The History of Contact Lenses*

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Introduction

The development of contact lenses is long and complex, starting mainly in Germany and then moving across Europe to the USA before going international. The authors have tried to keep things chronological; however, these developments do not fall into a nice convenient timeline. As you read the chapter, remember that the original ‘contact lens pioneers’ had limited equipment and materials available. They were truly working in the dark, and advancements happened only as new materials and new technologies became available. There were no antibiotics, so contact lenses were fitted by ophthalmologists only when clinically necessary, for conical cornea (keratoconus), symblepharon and other corneal diseases. Due to the working relationships between ophthalmologists and other eye care professionals, fitting soon devolved to dispensing opticians (around 1912) and later extended to optometrists (around 1935). As knowledge of the physiology of the cornea developed and materials and designs improved, so too did their success – not always as straightforward as it might appear, as some developments have solved one problem simply to replace it with another! At the time of writing, end-of-day comfort is still an issue, with some practitioners limiting wearing time to little more than it used to be in the 1930s.

Early Theorists

1508: Leonardo da Vinci (Italy) It had previously been assumed that, in his Codex D, folio 3, famously illustrating a man with his head lowered into a large bowl of water, da Vinci showed the invention of a contact lens (Ferrero 1952, Hofstetter & Graham 1953, Gasson 1976). However, in the retranslation by Robert Heitz, it is clear that this was not a prototype contact lens but the beginning of understanding corneal neutralisation (Heitz 2003).

1637: René Descartes (France, Holland, Sweden) described in his seventh Discourse of La Dioptrique a fluid-filled tube used to enlarge the size of the retinal image (Enoch 1956).

1685: Philippe de la Hire (Paris, France), a mathematician, presented his dissertations on the neutralisation of the cornea in 1685 and 1694 and speculated that myopia was axial or refractive. Sadly, his theories about accommodation and entoptic phenomenon were considered so controversial that his views on optics were largely ignored (Duke-Elder 1970).

1801: Thomas Young (Somerset, England) studied medicine in London and Edinburgh and physics at Gottingen. He conducted research into the eye, identifying the cause of astigmatism, and published a three-colour theory of perception. As a fellow at Cambridge University, he carried out his classic experiment on accommodation using a water-filled lens which he placed on the eye to neutralise the refractive effect of the cornea (Young 1801).

1827: George Biddell Airy (England), inspired by Thomas Young and cooperating with John Herschel at Cambridge University, experimented with his own astigmatism. He described not only the optical theory of astigmatism but also its correction with a theoretical back surface toric lens (Airy 1827, Herschel 1845).

1845: Sir John F. W. Herschel (Slough, England) was the son of Sir William Herschel, discoverer of Uranus. In his dissertation Light, he described the optical correction of malformed and distorted corneas using convex lenses applied to the eye. He suggested correcting ‘very bad cases of irregular cornea’ by using ‘some transparent animal jelly contained in a spherical capsule of glass’ and then went on to suggest whether ‘an actual mould of the cornea might be taken and impressed on some transparent medium’ (Herschel 1845).

1846: Carl Zeiss (Jena, Germany), a mechanic who was 30 years of age at the time, opened a small workshop and store in Jena’s Neugasse No. 7 to make scientific tools and instruments, telescopes and microscopes. This was the foundation of the company Zeiss (www.zeiss.com).

1851: Johann Nepomuk Czermak (Prague, Austro-German) developed a water-filled goggle strapped to the front of the eye to correct keratoconus, a device which he called

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†Sadly during the writing of this book, Tim Bowden passed away
the orthoscope. In 1896 Theodor Lohnstein developed a similar device, which he called the Hydrodiascope.

**1854: Keratoconus.** The first adequate description of keratoconus was published (John Nottingham, Great Britain).

**1859: William White Cooper (London, England)** was Queen Victoria’s oculist. He had glass masks made by artificial-eye makers Gray and Holford of Goswell Road, London, to protect the eye in cases of symblepharon (Fig. 1.1). These were clear glass shells very like scleral lenses but with no optic zone over the cornea.

**1882: Dr Xavier Galezowski (Franco-Polish)** suggested using a gelatine disc applied to the cornea immediately after cataract extraction. The disc was impregnated with cocaine and sublimate of mercury to provide corneal anaesthesia to relieve postoperative pain and antiseptic cover to prevent infection (Mann 1938). Here we see not only the first use of a soft and hydrophilic contact appliance but also the forerunner of the hydrophilic lens as a dispenser of ophthalmic medication. Local anaesthesia in the form of cocaine drops were widely used by 1886. Initially adopted by Karl Koller in 1884, the anaesthesia’s use in German ophthalmology became almost universal (www.rsm.ac.uk).

### Scleral Lenses

**1887: Friedrich A. Müller and Albert C. Müller (Wiesbaden, Germany)** were from a family of artificial-eye makers; they made and supplied a protective device for a patient of Dr Theodore Saemisch. The patient had surgical damage to the right eyelids leaving the cornea exposed, whilst sight in his left eye was impaired due to myopia and cataract. By making a glass shell, which encased but did not touch the cornea, the Müllers maintained fluid around the cornea, preventing its further desiccation. The protective shell looked like an artificial eye, although the cornea was left clear (Nissel 1965). The patient wrote a letter in 1908 (now lost) reporting that since 1887 he had worn the lens continuously, day and night, for 18 months to 2 years at a time (Müller & Müller 1910, Müller 1920, Mann 1973). In reality the lens needed to be replaced every 18 months to 2 years due to corrosion of the glass surface by the tears (Bowden 2009). The Müller brothers continued to produce thin, lightweight blown glass lenses with clear corneal regions and white scleral portions (Fig. 1.2), which were well tolerated. The optic portions were variable, and years later it was proposed that the excellent toleration of these glass lenses (and apparent avoidance of corneal oedema) was probably due to the characteristic aspheric shape of their scleral zones, producing loose channels for better tear flow and oxygen exchange.

**1888: Adolf Eugen Fick (Germany)** was an ophthalmologist who, after returning from South Africa, began work in the ophthalmic clinic in Zurich under Professor Haab. He was interested in keratoconus and experimented with making corneal moulds and constructing glass shells for rabbits’ eyes. He had glass scleral lenses made by Professor Abbe at Carl Zeiss in Jena for human cadaver eyes. The lenses had a back optic zone radius of 8 mm, optic zone diameter of 14 mm, a scleral band width of 3 mm, with a scleral zone radius of curvature of 15 mm. Fick described six patients on whom he had tried his lenses: One was keratoconic, and the other five had varying degrees of corneal opacity. In the keratoconic eye, he improved the vision from 2/60 to 6/36, but at the time he published, none of these patients was actually wearing the lenses for any length of time. He observed that:

- the radius of curvature of the cornea was steeper than that of the globe of the eye
- the conjunctiva flattened steadily away from the cornea
- clouding in the epithelial layer (corneal oedema, later called Fick’s phenomenon or Sattler’s veil) reduced as lens tolerance and wearing time increased.
- air trapped behind the contact lens on insertion retarded the onset of corneal clouding
- using a boiled solution of 2% grape sugar on insertion gave 8–10 hours wear by his rabbits before corneal clouding developed
- cosmetic (prosthetic) contact shells could be used when corneal scarring precluded good vision
- an iridectomy to produce an artificial pupil followed by a contact lens upon which an opaque iris and a black pupil was painted with a clear aperture positioned adjacent to the iridectomy could be used for conical cornea as an alternative to corneal tattooing, which often resulted in severe infection
- contact lenses could be used in aphakia where ‘the high degree of hypermetropia could be diminished by the increased curvature of the glass cornea’ thus increasing the power of the liquid lens.

