CHAPTER XXIX

50 Years of Advances in Fitting Procedures for Contact Lenses - An Overview

Introduction

Tolerance for contact glasses depends primarily on the agreement of the contact glass parameters with those of the cornea and sclera and, secondly, on the respect shown for the corneal metabolism and the maintenance of a space sufficiently large for the circulation of tears.

At the beginning of the 20th Century, neither ophthalmologists nor engineering professionals at *Zeiss* (Jena), seem properly to have understood this essential rule for good contact lens tolerance. In fact, *Zeiss* recommended the correction of the refractive error through the lachrymal meniscus and depended on a complex system based on the height of the corneal arrow modified as a function of dioptric power. They measured the distance between the corneal apex and the plane coinciding with the corneo-scleral limbus. Trial contact shells were classified in terms of arrow height. Users who tried to follow this method were frustrated by the absence of an instrument to measure 'corneal arrow height'. Some compared the corneal and scleral profiles with that of calibrated spheres, while others renounced all measurements and were content with trial and error as recommended by some manufacturers.

Heine's 1929 presentations and *Hartinger*'s, in the following year, recommended corneal keratometry, but did not direct the fitter towards a technique for the choice of haptic. It is to the credit of both *Istvan von Csapody*, and *Joseph Dallos* that each recommended and brought to fruition a reliable method for selecting the scleral portion of contact shells.

The considerations necessary to determine better measurement of the curvatures of the anterior segment were therefore oriented, firstly, to determining the height of the corneal arrow followed by scleral curvature. Secondly, they emphasized keratometry and thirdly ocular moldings. Later, they were to use profile-measuring techniques, including axial keratometry and corneal topography.

1 – Procedures for the measurement of ocular topography by mechanical contact.

Introduction

One must acknowledge the merit of authors who conceived, manufactured and exploited instruments in order the follow *Zeiss*'s recommendations to measure the 'corneal arrow' for the fitting of contact shells. Our research revealed evidence of a 'sclerometer' made by *Reinhard Friede*, a 'sclero-keratometer' of *Rudolf Helmbold*, the *Robert von der Heide*'s 'gauge', and the 'tholometer' of *Joseph Dallos*. We noted also metallic shells made for this purpose by *Jules Szymanski*. It is very probable that other physicians had also asked their technicians to construct probes and gauges adapted to measurement of the 'corneal arrow'. *Siegrist* (Berne, Switzerland) designed and used a few of these. [1] Also a gauge from the *Weve* era has been conserved in the Museum of Medicine in Utrecht.

Year	*Type*	*Author*	*Description*
1926	Probe	R. Friede	Sclerometer
1928, 1933	Gauge	R. von der Heydt	Small silver gauge
1930, 1933	Gauge	J Dallos	Tholometer
1931	Probe	R. Helmbold	Sclero-keratometer
1935	Gauge	Utrecht Museum	Curvature meter
1937	Probe	J. Szymanski	Metallic shells

Table 29-1

Chronology of the publications describing the principal instruments for measuring the height of the 'corneal arrow', the scleral and corneal profile, using mechanical contact.

After the presentation of the first contact glasses, manufacturers also noted the importance of adjusting the optical power of these to match eye-to-lens distance with regard to spectacle lens power. We thus became aware of several 'distometers' adapted relatively successfully from models described by *Rugg-Gunn* and *Schaefer*.

1.1 – Sclerometer of Friede (1926)

See figures 29-1 & 29-2, plate I, p.308

In 1926, *Reinhard Friede*, ophthalmologist (Jaegersdorf, Czechoslovakia) described an instrument for the measurement of the scleral curvature. This was described in German as a 'Stäbchen-Sklerometer' (stick-sclerometer). Thus he attempted to remedy the lack of an instrument suitable for the measurement of the diameter and curvature of the anterior sclera. Using several measurements in the same meridian duly documented point by point in a diagram, *Friede* calculated the profile of the sclera from limbus as far posterior as the equator. He admitted that his instrument had several disadvantages, notably that it measured only the total diameter and not the differences of curvature of one side of the sclera versus the other. His 'sclerometer' was, in fact, a precursor, most likely a prototype, the use of which was necessarily painstaking. Sadly, it was destined to pass into near total oblivion like so many of the instruments and devices arising from the fertile imagination of ophthalmologists from time immemorial [2]

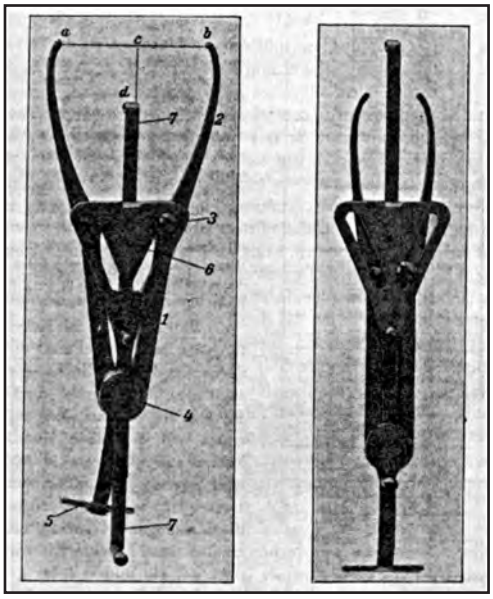


Figure 29-1

Friede's Sclerometer (open to the left, closed on the right). *A 'Stäbchen-Sklerometer' (stick/applicator-sclerometer) was introduced in 1926 by Reinhard Friede. Shaped like a geometrical compass with blunted edges, curved inwards, it is symmetrical and has a central pointer indicating the arrow between the plane of measurements and the summit of their axis of symmetry. According to Friede: "By measuring the respective diameters at two opposite scleral points and using juxtaposition of several of these measurements in one meridian, the curvature of the sclera could be measured."*

(Friede R., 1926a.)

1.2 - Von der Heydt's Gauges (1928, 1932)

See figure 29-3, plate I, page 308

In 1928, the ophthalmologist *Robert von der Heydt* presented to the Chicago Ophthalmological Society a gauge for measuring the height of the 'corneal arrow' intended to avoid the need for repeated trials of *Zeiss* contact shells. In a second communication (1932), he provided a more detailed description of his gauge and presented a more sophisticated model. He gave, however, a somewhat guarded assessment of the usefulness of such gauges: "*While these instruments are an aid in this work, they are not essential*." [(3)]

1.3 – Helmbold's Sclero-Keratometer

See figures 29-4, 29-5 & 29-6, plate I, page 308

The approach of *Rudolph Helmbold* (Danzig) differed from those of *Friede* and *R. von der Heydt*. As revealed in his article published in 1931, he had invented and had constructed an instrument for measuring the corneo-scleral curvature of the eye that was specifically tailored for selecting contact glasses. Justifiably, he noted that measurements with the ophthalmometers of *Helmholtz* and *Javal-Schiötz* were limited to the reading of the corneal curvature at two points of a given circumference. The fitter did not have available any procedure for simultaneous measurement of the corneal curvature, the height of the corneal arrow, the curvature of the sclera or of the sclero-corneal limbus. His 'Sclero-Keratometer' palpated, as it were, the whole anterior eyeball surface as far posterior as the level of the equator. The measurement of the limbal profile and the scleral curvature was, according to *Helmbold*, especially important for determining contact glasses tolerance. The author insisted that he had confirmed by slit-lamp examination the absence of epithelial lesions after measurements and that the best tolerance of the bicurved *Zeiss* sclero-corneal shells chosen according to the indications of his 'Sclero-Keratometer' confirmed that his initiative was well founded. His 'Sclero-Keratometer' was manufactured and distributed for a period of time by *Zeiss*. One can criticize the instrument for only providing measurements in one axis and not providing an overall picture of corneal curvature. [(4)]

1.4 - Dallos' Tholometer (1930, 1932)

See figure 29-7, plate II, page 309

Joseph Dallos presented a communication in 1930 to the Hungarian Society of Ophthalmology, in which he described an instrument based on the principle of the *Schiötz* tonometer. This instrument took the form of spherometer, intended to measure the height of the 'arrow' of the corneal segment, which it did by palpating, as it were, the distance from the corneal apex to the scleral plane. *Dallos* was to revisit his instrument two years later after he had perfected the tholometer by equipping it with fixed scleral rings corresponding to the radii of the scleral part of *Zeiss* contact shells. The tholometer could also be used for the measurement of the arrow of the contact glasses thus allowing, starting from measurements of the corneal surface and the posterior surface of the contact glass, calculation of the dioptric power corresponding with the lachrymal meniscus. [(5)]

1.5 - The Utrecht Gauge

See figure 29-8, plate II, page 309

The Museum of the University of Utrecht has conserved a gauge, the features of which are close to those of *von der Heydt* and *Dallos*. We did not find any documents in the literature regarding the use of this instrument, any more than the authors of the museum catalogue did. We do know however that Professors *Snellen* and *Weve*, and their assistant *Thier* took an interest in optical correction using contact glasses. The item, although not identified formally by the authors of the catalogue, is described as follows: "*Instrument for the measurement of curvature (?)*" . "*The brass instrument, which may have been intended for the measurement of curvature, consists of a horizontal, 8 cm long, arm to the end of which a peg in an open cage is attached. A graduated arc is mounted at the other end. There is also a vertical bar attached to the arm as handle, and an indicator with counterweight. This instrument is intended for the measurement of curvature, the edge of the cage could have been placed on the object, or the eye, under examination. Displacement of the peg causes the indicator to move over the scale and the curvature can be read from it*." [(6)]

1.6 – Szymanski's Metallic Shells

See figures 29-9 & 29-10, plate II, page 309

In 1936, the ophthalmologist *Jules Szymanski* (Warsaw, Poland) presented to the Polish Society of Ophthalmology and in the following years to the French Society of Ophthalmology, a collection of calibrated rings, called 'metallic shells' (coquilles métalliques) for the measurement of ocular curvatures. These were intended to replace the trial contact glasses made by *Zeiss*, the price of which was, according to *Szymanski* excessive. *Emile Haas* found that these calibrated rings were simpler to manipulate than the sclero-keratometer of *Helmbold*. However, the measurements were very approximate and there is little testimony on the use of these shells for measurement. In 1940, *A.N. Even* also proposed a similar series of plastic rings calibrated in 1/100 mm divisions for measurement of scleral curvature. [7]

1.7 – Trial Contact Shells and Lenses

Trial contact lenses were readily used for evaluation of corneal topography. Naturally, trial lenses changed as their constituent material and design improved. We will now distinguish three chronological periods: the period of corneo-scleral lenses made from glass, that of corneo-scleral shells made from plastic and that of corneal lenses.

1.7.1 - Glass Trial Corneo-scleral Shells.

Naturally, fitters were completing the mechanical estimation of ocular topography by means of experiments with trial contact glasses. Right from the period of glass contact shells, these were presented in luxurious boxes and were often sold for a high price. The first set of *Zeiss* shells was quickly replaced by larger sets. At a certain era of its

Scleral radius	*Corneal radius*	*Corneal zone diameter*	*Overal size*
11.00 -> 13.00 in 0.50 steps	5.00 & 5.50	8.00	20.00
"	6.00 & 6.50	10.00	20.00
"	7.00 & 7.50	12.00	20.00
"	8.00 &8.50	12.00	20.00
"	9.00 & 9.50	12.00	20.00
"	10.00 & 10.50	12.00	20.00
"	11.00	12.00	20.00

Table 29-2

Zeiss-Heine enlarged trial set

The trial set proposed by Heine comprises 70 contact shells.

Early Sattler's proposal of trial lenses for optical correction.

	Scleral radius	Corneal radius	Overall size	Dioptric power
	12.00 mm	8.00 mm	20.00 mm	-3, -6, -9, -12, -16 D.
	"	8.00 mm	"	+3, +6: +9, +12, +16 D.
*	"	7.50 mm	"	+3, +6, +9, +12 D.
*	"	8.50 mm	"	-3, -6, -9, -12 D.

(* Optional supplement)

Early Sattler's proposal of trial lenses for haptic fitting.

	Scleral radius	Corneal radius	Overall size	Dioptric power
	15.00 mm	8.00 mm	20.00 mm	afocal
	17.50 mm	"	"	"
	20.00 mm	"	"	"
	22.50 mm	"	"	"
	25.00 mm	"	"	"
*	15.00 mm	8.00 mm	22.00 mm	afocal
*	20.00 mm	"	"	"
*	25.00 mm	"	"	"

(* Optional supplement)

Zeiss-Sattler modified basic and supplementary trial set.

	Scleral radius (mm)	Corneal radius	Corneal diameter	Overall size (mm)	Dioptric power
	11.50 to 12.50 in 0.50 steps	8.00 mm	12.00 mm	20.00	afocal
	"	"	"	"	-16.00 & -12.00
	"	"	"	"	-9.00 & -3.00
	"	"	"	"	+3.00 & +6.00
	"	"	"	"	+9.00 & +12.00
*	11.00 to 12.00 in 0.25 steps	8.00 mm	12.00 mm	20.00	afocal
*	"	"	"	"	-16.00 & -12.00
*	"	"	"	"	-9.00 & - 3.00
*	"	"	"	"	+3.00 & +6.00
*	"	"	"	"	+9.00 & +12.00
*	12,75 & 13.00	8.00 mm	12.00 mm	20.00	afocal

(* Optional supplement)

Table 29-3

Trial contact shells as proposed by Sattler

In order to dissociate corneal from scleral fitting, Sattler proposed replacing the set of Zeiss-Heine's afocal trial shells by a two-series set of trial lenses. The first series suitable for optical fitting, the second series for scleral fitting.

Scleral radius (mm)	*Corneal radius*	*Corneal diameter*	*Overal size*	*Diopter power*
12.00 mm	7.00	12.00 mm	20.00 mm	afocal
12.20 mm	7.00, 7.50, 8.00	"	"	afocal
12.40 mm	7.00, 7.50, 8.00	"	"	afocal
12.60 mm	8.0	"	"	afocal

Table 29-4
Kollmorgen's early fitting set
The early Kollmorgen fitting set consisted of 9 afocal lenses with standardized optical zone diameter (12.00 mm) and overall size of 20.00 mm copied from the Zeiss series.

Scleral radius (mm)	Corneal radius (mm)	Corneal diameter	Overal size	Diopter power
11.40 - 12.00	7.00	12.50 mm	21.50 mm	afocal
11.40 - 12.00	7.50	13.00 mm	"	"
11.60 - 12.20	7.00	12.50 mm	"	"
11.60 - 12.20	7.50	13.00 mm	"	"
11.60 - 12.20	8.00	13.50 mm	"	"
11.80 - 12.20	7.00	12.20 mm	"	"
11.80 - 1240	7.50	13.00 mm	"	"
11.80 - 12.40	8.00	13.50 mm	"	"
12.00 - 12.60	7.00	12.50 mm	"	"
12.00 - 12.60	7.50	13.00 mm	"	"
12.00 - 12.60	8.00	13.50 mm	"	"
12.20 - 12.80	7.50	13.00 mm	"	"
12.20 - 12.80	8.00	13.50 mm	"	"
12.40 - 13.00	8.00	13.50 mm	"	"
12.60 - 13.20	8.00	13.50 mm	"	"

Table 29-5
Kollmorgen's 'new aspheric' corneo-scleral fitting set
In this set of 'aspheric' lenses with toric scleral part, similar to Müller-Welt shells, Kollmorgen introduced a corneal diameter exceeding 12.00 mm for the corneal part and a standard 21.50 mm diameter for the overall size.

