CHAPTER XXIV

The First Corneo-scleral Shells made from Synthetic Thermoplastic Materials

1 - Attempts and Discoveries

1.1 - First Attempts to Produce Contact Shells from Synthetic Materials

The first attempts to make contact shells from synthetic thermoplastic materials took place on the eve of World War I at the time when *Zeiss* and engineer *Albert Wigand* had registered in Germany an application for patents describing the manufacture of contact glasses made from Cellon and other celluloid-like materials. (1) The clinical trials for these shells that were molded on spherical matrices had been carried out at the Jena and Halle Eye Clinics. The results were disastrous because of the inadequacy of the shell geometry and the instability of the celluloid which, when contacted by tears, liberated camphorated derivatives. This failure affected research development at *Zeiss* resulting in loss of interest and mistrust in regard to plastics. Meanwhile, during the same era, *Dudragne* had carried out in France other trials of synthetic products. (2)

1.2 - Janislav and Victor Teissler's Celluloid Corneo-scleral Shells (1937)

At the time of the 1937 World Congress of Ophthalmology held in Cairo, the ophthalmologist *Janislav Teissler* reported clinical trials carried out at the Prague Ophthalmological Clinic during the previous year, in which contact shells made from Cellon, Celluloïd and Plexiglass were used. (3) These shells had been manufactured using hot molds under pressure at the Institute of Medical Physics at Bratislava, of which *Janislav*'s father, the Professor *Victor Teissler*, was director:

"*The equipment used for the manufacture of celluloid prostheses consists of a hollow metal cylinder of 5 cm diameter. Two concave metallic molds are placed in the bottom of this cylinder, one corresponding to the shape of the cornea, the other to the shape of the sclera. These molds can be changed or combined as desired, and, in the cylinder head, one can create for any prosthesis the desired radius of curvature A piston moves inside the cylinder, onto which one can construct the convex shape in any similar manner. Into the bottom of the cylinder, between the molds, one places a celluloid sheet of 0.2 mm thickness and the cylinder is thus hermetically sealed. The sealed cylinder is submerged in water at 80°C for five minutes and secured by a vise. The cylinder is cooled. Using scissors, the prosthesis is fashioned to a suitable form and the edges are rounded off. The whole procedure takes fifteen minutes*." (4)

The assessment of the clinical studies performed by *Janislav Teissler* is highly optimistic. He quotes the case of a patient "who did not himself realize that he had a prosthesis in his eye":

"*I then invited the patient to go and have a walk and to return as soon as he felt any pain or if he saw less clearly. Often, patients only came back in the evening to inform me that they felt nothing abnormal in their eyes, that they had good vision and that they were able to sleep through the whole night wearing the prosthesis. For the first time, they had the prosthesis in the eye for ten hours continuously and, when the eyes were examined, there were no traces of irritation.*" (5)

In the following years, two additional publications provided more details of the manufacture, fitting and tolerance of these shells. For manufacture in the laboratory of *Victor Teissler* at the Bratislava Institute of Medical Physics, the authors indicated that the celluloid sheets had a thickness of between 0.125 mm and 3.0 mm and were coated with paraffin oil before being placed between the two molds. They acknowledged that the celluloid shells resembled the contact shells of *Zeiss*, but had neither their optical quality nor their transparency. Moreover their surfaces were often cracked. Trials made with the German Plexiglas were more promising whereas those made with the French product Nidrosa were disappointing. (6)

For the fittings at the Prague Ophthalmological Clinic, *Janislav Teissler* bases these on slit-lamp observation of the scleral part of the contact lens. In the presence of corneal edema and eye discomfort on blinking, he increases the radius of curvature. With the occurrence of later discomfort resulting from vascular compression, he reduces the radius. Optical correction is obtained from the precorneal lachrymal meniscus. The fitting of high myopias is impracticable. The shape of the shells changes slightly a few days after their manufacture. Consequently, one should allow a certain time interval before using them. Celluloid contact shells have the advantage of some flexibility and elasticity, because celluloid softens at body temperature, becomes more malleable and adapts itself to the shape of the sclera. Some patients are able to wear their contact shells for up to 10 hours without any irritations or symptoms. Shells with low quality optics can also be used for the prevention of symblepharon in patients with chemical burns or for radiological investigation after incorporation of lead or platinum markers into the shell.

1.3 - The Introduction of PMMA

The situation evolved in 1936 after the marketing of polymethylmethacrylate and vinylpolyacetate by the firm *Roehm & Haas* in Philadelphia and Darmstadt. The German chemist *Otto Roehm* had discovered pmma in 1927 and had joined *Otto Haas* as associate in order to exploit manufacturing patents. Marketed in plaques in 1934 and in granulated form in 1937, manufacturing licenses were granted to chemical firms worldwide. During World War II, the initial company became divided into two separate companies: *Röhm Chemie* (Germany) and *Rohm and Haas* in the United States. Pmma was marketed under different registered names, Plexiglass, Plexiglas, Perspex, Lucite, Oroglas, Altuglas, Transacryl, etc.

The first pmma products did not correspond exactly with the specific requirements for contact lenses. However, quality rapidly improved. Optically comparable to glass, pmma is decidedly lighter. It can be molded, ground, polished and refinished. It is relatively rigid, practically unbreakable and can be repolished. The manufacture of pmma contact shells is more simplified compared to when glass is used. Plastic can be shaped and reshaped at low temperature, scraped, drilled, buffed, routed and polished. Its reduced thickness makes it lighter and lessens any foreign body sensation in the eye. Its great disadvantage resides in its impermeability to oxygen. The latter concept was still unknown to users of that era. Pmma was criticized, above all as it was liable to become scratched and could be damaged by certain solvents, notably acetone and nail varnish.

The *Zeiss* Company dominated the European continental contact lens market and their engineers remained faithful to as glass, which they considered to be the best optical material. In 1941, *Sattler*, while giving an assessment of his experiences of contact lens fitting over 25 years, was critical of pmma contact shells because of their greater liability to scratches. These caused conjunctival irritation. His opinion was shared by *Ferdinand Fertsch* (*Zeiss* spokesperson) who, in 1942, was very skeptical regarding overoptimistic publications on pmma contact shells. His conclusions remained in favor of glass as the preferred material:

"*At the present time, it cannot be firmly stated that a contact shell made from artificially produced resin is better tolerated than a contact shell made from glass. First of all, it is still true, as stated, that one can have success as well from a glass contact shell as with one made from artificial resin*." (7)

In his publication, *Fertsch* cites the names of European researchers who were using pmma: three physicians are mentioned: *Thier* at the Utrecht Ophthalmology Clinic, *Fritz* in Brussels and *Istvan von Györrfy* at the Budapest Ophthalmology Clinic. Also *Dudragne*, an optician in France, was mentioned. However, no publication from English-speaking countries was quoted.

2 - Combined Corneo-scleral Contact Shells

Throughout the first half of the 20th Century, contact lens fitters were waiting for the ideal contact shells that would combine a ground corneal part of optical quality (like the contact shells made by *Zeiss*), with a haptic part conforming to the scleral ocular profile. The haptic support of the available shells was, in effect, disappointing because of either the 'perfect sphericity' of the ground *Zeiss* contact shells or the subjective approximation of the blown shells of *Müller-Wiesbaden*.