**Professor Ernst Karl Abbe (Jena, Germany)** had joined Carl Zeiss’ optical works in 1866 as a research director. He
was a professor of physics and mathematics at the University of Jena and a prolific inventor and writer of scientific papers on optics. Abbe developed the first Zeiss contact lenses using glass produced by Otto Schott, the son of a family of glassmakers who refined the chemistry of glassmaking. Previously glassmaking was a cottage industry with highly variable results from one batch to the next and from one family to another (www.zeiss.com).

1888: Manuel Straub (Amsterdam, Holland) introduced ophthalmological solutions of fluorescein for the investigation of corneal lesions. However, their fluorescent properties under blue light were not recognised for another 50 years (Straub 1888, Obrig 1938a).

1889: Eugene Kalt (Paris, France), an ophthalmologist, investigated contact lenses as ‘orthopaedic appliances’ in the treatment of keratoconus. He noticed that the contact lens changed the shape of the cornea, and thus he laid some of the groundwork that led to orthokeratology.

1889: August Müller (Kiel, Germany), a final-year medical student, presented his thesis on optics. Abbe developed the first Zeiss contact lenses using glass produced by Otto Schott, the son of a family of glassmakers who refined the chemistry of glassmaking. Previously glassmaking was a cottage industry with highly variable results from one batch to the next and from one family to another (www.zeiss.com).

1889: August Müller (Kiel, Germany), a final-year medical student, presented his thesis Brillengläser und Hornhautlinien (Spectacle Lenses and Corneal Lenses) at the University of Kiel for his doctorate in medicine. This concerned the correction of his own 14 dioptries of myopia with contact lenses and made the first reference to a ‘corneal lens’. He had three lenses, measuring 15–16 mm across, made by Otto Himmel, a Berlin optician and instrument maker, which still exist in the Germanisch Museum in Munich. Due to his poor sight, Müller did not pursue a career in ophthalmology but went into orthopaedics. However, he noted:

- Adverse signs and symptoms of lens wear caused by ‘a disturbance of nourishment of corneal tissue’. This was validated in the 1950s, when it was demonstrated that the cornea required atmospheric oxygen, dissolved in tears, to maintain a normal respiratory status (Pearson 1978).
- Lens discomfort arose from pressure on the conjunctiva from the scleral zone of the lens.
- To avoid trapping air bubbles, he inserted his lenses under water; however, corneal oedema would develop within about 15 minutes due to the pH of water. Due to the discomfort, Müller used cocaine eye drops before lens insertion, but the toxicity of cocaine would have further inhibited his success (Müller 1889).

1892: Henri Dor (Lyon, France) an ophthalmologist, recommended the use of physiological saline solution to insert contact lenses. This remained popular until the early 1940s (Dor 1892).

1900: Dr Louis de Wecker (France and Germany) used a contact lens as a splint to retain a corneal graft in position during healing (Mann 1938).

1911: Allvar Gullstrand (Sweden) invented the slit-lamp, facilitating more detailed examination of the cornea.

1912: Heinrich Erggelet (Freiburg, Germany) commissioned Zeiss to make made ground glass ‘experimental contact lenses’ to induce artificial ametropia to test ‘the optical quality of the corrected curve glasses’ (Obrig & Salvatori 1957a). These were actually corneal lenses but were too heavy to wear successfully (von Rohr & Stock 1912, Mann 1938). Zeiss produced their first contact lens trial set for use by ophthalmologists. By this time over 2000 contact lenses had been made, mainly by Zeiss (Bowden 2009).

1916: Zeiss produced the first trial set especially for keratoconus (Rugg Gunn 1931).

1918: Zeiss made lenses with small lead pellets embedded in them to assist locating ophthalmic foreign bodies in conjunction with x-ray images.

1918: Leonhard Koepppe (Halle, Germany) was an ophthalmologist who described a contact lens for specialist observation of internal features of the eye using a slit-lamp biomicroscope. This type of short-use lens was termed a gonioscope (Koepppe 1918).

1920: Zeiss manufactured a four-lens preformed fitting set primarily for keratoconus. It was introduced and developed by Professor W. Stock (from Jena University), who was a sufferer of the condition (Stock, 1920). The first lens had a 12 mm back scleral radius, but later a full range from 10.0–14.0 mm in 0.25 mm steps became available (Dallos 1936). In the early 20th century, lens choice lay between the blown glass lenses produced by the firm of Müllers of Wiesbaden and the ground glass contact lenses such as those made by Carl Zeiss of Jena. The former were inferior in consistency of optical quality, but superior in comfort and duration of wear. Zeiss lenses could correct reasonable amounts of ametropia, but their maximum wearing time was between 30 minutes and 2 hours.

1922: Zeiss were granted a US and German patent for plastic (Cellon or celluloid) contact lenses. Appearance and discolouration stopped further development. Zeiss was also granted a patent for a lens formed between two lathe-cut moulds.

1927: Adolf Wilhelm Müller-Welt (Stuttgart, Germany), an artificial-eye maker (Müller-Welt, 1950), applied for a patent for the first fluidless blown glass lens (granted in 1932). The lenses, made from glass obtained from Schott of Jena, were blown over a series of preformed toric castings, which formed the scleral portion of the lens. These included areas of differing curvature to incorporate the insertions of the recti muscles (Schiller 1969). The unfinished corneal portion was later ground and polished to the desired prescription. He understood the stresses produced in the glass during lens manufacture and annealed the glass to improve durability (Figs 1.3, 1.4 & 1.5).

1929: Professor Leopold Heine (Kiel, Germany), an ophthalmologist, developed an ‘afocal’ fitting set for Zeiss (Heine 1929). This utilised the increasing range of back optic zone radii to form a liquid lens of various powers underneath the lens to correct ametropia. However, physiological requirements of the eye were sacrificed for vision.