Scleral radius	*Corneal radius*	*Corneal diameter*	*Overal size*
10.50 mm	10.50 mm	-	20.00
11.00 mm	10.50 mm	-	"
11.50 mm	12.00 mm	-	"
12.00 mm	12.50 mm	-	"
12.50 mm	13.00 mm	-	"
13.00 mm	13.50 mm	-	"

Table 29-6
Gualdi's six single-curvature trial contact shells

history, *Zeiss* was selling even more trial contact shells than prescription contact shells. (8)
Later, as the years passed, other manufacturers marketed their sets of trial contact shells. Amongst these, the most typical of these were those of *Kollmorgen*, of *Gualdi* and of *Feinbloom*.

a/ *Zeiss-Heine* and *Zeiss-Sattler* Glass Trial Contact Shells
See figure 29-11, plate II, page 309 & figures 29-12 & 29-13, plate III, page 310
Zeiss-Heine trial set. The enlarged set proposed by *Heine* comprises 70 contact shells, the radii of curvature of which range between 11.00 and 13.00 mm in 0.50 steps, with radii of corneal curvature between 5.00 and 11.00 mm in streps of 0.50 mm. The diameters for the optical zones vary between 8.00 and 12.00 mm, with a total diameter of 20.00 mm.

Zeiss-Sattler trial set. In order to dissociate corneal from scleral fitting, *Sattler* proposed replacing the set of *Zeiss-Heine*'s afocal trial shells by a two-series set of trial lenses.
The first series would be destined for optical correction, with an overall diameter of 20.00 mm, a standard haptic curvature of 12.00 mm, a corneal curvature of 8.00 mm and refractive power graded between -16.00 and +12.00 diopters.
The second series, suitable for scleral fitting, would consist of two sets of 20.00 and 22.00 mm of total diameter, a corneal curvature of 8.00 mm and finely gradated scleral radii curvatures. Subsequently, Sattler's trial set was modified by extending it to 90 contact shells by the addition of intermediate curvatures.

b/ Kollmorgen Glass Trial Contact Shells
Kollmorgen, as manufacturer, was very much in favor of glass for manufacturing, the technology for which had been dominated by the firm for the previous years. It was logical to assume that they would succeed in manufacturing glass contact shells following the European *Zeiss* and *Müller-Welt* models without great difficulty. When glass was replaced by pmma, *Kollmorgen* withdrew from the contact lens market and limited the firm exclusively to manufacturing glass products. (9)

c/ Gualdi's Monocurved Spherical Trial Contact Shells
See figure 29-14, plate III, page 310
In 1931, *Vincento Gualdi* of Florence (Italy) proposed to limit to six the number of trial contact shells due to the *Zeiss* sale price being to height. He based his decision on the principle that, in normal practice, scleral curvatures were in the range of between 10.50 mm and 13.00 mm. The six types of lenses he kept corresponded to these curvatures. They possessed a residual dioptric power around -1.00 to -2.00 diopters and had a total diameter of 20.00 mm. Their weight was 0.50 gram and their thickness 0.50 mm. (10)

1.7.2 – Pmma Trial Corneo-scleral Contact Shells

When pmma replaced glass, the manufacture of corneo-scleral contact shells was simplified and trial lens sets multiplied proportionately due to the increase in the number of manufacturers and their initiatives. Two groups of trial contact shells can be distinguished: those with spherical haptics and those with aspheric haptics.
- *Dixey*'s lenses with spherical haptics were amongst the most widely marketed lenses in Great Britain, followed by *Obrig*'s in the USA and *Courtis-Sais*' in Argentina.
- From among sets with aspheric haptics, those of *Hamblin-Dallos* were particularly successful in the Great Britain, those of *Müller-Welt* in Germany, of *Dudragne* in France and of *Feinbloom* in the USA.

a/ Trial Contact Shells with Spherical Haptics
Dixey's Trial Contact Shells (London) - The trial set of *Dixey* consisting of 30 afocal plastic ground contact shells with spherical haptics, was similar to that of *Zeiss* contact shells. These had a scleral curvature of between 11.00 and 13.50 mm in steps of 0.25 mm, a posterior corneal curvature of between 6.50 mm and 9.00 mm, in steps of 0.25 mm, a corneal diameter of around 11.00, in steps of 0.25 mm and a total diameter of between 20.00 and 25.00 mm. The *Dixey* contact glasses were marketed as two separate products: firstly 'concentric' contact glasses with the corneal part in the centre and, secondly, 'eccentric' contact glasses, the corneal part decentered by 0.50, 0.75 or 1.00 mm. (11)

Obrig's Trial Contact Lenses (NYC) - The smallest standard trial lens box made by *Obrig* Laboratories contained 10 plastic afocal contact shells, with a 20.00 mm total diameter for each. They were presented with several scleral curvatures: 5 contact glasses were associated with a corneal radius of curvature of 7.50 mm with scleral radii of curvature of 12.00, 12.25, 12.50, and 12.75, 3 contact glasses had a 7.00 mm radius of curvature with scleral radii of 12.25, 12.50 and 12.75. Added to these as an extra were two contact glasses with a 12.50 mm haptic, the one with a corneal radius of curvature of 6.50 for trials with keratoconus patients, the other had an 8.00 mm corneal radius of curvature used for high myopes. (12)

Courtis-Sais Trial Contact Shells (Buenos Aires) - The standard trial contact lens case made by *Courtis-Sais* contained 30 plastic contact shells, some of which, the most used ones, were in duplicate form. These contact glasses had a haptic of between 11.50 and 13.00 in steps of 0.25 and a posterior radius of curvature of between 6.50 and 8.00 in steps of 0.50 mm. (13)

b/ Trial Contact Shells with Aspheric Haptics
Hamblin-Dallos Trial Shells - Trial contact shells made by *Hamblin*'s (London) from glass and subsequently in plastic material that had been developed by *Dallos* were classified into groups depending on ocular pathology. They varied in shape, dimensions and in radii of curvature according to indication (14).

Müller-Welt Trial Shells - The *Müller-Welt* (Stuttgart) contact shells made from plastic shaped by blowing in molds were divided into three principal groups (A, B. and C), each group with a specific haptic curvature. An extended gamut of anterior and posterior radii of curvature together with various diameters for the optical zone and total diameter was provided for each group. The contact lens fitter had to have a very large selection of lenses to accommodate all variations.

Dudragne Trial Shells - According to *Dudragne* (Paris), the trial contact shells were molded starting with casts from thousands of ocular moldings. The complete set comprised 80 plastic contact shells. The unusual feature of the corneal part was that it passed towards the haptic without a limbal transition, but had a 'limbal zone' intended to avoid pressure on the limbus. Classification of the contact shells was determined by numbers and coded letters. The beginning fitter is recommended to research the best shell for placement onto a positive mold of the eye to be fit. Trial contact shells were often presented in luxurious boxes that were either lent or sold to fitters.

Feinbloom Trial Shells - Among American optometrists, 'Tangent-cone Plastic Contact Lenses' of *Feinbloom* (New York) were very successful. As described above, these had a nasally-displaced corneal part producing an unusually wide temporal scleral part. The haptic part was characterized primarily by its cone shape with angles between 43° and 49° and secondarily by its temporal part, the radius of curvature of which varied between 12.00 and 13.80 mm. Minor adjustments were made with special pliers. (15)

c/ Trial Corneal Contact Lenses

See figure 29-15, plate III, page 310 & figure 29-16 plate IV, page 311

When Solex Laboratories marketed *Tuohy* corneal contact lenses that were soon to be imitated by their competitors, boxes of trial contact lenses swamped the practices of contact lens fitters. Low cost manufacture facilitated their distribution. In order to distinguish one type from another, manufacturers complemented the smaller trial sets with large 'special' series that were often presented as small nice pieces of furniture.

1.8 – Instrument for Measuring the Distance from Eye to Spectacle Lens

See figures 29-17, 29-18, 29-19 & 29-20, plate IV, page 311

In the early days, *Zeiss* accorded great importance to the relative distance of the optical part of the contact lens in relationship to the spectacle lens. In 1932, *Rugg-Gunn* described his technique "*which I adopt of measuring the distance between the vertex of the contact glass-in-situ and the lack of any additional sphere that may be used to get full correction. The sphere is removed from the trial frame and a centrally perforated diaphragm substituted. Through the hole in the diaphragm, the plunger of a small instrument like a depth gauge is inserted until it touches the vertex of the contact glass. The distance is then read off in mm.*" (16)

As time went on, other 'distometers' were marketed with more or less success. Amongst these one can cite the 'distometer' (*House of Vision*) as illustrated by *Bier*, the 'parallax vertexometer' of *Zeiss*, the *Belgrade* 'Lenscorometer' and *Feinbloom*'s 'Contact-spectacle lens gauge'.

2 - Ocular Topography Using Molds

Introduction

Whereas recourse to ocular moldings had been already been made in 1888 by *Albert Eugen Fick* (Zurich) who used plaster of Paris on cadaver eyes and the method was periodically fallen back on in the years to follow, it was only in 1929 that the technique of molding was adapted to the eye in-vivo by *Istvàn von Csapodi*. Then, in the course of the following years, the procedures and products for taking imprints as well as the instruments for injection were improved and brought to perfection by *Dallos*, *Prister* and *Stephens* and subsequently by *Obrig*, *Feinbloom* and others, up to the point of obtaining a mold that perfectly copied the shape of the eyeball. The ocular mold was the reference criterion in the epoch of corneo-scleral contact shells, but lost its interest with the advent of corneal contact lenses.

Ocular moldings had the advantage of giving a representation of the corneal and scleral curvatures and guaranteeing reproducibility of the curvatures of the anterior surface of the eyeball including cornea, limbus and sclera. Molding did however have the disadvantage of being a momentary measurement liable to be falsified by pressures. The improvement of the shells and the instruments for taking moldings and the appearance of thermostable molding products was to make possible the taking of moldings even in the most complex cases.

Year	*Product*	*Author*
1929	Paraffins	Csapody
1930	Dentokoll	Csapody
1932	Poller's Negocoll	Dallos
1933	Dental wax	Prister
1933	Dental wax	Feinbloom
1936	Negocoll	Stevens
1938	Negocoll	Obrig
1940	Zelex	GB
1943	Moldite	Obrig

Table 29-7
Chronology of the most important products used for molding the human eye between 1929 and 1943.

2.1 - Csapody's Ocular Moldings (1929-1933)

2.1.1 - Early Experiments

In his first communication on his molding endeavors regarding the living human eye, presented in May 1929 to the Hungarian Society of Ophthalmology, *Istvàn von Csapody* reported the results and conclusions

from his early trials. In the same year, he published details in a German language publication. [17] According to current opinion from the era, tolerance of corneo-scleral contact shells would depend less on the corneal part (this being separated from the cornea by a liquid space) than on the scleral part. There was no method of measuring the latter.
Von Csapody had tried radiological methods after instilling the contrast product Lipiodol mixed with Collargol in order to obtain a lateral view of the eyeball and to facilitate the manufacture of contact lenses. These methods were, however, unsuccessful. The radiographic plates showed a good lateral view of the eyeball, but the results were too inconsistent. Then he tried moldings of cats' eyes and blind human eyes. He first used plaster of Paris but this was unsuitable because it was too adherent to the tissues. He also used cocoa butter, but the time for this to solidify was too long. He also used dental wax, but the temperature of the melting point of this was of too high. He tried several varieties of paraffin and mixtures of these products. [18]

2.1.2 – Eyeball Moldings using Paraffin.

Finally, *von Csapody* kept a paraffin mixture at a temperature of between 43 and 56 degrees that seemed to him to be the most convenient in terms of the suppleness at a convenient melting temperature. He had not at that time resolved the challenge of an injection that would maintain the product without compressing the eyeball and that would avoid sticking of the product to the eyelashes and lids. During this era, he used a glass tube 3 cm in length, splayed out at its extremity into which the paraffin flowed at body temperature, then was cooled with a frozen paraffin oil:

"*In order to take the imprint, a mold is necessary. The paraffin must not run onto the eyelids and be deformed when it is removed from the eye. For the protection of the lids, for fixation of the globe, for the taking of the mold and for its later management, I use a glass cylinder, the edge of which is splayed out and opens onto the eyeball. I have a certain number of these cylinders available, but the most suitable is one with an internal diameter of 18.5 mm and the external diameter, measured at the edge of 21 mm. (...) The cylinder I use is the right size for the adult eyeball. The usable part of the molding, which goes beyond the corneal margin, therefore the scleral ring, requires an external diameter of 18 mm and a width of about 3,5 mm. The glass cylinder has a height of 30 mm.*" [19]

Once the eye has been anesthetized, then lubricated by a drop of sesame oil *Csapody* prepares two paraffin mixtures. One of these is heated to between 38 and 40°, the other containing paraffin oil cooled by an ice bath. The warm paraffin is poured into a tube, then cooled in situ, with cold paraffin oil until an evenly congealed mass obtained. Some details are included in the instructions:

"*Some paraffin on the point of melting is poured into a glass tube that separates the lids and fixes the eyeball. In the anterior part of the ocular globe a temperature, close to a fever, is created. The paraffin must once again be frozen onto the eyeball by adding cold paraffin. Starting with a paraffin negative mold, plaster of Paris positive casts are prepared and starting with the latter, metallic molds are made that are used for the manufacture of contact glasses. According to a Zeiss courier (Dr. Hartinger) this molding procedure is of great possible benefit for making ground contact glasses.*" [20]

The positive lead cast, the surface of which is smoothed by means of a galvanic current with a copper or nickel layer, shows on keratometer that the curvatures of the final metallic component corresponded exactly to the corneal curvatures. *Csapody* has not encountered any particular reservations expressed by the patients, except that the need for cooling the paraffin in situ, (in order to make it more rigid before removal from the eye) sometimes felt uncomfortable.

2.1.3 – Dentokoll Trial Moldings

Several months later, after a presentation by *Dallos* to the Hungarian Society of Ophthalmology, *Csapody* announced, at the discussion period, that, on the advice of the dentist, Professor *Heinrich Salamon*, he was currently experimenting with Dentokoll, a gelatinous preparation, with intention to replace paraffin. The technique is simpler and the molds obtained are of larger diameter than the previous ones that were made using paraffin, which he had abandoned, for the time being:
"*Following the advice of Professor Salamon, the dentist, he had prepared moldings from the surface of the ocular globe using a gelatinous preparation called 'Dentokoll'. This product was more 'plastic' and is very elastic. It is used at body temperature. Csapody succeeded in preparing good molds in the living eye by using this product. These moldings have a greater diameter than those he had produced using paraffin with the help of a tube.*"[21]

2.1.4 – The Presentation of Ocular Moldings

In the following year (1930), *von Csapody* returned to paraffin, as he had demonstrated some moldings with this product before the German Society of Ophthalmologists in Heidelberg. At the time of a communication by *H. Hartinger*, he regretted that the manufacturers had shown no interest in making contact shells starting with some ocular moldings that he had sent them:

"*My experiments showed that it was possible to prepare an accurate mold from the surface of the living eye. To achieve this, one uses paraffin just at melting point. The mold, in the form of an accurate precise copy from the cornea and the neighboring sclera, allows the manufacturer of contact glasses to prepare the corresponding lens suited to the individual case. For molding, one uses a support, a glass tube, that separates the lids, fixes the ocular globe and which is also useful for later adjustments. Because paraffin goes out of shape easily, it is necessary to have it solidify while it is still in the eye. This is achieved by pouring frozen paraffin into the tube.*" (22)

Csapody adds: "*The taking of the imprint is painless and well tolerated by the patient. It does require however, a certain sleight of hand. The handling of the paraffin negative and its transposition to a plaster or metal positive cast requires know-how and technical training of an experienced technician.*" (23)

2.1.5 – Failure of Paraffin Molds

Three years later, in 1933, *Csapody* presented a further communication of his use of paraffin. The product appeared, as far as he was concerned, to be better suited for ocular molds after he had modified the injection tubes which were "*now provided with an opening under the lids and another orifice through which the air could escape. The largest diameter of molding obtained was 23.5 mm.*" (24)

However, the two firms that were approached for the manufacture of contact glasses starting from these molds had encountered significant technical problems in their realization. *Csapody*'s communication had been preceded by that of *Dallos*, who, at this period of history, had succeeded in resolving not only the molding problem by using *Poller*'s Negocoll, but also that of the manufacture of contact shells in molded glass with a ground optic. The only thing *Csapody* could do, was congratulate his colleague, then, in the future, defend his priority of having the idea and having carried out the first ocular moldings for the manufacture of contact lenses. (25)