2.1 - The Patents

Author	*Country*	*Filed*	*Patent #*
Möller E.	D	02.05.1930	128,595
Wilhelm B.L.	US	01.06.1928	1,782,331
	US	14.05.1931	1,929,228
Feinbloom W.	US	21.08.1936	2,129,305
Bausch&Lomb	GB	06.06.1937	493,366
Row D.	US	29.05.1936	2,117,770
Dannheim H.	D	24.03.1937	701,970

Table 24-1
Key patents for combined corneo-scleral contact lenses with a glass corneal portion and a thermoplastic haptic.

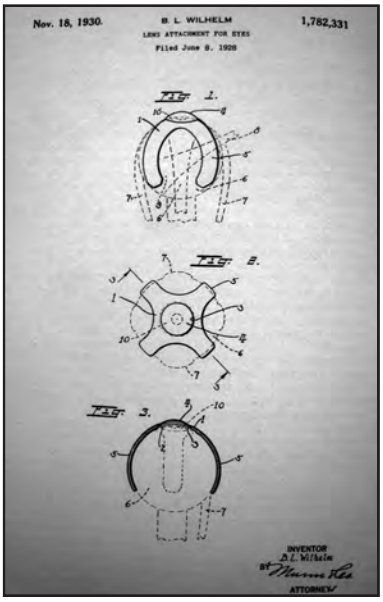


Figure 24-1
The first Wilhelm Patent (1928).
Illustration of the patent 'Lens Attachment for Eyes' assigned to B.L.Wilhelm for a device placed upon the eyeball, constructed from transparent flexible material which obviates the need for eyeglasses.
(US Patent # 1,782,331)

2.1.1 - Patents B.L. Wilhelm (1928, 1931)

The concept of a contact shell with a supple flexible haptic combined with a rigid optical part had been described from 1928 in a patent registered by *Benjamin L. Wilhelm* (Chicago). According to this patent, a rigid lens was fixed in a flexible structure composed of four curved and supple straps which required placement between the extrinsic ocular (recti) muscles. Three years later, he was to register another patent for 'a lens and cup formed of flexible material adapted to contact uniformly with the eyeball and holding said lens.' [(8)]

2.1.2 - Patent E. Möller (1930)

In 1930, *Ernst Möller* registered a patent in Germany for 'a combined contact-spectacle glass' (Kombiniertes Kontaktbrillenglas). This had a glass optical part and a peripheral part in an unbreakable material.[(9)]

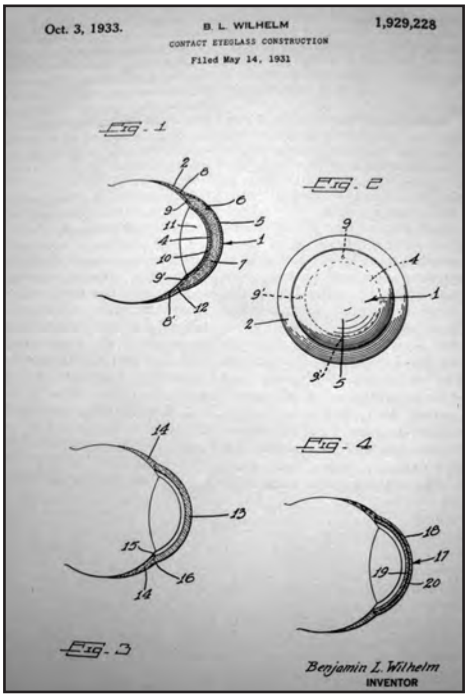


Figure 24-2
The second Wilhelm Patent (1931).*Illustration reprinted from patent, 'Contact Eyeglass Construction', assigned to B.L. Wilhelm for construction of a lens and cup-shaped lens container, which is adapted to be attached to the eyeball.*
(US Patent # 1,929,228)

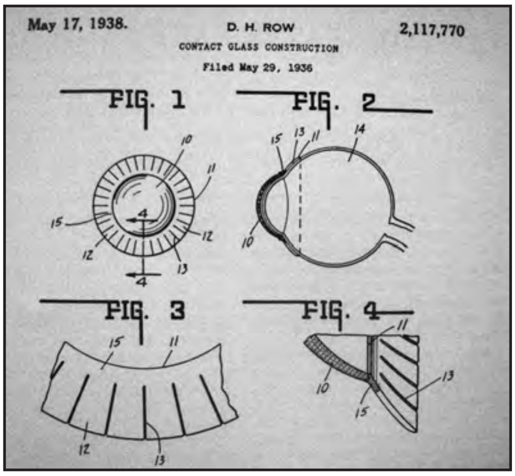


Figure 24-3
Row's Patent (1936). *Illustrations taken from patent 'Contact Lens Construction' assigned to Dunn Hamilton Row of Indianapolis, Indiana for construction of contact lens comprising a glass corneal lens and a flexible scleral rim being secured to each other at their adjacent edges. The scleral rim is provided with a plurality of radial slots forming separate flexible portions movable relative to each other for conforming to variations in curvature of the eyeball.*
(US Patent # 2,117.770)

2.1.3 - Patent D.H. Row (1936)

For 1936, one notes a patent registered by *Dunn Hamilton Row* (Indianapolis) for a contact shell associating a 'glass contact lens and a flexible scleral rim'.(10)

2.1.4 - Patents W. Feinbloom (1936 - 1938)

Then, *William Feinbloom* (NYC) registered several patents for combined contact lenses, each with a ground glass polished optic, blended into a scleral part of synthetic material obtained by molding from a living eye and of which the edge was ground and polished. These patents were supplemented in the following years by other patents specifying the plastics used and how to combine the plastic scleral rim with the glass corneal part. (11)

Figure 24-4
The Dannheim Patent (1937). *Illustration from the patent of Helmut Dannheim M.D. for an adherent glass consisting of a scleral part made from flexible synthetic material and a corrective contact lens made either from glass or hard transparent synthetic resin, fixed in the scleral part by a screw ring.* (German Patent # 701,970)

2.1.5 - Patent H. Dannheim (1937)

In 1937, the German ophthalmologist, *Helmut Dannheim* (Stuttgart), registered a patent for a combined lens comprising a 'scleral part made of flexible organic plastic material connected to a detachable glass corrective lens or other transparent rigid plastic material'. (12)

2.1.6 - Patent American Optical (R.J. Beitel Jr., 1938)

In January 1938, *Robert J. Beitel Jr.*, assignor to American Optical Co., registered a patent for a combined contact lens that comprised a rigid corneal part and a scleral part capable of flexibility. One part was made from "*synthetic resin of polymerized compound which is transparent and non-frangible of which there are now several types on the commercial market*." The other part was formed from a "*rubber or flexible material with means to hold the central lens portion. (...) This scleral portion is a separate piece, having means for engaging and holding the edge of the corneal portion. (...) This part may be flexible or resilient rubber or other suitable material adapted to rest on the sclera of the eye and hold the central portion of the lens in place.*" (13)