1930s: Josef Dallos (Budapest, Hungary), an ophthalmologist at the No. 1 Eye Clinic at the Royal Hungarian Peter Pazmany University (Fig. 1.6), developed an interest in the use of contact lenses and investigated various impression materials. He tried Negocoll (derived from seaweed and described by Dr Alphons Poller of Zürich) on a cadaver face and noted that the corneal surface was reproduced with a smooth, polished texture. He prepared a positive cast of this impression in the waxlike substance Hominit, and the smooth appearance of the visible corneal segment convinced him that Negocoll would be a suitable medium for ophthalmic impressions (Dallos, J., personal communication to Sabell, 1977). Dallos used Müller contact lenses as impression trays (Sabell 1980a) and filled the impression achieved with Hominit, making a positive cast. From this he made a negative cast with plaster of Paris which was then converted into a brass
die (Sabell 1980c) (Figs 1.7 and 1.8), i.e. a positive which he then used to thrust through a sheet of heated glass. The heated brass die was secured in the swinging arm of the press and pushed into the softened glass plate (initially using thin glass photographic plates) at a suitable temperature, as judged by its colour. The heat was then removed, and the glass solidified immediately. The central zone of these shells was then optically ground and polished. This method of manufacturing lenses, with some minor modifications, was also used for the acrylic materials introduced some 10 years later. Dallos laid down physiological principles for the fitting of scleral contact lenses. Working on the assumption that the natural body fluid offers the best chance of success, he set out to conserve the tear reservoir and to allow for its interchange by fresh tears. In 1933 Dallos suggested that if the front optic diameter were restricted to 8 mm (lenticulated), much higher powers would be achievable, whilst minimising thickness and weight.
Impression Materials

For a more detailed history of impression materials, see Section 8, History available at: https://expertconsult.inkling.com/.

Josef Dallos was the first to successfully take an impression of a living eye and use this mould to make a cast and from this make a contact lens. In 1935, Theodore Obrig started using Negocoll to produce corneal impressions using funnel-shaped blown glass shells that were 22 mm in diameter and 7 mm deep with a 25 mm-long hollow handle plugged with cotton wool to retain the Negocoll (Obrig 1938b). Negocoll was applied hot to the eye, so it was not a very pleasant experience even with corneal anaesthetics. In 1943 he introduced Ophthalmic Moldite, the first cold alginate impression material intended specifically for ophthalmic work using acrylic impression trays with hollow tubular handles and perforated bowls (Obrig 1943).

In 1945 ophthalmic Zelex, another cold setting impression material, was developed by Charles Keeler in Windsor, UK (Figs 1.9 and 1.10). Panasil C was developed by Kettenbach GmbH in 1987, which was withdrawn in 1993 but reintroduced in 1995 by Panasil light body.

1930+: Theodore Obrig (New York, USA), an optical technician working for Gall and Lembke, initiated the full clearance method of fitting scleral lenses by using a large optic zone, improving comfort by reducing corneal pressure. Although it was widely used in the USA and the UK, it had the following drawbacks (Dickinson & Hall 1946):

- Cosmetically, the lens was ugly.
- As the optic had to remain filled with fluid for the wearer to see, a glovelike seal was required on the scleral zone. Any bubbles trapped in the steep apex of the lens affected vision.
- Due to this seal, corneal oedema developed after some 2 hours of wear. Initially seen as a faint blue haze resembling tobacco smoke, this developed into the classic rainbow rings resembling glaucoma haloes, which was followed by photophobia, blepharospasm and an unpleasant sensation of heat.

Contact Lens Materials

The development of plastics brought a great change to the development of contact lenses. Various materials were tried, including cellulose nitrate (celluloid; highly flammable), cellulose acetate (used in spectacle frames), Bakelite (multiple household objects), polyvinyl acetate (emulsion paint and adhesives), polyacrylates (developed by Otto Rohm and Otto Haas, Darmstadt, and used in paint) and polystyrene (made by Imperial Chemical Industries (ICI)). In 1931 John Crawford and Rowland Hill, working separately for ICI in the UK, developed polymethylmethacrylate (PMMA), which had the registered trade name of ‘Perspex’, but it was also known as Lucite, Plexiglas and Diakon. Rohm & Haas were licensed to use the ICI process to make Plexiglas sheets in
1933: Hans Hartinger (Jena, Germany) of Zeiss suggested blending the sharp junction between the optic and scleral zones, giving the option of lenses with totally blended transitions (Dallos 1936).

1936: Carl Hubert Sattler, an Austrian ophthalmologist working in Leipzig, investigated the corneal oedema induced by wearing contact lenses which became known as Sattler’s veil (Sattler 1938).

1936: Josef Dallos, having accumulated so many glass shells from earlier impressions, was able to fit from his stock of ‘type shells’. He demonstrated that the secret of fitting scleral lenses was not just the initial selection or the initial impression but the careful tailoring of this first lens to the individual eye to allow adequate exchange of tears beneath the lens (Dallos 1936).

1936: Ida Mann (London, England) was the first woman to become a consultant ophthalmologist at Moorfields Eye Hospital (1927) and the first female professor at Oxford (1945). Together with fellow ophthalmologists Andrew Rugg-Gunn and Frederick Williamson-Noble, she visited Dallos in Budapest to learn the skills of making scleral lenses. They soon realised that the skills required were too complex to learn on a short trip and tried to persuade Dallos to move to the UK, but he refused.

1936: William Feinbloom (New York, USA) was granted a US patent for a bifocal scleral lens, but it was never made.

1937: Josef Dallos and George Nissel, Dallos’s brother-in-law, arrived in London. With war looming, Ida Mann had returned to Hungary, because, as a Hungarian of Jewish extraction, it was obvious that Dallos and his work were at risk. Ida persuaded Dallos to return to England with her. Gerald Wingate, who owned the Theodore Hamblin dispensing practices, had agreed to set up a contact lens clinic for Dallos in Cavendish Square, attached to their Wigmore Street premises, forming the first contact lens–only practice in the UK. A commemorative plaque, unveiled by his widow Vera Dallos-Pinter in 2010, marks the spot.

1938: Theodore Obrig (New York, USA) accidentally discovered that a blue filter introduced into a slit-lamp beam made the fluorescein solution fluoresce, thus enhancing observations of fit and corneal abrasions (Obrig 1938a). In the same year, Obrig, together with engineer Ernest Mullen, made the first US all-plastic contact lens using the newly manufactured (poly methyl methacrylate) ‘Plexiglas’. The material was lightweight, optically clear, nonreactive, easily moulded, ground and polished and inexpensive. However, Obrig was still using fluid-filled sealed scleral lenses, which meant that the saline solution filling the lens had to be changed every few hours to prevent corneal oedema. Often the pH of the saline was increased each time, a procedure known as stepping up. He set up the Obrig Laboratories to make these lenses.

1938: Dr István Győrffy (Budapest, Hungary), an ophthalmologist working in the Maria Street Eye Clinic (where Dallos had worked), was the first in Europe to use PMMA for contact lenses. He came across the material during a visit to Germany in 1938 (Győrffy 1964), and on his return to Budapest he developed a technique for moulding this sheet plastic and grinding the back and front optic surfaces. By late 1938 he had begun to fit PMMA scleral lenses and later went on to fit corneal lenses using this material (Győrffy 1968).

1938: C. W. Dixey & Son Ltd (London, England) introduced preformed PMMA scleral lenses, precision lathed from solid blocks of ICI Transpex materials which were easier to produce and modify (Dixey 1943, Ridley 1946). The lathe, developed by dispensing optician Harry Birchall and engineer Cyril Winter, allowed greater variability in dimensions and reduction in thickness, reducing weight by 60% (Graham 1959).