2.1.6 - Csapody's Priority

The priority for the idea and of the first trials of a method of reproduction of the geometry of the living human eyeball is awarded to *Csapody*. There is no doubt that paraffin was a poor choice of material that *Csapody* wrongly persisted in using, even after his experiments with Dentocoll and after having been apprised of the researches of *Poller* and *Dallos*. In 1935, he claimed on good authority, his right to the priority when he had the impression that *Dallos* had eclipsed it:

"*I was the first person to propose the manufacture of contact glasses, starting with molds taken from the eyeball. I was the first to have developed a procedure that gave an exact molded replica of the human anterior segment. I was able to state that one can prepare very exact molded replicas of the living mobile human eye using a procedure that is neither painful nor dangerous. The molds I produced were very accurate replicas, because the capillary adherence in the course of the solidification compresses the mold on the actual ocular surface, thus avoiding slippage and deformation.*" (26)

2.2 – Negocoll Ocular Moldings

2.2.1 – Poller's Negocoll (1931)

See figures 29-21, 29-22 & 29-23, plate V, page 312

Paraffin moldings, like the ones carried out by *Csapody*, were a complex procedure and were difficult to reproduce. During this historical time, however, molding procedures enabled significant technical advances and the technique was also being used in medicine, dentistry and anthropology, as well as criminology and museology. The credit for these advances reverts to *Alphons Poller* (Vienna), whose work 'Das Pollersche Verfahren zum Abformen an Lebenden und Toten sowie an Gegenständen' (Poller's procedure for taking molds from the living and the dead, just as in other objects) appeared in 1931 and was an authoritative reference. (27)

Provided it is correctly used, Negocoll reproduced in the finest detail the contour of an object and revealed fine texture. Because it had to be boiled before being applied, it was an aseptic substance. It could be reused after boiling of the leftovers and remainders. This could be repeated several times. Negocoll is a hydrocolloid that dissolves in boiling water to produce a homogeneous paste. When cooled, it solidifies on

reaching body temperature in from 30 to 60 seconds, depending on its concentration in water. It forms a substantial mass, reproduces all the small details, whereas it keeps its elastic consistency.
Negocoll was largely used, first in Europe and then, after 1936, in the USA: "*Negocoll is a tan-colored elastic hydrocolloid made according to the formula of Poller. It is a rather complex mixture, having agar as a base and cotton fibers to bind it and give it strength. It is chemically resistant to the growth of bacteria and fungi. It contains a large proportion of water and may be thinned or thickened like a sauce by adding to or boiling away the water content.*" (28)

2.2.2 – Dallos' Negocoll Ocular Moldings

See figure 29-24, plate V, page 312
After the year of its first marketing, *Joseph Dallos* adopted Negocoll for ophthalmic use. It was subsequently employed with different models of molding shells and injectors by thousands of users throughout the world. The best known of these was *Sattler*, *Weve* and *Thier* in Europe and *Stevens* and *Obrig* in the USA.
Indeed, it may be stated that both *Csapody* and *Joseph Dallos* (each originally from Budapest), became convinced of the advantages of contact lenses prepared from moldings. *Dallos* had previously proposed and introduced certain technical modifications of the ground *Zeiss* lenses. He had followed *Csapody*'s experiments with great interest at the Ophthalmology Department at the Hospital of Saint-Étienne. As distinct from his colleague, *Dallos* had obtained active support from Professor *Emil von Grósz*, Chief of the University Eye Clinic and had been given working space and the services of a technician (*Stefan Darvas*). As soon as he became aware of *Poller*'s technique, he had carried out some experiments with Negocoll that seemed to be the answer to his expectations expressed at the time of his previous research activities. *Dallos* had however not made any comment when *Csapody* described, three years earlier, his molding experiments using paraffin and Dentocoll. (29)

a/ Eyeball Models
Dallos revealed the results of his first investigations in June 1932, when he presented his first results from the use of Negocoll in human eye moldings. He made his presentation to the Hungarian Society of Ophthalmology under the title: 'Eyeball Models' (Bulbusmodelle). The proceedings of the meeting described in guarded terms an ocular mold obtained from imprints in the primary position and in the four cardinal directions of gaze:
"*The contact glasses and shells must be positioned on the eye in a very precise manner in order to remain supported in position continuously. For the preparation of contact glasses and shells prepared individually, it is necessary to have available models of a large part of the eyeball surface area. Using Poller's procedure, Dallos could mold the eye in the primary position and in the four cardinal directions of gaze. Putting the different components together he could reconstitute the surface model required.*" (30)

b/ 'Contact Glasses and Contact Shells'
In July of the following year (1933) in a communication, under the title 'Neue Kontaktgläser' (New Contact Glasses), then, in a lengthy publication in German, 'Über Haftgläser und Kontaktschalen' (Contact Glasses and Contact Shells), *Dallos* described his previous research studies in detail and how Negocoll could be adapted to the ocular molding process. He stated that *Csapody*'s paraffin wax moldings and those using other products of a similar nature turned out to be poorly suited and unusable:
"*For molding, I have not succeeded in utilizing Csapody's procedure: I had in fact not to deform the conjunctiva, either by pressure from the tube, or through the lid speculum. It was necessary to find a substance that would create the finest plastic bed against the conjunctiva and which would rapidly solidify. Plaster of Paris and other substances derived therefrom cannot be used without risks to the conjunctiva. Wax, paraffin and other similar products that only harden at certain temperatures produce risks of thermal burns to the eye. That was why I turned my attention to colloidal substances.*" (31)

Dallos applied the recommendations of *Poller* to use Negocoll for molding and Hominit for casting. Negocoll had the great advantage of non-adherence to the eyeball, but came with the disadvantage of a preparation procedure calling for boiling and controlling the temperature. Suitable equipment and a certain time interval for preparation were required.
During the taking of the mold, the eyeball has to remain fixed and immobile and avoid blinking. The placing of a fixation target, in the form of a luminous spot projected on the ceiling, can turn out to be advantageous. The patient is placed in a horizontal position and receives topical corneo-conjunctival anesthesia. While the eye is being anesthetized, Negocoll is prepared by boiling in a water bath and then gently cooled down to body temperature, confirmed by touch. The patient is asked to fixate the target. Negocoll is poured into a

molding shell that is then placed under the lids, like prosthesis. After the completion of this maneuver, excess Negocoll is not removed, for it acts like a pillow and maintains immobility of the eye. The patient has to keep the eye in the same position for a minimum of two minutes. The shell is only removed after five minutes, when the product is evenly and completely solidified. At this time the excess Negocoll is removed from the orbit and the lids. The shell is removed like an ocular prosthesis, possibly with the help of a strabismus hook. In the final stage, irrigation lavage is carried out until all that remains of the product is removed:
"*In order to mold the eyeball, I use a Müller contact shell that I half-fill with Negocoll paste, while kneading the paste continuously with my finger; I then allow it to cool down to ambient temperature. Then, I introduce the glass filled with boiled Negocoll into the anesthetized eye. One portion of the Negocoll remains between the shell and the eyeball, the remainder flows out and acts as a marker. After insertion of the contact shell into the eye, the patient is asked to look in the chosen direction as long as the Negocoll is flowing and not solidified. After several seconds, the glass with the Negocoll bed adherent to it is carefully removed and is immediately treated with 'Hominit' (material for positive). The glass shell acts as a rigid support to hold the Negocoll lamella which would otherwise dry out rapidly in air and lose its shape.*" (32)

Starting with the mold, *Dallos* made a positive cast: "*When the taking of the molding is successful, the positive contratype shows a shiny cornea with clear borders and a smooth conjunctiva without folds. The transition between cornea and conjunctiva is continuous and the surface of the model has a specific curvature which is almost standard, but which differs in different meridians. The surface of the eyeball does not therefore represent a rotation surface; furthermore, it is not at all like the geometry of two spherical surfaces, the one sliding within the other.*" (33)

In order to obtain a better impression of the actual eyeball profile, *Dallos* completed the molding of the eye in the primary position and made additional moldings in the four cardinal directions of gaze: "*When I determined that, starting with a single molding, (...) I could not draw adequate conclusions as far as the division of pressure from the inside surface of the contact glass on the surface of the eyeball, I decided to complement my analyses. I had the patient look in different directions (...) and I did a molding in each of these directions. On these moldings, the cornea has an eccentric position (I now use contact shells shaped as a consequence of this eccentricity for these models) and a large quadrant of the eyeball surface is added.*" (34)

Finally, he collected the four peripheral parts surrounding the central molding into the configuration of a sliced pie that afforded an overview of the ocular topography. He noted, "*even the periphery of the sclera is still covered by folded conjunctival tissue that is both elastic and thickened*". *Dallos* confirmed the reproducibility of the molding procedure by doing several moldings on each eye the results of which turned out to be identical. As soon as it was removed from the eye, the shell was immediately placed in the neck of a small bottle, which acted as a support. The impressed molding shell had to be filled right away with cold water in order to accelerate its hardening. In order to produce a positive cast, the molding is dried and filled with clear dental plaster or Hominit. This stone cast is marked with a horizontal line between the two canthi and with a R (right) or L (left) depending on the side from which it was taken.

2.2.3 - Stevens' Corneal Moldings (1936)

See figure 29-25, plate V, page 312 & figures 29-26 & 29-27, plate VI, page 313
The Negocoll molding technique was known in the United States in April 1936 when *Dallos* published his paper on molded contact lenses in the Archives of Ophthalmology. From that year onwards, *C.L. Stevens* was using Negocoll for molding of the human eye in his studies on the evolution of ketratoconus at the Institute of Ophthalmology of the College of Physicians and Surgeons (Presbyterian Hospital, NYC). *Stevens* used Negocoll by having it flow through aluminum tubes, one extremity of which had an inner oval shape of 15 x 18 mm and external dimensions between 19 x 24 mm. He drew plaster of Paris castings from these. The moldings provided excellent representation in relief, but mainly represented the cornea and, less so, the sclera, making them unsuitable and unable to be used for manufacturing contact lenses. Although focused on the corneae of keratoconic eyes, *Stevens*' publication made the Negocoll molding technique known in the USA and served as a model and reference for obtaining ocular molds intended for the manufacture of contact lenses. (35)

2.2.4 - Obrig's Negocoll Ocular Moldings (1938)

See figure 29-28, plate VI, page 313
In 1938, *Theodor Obrig* published in the Archives of Ophthalmology his experience of 400 Negocoll ocular

moldings resulting in a molding technique very similar to that of Stevens but adapted to the eyeball diameter. *Obrig* referred to *Dallos* and noted "*unfortunately we had not been aware of his previous paper on the same subject in German three years before*." (36)

While exploring ocular moldings with the regard of a novice, *Obrig* drew important conclusions from these, notably concerning the diameter of the cornea, which did not correspond in any way to what was generally accepted and remembered for contact shells. He also made note of the irregularities of the scleral geometry that was absolutely not spherical in contrast to the *Zeiss* contact shells. He concluded that the Negocoll molding procedure was harmless, but could, nevertheless be improved by the use of manual dexterity and with modified shell molds. In his manual of 1942, *Obrig* described the improvements that he brought to the molding technique with Negocoll. Surprisingly however, he abandoned Negocoll a year later, and replaced it with a new ophthalmic impression material of his own manufacture. This was Moldite. (37)

2.3 - Early Dental Wax moldings

2.3.1 - Prister's ocular moldings (1933)

See figures 29-29 & 29-30, plate VI, page 313 & figures 29-31 & 29-32, plate VII, page 314

In 1933, *Bruno Prister* of the Ophthalmology Clinic in Trieste (Italy) described a molding procedure in which dental wax was used for molding the anterior segment of the living eye. *Prister* devised an instrument to carry a thin oval dome plate of dental wax. The oval wax plate is slipped under the lids and pressed gently on the globe. The wax is kept soft and molded to the surface by means of pads of cotton wool dipped into hot water and applied directly to the eye. When it is considered that a satisfactory and useful impression has been obtained, the wax is hardened by the application of cold swabs. The carrier and the wax mold are then carefully removed from the eye. From the negative thus obtained a model of the mold is cast in plaster. *Prister* suggested that two casting be made and that one of them should be varnished to give a reflecting surface. From this he feels that one may judge how closely the cast approaches the ocular curvatures. From the second cast the contact lens can be made. According to authors contemporary with him, there was difficulty because of the lack of detail regarding the orientation and the positioning of the mold. (38)

2.3.2. Feinbloom's Scleral Wax Moldings

In the USA, *Feinbloom* used a dental wax procedure similar to that of *Prister* for making molds of the scleral part. In 1936, he described how he used a haptic conforming to the scleral part of the eye that did not require any topical anesthesia and therefore there was no need for a physician to be present. This was intended to enable the manufacture of 'semi-plastic contact lenses'. After keratometry, he chose glass cupola to cover the cornea without touching it and thereby maintaining good clearance. In parallel, he modeled, using 'green dental wax', a contact shell 0.60 to 1.00 mm in thickness of the size of the eyeball. He then cut off a circular area of 12.00 mm. After placing in the eye the corneal glass segment and the ring of warm scleral wax, this combination is allowed to remain in the eye for 10 to 15 minutes, so that the warm wax takes up the conformity of the sclera. At this stage, the eye is irrigated with cold water in order to harden the wax. After removing the wax, the mold is placed in iced water to harden it to fill it with dental stone. The casts thus obtained served *Feinbloom* to refine his researches and to develop several generations of contact lenses. Certain contemporaries, like *Obrig*, were critical:"*First, no details of the size or form of the cornea are obtained. Second, no detail of the scleral surface is obtained; at best only an approximation of the actual surface is possible. Third, there is too much chance for a distortion of the molding during its removal from the eye and before it is actually cast*." (39)

2.4 - The Moldite of the Obrig Laboratories

After being used for ten years, Negocoll, which originated in Europe, was replaced by other products (alginates) used for dental moldings. Thus, in 1942, *Obrig* introduced and marketed Moldite: "*We developed a technique for making casts of the living eye with Negocoll, which proved satisfactory. As might be expected the technique developed slowly over a period of seven years. It was superseded in fall of 1942 by the still more satisfactory Ophthalmic Moldite technique.*"(40)

This alginate gel had the advantage of being usable in cold temperatures without the need to boil the product. All that was needed was to mix 10 cc of product with 7 cc of water and to mix this with a spatula for two minutes. Moldite becomes a gel within five minutes of it being mixed or just three minutes after it has

been placed in the molding shell. Conversion to gel state can be accelerated by warmer water or slowed with cold water. When it is removed, the molding has to be immediately filled with a specific fixing solution: "*With the scarcity of agar-agar from which Negocoll and such preparations are made, due to war conditions, several manufacturers experimented with the alginates to produce molding materials particularly for dental use (...), changes were made in the formula eliminating the flavor, color and setting time. It was released for general use by Obrig Laboratories under the name of Ophthalmic Moldite Powder*."

Ophthalmic Moldite was to enjoy a great success and became rapidly the easier to use reference product, as *Bier*, in particular, was quick to notice: "*The Moldite technique, which is an alterative to that of Negocoll, eliminates temperature control, as the material is used with cold water*."

2.5 British Zelex

In Great Britain and other parts of the English-speaking world, Negocoll was replaced by a impression material called 'British Zelex'. This was introduced in 1938 on the initiative of *C. Davis Keeler*, *Clement Clarke* and *Theodor Hamblin*. It was also taken up in the USA, and amongst others, *Boshoff* described its use in that country: "*Zelex is described as a 'flexible colloidal material'. It is marketed as a fine pinkish powder, which does not deteriorate on storage. (...) In powder or paste form Zelex has no chemical or physical reaction on the eye. (...) The proportion of powder and water, as well as the temperature of the water, can be varied, depending, respectively, on the consistency of the paste and the setting time required by the operator.*"[41]

With a mixture of 5 cc of Zelex and an equal quantity of water, one obtains a product of usable consistency. Beyond this time, the product jellifies and must be introduced into the molding shells. Using warm water, the duration of preparation is shortened, with a large amount of water it is lengthened. The cast must be made immediately after removal of the molding from the eye because Zelex quickly shrinks.