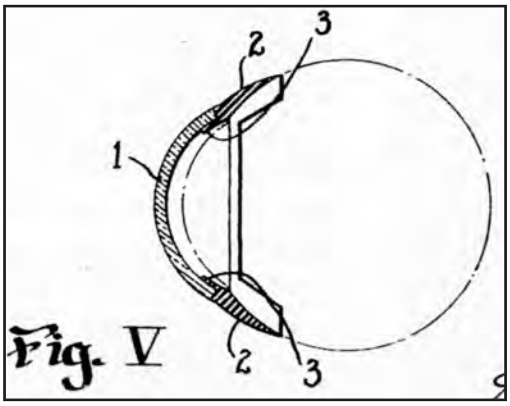


Figure 24-5
The Beitel Patent (1938).
Illustration of the combined corneo-scleral contact lens proposed by Robert J. Beitel. In Figure V, the scleral portion '2' is shown as a separate piece, having means '3' for engaging and holding the edge of the scleral portion '1'. (US Patent # 2,247,629)

2.1.7 - Patent American Optical (L.L. Gagnon & H.R. Moulton, 1938)

In the same year, *Louis L. Gagnon* & *Harold R. Moulton*, assignors to American Optical, registered a patent for a contact shell "*comprising a central visual portion of transparent lens medium and a surrounding supporting portion of (...) a relatively thin layer of synthetic resinous material having the characteristics of polymeric methyl methacrylate*." (14)

2.1.8 - Other Patents (1937-1946)

In the next few years and after pmma had been marketed, other patent depositions for combined contact lenses followed quickly. Among the most often referred to were those of *Edgar D. Til-*

lyer (AO) in 1937, of *Georges Nissel* and *William Peter Lambda* in 1945 for a 'glass corneal portion between two laminations of plastic material' and of *Raymond-André Dudragne* in 1944, etc. (15) In 1946, *Arthur James Forknall* (Nottingham) registered a patent for a combined contact lens of which the construction envisaged a junction between the corneal part and the scleral rim permitting the interchange of the two elements:

”*The removable corneal segment is attached to the scleral portion by a new process which permits the corneal segment to be easily changed from the originally fitting plano to a corrective lens*.” (16)

However, except for the patents of *William Feinbloom*, the literature provides little information of either the practicality, or the use in clinical practice, of such combined contact shells. It must therefore be admitted that such were only proposals and their realization was not as practical as they appeared to their inventors. In other words, these devices never found long-term application.

2.2 - William Feinbloom’s Combined Contact Lenses

William Feinbloom, as pioneer of these contact lenses, was well prepared to bring them into practical reality as he had followed their evolution for many years. He had presented his first communication on contact lenses on 15th December 1930, and this was followed two years later by a more thorough assessment taking account of the most recent *Zeiss* contact shells. (17)
He seemed to have been the only person in the field to bring his ideas successfully into practice. Between 1936 and 1939, he registered several patents, describing a 'combined contact lens' with a glass optic ground, polished and blended in a scleral part of plastic obtained by molding from a living eye and of which the edge was ground and polished:

“*Making a contact lens having a central glass portion properly ground to the patient’s visual requirements, and a scleral section made of a plastic resin molded to the computed curves required*.” (18)

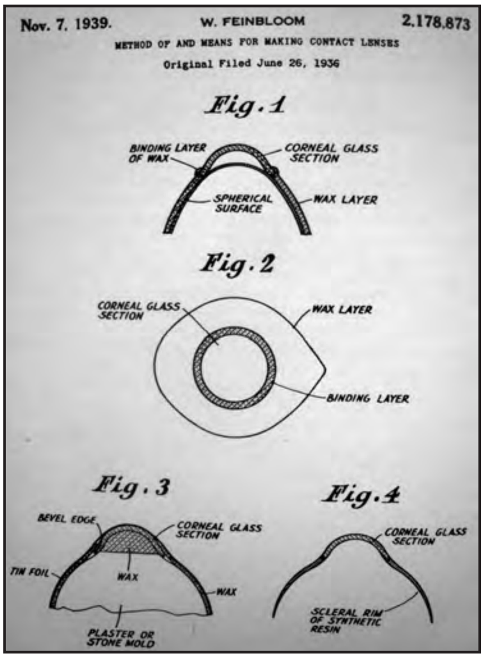
2.2.1 - The 'Semi-plastic' Contact Lens (1936)

In August 1936, *Feinbloom* presented a lecture entitled 'A Semi-Plastic Contact Lens' to the American Academy of Optometry. In this he described how the optic of ground polished glass was blended through 'vulcanization' into a scleral part obtained by molding from a living eye and of which the edge was ground and polished. (19) For molding the haptic part, he rejects the procedures using Negocoll and Dentocoll in favor of molding with dental wax limited to the scleral part:

“*A thin layer of wax is first pressed into the general form of the eye. In its center is placed a suitable corneal glass lens. The contour of this layer of wax is formed differently for the right and left eyes. (...) The impression contact lens is inserted under the lids. It is held in place by suction. The lids are allowed to close over the impression lens, (...) for approximately ten to fifteen minutes. During this time, the heat of the body, as well as the pressure of the lids, will mold the thin layer of wax accurately to conform to the surface of the eyeball. (...) At the end of the ten to fifteen minute periods, the eye is irrigated with ice water. This insures that the wax, which has already been conformed to the eyeball, will harden and not bend during removal from the eye (...) with a suction rubber nipple*.”

After being removed from the eye, placed in freezing water and then dried, the trial impression lens is filled with dental stone. Starting with this molding, *Feinbloom* makes two molds, between which and by means of a complicated process using a ‘wax model’, the resin periphery is molded and then vulcanized to the glass cornea:

“*The mold of the eye, with the glass corneal section in place, is covered with approximately 1 mm thickness of wax, to be known as the ‘wax model’. The wax model is invested in the lower half of a dental flask, and then tin-foiled. A female of the wax model is now formed in the upper half of the dental flask. The entire flask is then boiled for ten minutes to allow the wax to melt out. It then leaves a space between the male and female molds of the eye. The two halves of flask are separated. (...) The space between the upper and lower halves of the models is then filled with plastic resin. The flask is loosed and placed in the vulcanizer. The time and temperature of vulcanization is determined by the particular resin used, as well as the hardness and transparency desired. (...) The outer surface of the plastic contact lens is ground so as to leave the scleral portion*



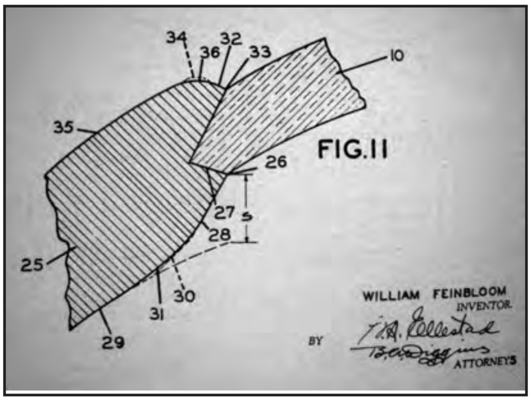


Figure 24-6
Feinbloom Patent (1936).