1938: Dallos developed a telescopic combination of a contact lens and spectacle lens as a low vision aid (LVA).

1939: Dallos devised an astigmatic scleral lens to correct lenticular and residual astigmatism.

1939+: Dallos successfully fitted 84 late-onset mustard gas keratitis casualties dating from World War I with scleral lenses (Fig. 1.11) (Mann 1973; see also Section 8, History available at: https://expertconsult.inkling.com/).

1946+: Josef Dallos and Norman Bier, working independently, formulated the fenestrated or ‘ventilated’ scleral lens (Bier 1945, Bier & Cole 1948, Dallos 1946). Earlier, Dallos had happened upon the idea by accident when he was forced to cut a 4 mm hole in a glass scleral lens to relieve the pressure on a ‘filtration scar’ (trabeculectomy) (Fig. 1.12).
to the front of each optic section, giving a small air space to provide clear vision underwater.

1948: **Arthur Forknall** (Nottingham, England), an optometrist, designed the ‘offset lens’ – again a scleral lens with a spherical optic and an aspherical scleral zone – attempting to give even pressure on the sclera (Forknall, 1948). It simplified fitting by eliminating the need to adjust the scleral zone radius when the total diameter was changed. This design was neglected by most contact lens practitioners until it was reintroduced by **Professor Montague Ruben** (originally an ophthalmic optician, then an ophthalmologist at Moorfields Eye Hospital) as an offset corneal lens in 1966 (McKellen, 1963).

1949: **Alexander Cross** reported that there were at least 31 members of the RAF during WWII wearing contact lenses whilst flying. These were mainly experienced pilots who had suffered traumatic cataracts (Cross 1949).

1950: **Frederick Williamson-Noble**, UK ophthalmologist, produced several scleral lenses with a small reading zone in the centre of the optic zone (Bowden 2009).

With increased interest in contact lenses invoked by the more comfortable and easier to fit corneal and soft lenses, you might assume that interest and development in scleral lenses waned. However, a small percentage of the population cannot be fitted with corneal or soft lenses, so for them sclerals remain the only option (For further information see https://expertconsult.inkling.com/).

1967: **Stephen Gordon** (Hungary, then Manchester, England), contact lens director of Hamblins (https://www.andrewgasson.co.uk/stephen-gordon-1922-2004/), together with J.P. Fraser, designed the ‘Apex lens’ (derived from ‘aphakic experiment’) specifically for the UK Hospital Service. The large semiscleral design was quite thick and heavy in aphakic prescriptions, but it provided stability of vision from its limbal locating characteristics (Ruben 1967). However, its long-term use in PMMA material led to corneal neovascularisation in many cases (Fraser & Gordon 1967). The design is still used in high-Dk materials for high prescriptions.

1970s: **John James Little** (Edinburgh, Scotland) and **Arthur Irving** (Northampton, England, working at David Thomas Contact Lenses) claimed to have fitted scleral lenses made from cellulose acetate butyrate (CAB), a gas-permeable material (personal communications, Bowden 2009).

1983: **Don Ezekiel** (Perth, Australia) reported, at the BCLA conference, making scleral lenses using two different rigid gas permeable (RGP) materials. It was later called the Gelflex Scleral and gained Food and Drug Administration (FDA) approval for use in the USA.

1992: **Ken Pullum** (Hertford, England) founded Innovative Sclerals to supply and fit RGP scleral lenses. An impression taken of the eye was then scanned, and the back surface of the lens was lathe cut using CAD CAM technology. The front surface was finished by hand to minimise the thickness (the company was bought by Bausch & Lomb in 2015).

1998: **Eaglet Eye** surface profiler was invented by Dr Frans Jongsm to measure the curvature of 20 mm in diameter of the front surface of the eye. It would take another 15 years to bring it to market.

2007: **William Masler**, Acculens president and Fellow of the Contact Lens Society of America, designed the Maxim scleral lens, later licenced to Bausch & Lomb.
2008: Dr Robert Breece designed the Jupiter lens. Later made by Visionary Optics in the USA and licenced to Essilor. The Jupiter was available in 15 mm and 18 mm diameters and usually had five curves organised into three zones, and it was available in three configurations.

2009: Scleral Lens Education Society was founded by Greg deNaeyer, Christine Sindt and Rob Breece (www.scleralens.org).

With the renewed interest in scleral lenses the Scleral Lens Education Society designed a classification system.

**Corneal lenses** (8–12.5 mm) are supported completely by the cornea and do not hold a tear reservoir.

**Corneal-scleral lenses** (12.5–15 mm) extend beyond the limbus, are supported by both corneal and scleral tissue and hold a limited tear reservoir.

**Scleral lenses** (15–25 mm) place all lens bearing on the sclera. Miniscleral lenses (15–18 mm) have a limited tear reservoir capacity, whilst full scleral lenses (18–25 mm) have an unlimited tear reservoir capacity.

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### Corneal Lenses

The ‘invention’ of corneal lenses is usually credited to Kevin Tuohy. Tuohy worked with Theo Obrig, later becoming an optical dispenser and partner in Solex, California, with Solon Braff and Xavier Villagram. Whilst a scleral lens of high negative power was being made, the corneal portion broke away, producing a perfect disc. This was something that had happened to lots of other lens makers. The disc was approximately his wife’s prescription, so Tuohy took it home for her to try. Success led him to design, manufacture and patent the corneal lens (granted in 1950). However, Zeiss catalogues show glass corneal lenses in 1912, 1923, 1932, 1965 and 1966 (Bowden 2009). Glass corneal lenses tended to be heavy and ride very low, whereas PMMA lenses, being much lighter, were raised by the upper lid after each blink, giving better performance. The Tuohy lens was a monocuscove flatter than flattest K (www.nova.edu), 11 mm in diameter and 0.4 mm thick. Two dioptres of corneal astigmatism was considered to be the limit of its corneal astigmatic correction (Bier 1957) (for further information see https://expertconsult.inkling.com/).

1946: Heinrich Wöhlk (Kiel, Germany), an engineer, became interested in contact lenses after his 8-D of hypermetropia was corrected by Professor Leopold Heine with Zeiss scleral lenses. Wöhlk’s first PMMA lens, the ‘Parabolar’, was similar in size to modern corneal lenses (Bier 1957). Wöhlk also developed a method of making PMMA lenses from raw material polymerised between quartz moulds (Bowden 2009).

1950: George Butterfield (Oregon, USA), an optometrist, produced a better-fitting corneal lens (than Tuohy’s) with progressively flatter peripheral curves, 9.50 mm diameter and 0.2 mm thick, to aid tear exchange.

1950: Kyoichi Tanaka (Nagoya, Japan) produced the first corneal lens made in Japan, hand carved from the PMMA windscreen of a Mitsubishi aircraft. Within 3 months not only had he designed corneal lenses that fitted and were comfortable, but he had also designed a machine to make 10 of them at a time. This was the start of what would become Menicon Contact Lenses.

