole field would have been dead and buried in the mid 1980s. Other techniques have been less effective in securing a good following and are still often considered to be experimental.

Current and former non-laser methods of changing refractive power may still have a place in our technology-driven future. Astigmatic keratotomy (AK) may continue being performed as a stand-alone technique but will have an increasing role in combined procedures. AKs have been used alongside cataract extraction, corneal graft surgery for some time and are creeping into the procedures carried out by some Lasik surgeons too. As laser technology improves, we may see surgeons attempting to perform AK with a laser beam for better accuracy as was attempted back in the early days of excimer lasers.[3]

Intra-stromal rings will be but a distant fading memory, as will implantable contact lenses (aphakic intraocular lenses). Unpredictability, problems and instability with intrastromal rings are already showing the imminent demise of this procedure. Similarly, anterior chamber complications or secondary cataracts are leading to a loss of interest in implantable contact lenses. Although attempts will continue, with limited success, to try and establish a reversible technique with an inert implantable lens or gel, probably into the anterior chamber.

Probably the biggest improvement the future will yield will be in lasers themselves. Developments in this area have already been phenomenal.[4] But the Holy Grail of lasers will be found in using a beam that produces a smoother ablation, a laser fluency that is independent of ambient temperature and gaseous volume. Smoother corneal ablations will be possible using lasers that have a more consistent beam homogeneity. Solid-state lasers will play an important role in the future of laser refractive surgery, since they do not show the gaseous fluctuations that can be observed with current excimer lasers, thus eliminating problems of irregular post-surgical corneal topography (such as central islands). These newer lasers will contain an active element supported by a crystal, similar to technology used in the ruby lasers found in the archives of ophthalmic history.

Solid state lasers in the year 2020 will be much more compact than current excimer lasers and in the future we may see them being mounted on slit-lamp tables like current Holmium lasers. However, by 2020, Holmium lasers will be dead and buried. In quietened corridors of refractive surgery clinics, we will hear young refractive surgeons wryly asking older colleagues about 'that laser which caused localised shrinkage of the cornea by applying thermal burns'.[5] Similarly, in the year 2020, when reviewing current methods of PRK and Lasik, the question will be asked why such primative techniques, were carried out. The advent of newer techniques will mean that the idea of permanently removing a disc of Bowman's membrane (as in PRK) or cutting a corneal flap (as in Lasik) will no longer be necessary. Laser refractive surgery will involve using a laser beam that is focused at the stromal level, without having to debride the epithelium (by mechanical or chemical methods) or the creation of a flap with a microkeratome.

The actual procedure that will be used with the new lasers will be simple when compared to our current methodologies. Between two and eight micro-fenestrations will be made with a spot of laser energy, to roughly half the corneal thickness. These micro-fenestrations will be placed at equal points around the peripheral edge of the ablation zone. Then a blunt, flexible needle will be inserted through each hole and out of another, to create an irrigation channel. The new solid-state laser will then be focused at the required depth in stroma and an ablation will be made. An isotonic solution will be washed through the irrigation channels. The debris that will be formed as a result of the laser evaporation of the stromal tissue will be expelled through the irrigation channels. In a myopic patient, for example, the resultant cornea will have a central section that has been excised and the residual cornea will collapse around it, leaving an overall flatter area centrally. In hyperopes the mid-peripheral cornea will be ablated and the residual cornea will collapse around it. In all cases the ablation will be a sub-stromal ablation with a smooth surface.

The new lasers with their beam homogeneity will be linked to corneal topography video-keratoscopes to produce smooth ablations in the cornea. The corneal topography units will be descendants of current scanning and rasterstereography apparatus such as the Orbscan unit.[6] These types of corneal topography units show corneal shape as height maps and not radius of curvatures like Placido-disc corneal topography.[7] Using the link between lasers and corneal topography units, surgeons will be able to ablate only the desired area of the cornea to the required depth.[8]

The lasers of the future may be similar to ones already being experimented with in Germany using pulses created by a titanium-sapphire oscillator. This work involves cutting a corneal flap and a lenticule simultaneously with the laser. The flap is then peeled back and the lenticule removed, thus altering the corneal shape and refractive power.[9]

Predictability is the last frontier that refractive surgeons will have to tackle. In the past corneal models have been derived to allow better predictability in AK surgery[10] and similar models have been attempted for PRK and other refractive techniques.[11,12] In the year 2020, however, Bill Gates will have introduced a computer with processing power beyond our current imagination. This will enable specialists in refractive surgery to devise a computer-driven model for refractive surgery. This model will allow the operator to view a perfect schematic computer-simulation of the patient's eye. The operator can generate changes to the shape and thickness of the cornea and the computer will precisely generate how these changes will affect other ocular dimensions. Drug therapy will allow better predictability of the healing response and the only unpredictable factor remaining will be patient satisfaction.[13]

The presbyopic patient will remain the only elusive refractive case that will continue to be dependent on spectacles. The limited success of the current, relatively new procedure of inserting inert bands into the sclera to try and regain some type of accommodation for the patient, will probably mean the demise of this technique. The pinpoint accuracy that new solid-state lasers described above will offer in the year 2020 will mean that attempts will be remade at creating a multifocal ablation in the cornea.[14]

Current drug therapy in refractive surgery is mainly concerned with improving pain relief or the healing response,[15] but new-age chemists of the future may produce anti-ageing products that can be injected into the ageing crystalline lens preventing presbyopia. Drugs that cause shape changes in the cornea and crystalline lens will also have been attempted for non-presbyopic refractive problems.