Top - *Illustrations extracted from the patent 'Contact Lens with a Scleral Rim of Synthetic Resin' assigned to William Feinbloom for a method for manufacturing a mold of the eye and making the scleral rim of the contact lens fit the mold of the individual eyeball itself. The lens will be separated from the eyeball by a molecular layer of tears. The scleral rim is of a synthetic resin conforming to the shape of the white of the eyeball.* (US Patent # 2,129,304)

Below - *Illustrations extracted from the Patent 'Contact Lens' assigned to William Feinbloom for, inter alia, a contact lens comprising a glass corneal lens and a scleral rim portion of moldable synthetic resin, having its surface of contact formed with projections and depressions, so that only the projections contact the sclera and the area of contact is thus reduced.* (US Patent # 2,129,305)

at the desired thickness of approximately ½ mm. Any resin that adheres to the inner or outer surface of the glass is easily removed by grinding."

Finally, the external surface and the edges are polished in order to remove the barbs and irregularities from the resin:

"*The inner surface of the lens will already be smooth. The outer surface as well as the edges must be carefully polished in order to insure a smooth surface*."

Feinbloom concludes:

"*We use a glass corneal center and bind it with a plastic resin. This resin, when vulcanized, develops the properties of being transparent, hard, acid-resisting and capable of high polish, thus insuring a smooth surface. The complete vulcanized lens is 0.5 mm thick throughout. The edges and surface are ground and polished*."

Feinbloom had the good fortune to find in *Georges S. Weith*, Chief of Research Division of the Bakelite Corporation of America, an attentive collaborator who allowed him to carry out numerous trials using diverse plastic materials:

"*It was through his industrious efforts that plastic resin having suitable physical properties was finally developed.*"

The patents of *Feinbloom* cite certain of the materials used. In 1936 "*Luxene or other suitable synthetic resins*", then in 1938 different plastic materials:

"*The polyvinyl resin sold under the trade name Vylon, the pyroxylin resin sold under the trade name Tepperite and the polyacrylate resin sold under the trade name Kallodent*." [20]

He notes also that the "*urea resins such as those sold under the trade name Plaskon and Beetle, are satisfactory from a molding standpoint, but in their present form, the urea odor makes them undesirable*." Finally *Feinbloom* describes his preference for Bakelite XR-10247:

"*I prefer to use a thermosetting resin of the phenol formaldehyde type. One resin of this type which has been tried and found satisfactory, is the resin sold by the Bakelite Corporation under the identification number XR-10247. This resin has all of the desired properties and its ease of molding makes it preferable*."

These trials also aroused the interest of *Bausch and Lomb* with whom he had entered into discussions and who were associated with his research projects and patents for some time. [21] Taking into account that ocular molding required a local anesthetic, of which the use was reserved to physicians only, *Feinbloom* collaborated for several years with physicians. In order to circumvent this obstacle, he proceeded to moldings without anesthesia after 1941 by covering the cornea with a 'glass contact lens' that widely bridged over the sensitive areas. [22] After 1939, he used preformed contact shells for eyes with commonly occurring geometry. *Müller-Welt* contact shells with plastic toric haptics and glass corneas inspired these. The 'T-series' that was usable in most cases had a posterior optical radius of curvature of 8.50 mm and required a corneal clearance of around 0.50 mm following good fitting of the scleral part. The trial case of Series T contained 64 shells: 8 with spherical haptics and 56 with toric haptics. The 'U-series' was recommended for keratoconus patients and difficult cases. It had clearance increased to 1.00 mm with a posterior radius of curvature of 7.50 mm. The haptic part was available both in spherical and toric forms. For fitting, *Feinbloom* described a 'trial case approximation'. For these contact shells with opaque haptic, monitoring of scleral fitting was particularly challenging as it was necessary to choose the best horizontal and vertical meridians allowing good corneal and limbal clearance.
However, *Feinbloom*'s combined contact shells of whatever model were fragile and the junction between the glass cornea and the sclera made from synthetic material did not have the expected stability.

2.2.2 - The Evidence from Mostyn-Brown (1936)

We possess especially interesting evidence from *Maurice Mostyn-Brown* who visited *Feinbloom* in the summer of 1936 while he was on a tour of inspection to America on behalf of the *C. D. Keeler Company* of London. His description of the 'Feinbloom method' is both objective and fascinating:

"*He had about five patients when I went in and I subsequently learned that the young lady who opened the door to me was from Texas and had been wearing contact lenses since about 9 o'clock in the morning and, until it was pointed out to me, I was totally unconscious of the fact. This young lady wore the lenses on this day for seven hours continuously before she appreciated any real discomfort*." [23]

He indicates the collaboration between *Feinbloom* and *Bausch & Lomb*, but also the source of conflict by reason of the divergent interests between *Feinbloom*'s personalized method of fitting and the desire of *Bausch & Lomb* for mass production:

"*I understand that Feinbloom holds patents on this lens but unfortunately I cannot ascertain whether it is on the method of molding the application of glass to a plastic scleral curve or what, but he has tied up with Bausch & Lomb. They naturally look on this from the commercial point of view and do feel that the lenses should be offered only in fixed dimensions as designed, whereas Feinbloom does feel that in most cases moulding is essential*."

The method of approach and the principle of *Feinbloom*'s technique are unique and original:

"*Feinbloom has assumed and I have medical confirmation of this that in most cases the eyeball is not spherical. Therefore, for the purpose of a fixed fitting set (...), a toric contact lens should be used. The meridian difference between these two curves can be varied according to actual clinical findings. The other important* *principle is in the optical portion of the lens only [and which] is made of glass. This is similar in contour to the Zeiss corneal portion and is 12 ½ mm in diameter. The lens portion is then molded into a plastic material, which makes the scleral portion. (...) Feinbloom claims to have found a material which will not react to the lachrymal discharge*."

Mostyn-Brown also describes the standard fitting procedure for contact shells:

"*The method of procedure is first of all to have made up by Bausch & Lomb a series of positive and negative toric (scleral) casts of the complete contact lens. (...) [This is] as low as 10.5 to 13 in the horizontal meridian and from 10.5 to 13 on any of these lenses in the vertical meridian. The trial lenses themselves are actually stored in a case of these positive molds. When treating the patient, Feinbloom first of all selects lenses from the trial case, which he fits into the eye always without anaesthetic. By process of elimination, a combination of horizontal and vertical meridians powers are arrived at, which will best suit the patient. Having found a lens which is suitable, he then either keeps the patient around the office or sends him away to wear it for three or four hours to check their tolerance. (...) If the patient is uncomfortable, it cannot fit. In these cases he usually decides to make a mould*."

For molding, *Feinbloom* no longer uses Negocoll because it takes too long to solidify and become rigid. He has however developed a technique using dental wax:
"*When with his trial contact lenses he has determined the dimensions of the scleral curves (...) Feinbloom takes the positive part of the cast on which the lens is stored and proceeds with his warm hand to mold an ordinary thin sheet of dental wax over this. With the aid of a pair of dividers, a hole is cut out of the center and one of the optical glasses of raised corneal portion is inserted. This is sealed in position with pink wax and a hot spatula. (...) Then, with a penknife, he trims the rough off the outside edge of the wax. (...) The wax-moulded contact lens is removed and placed in ice water with plenty of ice in it, to keep the wax rigid. (...) A 2% solution of Butyn is administered to the patient's eye (...). The wax lens is then placed in the patient's eye in the usual manner and the eye is closed. Ten or fifteen minutes are sufficient to soften the wax and allow it to assume the exact contours of the cornea to which it is fitted. (...) A little manipulation of the hand on the closed lid serves to relieve any apparent pressure. The contact lens is then removed from the eye very carefully and immediately returned to ice water.*"

He then makes a positive in plaster:

"*We now have a perfect positive more quickly produced than by the Dallos method which is suitable for making up a moulded contact lens*."