1952: Frank Dickinson (St. Annes, England), Wilhelm Sohnges (Munich) and John C. Neil (Philadelphia, USA) cooperated with modifications to the corneal lens and its introduction into all three countries. It was lathe cut in the UK and either lathe cut or moulded in Germany. The monofocal lenses were fitted approximately 0.65 mm flatter than flattest K with a diameter of 9.5 mm correcting up to 4 D of corneal astigmatism. Dickinson’s wife, Muriel, coined the name ‘Microlens’. According to Dickinson, they were much better than the larger Tuohy lenses (Dickinson 1954)!

Both the Microlens and the Tuohy lens produced heavy apical touch, causing corneal erosions. However, the smaller, thinner Microlens covered less of the cornea, thus reducing corneal oedema.

1955: Norman Bier (Munich, Germany, then London, England) introduced his contour lens, a 9.50- diameter corneal lens with multiple back surface curves fitted in alignment with the cornea and a peripheral curve 1.25 mm wide to reduce the incidence of corneal erosions. Bier postulated that flatter corneas required greater peripheral curve flattening relative to the back optic zone radius (BOZR) than steeper corneas. He recommended fitting sets where peripheral flattening ranged from 0.3 mm for a BOZR of 7.3 mm to 0.7 mm for a BOZR of 8.5 mm. From about 1960, fitting sets used a standard peripheral flattening and later a constant edge lift for simplicity. Bier also laid down the principles of apical clearance fitting (Bier 1956a,b).

1955: John de Carle, an optometrist in London, developed a bifocal corneal lens of concentric design with a centre portion focused for distance correction, surrounded by the reading portion. This was based on an idea of ophthalmologist Frederick Williamson-Noble, who had observed unlikely distance and reading vision by a patient with central cataacts. Dallos had previously made scleral bifocal lenses from the same inspiration (Fig. 1.14) (de Carle, J., personal communication to Sabell, 2004). One had a central distance portion, the other a distance portion at the top and reading segment below. These had limited success due to difficulty with translation of the lens. The de Carle corneal version was more successful.

Between 1960 and 1970 corneal lenses continued to develop. Narrower intermediate and peripheral zones in multicurve lenses led to numerous variations of back surface designs: aspheric corneal lenses with tangential conic peripherals (Thomas 1968, Stek 1969), continuous offset biconvex lenses (Ruben 1966, Nissel 1967), lathe-cut continuous aspheric lenses (Nissel 1968) and the ‘Kelvin continuous curve’ lens designed by Raymond Kelvin Watson. Lenses could be fenestrated to minimise central corneal oedema, truncated in weighted prism ballasted cases or back or front surface toric. The quality of vision from PMMA corneal lenses generally surpassed that of soft lenses, which were starting to become available, but comfort was limited and corneal hypoxia common.

### Rigid Gas-Permeable Materials

1970: Titmus Eurocon of Germany launched the Persecon GP lens made from CAB with an elliptical back surface (personal communications with Peter Höfer). This was the first
material available that would transmit a small amount of oxygen.

1971: **Leonard Seidner**, an optometrist with Polymer Optics laboratories, together with his brother Joe, an engineer, commissioned Norman Gaylord, a polymer chemist, to produce a new material. The ‘Gaylord patent’ was awarded in 1974 for the first silicone/acrylate rigid gas-permeable material.

1979: **Polycon**. The first commercially successful RGP lens was designed by Donald Korb to fit in alignment with the cornea and to be ‘lid attached’ (personal communication with Don Korb).

1979: **CAB** was approved by the FDA in the USA. CAB contained 2% water when fully hydrated and had better in-eye wetting properties than PMMA and was comfortable. However, CAB was dimensionally unstable, could not be tinted, was difficult to manufacture and had poor oxygen permeability. Silicone acrylate materials were more gas-permeable than PMMA and CAB, but silicone is hydrophobic. Methylnmethacrylic acid was therefore added to improve hydrophilic qualities, but made the surface more prone to cracking. Fluorine, another hydrophilic component, was incorporated (Morris 1980) to allow a reduction in the content of methacrylic acid. Gas permeability and hydrophilic properties could thereby be maintained whilst surface problems were reduced. The addition of fluorine allowed other manufacturers to produce RGP materials without being restricted by the Gaylord patent.

1982: **Boston II Material** was granted FDA approval. Perry Rosenthal, an ophthalmologist from Harvard Medical School, Boston, together with Louis Mager, a physicist, and Joseph Salamone, professor of chemistry at the University of Massachusetts, Lowell, set up Polymer Technology in 1974 to investigate oxygen-permeable materials for contact lenses. In 1975 they began producing Boston RGP materials from a silicone/acrylate combination. Boston I was sold to a Canadian company, Boston II was developed and widely used, Boston III was researched but never released and Boston IV is still widely used today. Each development produced higher oxygen permeability. Polymer Technology was sold to Bausch & Lomb in 1983 (Bowden 2009).

The transition of wearers from PMMA to RGP materials was gradual. At first, standard PMMA lens designs were ordered in RGP materials. However, it was soon found that RGP lenses could be fitted in alignment with the central cornea with larger optic zones and reduced edge clearance, thus producing more comfortable, optically stable lenses. RGP lenses became available in spherical, toric, bitoric, bifocal, keratoconic and scleral designs.

1982: **Diffrax RGP bifocal lens** (Fig. 1.15) by Pilkington was a simultaneous-focus bifocal using a diffraction grating to create distance and reading foci. The gratings produced interferometry patterns with good resolution (Ruben 1989), similar to the technology used to produce holograms. The design worked well but needed to be fitted steep to avoid the diffraction grating imprinting the surface of the cornea. It was expensive to make, and the gratings tended to attract deposits.
1984: Brien Holden and George Mertz reported that oxygen demand of the cornea range from 7.5 to 21% and suggested that a level of 10% oxygen must be available to the cornea to prevent oedema.

1989: G&T Labs in Chicago received FDA approval for the Tangent Streak Bifocal (Fig. 1.15).

1989: Paul Rose of New Zealand launched the Rose K system for keratoconus.

1997: Wesley-Jessen PBH launched the Asphericon, a full back surface aspheric RGP lens with three different eccentricities, the only lens at the time to offer this (personal communication with Ron Loveridge).

Further materials and lens designs followed, with higher and higher Dk and better surface-wetting characteristics, allowing overnight wear of rigid lenses.

**Soft Lenses**

1952: Otto Wichterle (Prague, Czechoslovakia) was professor of chemistry and director of the Institute of Macromolecular Chemistry of the Czechoslovak Academy of Sciences (Fig. 1.16). He worked with his assistant, Drahoslav Lim, on a new, water-swellable gel for human prosthetics. They produced a cross-linking gel, 2-hydroxyethyl methacrylate (pHEMA). It was transparent, absorbed up to 40% water and exhibited good mechanical properties (Dreifus 1978).

1953: Wichterle thought HEMA could be suitable for contact lenses and gained his first soft lens patent.