2.6 – Other Products used in Molding

See figure 29-33, plate VII, page 314

Many other types of colloid, alginates and dental waxes have been tried with a view to their being used in the eye. Their main disadvantage is their tendency to adhere to the eyelashes and lids. If they are used following dental procedure, colloids are not sufficiently fluid for ocular use, but when they are stretched out in water with the desired fluidity, they no longer have the desired performance and require too long a contact. The following two are often cited, amongst others:

MODELOID D

This is how *Leopold Dreifuss* used this product: "*He uses a molding material of his own manufacture called Modeloid D. Modeloid was initially devised to produce castings of anatomical specimens and actual disease conditions in situ on the living human body. (...) It is similar in many ways to Negocoll. (...) There are several criticisms of the procedure and the material itself. (...) Casts made with Modeloid have shown a serious lack of detail in the region of the limbus*."

KERRR'S HYDROCOLLOID

S.Maisler (San Francisco) developed this reversible hydrocolloid in 1939 with *J.J. Jansen*. It facilitated more rapid ocular molding. Presented in a tube (like toothpaste) it is immersed into warm water in order to soften its content before expressing the gel from it. The product does not adhere to the silver molding shells that the author conceived and had to perforate in order to evacuate excess gel and which he preferred to those made from more fragile glass. The casting is made in the classical manner using dental plaster. *Arno Town* (New York) also described good results with 'Kerr's Dental Wax' gauge 20 and a positive in dental stone. [42]

2.7 - Evolution of Molding Shells, Molding Cups and Other Accessories required for Performing Moldings

See figures 29-34, 29-35, 29-36, 29-37 & 29-38, plate VII, page 314 & figure 29-39, plate VIII, page 315

Success in performing moldings depends for the most part on the use of contact shells, specifically adapted for molding purposes. It has been recognized that, the larger the shell, the larger the area of sclera that is

included in the mold. However, the mold must be conducive to easy insertion and not press on the eyeball, whether by pressure on the eyelids or due to inappropriate size or fit. The design of such molding shells has evolved over several eras. Thus, *Obrig* stated: "*our first casting shells were made with the aid of Müller's shell lenses in a manner similar to that used by Dr. Dallos." At that time, Obrig tried out various other casting shells. His ophthalmologist friend Harry Eggers "suggested that the Müller lens might be more easily manipulated if a handle were attached to it in some way." The shells were initially round and made from soft glass, then they were made oval with dimensions of 24x27. Nevertheless, "the glass eye shells were fragile and broke readily. Plastic molding shells 24 x27 mm gave sufficient coverage and were easily inserted*."

According to *Dickinson*, *Obrig* was the first to use a contact shell with a hollow stem into which he introduced a short length of cotton thread. When Negocoll solidified, it did so on the cotton thread and the risk of retention of the mold on the surface of the eye was thus reduced. *Obrig* also introduced perforations in order to favor evacuation of excess molding product, thus minimizing the risk of separation of the shell and the mold. In addition, "*it soon became apparent that, within [limits], the larger the contact lenses were made, the better they were tolerated. [The] small-sized molding shells were discarded." Obrig obtained his best results with plastic shells provided with 20 mm handles. These were available in three sizes, "small" with an over-all size of 22x24 mm and a sagital depth of 11 mm: "medium" with over-all size 23x25 mm and 11.5 mm sagital depth of 12 mm add "large" with over-all size of 24x26 mm and sagital depth of 12 mm. The long sides of the shell were slightly arched like an eyecup. The shell walls were pierced with multiple perforations of about 2 mm in diameter*."

Subsequently, each user employed the model of mold best suited to his practice and experience. The shells were made with a variety of depths and numerous diameters. A number of preparations for coloring the handles or shells were tried. *Andersen* preferred shells with flat handles, which guaranteed horizontal position, even when the alignment points were covered by the molding product. *Dickinson* described a Bakelite funnel mounted on a hollow handle, into which is inserted a thread, the end of which is fed into the hollow handle and secured with forceps. *Policoff* patented an 'Eye-molding Apparatus' and *Györrfy* recommended a moulding shell whose "*handle has a central hole to which a 'record' syringe could be fixed*". This recommendation was soon widely adopted as *Obrig* indicated: "*An alternative and generally more satisfactory method is using a syringe for injection of Moldite. If this technique is followed, the casting will have a higher gloss and it will be possible to separate it from the negative mold with no damage to the mold*."

Other Accessory Devices and Options

See figure 29-40, plate VIII, page 315

In 1939, *Carrol Weeks* described the technique of ocular molding. He noted that, in certain patients, the eyeball was so asymmetrical that standard contact lenses were not tolerated. He showed that the limbal transition zone (between corneal and scleral curvatures) merited particular scrutiny. In 1944 *Anderson* presented a movie illustrating the techniques of molding and fitting of contact lenses at the first National Contact Lens Conference [43]. Starting with the first molding experiments of *Csapody* and *Dallos*, immobilization of the eyeball had been identified as an essential element in the success of molding. Thus, in 1940, *Julian Chisholm* (Boston) proposed that an '*adjustable fixation target*' be used to immobilize the contralateral eye. Also, *J. Mullen* designed a lid-retractor intended to facilitate and simplify the insertion of the product of molding under the upper eyelid. *M. H. Kauhl* and *D.G Hummel* found that "*as the fixation target held on the cross arm of a floor stand requires space close to the patient and interferes with the free movement of the assistant, the target is placed on the ceiling and can be brought as close as necessary to the patient*."[44]

2.8 – The Duplication of Molds

See figure 29-41, plate VIII, page 315

As soon as it is removed from the eye, the molding shell, along with the molding, is placed in a supporting structure, e.g. the neck of a small bottle. With certain molding products, the mold must be immediately filled with cold water in order to accelerate hardening. The mold is eventually dried and is then filled flush with casting product, in order to produce a positive cast. *Poller* advised that Hominit, Granulit or Celerit be used with his own additive that he had devised. Later on, other 'dental stones', such as Albastone, Calestone, etc, replaced these products. The stone casts were then marked with markers, e.g. a horizontal line between the medial and lateral canthi plus an R (right) or L (left), depending on which side. These casts were later transferred to a positive mold where the marker points were re-applied, the limbus identified along with "R" or "L' and the patient's name [45].

3 – Keratometry and Corneal Topography using Corneal Reflections

See figures 29-42 & 29-43, plate VIII, page 315 & figure 29-44, plate IX, page 316

Many years before contact lenses were invented, *Helmholtz*, *Javal*, *Placido* and *Gullstrand* had laid down the fundamentals required for keratometry:

- In 1855, *Hermann von Helmholtz* likened the cornea to a convex mirror that reflected the image of two mires that were presented at infinity across a telescopic system set in coincidence with a system of adjustable thin plates with parallel surfaces. The angle formed by these parallel plates corresponded with the corneal radius of curvature. The instrument acted independently of the distance of examination, but the head of the patient had to be immobilized and the eyes had to be fixated on a reference mark. During this era, *Helmholtz*, measured peripheral corneal flattening by moving the fixation point.
- In 1881, *Emile Javal* and *Hjalmar Schiötz* described a method for measuring corneal curvatures based on the principle that the cornea reflected the images of two targets of differing appearance. These objects could be moved on an arc of a circle on which a vernier indicated the corneal radius of curvature at the junction between the points of reflection of the two images.
- In 1882, *Antonio Placido* proposed complementing the numerical values for corneal curvatures given by the *Helmholtz* and *Javal* instruments by a procedure that provided an over-all view of the corneal curvatures. The original *Placido* disc had a diameter of 23 cm, its rings serving as object for the convex mirror formed by the cornea. Although these instruments were successively improved and modified, the *Placido* principle had the disadvantage of requiring immobility of the head and a fixed target for visualization, given the risk of otherwise producing incorrect and unhelpful tracings.
- In 1896, *Gullstrand* photographed a *Placido* disc reflected by the cornea. Photography eliminated errors due to mobility of the head and the object requiring to be fixated and thus made more precise interpretations possible. Although corneal photokeratometry excited little interest as concerned scleral contact glasses, it became important for corneal contact lenses; thus the procedure experienced a rejuvenation of interest.

3.1 - Keratoscopes , Reflexographs and Keratographs

See figures 29-45, 29-46 & 29-47, plate IX page 316 & figures 29-48 & 29-49, plate X, page 317

It would take too long to list all the improvements, modifications and improvements as well as describing the many uses of these instruments which were introduced for documenting corneal topography. We should note, however, that, in the era of the first *Zeiss* corneo-scleral contact shells, *Heine* and *Hartinger*, (their promoters) emphasized the supreme importance of keratometry for the measurement of the dioptric power of the lachrymal meniscus trapped between the cornea and the contact shell. This was because *Zeiss* relied solely on scleral support with a bridge over the corneal area of its contact shells. It was only after the publications of *Dallos*, *Obrig* and *Feinbloom* that it became evident that these corneo-scleral shells, and the corneal contact lenses that followed, had to conform physiologically to the whole of the ocular surface, the parameters of which could be read off the keratometers. This perhaps would explain why instrument-makers like *Zeiss* did not introduce instruments specifically adapted to the choice of contact lenses, although they marketed several models of keratometers. However, the principle of recording on photographic paper rays reflected from the cornea originating from a light source at infinity was used by both *Hartinger* and *Amsler*, followed by *Fischer* and *Berg*. Nevertheless, these prototypes were only used in certain specialized centers and contact lens fitters employed essentially the then currently available models of *Javal* and *Helmholtz* [46].

3.2 - The Pathway Towards Topographic Keratometry

See figures 29-50 & 29-51, plate X, page 317

In 1960 *Bonnet* and *Cochet* described a method of topographic keratometry applicable to contact lenses. They defined a law of linear flattening in each meridian. Following their experiments, *Cochet* and *Amiart* had designed a topographic keratometer consisting of two arcs furnished with reflecting spots. During the same era, research studies by *Soper*, *Samson* and *Girard* in Houston (Texas) and carried out in 1962 and 1965 resulted in a simple and easy-to-use topographic instrument, the 'Topogometer', that could be fitted to the current keratometers. The instrument could be used to measure the spherical corneal area with precision and could also provide measurements of the corneal curvatures in areas outside the central area. Other systems for measuring curved surfaces, such as the 'PEK' of *Wesley-Jessen*, the 'Jessop Peripheral K Disc' and the 'Corneopter' were developed during this time [47].

4 – Examination of the Lateral View of the Eye using Photography and Radiography

It was tempting to study the cornea and corneo-sclera in lateral view using photographic procedures and even lateral radiographs. Most of these initiatives have been described in previous chapters. Let us emphasize briefly that, already in 1929, *Csapody* had performed photographic and radiographic measurements of the lateral view of the eye after instillation of various eye drops. In 1935, *Andrea Biffis* (Padua, Italy) performed measurements of the curvature of the anterior segment that were completed by photographic measurements of cadaver eyes. She concluded that the anterior segment of the sclera was aspheric. In 1938, *George Nissel* (London, U.K.) submitted a patent for a method "*of taking photographs of at least two meridians of the eyeball*" to deduce from these the most suitable contact shell curvatures for the individual fit of the patient [48].

5 - Evolution in the Fitting Practices for Contact Shells and Lenses: a 50-year Survey

In the course of the first fifty years of commercialization, marketing of contact lenses, education of practitioners and changes in fitting techniques developed enormously. Chronologically four distinct phases can be identified:

- An empirical fitting procedure for the first glass corneo-scleral contact shells,
- An attempted physiological approach to fitting, using ocular moldings,
- The introduction of plastic materials into the manufacture of corneo-scleral shells,
- The corneal lens era.

5.1 - Fitting Glass Corneo-scleral Shells: an Empirical Approach

From the time of the first glass corneo-scleral shells, *Carl Zeiss* guaranteed their exclusivity by giving fitters only the bare minimum of recommendations for choosing, fitting, inserting and caring for the contact lenses of their manufacture. [49] In fact, the company used the same methods that they used to manufacture spectacle lenses, the geometry and the optics of which had to correct the refractive error. The human eye was treated as a schematic eye with perfect sphericities. The only difference for manufacturing purposes was reduced vertex distance. Optical correction was achieved by the lachrymal meniscus, the thickness of which was calculated as a function of keratometer readings taken from the *Javal* keratometer, the refractive power of the spectacle lenses and the spectacle vertex distance. The fitter did not know the coordinates of the definitive shell at delivery and could only note and agree with the often mediocre optical correction and tolerance obtained. The product information furnished by the manufacturer was inadequate, as *von der Heydt* noted: "*Information as to the methods of fitting contact lenses has not heretofore been freely available. The subject has been glossed over as if it were a simple matter needing no elucidation*" [50]
The *Heine* manual was not, strictly speaking, a fitting guide, but one that merely documented *Zeiss* recommendations. Taking into account that, during this era, eye care professionals were searching basically for improvement in optical correction in patients with keratoconus and high refractive errors, so-called '*success*' was reached with a merely approximate correction of refractive error and vision. No objective criterion of safety or tolerance was mentioned by the pioneers of this epoch. They supported the assertions of *Zeiss* that their shells, being geometrically perfect, could not possibly be the cause of intolerance. This could only result from the imperfect sphericities of the ocular globe.
A departure from this unsatisfactory position occurred after 1927 when *Zeiss* announced the possibility of including a ground optical correction of up to 6 diopters, on the anterior surface of the contact glass. In 1930, the company abandoned the standard initial haptic curvature of 12 mm in favor of a more extended set of trial lenses. In course of a brief collaboration with *Dallos*, *Zeiss* marketed shells with a super-elevated optic portion with reduced diameter of the optic along with intermediate optic radii. However, in the absence of procedures for measuring optical geometry, the choice was random and subjective. Trials with the *Friede*,

Helmbold, *von der Heydt* and *Dallos* instruments for measurement of topography bear witness to the trouble taken by the fitters of the time to fulfill the requirements of a good fit.

Very differently, the blown glass shells of *Müller-Wiesbaden* were produced and fit by the trained eye of an expert glass blower. The optical correction depended, here too, on the lachrymal meniscus, but the haptic part grossly resembled the patient's sclera, in whose presence the shells were blown. Depending on the results of the trials and adjustments, their stay in Wiesbaden could last one to two weeks. When blown glass shells were broken, it was necessary to restart the procedure of manufacture and fit. Several devotees, e.g. *von Clausen* (Halle), possessed a large collection of blown shells from which to choose the one best tolerated. During discussions at congresses after frequently over-optimistic presentations, attendees noted the disadvantages of both manufacturers' products and wished for shells of *Zeiss* optical quality but with the scleral geometry of *Müller-Wiesbaden*.