For the manufacturing of molded contact shells, *Feinbloom* first prepares, in addition to the positive, a plaster negative cast and then:

"*These positive and negative casts are either lined with tinfoil or silver paper, because the plastic moulding material must be vulcanized between metal only. The material is then placed in between the casts and these are squeezed together in a special device made of brass and vulcanized in a heat chamber.*"

Mostyn-Brown admits that, at the time of his

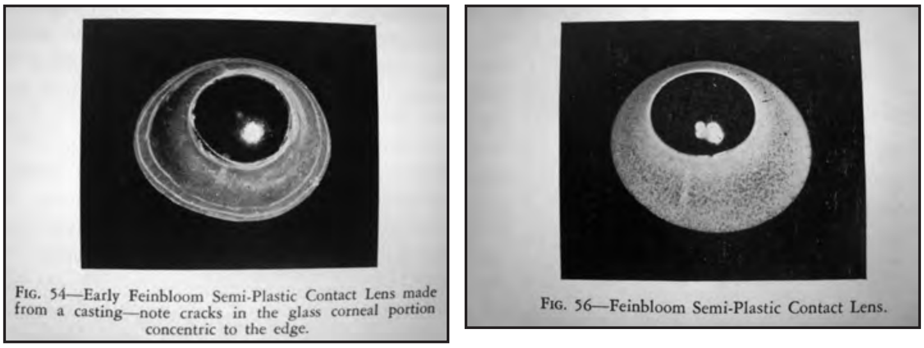


Figure 24-7
Obrig's appreciation on Feinbloom's Semi-Plastic Contact Lens.

Left - *Early Feinbloom 'Semi-Plastic' Contact Lens. According to Obrig, the edges of the glass corneal portion cracked, more or less concentrically with the bezel edge, most likely due to a difference in the coefficients of expansion and contraction of the two materials, or possibly from warping of the plastic rim.* (Obrig 1942)

Right - *According to Obrig, the next Feinbloom combined contact lens consisted of a transparent glass corneal portion combined with a whitish nearly opaque scleral band 0.5 mm thick and approximately 24 mm round in overall size. In Obrig's opinion, this lens proved as unsatisfactory as its predecessor.* (Obrig 1942) visit, *Feinbloom* did not reveal all the details to him:

"*I don't know whether it is steam direct or whether only hot air is used. The other procedure about which I am not sure is the method in which the glass is introduced into the subsequent plastic mould.*"

This unedited evidence in 1936 thus illustrates in an original way the situation regarding *Feinbloom*'s activities in NYC.

2.2.3 - Obrig's Appreciation (1942)

Several years later, *Theodor Obrig* gives a more guarded appreciation of the activities of his rival:

"*The plastics available during this experimental period would not remain colorless and clear. (...) The edges of the glass corneal portion cracked, more or less concentric to the bevel edge, due most likely to a difference in the coefficient of expansion and contraction of two materials, or possibly from the wrapping of the plastic rim. (...) With the rapid development of the modern plastic and efficient methods of molding these plastics, Feinbloom refined and improved both the form and the binding of the two elements of his lens*." [24]

According to *Obrig*:

"*The lens consists of a transparent glass corneal portion, combined with a whitish nearly opaque scleral band 0.3 mm thick and approximately 24 mm round in overall size. The corneal portion is 24 mm in diameter and decentered nasally, so that the temporal portion of the scleral band is 10 mm wide, while the nasal portion is 7 mm wide*."

2.2.4 - Feinbloom's Abandonment of Combined Contact Shells (1945)

Preformed shells made entirely from plastic soon challenged *Feinbloom*'s toric haptic combined shells. These were *Müller-Welt*, *Kollmorgen Toric* and *Obrig* Sclero-Fit.
In 1945, *Feinbloom* discontinued marketing in favor of a new series entirely of plastic material. This new series kept the characteristics of the preceding lenses that had asymmetric haptics and were suitable for the majority of fittings, notably Tangent Cone or Feincone Preformed Lens. [25]

3 - The First Pmma Corneo-scleral Contact Shells (1937-1940)

3.1 - Honors and Priorities

Had *Zeiss* remained faithful to glass, there would not have been, by the same token, as many European or American researchers and laboratories for custom manufacture using pmma. This applied from the moment pmma was marketed for the manufacture of corneo-scleral contact shells.
The priority of this utilization gave rise to numerous retrospective claims, favored by the lack of communication between Continental Europe and the English-speaking world during World War II (1939-1945). Thus it is common to attribute the first use of pmma for the manufacture of contact shells to *Mullen* and *Obrig* in the America, taking into account that *Obrig*'s book appeared in 1942. This volume dedicated 18 pages to the history of their own researches on plastic contact lenses for which they claimed the discovery. This author, however, omitted to mention the works of any European researchers, notably *Györffy* in Budapest, *Thier* in Utrecht, *Fritz* in Brussels and *Dixey* in the British Isles. According to *Györffy*, it would be difficult to determine the exact chronology of the priority of the first pmma contact lens, while *Fertsch*, in his first assessment of plastic contact shells, restricts himself to describing their evolution in Continental Europe and, aside from the citation of patents, is apparently unaware, in his turn, of the American researches in the field. [26]

Author	Country	Date	Patent #	Peculiarity
Wigand A. (Zeiss)	D	1918	368,770	Celluloid, Zelon
I.G. Farbenindustrie	D	09.04.1936	1,377,416	Organic polymerization products
I.G. Farbenindustrie	F	24.11.1936	805,592	Adherent glasses and contact shells
I.G. Farbenindustrie	GB	18.11.1937	490,397	Adherent glasses and contact shells

Table 24-2
Key patents for corneo-scleral contact lenses entirely made of synthetic thermoplastic resins.

Author	Country	Date	Reference	Peculiarity
Teissler J. & V.	CZ	1937	Ophth. Congress Kairo	Celluloïd, CAB
Thier PFX.	NL	10.12.1938	Utrecht	Synthetic resins
Mullen & Obrig	US	1938	According to Mandel	PMMA
Fritz A.	B	30.04.1939	Belgian Ophth. Soc.	Ocular mouldings
Györrfy Iv.	H	07.10.1939	Hungarian Ophth. Soc.	Plexiglas

Table 24-3
First publications and presentations on corneo-scleral contact lenses entirely made of synthetic thermoplastic resins (1937-1939).