1956: Walter Becker (Pittsburgh, USA), an optometrist, developed silicone elastomer lenses with very high oxygen transmission, but they did not wet well and tended to stick to the eye.

1957: Wichterle used closed polystyrene moulds to make about 100 soft lenses from HEMA. These were not successful due to the edge damage when removed from the mould (Bowden 2009).

1961: Wichterle continued his experiments at home to transform hydrogels into a suitable shape for a contact lens. Using his son’s construction set he assembled the first prototype of a centrifugal casting device driven by a bicycle dynamo connected to a bell transformer. All the glasswork was blown by Otto. Production of the first wearable lenses, on Christmas afternoon 1961 at his kitchen table, was announced in New Scientist January 18, 1962 (Wichterle et al. 1961) (Fig. 1.17).

1964: Geltakt and SPOFA were the first production soft lenses by the Wichterle method manufactured by Protetika in Prague (Fig. 1.18). The lenses had a single aspheric back surface curve produced by spin casting, 10–13 mm in diameter. This was steeper than the cornea, but they conformed to shape, as the material was so flexible. The optical quality varied, as did the power and thickness, due to changes in humidity during manufacture. Corneal oedema often limited the wearing time to less than 8 hours, but they were popular because they were supplied free by the government. Some doubts started to emerge concerning the bacterial contamination of soft lenses (Larke & Sabell 1971).

In 1964 the Czech Academy of Sciences and Arts sold the patents to Robert J. Morrison, an optometrist from Harrisburg, USA. Patent lawyers Martin Pollak and Jerome Feldman, owners of the National Patent Development...
1967: Hydron Ltd (UK) saw the potential of the product and were involved in the transfer of Morrison’s rights to Bausch & Lomb (Bowden 2009).

1964: Kyoichi Tanaka of Menicon produced the first soft lenses made in Japan.

1965: Nissel and Morrison used buttons of dehydrated HEMA material to develop new lathe-cutting techniques so they could apply conventional back surface designs (Turner, 1964a,b). The Czech lenses were used internationally by institutes and hospitals experimenting with the new material.

1965: Allan Ison, a New York optometrist and owner of Frontier Contact Lenses, Buffalo, USA, set up Griffin Laboratory in Toronto, Canada, to develop a new lens outside the jurisdiction of the FDA. Working with Ken O’Driscoll, a polymer chemist from Waterloo University, Ontario, Canada, they produced a new hydrogel material called Bionite. It was a copolymer combining HEMA with a pyrrolidone ring, producing a higher water content than HEMA but a lower tensile strength. Initial lenses had problems with tearing, variability of fit and unreliable optics.

The FDA approved the lens as a therapeutic or bandage lens, but it was widely used elsewhere as the Griffin Naturalens for refractive errors. It was 15.5 mm in diameter, had 60% water content and was disinfected by soaking in 3% hydrogen peroxide followed by neutralisation with saline (Ison 1972). The Griffin lens was sold to American Optical and renamed Softcon; it was subsequently sold to CIBA Vision and became the basis for their Focus and NewVues lenses.

1966: Seymour Marco, Don Brucker and Dave Ewell in the USA made their own soft lens materials and lenses, one being etaficon A, which was later used by Johnson & Johnson in their Acuvue range (Bowden 2009).

1967: Hydron Ltd (UK) was formed jointly by the NPDC and Smith & Nephew Associated Co. Ltd, to investigate other products made from Hydron (the registered name for poly-HEMA). These included nail extensions, antimariengi paint, hull coatings, stoma dressings, burns dressings, artificial blood vessels, stents and many more.

1968: The US Government decided that soft lenses should be regarded as a drug, thus needing FDA approval before their general use. This required extensive premarket testing, toxicologic and clinical trials, regulatory procedures and extensive documentation, slowing the introduction of new designs and materials to the American market. The long, safe use of PMMA lenses allowed them to be exempt from these regulations. During this period, work was being carried out, both in America and the UK, on another type of soft lens material. Instead of HEMA, it contained a copolymer of methylmethacrylate (MMA) and had a pyrrolidone ring as the hydrophilic unit – MMA/PV (Morris 1980). The concentrations of the monomers could be altered, producing differing water contents, rigidity and swell rates.

1970: John de Carle began experiments on his kitchen stove developing a soft lens with a water content similar to that of the cornea to improve comfort and safety for extended wear. He founded Global Vision with Geoff Galley and named the lens PermaLens (HEMA/VP). The company was later bought by Cooper Laboratories, signalling the start of CooperVision. The water content was more than 70% for extended wear on healthy eyes, sometimes for 6 months or more without removal. John and his wife were always the first to trial any development of the lenses or material (de Carle 1983). The lenses were 11.5 mm in diameter, although 13.5 mm was available, fitted in alignment or slightly steeper than the cornea.

1970: Contact Lens Manufacturing (CLM) (UK) launched Sauflon lenses, a lathe-cut, 79%-water soft lens made from MMA/PV, invented by Donald Highgate and John Frankland, and Sauflon 85, available in the UK for extended wear and therapeutic use (www.eyetech.me.uk). CLM was founded in 1964 by optometrist David Chulow and science graduate Philip Cordrey to provide lenses for their contact lens-only practice set in three elegant townhouses in Earls Court, London (Highgate & Frankland personal communication).

1971: Bausch & Lomb (USA) were finally granted FDA approval to market spun-cast SofLenses as a lens, although they had originally wanted it classed as a drug.

1972: Dow Corning bought a silicone elastomer material from Breger Müller-Welt of Chicago and produced a flexible lens called SILCON. Silicone rubber is highly oxygen permeable, so normal levels of atmospheric oxygen reached the cornea. The lens surface was treated to improve its wettability, but this was prone to breaking down, and it suffered badly from surface deposits. In 1984 they sold the silicone elastomer licence to Bausch & Lomb.

1972: Hydrcon Lenses Ltd (a UK subsidiary of Hydron Ltd) started supplying lenses which were lathe cut from solid buttons of dehydrated pHMA. The optic zone diameter decreased as the power of the lens increased, and the initial lens was fitted 1 mm flatter than flattest K and 2 mm larger in diameter than the corneal diameter. The edge geometry remained constant: a 0.6 mm-wide peripheral curve of 12.25 mm radius cut onto the posterior surface, giving 0.18 mm edge thickness. Diameters ranged from 13.5–15.0 mm, although 14.0 and 14.5 mm were most common. The fitting set contained around 30 hydrated lenses in glass bottles with screw tops. After use the lenses were cleaned with 0.9% saline, replaced in their glass vials in fresh saline and heated to 90°C in a lens hygiene unit for at least 15 minutes (Hydrcon Fitting & Service Manual 1973).

1972: Titmus Eurocon began production of the Weicon pHMA lens. It was lathe cut with a spherical front surface and characteristic elliptical back surface with a choice of two back central optic radii: F (flat) and S (steep). In 1983 Titmus Eurocon was sold to Ciba Geigy.

1972: Peter Fanti (Hamburg, Germany) patented the thin zone stabilisation soft lens, later manufactured as the Weicon toric lens. This was dynamically stabilised using the blinking action to keep the lens oriented correctly.