VITAL STAININGS

Vital colorants derived from aniline dyes were used from the end of the 19th Century by *Paul Ehrlich* as histological and vital stains in tissue investigations performed on the ocular media. Most important were Fluorescein and Methylene Blue, but Rose Bengal, Mercurochrome and Trypan Blue also had their place. *F.E. Müller* recommended Fluorescein in 1920 for making observations on the conformity of blown shells. *Fischer* used Methylene Blue in 1929 to compare penetration of tears under *Müller* and *Zeiss* shells. In 1932, the use of Fluorescein was recommended in the United States by *von der Heydt*. Expansion in use occurred after 1938, when *Obrig* combined fluorescein with a dense blue filter placed on the slit lamp. Thus he observed the liquid space between cornea and optical part of the shells. Such increase in use was facilitated by the introduction of a 'New Hand-held Slit Lamp' to check the fit of shells on the eye. *Neill*, however, put forward serious objections to this technique and proposed an interesting alternative. He used a Fluorescein eye drop of lower concentration and an ultraviolet lamp equipped with a more appropriate filter. Later, *Otto Barkan*, *Frederic A. Wies* and *E.B. Hague* described alternative lamps and filters, whereas *Reuben Greenspoon* proposed observing Fluorescein clearance under contact lenses. He used an eye drop composed of three drops of 2% Fluorescein added to a bottle of 10% Neosilvol. (51)

CORNEAL CLOUDING

From the time of the first contact lens fittings, the wearers of such lenses observed the appearance of a fog three to eight hours after insertion. This progressively increased in density, but disappeared 15 to 30 minutes after the lens was removed. Objectively, observers noted a disturbance in the corneal epithelium and edema in severely affected patients. Corneal physiological studies on the transparency and permeability of the cornea to gases and metabolites by *F.P Fischer* confirmed the difficulties related to the wearing of contact lenses at this time. They increased the doubts expressed regarding the use and fitting of contact shells of whatever type. The evidence of *Schnaudiegel* is often quoted: this was the female who expressed preference to re-undergo all the labor pains associated with seven pregnancies rather than submit herself a second time to the trials of *Zeiss* and *Müller* contact shells! The persistent denials of the *Zeiss* engineers were upheld by the studies of the asymmetry of the ocular globe by *J. Strebel* (Lucerne). This author stated a 'law of asymmetry of the anterior scleral 'calotte' (cap)'. Meanwhile, *Zeiss* condemned the incompatibility of liquids used for lens insertion and the lack of their periodical renewal. (52)

5.2 - An Approach to Physiological Fitting by Ocular Moldings

The situation improved slightly after the publication of *Dallos*'s works on ocular moldings and an optical grind of the molded glass shells. This remarkable advance was first recognized in Europe, then, several years later, in the United States, where it was supported by favorable comments such fitters as *Feinbloom*, *Greenspoon* and *Obrig*. Thus, the importance of scleral support and lachrymal circulation at the cornea was finally demonstrated. Attentive observers noted that corneal symptoms were less pronounced when a bubble of air was included between shell and cornea. *Sattler* deduced that refractive error correction by lachrymal meniscus was a major error. Persistent intolerance under traditional shells was attributed to the liquid of the precorneal space. This liquid, according to *Feldmann* had to be isotonic with tears, maintained at the correct temperature and prevent the accumulation of CO2. By the same token, solutions used for insertion had to have a composition approaching that of tears and prevent corneal anoxia by their acidification. Ini-

tiatives favoring the most varied liquids and those judged to be the most effective brought success to their manufacturers and were used as excuses in unsatisfactory fits. However, during this era, *Dallos* had already demonstrated the pathway to a successful fit: this was however the use of glass and the *Dallos* approach was not suited to mass production [53].

5.3 - Advances in Corneo-scleral Contact Shells made from Plastic Materials

After the introduction of plastic materials [54], the manufacture of contact shells from moldings became more current as evidenced in the works of such fitters as *Obrig*, *Feinbloom, Dickinson, Bier, Beacher* and *Anderson*. Technical difficulties meant that, with few exceptions, corneo-scleral contact shells were fit basically by the manufacturers, their technicians, or in manufacturer-dependant 'Contact Lens Fitting Institutes'. Often, manufacturers would jealously guard the geometric coordinates of their shells. The fitter, after having sent in the cast, received, most times, several trial shells. He or she then indicated from these the one that seemed to be the best tolerated and included their comments on the examination under Fluorescein. The manufacturer used this information to deliver the best fitting lens. The procedure, often repeated several times also justified the high prices of the shells. We have two particularly interesting references from this era: the proceedings of the '*First National Contact Lens Conference*' held in 1944 (organized by *Obrig*) and the report of *Bier* describing his 1947 visit to the principal manufacturers and fitters in the United States of America. The professional organizations tried to interest their members in the fitting of contact glasses, but they had to come to terms with the manufacturers and comply with their demands for exclusivity. Only in the United Kingdom of Great Britain, thanks largely to the involvement of the ophthalmic surgeons of Moorfields Eye Hospital and the inspiration of *Dallos* (recently arrived from Hungary) had the capability of creating a unique center of excellence that was later emulated throughout the world.

5.4 - Corneal Contact Lenses

The discovery of corneal lenses by *Tuohy* [55] and *Nugent*'s publications produced a radical change in the evolution of contact lenses, since it was recognized for the first time that a contact lens could be worn without scleral support. This had not been imagined during the previous fifty years. It is necessary to state, however, that *Tuohy*'s first generation of 'big and flat' corneal contact lenses responded only imperfectly to the physiological requirements of the cornea and lachrymal circulation. The lenses of *Butterfield*, *Stimson* and *Hornstein* had characteristics that were distinctly more suitable. However, contrary to the latter, *Tuohy* and Solex had benefited from the support and the cautious advice of *Maurice Nugent* (Los Angeles, who was the Professor of Ophthalmology). Without any doubt, the publications of the latter facilitated and favored the attribution of the patent and the dissemination of encouraging results from the first trials. In fact, in comparison with the corneo-scleral shells in use during the era, these first trials gave distinctly more favorable results, thus explaining the success and enthusiasm for corneal lenses when the results were published.
During the first years of quasi-exclusivity, Solex Laboratories tried to link in the fitters to their company by not delivering the geometric coordinates and provided lenses, which were only designated by letters and numerical codes. The practitioner sent in the keratometer readings and received three lenses in return. He then indicated the lens that seemed the best fit, added their own observations before and received in return a lens of which the optic, geometry and the Fluorescein image were the most suitable. This non-transparent process maintained for a short period the monopoly of Solex and the Fitting Centers founded by the company. However, in 1953, a new evolutionary development came to light hardly three years later, when it became apparent that the 'big and flat Tuohy lenses' were an even worse concept. Initiated by *Dickinson*, *Neill* and *Söhnges*, 'small and light microlenses' took their place, thus opening the pathway to further improvements. It fell to the Plastic Contact Lens Company (Chicago) of *Wessely* and *Jessen* who, playing the double card of advertising to the public at large as well as providing education programs for practitioners, were soon to capture the American market, then world-wide. *W-J* introduced the principles of industrial management, marketing and accounting to this greater market. At this time, the manufacturer was to become the principal instructor for the untrained practitioner and it was only later and with timidity that professional organizations and instructors in Schools of Optometry and Faculties of Medicine moved forward to take up the challenge. Except for some research laboratories, the interest of these institutions and other laboratories was to focus on 'new materials', hydrogels and PMMA co-polymers. [56]
Indeed, as the 1970s approached, a further major development and break with the past would occur with

the announcement followed by marketing of hydrogel soft lenses and lenses made from new gas-permeable materials. The replacement of traditional corneal lenses by lenses made from new materials was gradual but relentless. Parallel to these tumultuous events, other major changes were to occur. These included improvements in the techniques of corneal topography and objective investigation of corneal tissues.

PLATES I-X

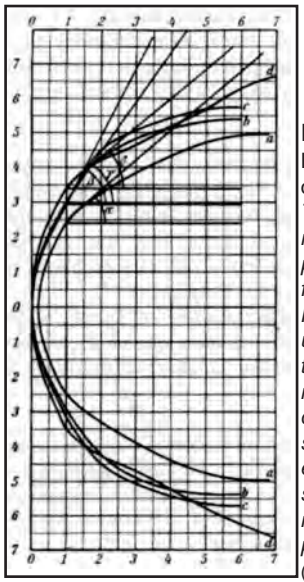


Figure 29-2
Diagram of the corneo-scleral profile obtained with Friede's 'Sclerometer'.
The measurements from the 'Sclerometer' are documented in a diagram, point by point. They describe the profile of the sclera as far as the equator. Friede thought he would be able to use the sketch for the choice of contact lenses. These painstaking measurements demonstrated significant differences between the scleral measurements that can exist between each eye. Friede published his measurements for four pathological eyes: microcornea, mild hyperopia, high hyperopia and buphthalmos.
(Friede R., 1926a.)

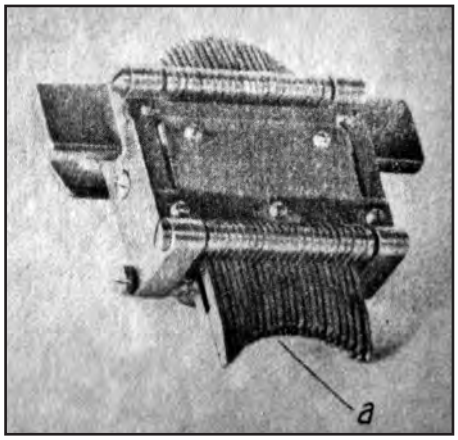


Figure 29-4
Helmbold's 'Sclero-Keratometer'.
The 'Sclero-Keratometer' was constructed in 1931 by Rudolf Helmbold and comprised 42 sliding sticks (applicators) in a case. These were aligned in a row 20.00 mm in width. After calibration on a plane surface, the 'Sclero-Keratometer' is placed on the anesthetized cornea. "When the sticks touch the whole surface width of the cornea with their extremity, one closes the stop-gate. The measurement thus obtained is documented immediately onto paper by pencil tracing or against calibrated discs (from 7 to 13 mm radius) attached to the instrument. Taking an average of several measurements is recommended." (Helmbold R., 1931)

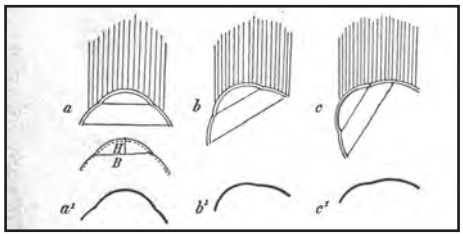


Figure 29-6
Ocular profiles (lateral views) obtained with the Helmbold 'Sclero-keratometer'.
According to Helmbold, the profile obtained by the 'Sclero-Keratometer' is transferred to a diagram that could serve as a model for the manufacture of the corresponding corneo-scleral shells. "By rotating the globe, limbal topography can be measured, likewise that of the adjoining sclera, of which the curvature is essential for the support of sclero-corneal contact shells." (Helmbold R., 1931)

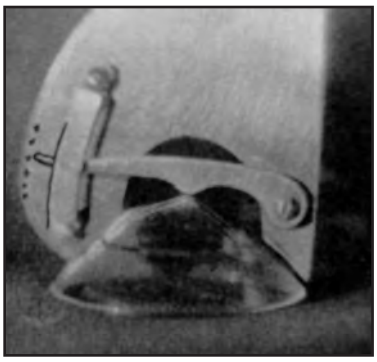


Figure 29-3
Von der Heydt's contact glass gauge.
In October 1928, Robert von der Heydt demonstrated to the Chicago Ophthalmological Society "a simple small gauge on the order of a tonometer to measure the height of the cone. The necessity of trying all four of the trial contact lenses was thus avoided." In March 1932, he presented a newer model with more sophistication: "One was a simple silver ring of 13 mm diameter to rest on the scleral border, supporting a plunger, on the order of a tonometer, and another was made with a lever and scale. This can be used on the anesthetized eyeball as well as on the contact glass for the purpose of measuring the height."
(Heydt v.d.R., 1928, 1932)

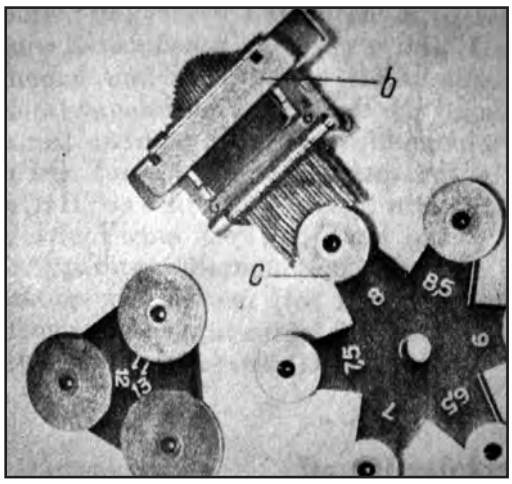


Figure 29-5
Calibrated scleral and corneal gauges used with Helmbold's Sclero-Keratometer.
The profile obtained with the 'Sclero-Keratometer' can be compared with calibrated gauges or reference spheres with radii of corneal curvature (6 to 8.5 mm). Likewise, scleral radii of curvature (11, 12, 13 mm) should be compared, identical to those of early Zeiss ground contact glasses.
(Helmbold R., 1931)

Figure 29-7
The Tholometer of Dallos.
Joseph Dallos had a 'tholometer' constructed according to the principle of the Schiötz tonometer.
The first version (1930) had supporting rings for placement on the base of the sclera and a probe equipped with corresponding rings for positioning at the limbus. In this version, the tonometer measures the heigh, the arrow, of the scleral curvature: "The tholometer (an instrument for measuring curvatures) consists essentially of a ring, the dimensions of which correspond to those of the scleral part of Zeiss contact glasses. By placing the instrument gently on the eye, a mobile axial pivot indicates the relative protrusion of the cornea-expressed fractions of a millimeter. Thus, 0.02 mm is still readily measurable."
The second version (1933) measures the prominence, the arrow, of the cornea with reference to the limbus. The calibrated ring is placed at the limbus and the probe touches the summit of the cornea: "First, I had the fixed scleral ring changed for the radius of 12 mm into a support into which one could fix the exchangeable rings of various radii (11, 11.5 etc. up to 14 mm)."
(Dallos J. 1931b, 1932, 1933, 1936b)

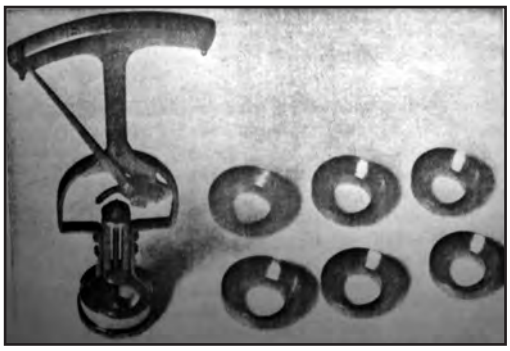


Figure 29-8
The gauge of the University Eye Clinic at Utrecht.
The Utrecht University Museum has conserved a gauge that could be used for measuring the corneal arrow. The authors of the museum catalogue have not identified it formally. They merely referred to it as "An instrument for the measurement of curvature".
(Tonkelaar I.d., Herkes H., Leersum v.G.K., 1996)

Figure 29-9
Szymanski's metallic shells.
Jules Szymanski presented to the Polish Society of Ophthalmology in 1936 a recommendation to use his metallic rings in order to measure the curvatures of the sclera and cornea. Some were calibrated 11, 12 and 13 and these corresponded with the haptic radii of curvature of Zeiss contact shells. They could be used to measure scleral curvatures. The others, intended for the measurement of corneal curvature, were "metallic shells of radii 6, 7, 8 and 9 millimeters, each with a diameter of 10 mm for adjusting to the cornea." (Szymanski J., 1936)

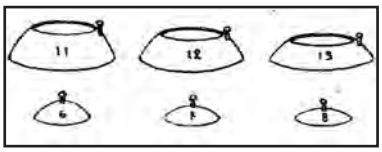
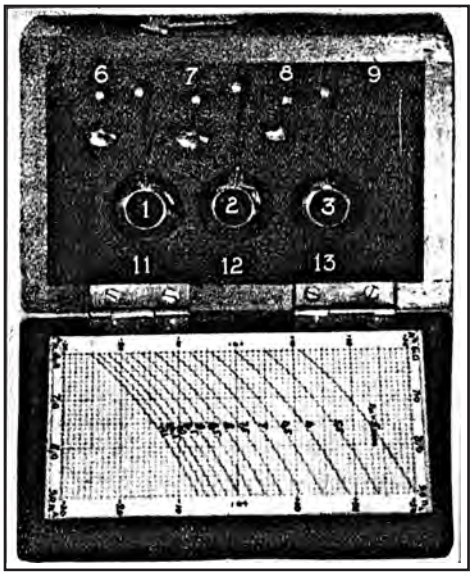


Figure 29-10
Box of Szymanski's metallic shells.
In his presentation to the French Society of Ophthalmology in 1937, Jules Szymanski proposed using his metallic rings to replace Zeiss trial lenses. The shells are presented in a box containing a handle for manipulation and an abacus similar to Hartinger's abacus.
(Szymanski J. 1937)



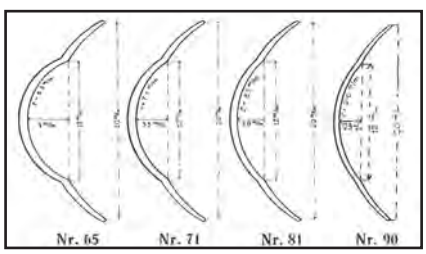


Figure 29-11
Table of the four first Zeiss trial contact glasses.
(Zeiss Carl, 1927a)

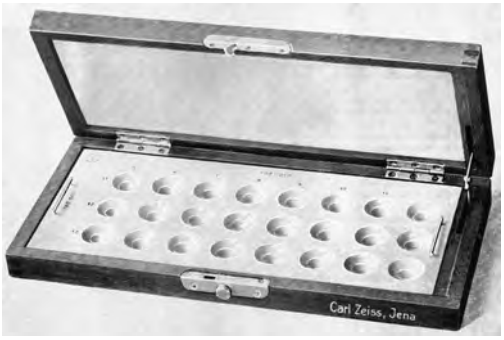


Figure 29-12
Box for a set of 21 standard Zeiss-Heine trial standard 'adherent lenses'.
The bottom of the wooden box consists of a fixed Bakelite plate. The cover of the box is twice the expected thickness due to upholstering. A similar case of smaller dimensions is provided with 18 complementary shells.