3.2 - The Patents describing Contact Shells made entirely from Polymerized Materials (1936, 1937)

The first patents describing contact shells made entirely from polymerized plastic materials were registered starting in 1935 by *IG Farbenindustrie* in Germany, France and in the years to follow in practically all other countries throughout the world, for 'adhering glasses and contact shells' (Verres adhérents et Coquilles de contact, Haftgläser und Kontaktschalen). The patents of *IG Farben* covered the manufacturing rights for contact lenses made by using polymerization products, optically empty and stable in the light, made of non-saturated organic compounds and already foresaw certain other possibilities, e.g. injection or molding, that were only exploited some years later. According to the claims, the techniques of manufacture of the contact lenses by injection or molding under pressure between two matrices were remarkable for their ease of operation and low cost compared with grinding, molding and polishing as used previously:

“*Contrary to that, the product of polymerization permits the manufacture of completely adherent glasses by means of a simple molding operation under pressure or injection. Grinding is excluded. The two surfaces of the adherent lens, both contact and external surface can be obtained in one simple molding operation under pressure or by injection between a matrix that has the shape of the anterior surface of the eyeball on one surface and an embossing outer stamp corresponding to the desired refractive power on the other. (...)*
The simplicity and the low cost of manufacture by pressurized molding or an injection process allows the provision of an extensive choice of contact glasses available for stock. This is in marked contrast to the high cost of molded and ground contact glasses.
The polymerization products allow individual fitting of the adherent glasses. This is because a matrix in the shape of a positive model of the eyeball is provided from the eye by molding.” (27)

The formulation 'Adherent contact glasses and shells derived from polymerization products that included optical properties and transparent to light' consequently covered numerous procedures involving inventors and developers of corneo-scleral contact lenses.
In the following years, one cites an English patent registered by *Wingate* (1937) for an corneo-scleral bispheric lens in synthetic material that was obtained by heat molding. (28)

3.3 - Theodor Obrig and John Mullen (1938-1939)

The optician, *Theodor E. Obrig* was, before World War II, one of the most active importers, manufacturers, and fitters of contact lenses made from glass in America. He first employed *Zeiss* contact shells and then adapted the molding techniques of *Dallos* and *Stevens* to the manufacture of glass contact shells. He proposed the examination with fluorescein using cobalt blue light and then made an agreement with *Zeiss* for the production of glass contact shells that consisted essentially of a haptic derived from ocular moldings that he had carried out in his NYC office, but also equipped with *Zeiss* (Jena) ground optics. (29)

Before his collaboration with *Zeiss* had ended on the eve of World War II, *Obrig* had already developed an interest in lighter-than-glass plastic transparent materials. These were suited for molding of the haptic following the technique of ocular imprints that he employed. He only had to refine his procedure for grinding and polishing of the optical part. To achieve this aim, he became an associate of *John E. Mullen* in the short term. *Mullen* was an engineer and also a multi-talented inventor who had registered numerous patents for inventions. Shortsighted, himself, he followed various initiatives for visual correction with interest, particularly those of *Feinbloom*. He had invented, patented and manufactured a lathe for grinding his own bispheric corneo-scleral shell in an acrylate block. In 1938, he founded a laboratory in Worcester, Mass. where he produced acrylate bispheric contact shells that resembled the contact shells of *Heine-Zeiss*. He seems to have been the first individual not to use the molding procedure and to grind the shells in a block of pmma. His patents covered both grinding and polishing of corneo-scleral contact shells (cutting, grinding and lapping). When *Mullen* became an associate of *Obrig* with intent to found in Boston the *Mullen-Obrig Laboratories*, the partnership could use their equipment for grinding and polishing the optical zone with the haptic molding technique of *Obrig*. This allowed the development of corneo-scleral contact shells. These resembled the most recent generation of *Zeiss* shells with molded haptic. The partnership between *Mullen* and *Obrig* lasted for only a short time, however, and separation of the partners occurred in 1939. (30)

After this rupture, *Obrig* discontinued manufacture and after various episodes, including cooperative trials with *Bausch and Lomb*, he founded his own laboratory in 1940: the *Obrig Laboratories Inc.* of New York. He developed the 'All-Plastic Molded Contact Lens' for which he rationalized production aided by several employees, each specializing in one area of manufacture. His modest beginnings achieved rapid success enabling him to enlarge his staff and to take on *Philip L. Salvatori* as associate. The latter became *Obrig*'s specialist fitter. (31)

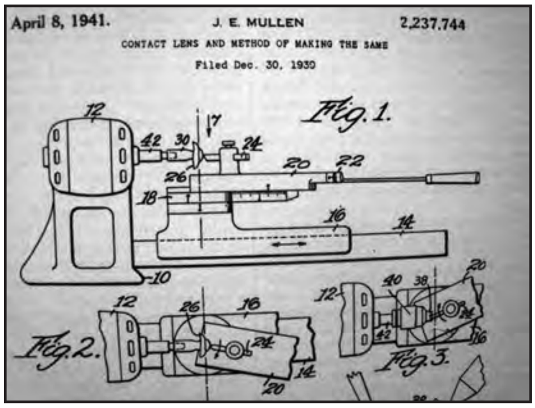


Figure 24-8
Patent of John Mullen (1939).
Illustrations extracted from the patent, 'Contact Lens and Method for Making the Same', assigned to John E. Mullen, for covering, inter alia, a method of making a plastic contact lens which comprises a radius-cutting machine with "two axes of rotation, the one on which the lens turns, and the other, the pivot about which, as a center, the turning tool swings." (US Patent 2,237,744)

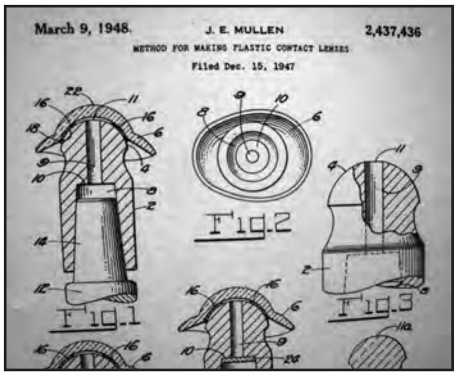


Figure 24-9
Patent of John Mullen (1947).
Illustrations extracted from the patent 'Method for Making Plastic Contact Lenses' assigned to John E. Mullen for covering, inter alia, the method of carrying out various operations such as machining, polishing and other operational procedures on a plastic contact lens having a corneal portion and a scleral portion.
(US Patent # 2,437,436)

3.4 - István von Györffy (1938-1944)

After the emigration of *Joseph Dallos* to London the contact lens laboratory of the Budapest Ophthalmological Clinic was confided in 1937 to a young physician by the name of *István von Györffy*. The latter assumed, with some difficulty, the technique of manufacture of contact lenses by molding, using glass. In the course of a trip to Germany, while visiting his sister in that country, he brought back several sheets of Plexiglass to Budapest, the existence of which he had learned about by only by chance. He succeeded in formatting his first contact shells made from organic resin using plaster molds and he fit his first patient, a female, in December 1938.