1975: Duragel MMA/PV material was developed by IH Laboratories in the UK. It was a 75%-water-content material and was supplied as dehydrated buttons to many contact lens manufacturers to make their own branded lenses such as Scanlens 75.

Over the next few years, soft contact lenses became increasingly successful. Available as low (38%), medium (50–65%) or high (68–80%) water content, they were produced either by spin casting or lathe-cutting. Spin-cast lenses were limited in design, with the front surface being formed by the shape of the die, while the power and shape of the back surface depended upon the amount of material used, properties of that material (viscosity, etc.) and rate of revolution. These lenses could be mass produced, whereas lathe-cut lenses...
The History of Contact Lenses

1975: **Tom Shepherd (UK)** filed a patent application for cast-moulded soft lenses (Bowden 2009). A measured amount of lens material was injected into the space between two dies, with polymerisation taking place when the mould was full. Although costly to set up, no lens material was wasted, and lens production could be significantly speeded up. This method of manufacture eventually led to the production of disposable lenses.

1976: **Soft toric contact lenses** were approved by the FDA. These had been evolving for several years.

1977: **K L Rowley (Kingston upon Hull, England)** opened a specialist contact lens practice. He designed a truncated soft translational bifocal lens with prism ballast. In the same year Focus produced bifocals with either a translational or concentric design. Many small labs followed suit using older hard lens designs.

1978: **Hydrocurve soft toric** gained FDA approval. This was the first soft toric available in the USA. Hydron produced a 38%-water HEMA, lathe-cut, truncated, prism-ballasted toric lens called the ‘Rx toric’. It was a stable lens that could correct high degrees of oblique astigmatism. A major change was the design of the Hydron Z6 Toric, which had a centre thickness of 0.06 mm with no truncation. Modern lenses now are generally a combination of prism ballast and thin-zone technology with either a front or back toric surface.

1979: **Hydron Z6** marked the breakthrough of the simple three-lens fitting sets (from previous 20 or 30 lenses). The first thin (0.06 mm centre thickness) lathe-cut spherical lens, the iconic Hydron Z6, had three standard BOZR (8.4, 8.7 and 9.00) and one standard diameter (14 mm) (Hydron lenses fitting and service manual, 1973) (Fig. 1.19).

1980: **Geoff Galley (UK)** set up CV Labs to develop soft lens moulding. By exerting more pressure on the male and female parts of the mould during polymerisation, he solved the problem of producing good edges on moulded lenses.

1981: FDA approval was given for the use of extended-wear soft contact lenses to correct refractive errors. Non-powered therapeutic lenses had been approved for extended wear in 1971.

1982: **Danalens**. The first lens manufactured and marketed as a disposable lens, the Danalens was invented by Michael Bay, a Danish ophthalmologist (Fig. 1.20). Concerned about damage caused by extended-wear soft lenses, he decided to visit Scanlens in Sweden to see whether he could determine what the problem was. He decided that there must be a better way of making lenses, so he set up a small team who developed a new method of moulding lenses. Called the Stabilised Softlens Moulding system, the lens came out of the mould hydrated with a diluent to keep it soft, which was exchanged for saline before packaging. This produced more consistent lenses at a lower cost, allowing more regular disposal. Bay set up the MIA Lens Company (named after Michael, his wife Inga, and their daughter Annette) and tried various different wearing modalities, preferring weekly extended wear, but settled on 2 weeks of extended wear due to limitations in production. They were launched via Synoptic, a Danish optical chain, with people queuing around the block to get their hands, or eyes, on these new lenses. Bay also set up the regular supply route with monthly payments and regular rechecks (Bowden 2009).

1982: **Vistakon** was founded when Johnson & Johnson bought Frontier Contact Lenses (Florida, USA) from Seymour Marco and signalled their entry into the contact lens business.

1983: **Vistakon** bought the Stabilised Softlens Moulding system of Michael Bay.

1983: **Hydron Zero Toric**. First cast-moulded toric.

1984: **Bausch & Lomb’s Crescent soft bifocal lens**. A truncated, prism ballasted, translational, segmented lens.

1985: **The ALGES** (Automated Lens Generating System) soft lens was launched in the UK. This had a small central

1989: Ron Hamilton and Bill Seden (Livingston, Scotland) formed the Award company and developed their daily disposable Premier lens as part of the final packaging. Award was later bought by Bausch & Lomb, and Hamilton went on to found Daysoft. Amongst other innovations was using one part of the mould disposable Premier lenses that used a new moulding technique. The Acuvue lenses were launched as weekly extended-wear lenses. Later shown to stand up to the rigours of daily wear, the lenses were discarded after 2 weeks.

1987: Hydron launched the ‘Acuvue’ Disposalens (Fig. 1.21). Using their vast knowledge and resources from the pharmaceutical industry, they took the crude MIA lens and changed the material to etaficon A, which already had FDA approval, geared up production, improved quality and streamlined packaging. The Acuvue lenses were launched as weekly extended-wear lenses. Later shown to stand up to the rigours of daily wear, the lenses were discarded after 2 weeks.

1990: Bausch & LombOptima soft toric. This lens was spin cast slightly thicker than usual, and then one side was lathe cut.

1998: CIBA’s Night & Day and Bausch & Lomb’s Pure-Vision silicone hydrogel lenses (SiH) were test marketed. Unlike the old silicone elastomer lenses, silicone hydrogel lenses contain water (Night & Day 24%; PureVision 36%), which allows fluid and ions to pass through the material, in conjunction with better surface treatments, better moulding technology and disposability.

1999: Night & Day and Pure-Vision were launched for monthly continuous wear.

1999: vCJD. Variant Creutzfeldt–Jakob disease was recognised. The UK’s Department of Health and the General Optical Council guidelines stated: ‘As a general rule a contact lens should not be reused on another patient … except in special circumstances in which complex diagnostic lenses may need to be used in the management of patients’ (www.official-documents.co.uk). This restricted the reuse of trial fitting sets in the UK.

Enormous investment in equipment and advertising popularised the daily disposable contact lens. The logistics of 1-day disposable lenses are phenomenal, with each patient requiring approximately 730 lenses a year.

Other Lenses

1966: John de Carle awarded British patent 1,045,065 describing a contact lens constructed from a plastics material where the skirt is softer and more flexible than the central part of the lens. This flexible layer could be on the back, front or totally enclosing the lens. The central portion could be made of methyImethacrylate or ethyl acrylate or a copolymer of methyImethacrylate with ethyl acrylate, whereas the skirt could be made from a homopolymer of vinyl chloride, a copolymer of vinyl acetate or from a fluorinated copolymer of ethylene and propylene (de Carle personal communication).


1971: Magatini and Shibata, both Japanese, made a central rigid lens cemented to a soft lens to improve vision (Bowden 2009).

1971: H I Zeltzer (Boston, USA) was granted a US patent for X-Chrom lenses to help improve colour vision differentiation (Bowden 2009).