Probierhaftgläser nach Prof. Heine

des Sklerateils des Fragrandes in mm		Krümmungsradius der augenseitigen Glasfläche des Hornhautteils in mm						
		5	6	7	8	9	10	11
		Bezeichnung						
Probiersatz I (21 Haftgläser)	11	1/5	1/6	1/7	1/8	1/9	1/0	1/1
	12	2/5	2/6	2/7	2/8	2/9	2/0	2/1
	13	3/5	3/6	3/7	3/8	3/9	3/0	3/1
		5,5	6,5	7,5	8,5	9,5	10,5	
Probiersatz II (18 Haftgläser)	11	1/55	1/65	1/75	1/85	1/95	1/05	
	12	2/55	2/65	2/75	2/85	2/95	2/05	
	13	3/55	3/65	3/75	3/85	3/95	3/05	

Auf Wunsch können auch Probierhaftgläser mit einem Krümmungsradius des Sklerateils von 10,5, 11,5 und 12,5 mm geliefert werden. Auch ist es möglich, Gebrauchshaftgläser mit stetigem Übergang vom Kornea- zum Sklerateil, mit erhöhtem Kornateil oder ovalem Sklerateil anzufertigen.

Figure 29-13
Notice of the Zeiss-Heine trial 'adherent lenses'.
In 1934, the early Zeiss-Heine trial shells in the standard box are presented with combinations of three scleral radii of curvature: 11.00, 12.00 and 13.00 mm. The 21 afocal shells have radii of curvature in steps of 1.00 mm, between 5.00 and 11.00 mm. The contact shells of the complementary box of 18 shells have intermediate steps of 0.50 mm for their corneal radii of curvature.
The notice gives the additional information that shells with scleral radii of 10.50, 11.50 and 12.50 are also available. The definitive shells can be furnished with a transition at the limbus, with a super-elevated corneal part, or with an oval total diameter. (Zeiss Carl, 1934)

Figure 29-15
Presentation lens cabinet for Dudragne's plastic corneo-scleral contact shells.
Top: The facade of the Dudragne case turns back (folds) and the coverlet can be lifted, revealing four drawers, each with 40 cupules of which each contained a contact shell.
Below: A Dudragne presentation case in varnished wood (34 cm in width, 24 cm in depth and 12 cm in height). (Private collection)

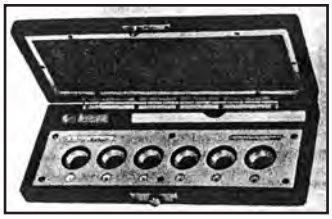


Figure 29-14
Small case with six Gualdi's trial contact lenses.
Taking into account the reduced number of trial lenses recommended by Gualdi, a small case was all that was required for arranging and stowing the six spherical monofocal contact lenses.
(Gualdi V., 1931, 1934)

Figure 29-16
Chests of drawers for trial corneal contact lenses.
The luxury wood cabinets made by Wöhlk-Contact-Linsen (above) and Titmus-Eurocon (below) can contain several hundreds of corneal contact lenses in their drawers.
(Private Collection)

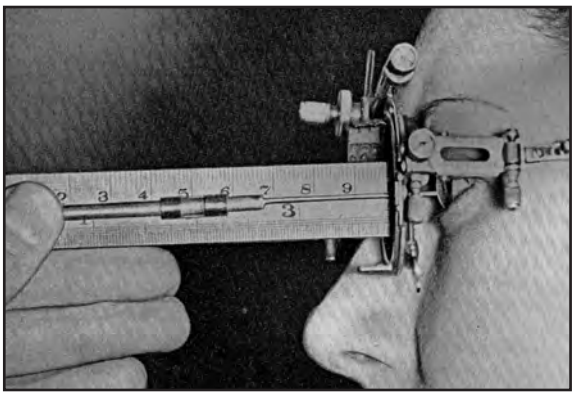


Figure 29-17
Dickinson's measurement of the vertex distance.
In their publication, Dickinson and Clifford-Hall described the development of a modification of Rugg-Gunn's 'vertex distance measurer': "The drilled trial lens is mounted in the same cell of the trial frame from which the refractive lens has been removed and the pointer is moved forward until contact is made with the apex of the inserted contact lens."
(Dickinson F., Clifford Hall K.G. 1946)

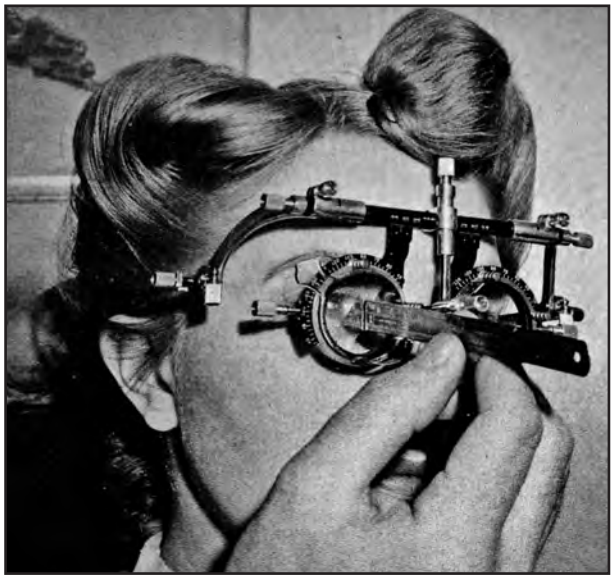


Figure 29-18
Anderson's measurement of the vertex distance.
Anderson described the measurement as follows: "If the correction is stronger than plus or minus four diopters, it is necessary to measure carefully the vertex distance (the distance between the posterior surface of the spectacle trial lens and the vertex of the anterior corneal surface of the contact lens). This is most easily and accurately done with a steel rule and a stenopeic slit. The stenopeic slit is placed in the same cell of the trial frame as the strongest lens used in the refraction." (Anderson A.L., 1944)

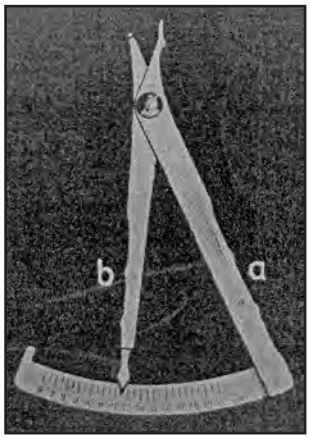


Figure 29-19
Schaefer's early distance gauge.
In 1939, Bertram Schaefer (Chemnitz) described an 'Entfernungsmesser' (a distance gauge) that resembled a pair of scissors that he used for the measurement of the distance between the anterior surface of the contact lens inserted into the eye and the glass of the additional spectacle lens necessary for the correction of a high refractive error. The principle of this instrument was to serve as a model for generations to follow for 'distometers'.
(Schaefer B. 1939a, b)

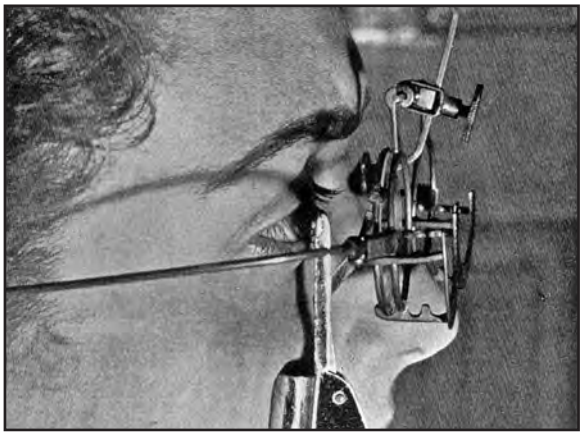
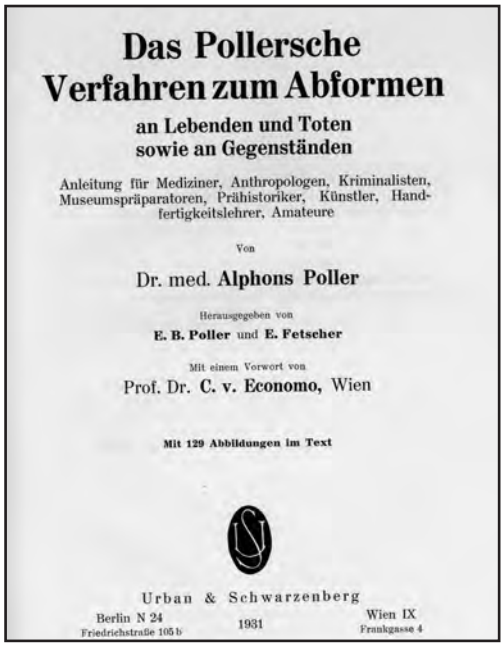


Figure 29-20
The 'Distometer', an adapted form of Schaefer's distance gauge.
According to Bier: "the instrument shown is preferable to the customary stenopeic slit and rule. It permits simpler and more accurate assessment of the back vertex power; the refractive lens does not have to be removed from the cell of the trial frame. Discrepancies in measurement are thus avoided. The instrument illustrated is called a 'Distometer' and is made in the USA. The scale for reading the vertex distance is calibrated in millimeters." (Bier N., 1957)



Das Pollersche Verfahren zum Abformen

an Lebenden und Toten sowie an Gegenständen

Anleitung für Mediziner, Anthropologen, Kriminalisten, Museumspräparatoren, Prähistoriker, Künstler, Handfertigkeitslehrer, Amateure

Von

Dr. med. **Alphons Poller**

Herausgegeben von

E. B. Poller und **E. Fetscher**

Mit einem Vorwort von

Prof. Dr. **C. v. Economo,** Wien

Mit 129 Abbildungen im Text

Urban & Schwarzenberg

Berlin N 24 Friedrichstraße 105 b — 1931 — Wien IX Frankgasse 4

Figure 29-21
Title page of Poller's manual on the Negocoll molding procedure.
The manual of Alphons Poller 'Das Pollersche Verfahren zum Abformen an Lebenden und Toten sowie an Gegendständen' (Poller's procedure for taking molds from the living, the dead, and from objects) published in 1931, served any years as an authoritative source of reference.
(Poller A., 1931)

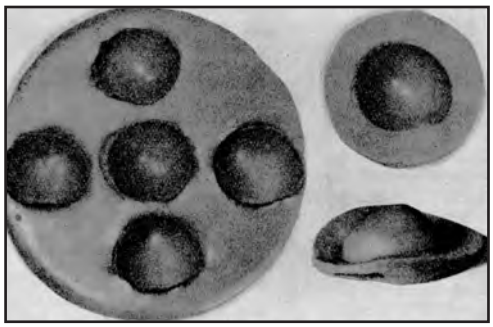


Figure 29-24
Dallos' eye moldings.
On the left: five partial moldings with, in the centre, molding in the primary position. Surrounding this, moldings in the four cardinal directions of gaze. On the right: above: the reconstructed model; below: the same in lateral view (profile).
(Dallos J., 1933b)

Figure 29-22
Poller's Negocoll for the molding of objects, tissues and organs.
Puller's Negocoll was marketed by 'Laboratoire Technique Apotela A.G.' (Zurich, Switzerland) in metallic boxes of 5 kg and 1 kg. It was presented in the form of granules and could be modeled by pressure from the hands. (Poller A., 1931)

Figure 29-23
Products and utensils for Negocoll molding of objects, tissues and organs.
In this figure, Poller illustrates the products and utensils necessary for Negocoll molding: a Bunsen burner with tripod, bowls and containers, forceps for manipulations, Hominit and Celerit prisms. (Poller A., 1931)

Figure 29-25
Products and utensils for Negocoll moldings by Stevens' technique.
In this figure, Stevens illustrates the products and materials he used: Negocoll, small and large size aluminum container tubes, small double boiler, small electric heater, one eye speculum, thermometer, five beakers, Pontocaine, gauze sponges, teaspoon, red crayon pencil, regular dental plaster, glass plate, two plaster mixing bowls and spatula. (Stevens C.L. 1936)

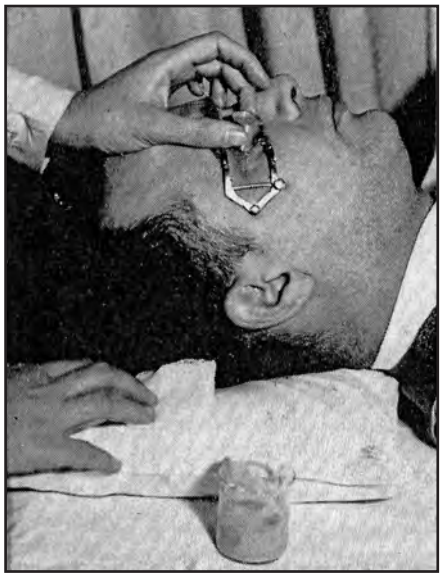


Figure 29-26
The container tube is held in place upon the eyeball for molding by Stevens' technique.
While holding the container tube in place, the Negocoll is poured in directly upon the cornea. The tube is held in place for approximately five minutes until the Negocoll sets.
(Stevens C.L. 1936)

Figure 29-27
Three Stevens ocular casts.
From left to right: normal cornea, moderate cornea, and marked conical cornea.
(Stevens C.L. 1936)

Figure 29-28
Obrig's equipment for making casting.
The equipment consist of a set of molding shells, Poller's Negocoll, a double boiler, a sterilizer, two 50 cc pyrex beakers, one 250 cc beaker, a thermometer, molding shells of variuous sizes, a stainless steel spatula, demitasse spoon, cotton, gauze pads, absorbent tissues, cotton tipped toothpicks, a local anesthetic, epinephrine hypochloride, small narrow-mouthed bottles, a small plaster bowl, french regular dental plaster or albastone, sodium chloride or Ringer solution, undine or syringe for washing out eyes, a muscle hook.
(Obrig TE., 1938a)

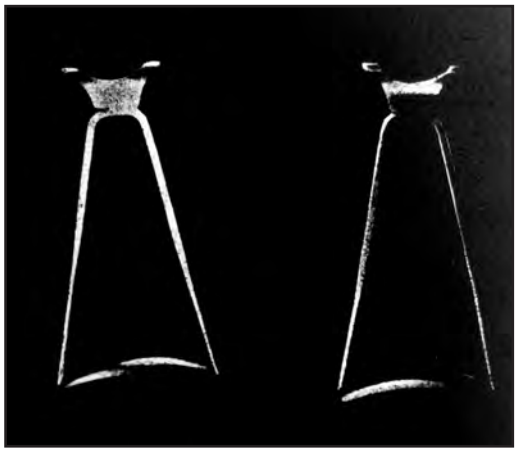


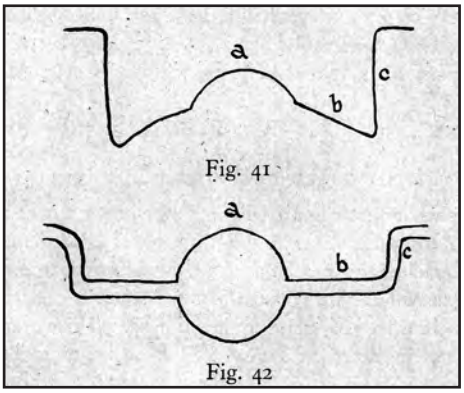
Figure 29-29
Prister's imprint-carrier.
The curved tray of the imprint-carrier is covered with dental wax at body temperature in order to adapt it to the corneo-scleral profile.
(Prister B., 1932b,)

Figure 29-30
Holding the imprint-carrier by Prister's technique.
The manner recommended by Prister for holding the imprint-carrier while filled with a negative wax mold in order to remove it without deformation.
(Prister B., 1932b)

Figure 29-31
Transfer of the negative mold to plaster cast by Prister's technique.
The negative wax mold held on the implant-carrier is transferred to plaster of Paris in order to obtain a plaster cast.
(Prister B., 1932b.)