Aus der Universitäts-Augenklinik Budapest
(Direktor: Prof. Dr. Josef Imre)

Kontaktschalen aus Kunststoffen

Von Dr. **István von Györffy,** Assistenzarzt der Klinik

Mit meinem gegenwärtigen Bericht möchte ich eine neuere Form der Kontaktschalen beschreiben, mit der man sich noch wenig befasste, die aber im Falle endgültigen Bewährens in grossem Maße zur Verbreitung der Kontaktschalen beitragen wird. Wie schon der Name besagt, ist hier eher von einer technischen Neuerung die Rede, trotzdem halte

Figure 24-10
Istvàn von Györffy's first publication on plastic contact lenses (1940).
On the 8th of October 1939, Hungarian ophthalmologist, Istvàn von Györffy, had presented his first results of manufacture and fit of corneo-scleral contact lenses made from plastics at Budapest University Clinic. The paper was published several months later under the title 'Contact Shells from Plastics' (Kontaktschalen aus Kunststoff) and thus represents the first publication on this subject within the European Continent. (Györffy I.V., 1940, 1941a)

In the course of the following years, he presented his results (in October 1939 and then in April 1940) to the Hungarian Society of Ophthalmology. [32]
In 1940, he published the first article in Europe (in German language) detailing the all-plastic contact lenses. The article was entitled 'Contact Shells derived from Synthetic Products' (Kontaktschalen aus Kunststoffen) and he summarized his research projects between 1938 and 1939 using pmma shells produced according to the molding techniques of *Dallos* and fit under fluorescein control. He cited the contemporary celluloid trials of *Teissler* and those that *Thier* had undertaken, independently of his own. [33]
He then described the technical details of the manufacture of contact shells and the original solutions that he had found in order to resolve the problem of surfacing the optical parts. Starting with ocular moldings according to *Dallos*, using Negocoll or Formalose that he filled with Stonex (a hard plaster) he made a positive contra-type mould. A plaque of pmma with a thickness of 0.50 mm to 1.00 mm was heated and then pressed onto this positive. Then the rough model was trimmed to the size required and its edges were worked over and polished. *Györffy* stressed the excellent thermoplasticity and tolerance of pmma, the facility for retouching and the ease of making copies. He noted that the wettability of pmma was less than that of glass, but that its lightness and resistance represented a substantial advantage for production and for patient comfort. Fitting was carried out with fluorescein and he recommended the use of *Feldmann*'s liquid individually adjusted to the pH of the patient's tears. Above all, he had refit pmma contact lenses in several patients who had become intolerant to heavy glass contact shells fit by *Dallos* during the previous years.
Györffy presented new results in the following years. These signaled a reference for that era in Continental Europe to the composition of the tears and the visual veil. Later on, he recalled these pioneering years on several occasions. [34] He was critical particularly of the Anglo-Saxon authors and their imitators who failed to cite the pioneers of Continental Europe:

"*The facts regarding the true history of the development of the molded All-Plastic Contact Lens are omitted not only in Obrig's work, but were left out from the books by Dickinson and Clifford Hall (1946), Raiford (1961) and probably other English publications, because most likely those authors have not consulted the non-English literature with the accuracy due to the subject*." [35]

3.5 - Petrus Franciscus Xavierus Thier (1938-1940)

In the Contact Lens Manufacturing Laboratory of the Utrecht Ophthalmology Clinic, *Petrus Franciscus Xavierus Thier* used pmma as a replacement for glass for the manufacture of contact shells. He used the *Dallos* ocular molding technique. He described the research projects he had undertaken in January 1938, but it was not until the December of the same year that he presented the results obtained with his first contact glasses made from synthetic acrylates, notably Plexiglass. *Thier* stressed the possibility of grinding the optical part, which remained quite rigid in order that it should not be put out of shape by the weight of the eyelids. The peripheral part retained a certain suppleness, which allowed molding onto the conjunctiva. These contact glasses were 50% lighter than their glass equivalents. They were unbreakable, quicker to manufacture and without observed ocular irritation. [36]
At the time of the discussion, Professor *Weve*, who was the director of the Utrecht Ophthalmology Clinic, stressed the advantages of these lenses, of which the manufacture was relatively easy and inexpensive. When questioned as to whether the duration of life of Plexiglass equals that of glass, his response was that this material scratched more readily than glass and that the optical part should be repolished twice a year by a simple and rapid procedure. *Thier* having left Utrecht because of the war, he recalled his results again in 1940, but did not give any more details. [37]

3.6 - Adrien Fritz (1939-1940)

In April 1939, *Adrien Fritz*, an ophthalmologist from Belgium, presented his experience with the 'contact glass made from an organic substance and custom-molded'. The author recommended taking an imprint from dental wax and using this as a starting point he made a hard matrix onto which the plastic material was molded under pressure. The corneal part was then ground in order to correct the refractive error. *Fritz* attributed the success of these fittings to the lightness and the fineness of the shell, but did not provide any clinical case histories. In the course of discussions, *R. Weekers* (Liége) drew attention to *Teissler*'s recent publication on celluloid contact lenses at the International Cairo Congress. However, *Fritz* responded that these shells were not produced by individual molding, but by bending of celluloid sheets on matrices set up in series. Cellon splits and is not perfectly transparent. The serial prostheses of *Teissler* do not have any optically worked corneal parts. The most up-to-date synthetic materials, notably Plexiglass that he uses, require more powerful technical approaches, but they have the advantage of being perfectly transparent and have a cohesion superior to that of *Cellon*. (38)
In the following year, *Fritz* proposed the interposition of a therapeutic shell made from pmma for use in patients with ocular burns and placed between the eyeball and the lids. This was fitted in its center with a screw hole onto which was fixed the adapter of an ointment tube, which would have the advantage of renewing the treatment without having to remove the contact shell. The following publications of *Fritz* only appeared after the War, when he presented more of his numerous original articles on scleral shells made from plastic materials. (39)

3.7 - Other Pioneers

Towards 1942, *C.W. Dixey & Sons*, who were the distributors in the United Kingdom for *Zeiss* lenses, announced the manufacture of plastic ground contact lenses as the result of his two years of research. On the approach of the war, *Harry J. Birchall* the director of *Dixey*, had in fact demanded from his collaborators, amongst whom was their engineer *Cyril Winter*, the development of lathes for grinding the glass contact shells and imitating those of his former supplier from whom he was separated. Imperial Chemical Industries (ICI) placed Transpex at his disposition, thus facilitating the passage towards the production of contact shells from plastic materials, as much molded on steel molds as ground on lathes developed by him. According to certain authors, the manufacture of these shells was contemporaneous with the production from the Continent. (40)

In France, *Raymond André Dudragne* was cited in 1942 by *Fertsch* from among the users of contact lenses made from pmma. *Dudragne* had, in fact, registered several patents for the manufacture of contact shells since 1940. Several of these patents mentioned the possibility of using, in place of glass, plastic materials, synthetic resins, and combinations of these. According to several witnesses, he began trials around this period in history but, being salaried by *Lissac Brothers* Optical Company in Paris, he did not publish the results of his research projects. (41)

Engineer *Heinrich Wöhlk* is often cited in Germany for his experiments with plastic materials that were available to him thanks to his being employed by *Anschütz & Co*. in Kiel. Had it not been for the outbreak of War, he would have succeeded in fabricating combined contact shells suitable for his own eyes on which he had performed wax moldings.