These new pharmacological advancements will attract only a small following due to lack of predictability. However, hope is on the horizon for those approaching presbyopia in the year 2020. Major leaps forward in electronics will yield tiny video cameras that can be implanted into enucleated sockets connected to the visual cortex. In the year 2020 this will still be an experimental procedure, but we can expect that it will be commercially available in the middle of the next century. Nevertheless, understandable patient reservations about being enucleated will stop this technique from becoming popular in routine presbyope cases, but this science fiction-style advancement will be extremely useful for partially sighted patients.

By 2020, contact lenses will play only a small part in the market. Refractive surgery advances will mean that patients opt for surgical intervention as soon as their refractive error is stable. In the years before they achieve stability, patients will choose spectacles or contact lenses. Although risk of eye infection from new super bugs will mean that patients lose faith in being totally contact lens dependent.[16] Spectacles will increasingly become more of a fashion accessory and thus will become more popular than contact lenses in that odd minority of patients not opting for refractive surgery.

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All space age techno or back to basics? **Tamsin Kingswell** asked six optical figures to predict the future for frames

frames of the future

'We will see many more individual looks. Universal looks will disappear because opticians will be stocking a wider range of frames and people will want more than one. As far as styles are concerned, screws will not be visible and lenses will be interchangeable. There will be a continuity of fashion in terms of size and shape (lightweight and sophisticated). There will be more room to be artistic and creative with frames, especially as production advances may mean that hand-finished techniques can be carried out by machine, making them more accessible. Frames are not going to go away however brilliant surgical processes become as they have been absorbed into fashion. However, opticians may need to be more specific and look much harder at how they stock frames.'

◆ *Mary Rose Cooney, creative consultant, Safilo*

'We will see the death of the designer frame; the days of the label are numbered. Quality and craftsmanship will takes its place as the main priorities for the wearer. Of course, there will be plenty of space-age technology; we will be looking at virtual reality, telephone calls by sight. I don't think we've even started yet. The market place will become more global and there will be fewer players out there. It makes sense that big global companies, such as Safilo, will want more of the market and will swallow up the smaller companies. However, greater craftsmanship and quality will be a way for the smaller boys to survive.'

◆ *Andrew Actman, eyewear designer and entrepreneur*

'When I think back over the past 20 years, eyewear has not changed that much. Laser surgery will have an impact, but no more than any other form of cosmetic surgery. As for frames, they are likely to become more streamlined and there may be more use of different metals such as titanium as well as an end to fiddly screws for supporting frames. Contact lenses will inevitably move further towards disposability. My chief worry, however, is that selling spectacles as a profession will be held in less regard than it is now. This is particularly of concern to those who want to keep it upmarket. We may be defeated by market forces including the big chains that pile it high and sell it cheap. It is little comfort to me that by 2020, I won't be worrying about it.'

◆ *Gail Steele, dispensing optician, Auerbach & Steele*

'Fashion goes round in phases and in the next 20 years, we will see metal and then plastics, bright colours and dark ones; 20 years certainly won't change that much. The main threat to frames is laser surgery, which has already made a big impact in the US. But over here it will take a long time in terms of evaluating results and people are scared enough of contact lenses. However, we will always wear frames, but probably more as a fashion accessory and a statement. Frames will be more vibrant and more exciting than in the past.'

◆ *Jason Kirk, designer, Kirk Originals*

'Who knows what we will be designing in 2020? I think it is important that this year 750,000 Americans will be having corrective laser operations, so there may be no need for mass-produced frames. People who choose to wear frames may be wearing them more as an accessory, more like jewellery. As far as materials are concerned, titanium is the material of the moment but just a few years ago it was difficult to work it in anything but wire. Now new technology has made that possible so it follows that there may well be advances in new materials. Optical designers are good at waiting to see what happens and then reacting quickly to trends, so what happens in the next 20 years very much depends on outside forces.'

◆ *Alison Magee, designer, Face à Face*

'We have already seen a blossoming in the interest in frames and that will continue. People will own more than one pair and this will be supported by a reduced cost through new technology. As far as style is concerned, we are going to see a polarisation. Either incredibly minimal and practical or outrageous and flamboyant. Material will play a part in this and if you consider the advances made since the 1980s, when we got into epoxy resin, then there has to be plenty of change in the next 20 years. I also think that we will be seeing a different way of selling. The Internet and web sites will mean that shoppers have a global view of the market which will really open up their choice of style.'

◆ *Angela Campbell, dispensing optician*