Figure 29-32
Prister's plaster casts.
Lateral view (profile) of the plaster casts obtained by Prister. From left to right: myopic eye, emmetropic eye and hyperopic eye.
(Prister B., 1932b.)

Figure 29-33
Beacher's eye cover sheet for eye impression without anesthesia.
Lester Beacher recommended a plastic cover instrument to be placed over the eye in such a manner as to cover the cornea. The illustration shows: the cross-section of the cover instrument (Fig. 41); an upon view of the instrument (Fig. 42). Legend indicates: (a) elevated circular corneal section, (b) narrow scleral portion, (c) handle. After the impression is made, the cover instrument can be separated from it or one can leave the cover instrument within the negative and proceed to prepare the positive.
(Beacher L.L., 19441a, b)



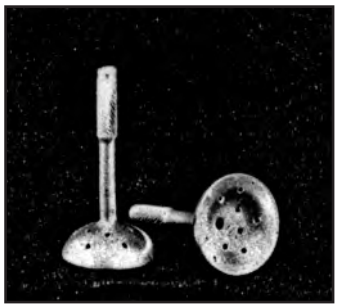


Figure 29-34
Maisler's Malleable Molding Shells
In 1939, S. Maisler proposed a gel called "Kerr's Hydrocolloid." He therefore used very thin silver shells (obtained from Trainer and Parsons, San Francisco). These could be made of varying thicknesses, some sufficiently thin to be malleable and adjustable in contour and circumference.
(Maisler S., 1939)

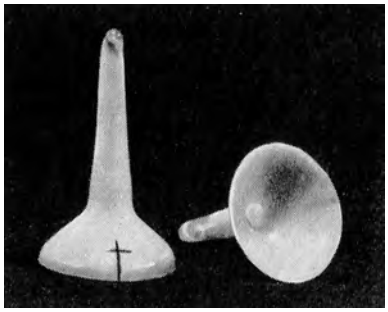


Figure 29-35
Obrig's Early Glass Molding Shells
The first casting shells were manufactured by ocularists, who used the same soft material that was used in making ocular prostheses. According to Obrig, these early shells were round in shape and had a diameter of 22 mm. They were very fragile and broke easily.
(Obrig T.E., 1942)

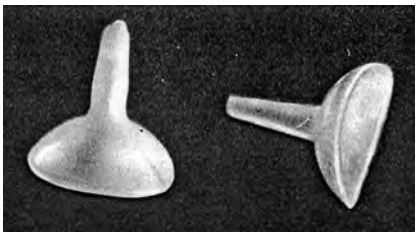


Figure 29-36
Obrig's Second Generation Glass Molding Shells (1938)
The second generation of casting shells made from glass was oval and had diameters of 22x24, 23x25 and 24x26 mm. The long sides were arched in much the same manner as an eyecup. The depth of the shell from the lowest portion of this arch to the integral hollow handle is about 7 mm. The handle was 25 mm long, hollow and tapering slightly to a sealed far end. These were also blown in opalescent soft glass of the same type as that used for making prostheses.
(Obrig T.E., 1938a)

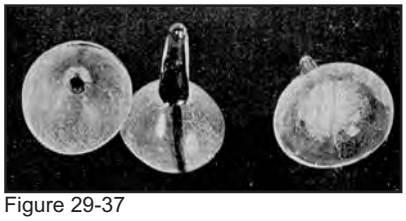


Figure 29-37
Obrig's Early Type of Plastic Molding Shells
Early plastic molding shells were constructed that were similar to the preceding model made from glass. Not only were they easier to manufacture, but also they were also unbreakable. (Obrig T.E., 1942.)

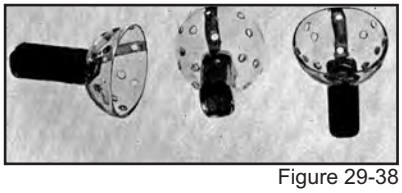


Figure 29-38
Obrig's Newer Type of Plastic Molding Shells (1942)
The newer types of plastic molding shells were perforated and covered most of the sclera. Their size facilitated easy insertion under the eyelids. They were equipped with a handle of 25 mm in length. The multiple perforations and the hollow handle allow the excess molding gel to escape as the shell is placed on the eye. Any pressure on the eyeball was thus eliminated. (Obrig TE., 1957.)

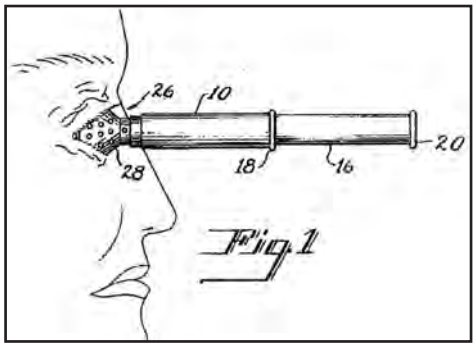


Figure 29-39
Policoff's Eye-molding Apparatus
In 1947, William Policoff filed a patent for an "Eye-molding Apparatus". The figure shows the apparatus in position (lateral view) and in engagement with the eyeball. (Legends by number show: 10) Hollow Tubular Housing, 16) Plunger, 28) Perforated cone overlying the eyeball in various sizes as determined by the size of the patient's eye, so that the device adequately cleared the cornea and the sclera.) (Policoff W., 1947)

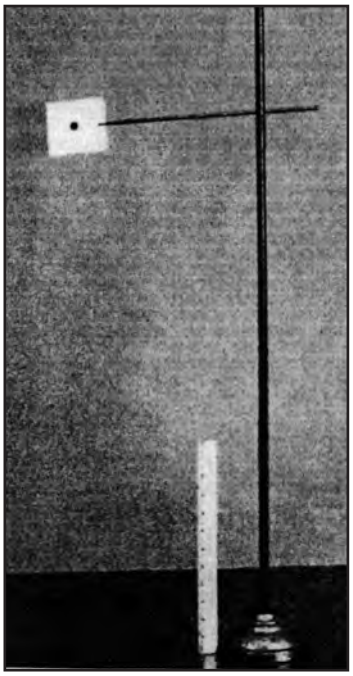


Figure 29-40
Chisholm's Adjustable Fixation Target.
In order to help fixation, an adjustable arm for a marker was devised as shown in the illustration. A heavy black circle containing a large black dot in the center of the card serves as marker.
(Chisholm J.F., 1940)

Figure 29-41
Shell With Negocoll Mold And Plaster Cast In Bottle
The molding shell with the Negocoll molding is placed handle-down in a small narrow-mouthed bottle. French's dental plaster or some good dental stone is poured into the molds. The molds and cast should not be touched for half an hour. At the end of that time, a line should be drawn across the cast from the inner to the outer canthus.
(Obrig T.E., 1938)

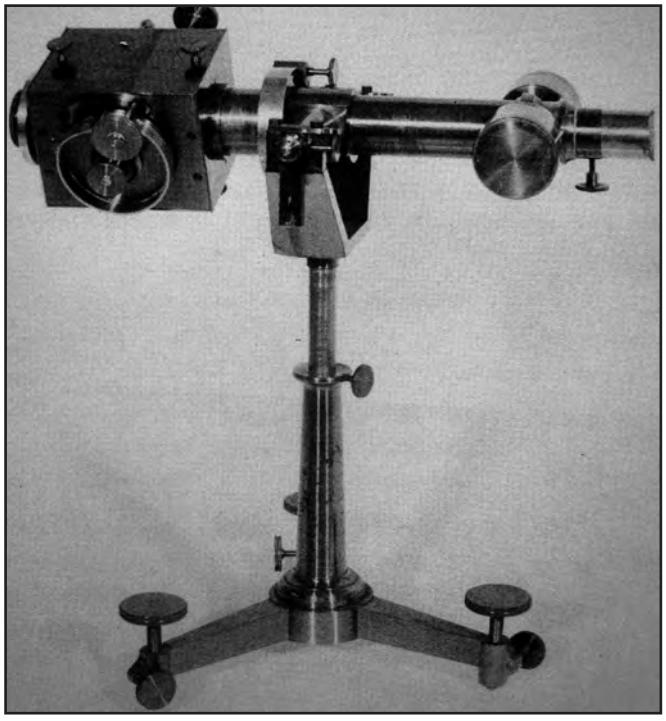


Figure 29-42
Early Keratometer of Von Helmholtz (1855)
This first model was described in 1855 and was based on the construction of the heliometers, the latter being a double-image micrometer used for measurement of the diameter of the sun. Hermann von Helmholtz used the principle of the heliometers. His ophthalmometer did not double the image (the sun), but two distant markers, which produced catadioptric images of the cornea. With the half of the adjustable plane parallel glass plates, the two images could be overlapped. The angle between the glass plates could be used to calculate corneal curvature.
(Helmholtz H. v., 1855; Haugwitz T. v., 1986)

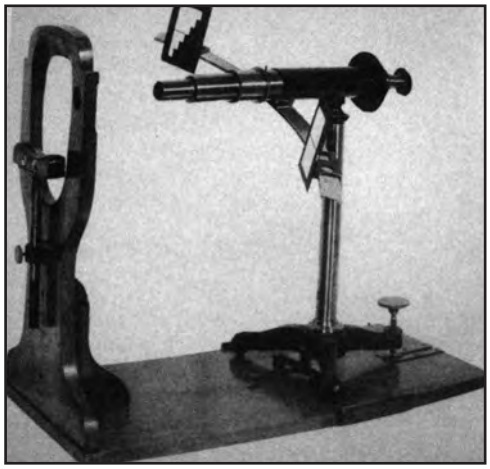


Figure 29-43
Javal-Schiötz Keratometer (1881)
In this model presented in Paris in March 1881 by Emil Javal and Hjalmar Schiötz, only one of the targets could be moved. Javal used a staircase and rectangle as mires. Later on, the mires were mounted on an arc, and were eventually able to be adjusted by a screw and cogwheel. Later models had a mechanical arrangement for the simultaneous opposite movement of the mires. This type of keratometer, commonly called "The Javal" was later produced by many companies with many modifications.
(Javal E., 1881; Haugwitz T.v., 1986)

Figure 29-44
Placido's Disc (1882)
The disc with concentric rings described in 1882 by the Portuguese ophthalmologist Antonio Placido was large in size. It was provided with a holding handle and possessed in its centre an orifice for observation of deformation of the rings reflected from the corneal surface. Subsequently, the Placido principle was followed by less bulky devices with different designs.
(Placido A., 1882)

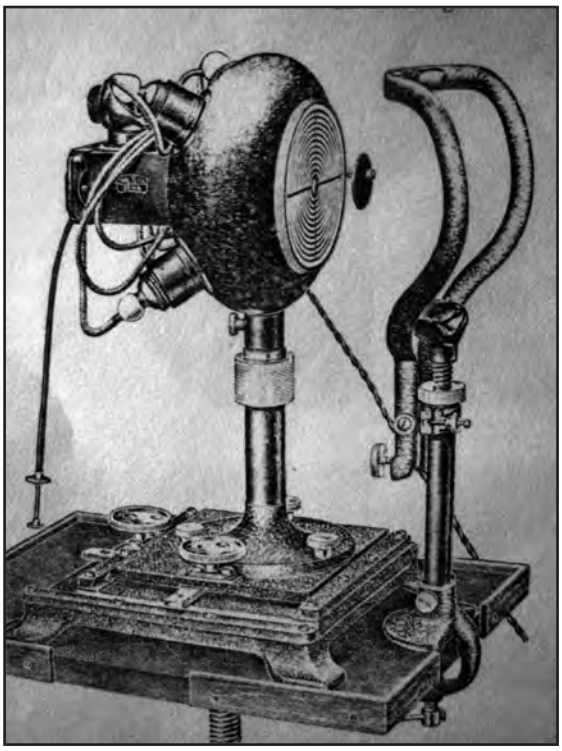


Figure 29-45
Zeiss-Amsler "Photo-keratoscope" (1930-1932)
Following Amsler's suggestion, Zeiss introduced in 1930 a photographic keratometer intended for the study of keratoconus. This was subsequently manufactured, starting in 1932. Four 40-Watt electric bulbs illuminate from behind a Placido disc painted on a translucent plaque. The patient is required to fixate on the center of the disc and a black occluder occludes the other eye. The camera itself is in the center of the disc.
(Amsler M., 1930; Hartinger H., 1930b, 1932a, b, c)

Figure 29-46
Zeiss-Fischer "Corneal Reflectograph"
Designed by Fischer and manufactured by Zeiss, this "Corneal Reflectograph" was used for the study of corneal deformations after cataract surgery in order to provide a photographic image of corneal topography.
(Fischer FP., 1928, 1932b; Hartinger H., 1932b)

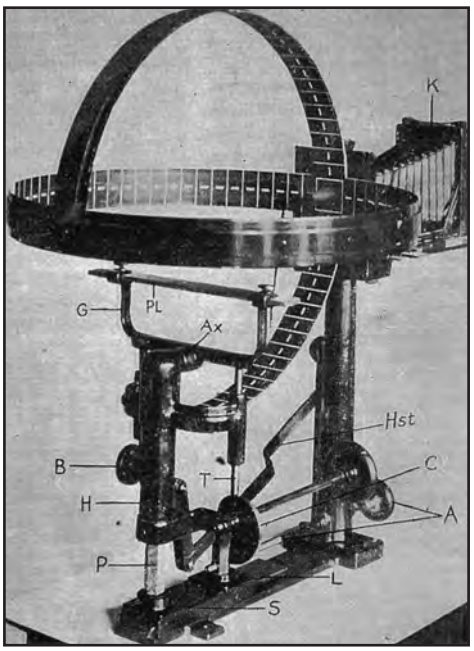


Figure 29-47
Berg's "Photographic Keratograph"
Photographic documentation of the corneal reflections was used by F. Berg in 1929, with the purpose of monitoring cicatricial deformities of the cornea after cataract surgery.
(Berg F., 1929, 1930)

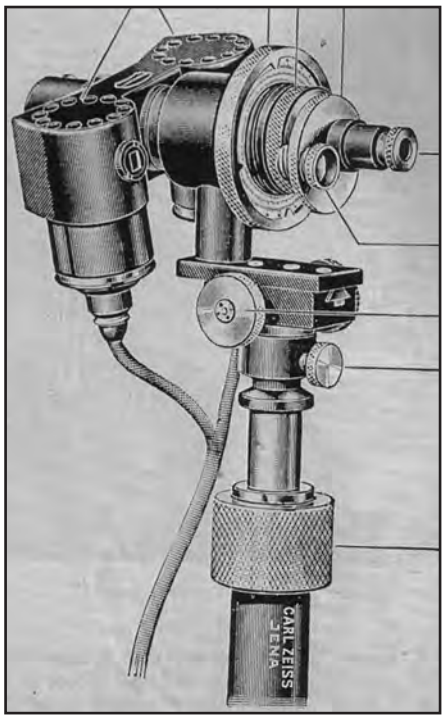


Figure 29-48
Zeiss-Hartinger Keratometer (1934)
The classic Helmholtz keratometer was modified and perfected by Hartinger and served as a model for several generations of keratometers.