4 – The Great Rupture

In fact, there occurred, in the course of World War II, a radical rupture in the development of contact lenses between Continental Europe and America and the British Commonwealth.
Dickinson-Hall noted this:

"*It is regrettable that war conditions have prevented our gleaning any reliable information on developments in Europe since 1939. Apart from the occasional acquirement of German contact lenses worn by Luftwaffe personnel shot down by Allied airmen, little or nothing has been seen of the work of contemporary European contact lens workers. It is more than probable that the Zeiss concern succeeded in producing both ground and molded plastic lenses in the early years of the war. We have inspected examples of German transparent plastic material admirably suited to the fabrication of contact lenses*." (42)

Knowing that *Zeiss* had remained faithful to glass, it is probable that a number of contact shells referred to in this citation also originated from *Müller-Brothers* in Wiesbaden or also, as reported by a contemporary witness, from *Müller-Welt* in Stuttgart:

"*During World War II, Adolf (Müller-Welt) and his wife Ruth traveled throughout Germany and German-occupied Europe fitting glass scleral lenses to German officers who, in those years were not allowed to wear eyeglasses while in uniform. Adolf and Ruth would take with them cases of lenses numbering in the tens of thousands and having a sufficient quantity of all practical corrections to meet any need. This contribution to his country has been totally ignored by people in the contact lens business who profess to record the history of contact lenses.*" (43)

Notes in Chapter XXIV

1. See volume II, chapter 18, pp. 289-292: The 'Cellon' experiments.
2. According to Györffy I.v., 1980, these trials took place in 1933.
3. Teissler J., 1938a. Presented in 1937 and published in 1938.
4. "L'appareil servant à la fabrication des prothèses en celluloïd se compose d'un cylindre creux en métal de 5 cm de diamètre. Dans le fond on place deux moules métalliques concaves, l'un correspondant à la forme de la cornée, l'autre correspondant à celle de la sclérotique. On peut changer et combiner ces moules à volonté et dans le fond du cylindre, on peut créer la forme concave de toute la prothèse ayant les rayons de courbure voulus. Dans le cylindre se meut un piston sur lequel on peut construire d'une manière analogue la forme convexe. Dans le fond du cylindre, entre les formes, on met une feuille de celluloïd de 0,2 mm d'épaisseur et on ferme le tout d'une façon étanche. On plonge l'appareil pour cinq minutes dans l'eau à la température de 80°C et l'on serre avec une vis. On laisse refroidir. A coup de ciseaux, nous donnons à la prothèse la forme convenable et nous arrondissons les bords. Toute la fabrication demande un quart d'heure."
5. "J'ai invité ensuite le malade à aller se promener et à revenir dès qu'il sentirait une douleur ou bien dès qu'il verrait moins bien. Souvent les malades ne sont rentrés que le soir en déclarant qu'ils ne sentent rien dans l'oeil, qu'ils voient bien et même qu'ils pourraient dormir toute la nuit avec la prothèse. Pour la première fois, ils avaient la prothèse appliquée durant dix heures de suite et après examen de contrôle de l'oeil, il n'y avait aucune trace d'irritation."
6. Teissler J., 1938b; Teissler V., 1938.
7. Sattler C.H., 1941; Fertsch F., 1942: "Zur Zeit wird man eindeutig nicht sagen können, ob an sich eine Kunstharzschale besser vertragen wird als eine Glasschale. Zunächst is es jedenfals noch so, dass man sowohl mit einer Haftschale aus Glas als einer aus Kunstharz zum Erfolg kommen kann."
8. Wilhelm B., 1928, 1931.
9. Möller E., 1930.
10. Row D.H., 1936.
11. Feinbloom W., 1936a, b, c, 1937b, 1938.
12. Dannheim H., 1937. "Scleraler Teil aus schmiegsamen organische Kunststoff, und einer lösbar verbundene Korrektionslinse aus Glas oder einem hartem durchsichtigen Kunststoff."
13. Beitel R.J., 1938.
14. American Optical, 1938b.
15. American Optical (Tillyer), 1937b; Nissel & Lambda, 1945; Dudragne R., 1944a.
16. Forknall A.J., 1946, 1947.
17. Feinbloom W.M., 1931: Presentation on the 15th December 1930 before the Ninth Annual Meeting of the American Academy of Optometry at Omaha, published in 1931. - Feinbloom W.M., 1932: corresponds with the publication of the preceding document in order to include the publications of Heine and Hartinger.
18. Feinbloom W.M., 1936a, b, c, 1937a, b, 1938.
19. Feinbloom W.M., 1937a. Presentation on 23rd August 1936 to the American Academy of Optometry.
20. Feinbloom W.M., 1936 a, 1938.
21. Bausch & Lomb, 1937.
22. Feinbloom W.M., 1941c.
23. Mostyn-Brown M., 1936. This report has been kindly sent to us by Mr. Richard Keeler.
24. Obrig T.E., 1942.
25. Feinbloom W.M., 1945a, b.
26. Györffy I.v., 1980; Fertsch F., 1942.
27. IG Farbenindustrie Aktiengesellschaft, 1936a, b. Registration of patent requests were submitted on 8th April 1936 in Berlin, Germany and on 1st May 1936 in Paris, France.

"Demgegenüber ermöglichen die Polymerisationprodukte die Herstellung von sehr vollkommenen Haftgläser durch ein einfaches Press- oder Spritzverfahren unter völliger Ausschaltung des Schleifprozesses. Beide Flächen des Haftglasses, Auflagefläche und Aussenfläche, können durch Pressen oder Spritzen zwischen einer Matrize von der Form der Augapfelvorderfläche und einem entsprechend der gewünschten Korrektur linsenförmigen Stempel in einem einzigen Arbeitsgang hergestellt werden (...)

Die polymerisationprodukte ermöglichen eine individuelle Anpassung des Haftglases in der Weise, dass von dem Auge mittels eines Abgusses eine Matrize in Form eines positiven Modells des Auges hergestellt wird."

28. Wingate G.H., 1937.
29. Stevens C.L., 1936; Obrig T.E., see par: 1938a, b see chapter 22, § 5: 'The contributions of Obrig'.
30. Mullen J.E., 1939, 1940, 1947.

31. According to Obrig T.E., 1942, p. 192-193 and Obrig T.E., Salvatori P.L., 1957, pp.189-190.
32. Györffy I.v., 1939, 1940b, c. Presentations to the Hungarian Society of Ophthalmology on 7th October 1939 and 14th April 1940. - Györffy I.v. 1984, and personal communications.
33. Györffy I.v., 1940a. Often cited erroneously with the year of publication of the article reference in the Archives of Ophthalmology.
34. Györffy I.v., 1941a, b, 1942a, b, 1944a, b, 1966b, 1980, 1982, 1984.
35. Györffy I.v., 1964b.
36. Thier, P.F.X., 1938a, b. Presentation to the Netherlands Ophthalmological Society on 29-30th January 1938, in Utrecht. - Thier, P.F.X., 1939a, b. Presentation on 10-11th December 1938 to the 97th meeting of the Netherlands Ophthalmological Society.
37. Thier, P.F.X., 1940a, b.
38. Fritz, A., 1939. Presentation on 30th April 1939 to the Belgian Society of Ophthalmology.
39. Fritz A., 1940.
40. Cited by Dickinson F. & Clifford Hall K.G., 1946 and by Bowden T.J., 2009.
41. Dudragne R., 1944a, b, c. Personal communication from R. Rocher in December 1999.
42. Dickinson F. & Clifford Hall K.G., 1946 p.30.
43. Personal communication from Ms. Mueller-Welt Caffrey and <http://mueller-welt.com>.