1974: Titmus Eurocon launched the Weicon Iris print and the Weicon Iris hand-painted soft lenses, the first cosmetic coloured soft lenses. The original painted lenses used opaque colours which gave a false look to the eye. As more paint was used, the lens became thicker, changing its fitting characteristics and producing a stiff, uneven lens.

John de Carle was one of the first to experiment with tinted lenses, having had the idea from a fluorescein-contaminated soft lens (de Carle, J., personal communication to Sabell, 2004). As an experiment, de Carle dropped vegetable dye into his wife’s eye while she was wearing a high-water-content lens. The lens absorbed the dye, producing a desirable colour, which changed during the day as the dye leached out. Subsequently, many of de Carle’s patients, and others, adopted this technique.

1977: Saturn Lens, a combination or hybrid lens, was manufactured by Precision-Cosmet with an RGP centre of 8 mm diameter bonded to a hydrogel soft skirt, giving a total diameter of 14.3 mm. More comfortable than corneal lenses and providing better vision than soft lenses for keratoconic eye, the Saturn lens was prone to splitting at the RGP–soft junction, especially as it dehydrated, and its oxygen transmissibility was low.

1984: Saturn II was an improvement on the initial design.

1986: Wesley-Jessen produced their first dot matrix–printed coloured lenses using both opaque and tinted dots and mixtures of collaret patterns. These allowed the eye’s natural colour to show, providing a natural depth of colour.

1987: Hydron produced a solid, opaque coloured lens, which produced an unnatural look.
1989: CIBAVision launched Spectrum Visitint soft lenses with a handling tint.
2005: Ultravision launched Kerasoft Durawave, designed by John Clamp, a soft lens for keratoconus and post grafts.
2005: SynergyEyes received FDA approval for their hybrid lenses designed to correct ±2 D with up to 6 D of astigmatism. The patented process HyperBond™ gave an exceptionally strong interface between the high-Dk RGP centre and low-water-content soft components.
2011: Triggerfish was launched by Sensimed in Switzerland. An SiH smart contact lens monitored the intraocular pressure over a period of time; it contained a microchip and electronic circuitry (see Chapter 27).
2014: Google embarked on a project to test the ability of a smart contact lens to detect and monitor the glucose level in the tears of diabetics.
2015: Air Optix Colours, the first SiH monthly coloured lens, was launched by CIBAVision.

Corneal topography and Orthokeratology

The development of orthokeratology is another example of great ideas awaiting the technology to catch up. Also known as Ortho-K, Corneal Refractive Therapy and Overnight Vision Correction, this is a method of changing the refractive power of the cornea by the application of a rigid contact lens. Nowadays it has become a very straightforward technique with a high degree of predictability. However, this has only been made possible by the ability to accurately measure the shape of the cornea both before and after treatment, high-transmissibility materials and accurate lathing.

1619: Christoph Scheiner (Swabia, Germany) first compared the size of reflections from the cornea to reflections from glass balls of known radius.
1769: Jesse Ramsden (Halifax, England) constructed the first keratometer, although Hermann von Helmholtz (Potsdam, Germany) improved on his design, producing keratometers much as we know them today.
1847: Henry Goode (Cambridge, England), a physician, inspired by the observations of George Biddell Airy on astigmatism, reported on the use of his keratoscope. Antonio Placido (Portugal) independently produced a similar device in 1880.
1888: Photinas Panas (Cephalonia, Greece, and Paris, France) reported on the work of Eugene Kalt, his young assistant, to the French Academy of Medicine. Kalt had fitted a patient with keratoconus with blown glass shells that compressed the cornea. Panas reported that ‘they were tolerated perfectly for many hours... The very thinned cornea moulds itself exactly to the lenses in their concavity and becomes, in fact, reshaped’.
1896: Allvar Gullstrand (Uppsala, Sweden), an ophthalmologist, developed many of the optical concepts of photokeratoscopy by describing the mathematical analysis and calculating the topography of the cornea before the advent of computers.
1930s: Zeiss developed the first commercial device for photokeratoscopy.
1950: Joseph Soper (USA) developed the topogometer. This was an attachment for the keratometer to determine curves of the cornea away from the optical cap (Power 2000).
1950s: Wesley-Jessen developed the Photo Electric Keratoscope (PEK). Townsly, Mandell and Jessen introduced this device around 1969.
1956: Robert Morrison (Harrischburg, USA) conducted a myopia control study with PMMA lenses: with 1000 teenagers fitted 1.50–2.50 D flatter than flattest K, he found there was no myopic progression (Bowden 2009).
1956: Newton Wesley (Oregon, USA) noticed that after several hours of contact lens wear, patients noticed a blurring of vision when they returned to their spectacles. He described this as ‘spectacle blur’, a flattening of the cornea (McQueen 2003).
1957: Frank Dickinson (St. Annes, England) commented on the use of microcorneal lenses in the reduction of the progression of myopia (Dickinson 1957).
1960s: Jesse and Wesley observed that when rigid contact lenses were fitted flat, the patient stopped becoming more myopic and could actually reverse his prescription over time. Many patients improved to the point where they no longer needed any corrective lenses and could see 6/6 (20/20) for short periods.
1962: George Jessen formalised his ideas for the ‘reduction, modification or elimination of visual defects by the programmed application of contact lenses’. He called this Orthofocus using the Cycon lens (Bowden 2009).
1962: Victor Chiquiar-Arias met with 15–16 practitioners in the USA, and the term orthokeratology was decided upon: ortho to straighten or change; kerato for cornea, and ology for science. The Society of Orthokeratology was formed the same year (Ruben and Guillon 1994).

The rationale was that if normally fitted lenses would change the cornea, why not do it on purpose to help the patient? Jessen was the principal innovator in this direction and wore a PMMA lens for 12 years, achieving up to 3 months lens-free using lenses as a night retainer, much like a dental device. The National Eye Research Council Foundation (NERF) sponsored four universities to study the effects of Ortho-K.
1964: Charles May and Stuart Grant, both US optometrists, published ‘Emmetropization through contact lenses’, one of the first articles on the subject. May used the PEK to measure the change in corneal curvature whilst developing his ideas of Ortho-K. Initially PMMA lenses were worn during the day to mould the cornea to a new, flatter shape. The effect was not well controlled, with only small power changes being achievable over several months.
2010: Jaume Paune Fabre (Barcelona, Spain), an optometrist, developed an Ortho-K lens to correct hypermetropia. Further work is being conducted by Pauline Cho, the CCLRU and many others on the use of Ortho-K in myopia control in young myopes. The development of Ortho-K still has a way to go.

For more on Ortho-K, see Section 8, History, available at: https://expertconsult.inling.com/ and also Chapter 19.

Summary

What does the future hold for contact lens wearers? Work progresses on antimicrobial lenses, lenses to change colour
Acknowledgements

Sadly during the writing of this chapter Tim Bowden passed away. Tim was a pioneer himself in researching contact lens history. He presented at many visionaries conferences and was awarded the OTTO Wichterle Gold Medal for his services to contactology by the Czech Contact lens society in 2012.

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