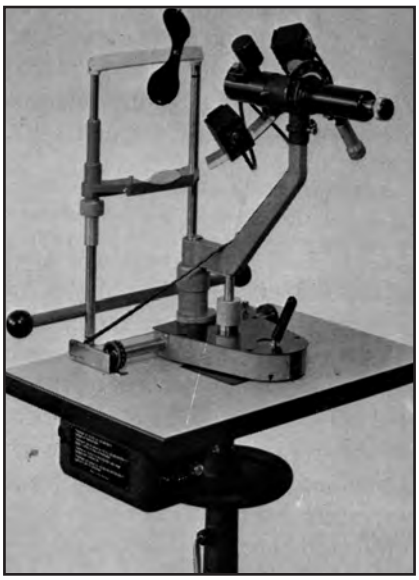


Figure 29-49
Current Model of the Haag-Streit Keratometer
The keratometer model according to Javal-Schiötz was widely marketed by most of the eye instrument manufacturers.

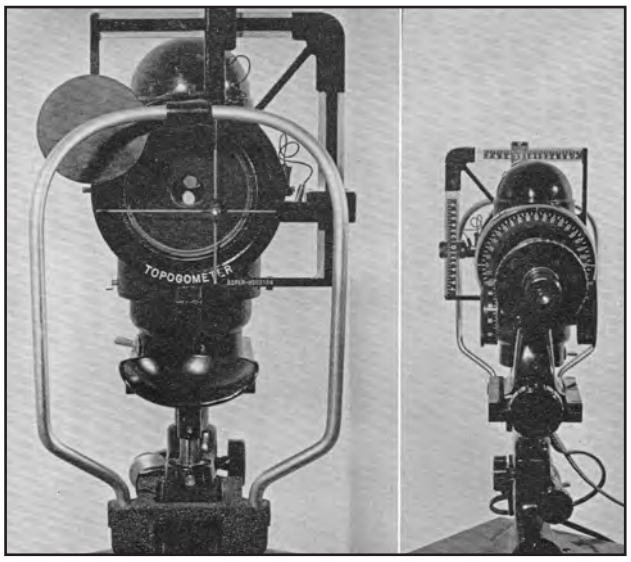


Figure 29-50
Girard Topogometer attached to the Bausch & Lomb Keratometer
This topogometer consists of a luminous source fixed in front of the keratometer by removing the two aligning poles on either side. The movable light source is thus fixed over the front of the instrument. With the patient's eye fixating the light source, the visual axis can be decentered from the keratometer's optical axis. The attachment has a graduated scale, which indicates, in steps of one tenth of a millimeter, the decentration of the visual centre. The amount of decentration over which the curvature in any meridian does not change is a measure of the regularity and diameter of the surface.

(Soper J.W., Sampson W.G., Girard L.J., 1962)

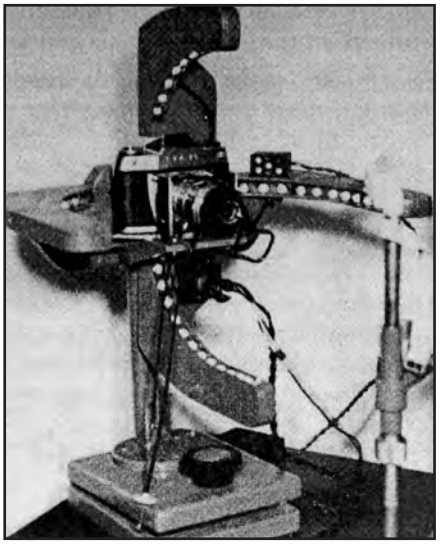


Figure 29-51
Topographic Keratometer of Cochet and Amiart (1966)
This instrument consists of two arcs of perpendicular circles with a series of luminous points comprising illuminated balls. These are separated by angles of 2° 30, between 10° and 40° on each half meridian. A camera is placed in the center of this set-up, with a fixation point at the center of its objective and flanked by two luminous bars, the images of which permits telemetric visualization.

(Cochet P., Amiard H., 1966)

Notes in Chapter XXIX

1. According to Friede R., 1926c.
2. Friede R., 1926c.
3. Heydt v.d. R., 1929: Presentation on the 22nd of October 1928 to the Chicago Ophthalmological Society & Heydt v.d. R., 1932: Presentation on the 21nd of March 1932 to the Chicago Ophthalmological Society. (See chapter 22, § 1.1.2).
4. Helmbold R., 1931.
5. Dallos J., 1931b: Presentation to the Hungarian Society of Ophthalmology on 28th and 29th June 1930 at Debrecen, Hungary & Dallos J., 1932a: Presentation to the Hungarian Society of Ophthalmology on 19th March 1932 in Budapest. (See chapter 21, § 2).
6. Tonkelaar Id., Henkes H., Leersum v.G.K., 1996.
7. Szymanski J., 1936, 1937. (See chapter 23, §5.2) - Haas E., 1937; Even A.N., 1940.
8. See chapter 20.
9. See chapter 22, § 6.1.
10. See chapter 23, § 3.1.
11. See chapter 26, §1.1.4.
12. See chapter 25, §1.
13. See chapter 25, §3.1.
14. Detailed description may be found in chapter 23 § 1.2.1 & table 23-1.
15. See chapter 25, § 2.5.
16. Rugg-Gun A., 1931a, 1932. - See chapter 23, § 1.2.1
17. Csapody I.v., 1929a, b.
18. Lipiodol: trade mark passed into common language for a contrast iodine solution used in radiography. Collargol: a colloidal solution with a silver base used as an antiseptic.
19. « Zum Gusse ist eine Form notwendig. Ohne diese Form klebt das Paraffin mit den Augenlidern zusammen und wird bei der Abnahme hin- und hergekrümmt. Zum Schutze der Augenlider, zur Fixierung des Bulbus, zur Abnahme des Abgusses und zur weiteren Bearbeitung desselben ist der von mir gebrauchte Glaszylinder geeignet, dessen etwas getriebene Ränder am Augapfel liegen. Von den angefertigten verschiedenen Glasformen entsprach am besten ein Tubus, dessen innere Durchmesser 18,5 mm, äußerer Durchmesser - am Rande gemessen - 21 mm beträgt. Der von mir gebrauchte Zylinder paßt für jedes erwachsene Auge, leider aber können die Dimensionen nur unbedeutend vergössert werden. Der brauchbare Teil des Abgusses, welcher über die Hornhaut reicht, der Skleralring also, hat demnach einen äußeren Durchmesser von 18 mm und ist ca. 3,5 mm breit. Der Glaszylinder ist 30 mm hoch. » (Csapody I.v., 1929a).
20. «Geschmolzenes Paraffin von niedrigem Schmelzpunkt wird in einen Glastubus gegossen, welcher die Lider auseinanderhält und zugleich den Bulbus fixiert. Im vorderen Teil des Bulbus entsteht eine dem Fieber nahestehende Temperatur. Das Paraffin muß noch am Auge durch übergießen von ausgekühltem Paraffin abgekühlt werden. Vom Paraffinnegativ werden Gipsabgüsse und von diesen ein Metallabguß verfertigt, der zur Anfertigung der Kontaktgläser dient. Nach brieflicher Mitteilung der Zeißwerke (Dr Hartinger) verspricht ein derartiges Abgußverfahren bei der Herstellung von geschliffenen Kontaktgläsern große Vorteile. » (Csapody I.v., 1930).
21. Dallos J., 1930a, b & discussion Csapody I.v., 1930a. Presentation to the Hungarian Society of Ophthalmology on 29th November 1929. « I.v. Csapody hat auf Vorschlag des Zahnarztes Prof. Salamons von der Bulbusoberfläche Abgüsse mit dem Gelatinapparat „Dentokoll“ verfertigt. Letzteres ist sehr plastisch, dabei aber sehr elastisch, ist bei Körpertemperatur anwendbar. Es ist ihm gelungen, mit diesem Präparat sehr gute Abgüsse vom lebenden Auge herzustellen, die einen größeren Durchmesser hatten als jene Abgüsse, die er mit Paraffin unter Benützung eines Abgusstubus gemacht hat. »
22. « Meine Versuche haben gezeigt, daß es möglich ist, genaue Abgüsse der lebenden Bulbusoberfläche herzustellen. Man wendet dazu Paraffin von niedrigem Schmelzpunkt an. Falls wir dem Hersteller der Haftgläser ein Modell in die Hand geben können, das ein genaues Abbild der Hornhaut und der angrenzenden Sclera darstellt, sind wir imstande, nach diesem Modell von Fall zu Fall das entsprechende Glas verfertigen zu lassen. Zum Gusse ist eine Form notwendig, ein Glastubus, welcher die Lider voneinander hält, den Bulbus fixiert und auch bei der Abnahme und weiterer Bearbeitung des Abgusses hilflich ist. Da sich Paraffin leicht deformiert, muß man es noch am Auge zum Erstarren bringen, und zwar durch eisgekühltes Paraffinöl, das man in den Tubus gießt.» (Csapody I.v., 1930b).
23. Hartinger H., 1930a, b; Csapody Iv., 1930b. Presentation and Discussion to the German Ophthalmological Society on 13th June 1930. - « Die Abmodellierung des Auges ist unschädlich, dem Kranken leicht erträglich und bei gewissen Handfertigkeit leicht durchzuführen. Die Bearbeitung des Paraffinnegativs, die

Übertragung auf Gips oder Metall verlangt schon technische Übung und Erfahrungen und wäre auch von einem Techniker auszuführen. »

24. Csapody I.v., 1933. Presentation to the Hungarian Society of Ophthalmology on 10th July 1933. « Sie besitzt eine Oeffnung unter den Lidern und eine Oeffnung, durch die die Luft entweichen kann. Der Durchmesser des größten ausführbaren Abdruckes ist 23,5 mm."

25. Dallos J., 1933a; Csapody I.v., 1935.

26. «Als erster wählte ich die Abmodelierung des Augapfels als Grundlage für die Bestellung von Haftgläsern. Mir ist es das erste Mal gelungen, ein Verfahren auszuarbeiten, das den genannten Abguß der vorderen Oberfläche des lebenden Auges ermöglicht. Ich konnte feststellen, dass man Abgüsse vom beweglichen Auge durch ein schmerz- und gefahrenloses Verfahren verfertigen kann, die ganz genau sind, da die kapillare Adhäsion den Abdruck während der Erstarrens an die Augenoberfläche anpreßt und so gegen Abgleiten und Deformation schützt. » (Csapody I.v. 1935)

27. Poller A., 1931. Negocoll was sold by Laboratoire Technique Apotela A.G. (Zurich, Switzerland).

28. Stevens C.L., 1936; Obrig T.E., 1938a, 1942.

29. Dallos J., 1930a, b, 1931a, b, c, d, 1932a - See chapter 21, § 2: "The Dallos Alternative".

30. Dallos J., 1932b. (Hungarian Society of Ophthalmology, 10-12 June 1932): " Haftgläser bzw. Kontaktschalen müssen dem Auge auf eine ganz bestimmte Weise anliegen, um dauernd gut vertragen zu werden. Zur Herstellung von individuell geformten Gläsern sind Modelle von einem großen Teile der Oberfläche des Bulbus notwendig. Mittels des Pollerschen Verfahrens konnte er das Auge in der Primärstellung sowie in 4 Seitenstellugen abformen und durch Zusammenbauen der Teilformen das gewünschte große Oberflächenmodel rekonstruieren. »

31. Dallos J., 1933a. Presentation before the Hungarian Society of Ophthalmology, 9th to 11th July 1933; Dallos J., 1933b: « Zum Abformen konnte die sinnreiche Methodik von Csapody nicht gebraucht werden, da es eine Bedingung war, die Bindehaut nicht zu deformieren, weder durch umschriebenen Druck (Tubus usw.) noch Zug (Lidhalter usw.). Es sollte eine möglichst dünne Schicht einer plastischen Substanz an der Bindehaut möglichst rasch erstarren. Nachdem Gips und gipsartige Substanzen an der Bindehaut ohne Gefahr nicht anwendbar sind, weiterhin Wachs, und Paraffin und derartige Stoffe nur bei solchen Temperaturen ihre Konsistenz gehörig und schnell genug ändern (beim Einlegen fast flüssig, beim Abnehmen unbiegsam), die dem Auge ebenfalls schädlich sein können, wandte ich mich zu den leimartigen Substanzen. »

32. « Um den Bulbus unter den obenerwähnten Bedingungen abformen zu können, verfuhr ich so, dass ich eine ungefähr passende Müllersche Schale mit dem breiartigen Negokoll halb fülle, dann mit einem Finger knetend auf Zimmertemperatur abkühlte und das mit Negokoll-Brei dick bestrichene Glas in das kokainisierte Auge einsetze. Es bleibt dabei eine Schicht Negokoll zwischen Schale und Auge, das übrige läuft aus und wird beobachtet. Nach dem Einsetzen des Glases läßt man den Patienten in der entsprechenden Richtung fixieren, solange, bis das ausgelaufene Negocoll erstarrt ist. Nach einigen Sekunden wird nun das Glas samt dem Positivmaterial « Homilit » weiterbehandelt. Die Glasschale dient als starre Stütze der sonst leicht deformierbaren Negokoll-Lamelle, die an der Luft durch Eintrocknen bald ihre Form einbüssen würde. » (Dallos J., 1933b).

33. « Das so erhaltene Positiv weist bei guter Technik eine spiegelnde Hornhaut mit scharfem Rande und runzelfreie, glatte Bindehaut auf. Der Uebergang zwischen Hornhaut und Bindehaut ist stetig, die Oberfläche des Modells ht eine eigenartige, fast einheitliche Krümmung, die jedoch in den einzelnen Meridianen verschieden ist. Die Augenoberfläche bildet demnach keine Rotationsfläche; um so weniger hat dieselbe mit zwei ineinander geschobene Kugelflächen etwas gemein. » (Dallos J., 1933b).

34. « Aus den Messungen einer einzigen zentralen Abform mit der Hornhaut in der Mitte (...) diese Schlüsse zu ziehen, wäre allerdings bedenklich. (...) so ging ich ein Schritt weiter. Ich ließ den Patienten nach verschiedenen Richtungen blicken, und nahm in jeder Blickrichtung je eine Abform. An diesen Abformen ist die Hornhaut exzentrische gelegen (ich benütze jetzt zu diesen Modellen entsprechend geformte Kontaktschalen), dazu gesellt sich je ein Quadrant der Bulbusoberfläche in einer besonders großen Ausdehnung. » (Dallos J., 1933b).

35. Dallos J., 1936; Stevens C.L., 1936. - See chapter 22, § 3.1.

36. Obrig T.E., 1938 a, b. See chapter 22, § 5: 'The Contributions of T.E. Obrig (1937-1938)'.

37. Obrig T.E., 1942, 1943.

38. Prister B., 1933b. See chapter 23, § 3.2. - Obrig T.E., 1942.

39. See chapter 24, § 2.2. - Feinbloom W., 1940, 1941c, 1942. - Obrig T.E., 1942.

40. See chapter 24, § 1.2 – Obrig T.E., 1943 – Moldite is obtained from Obrig Laboratories, Inc. of 49, 51st Street, New York, 22 NY.

41. Zelex is manufactured by the Amalgamated Dental Co Ltd., 7 Swallow Street, Piccadilly, W.I. and

by L.D. Caulk Co. Laboratory, Milford, Del. - Boshoff P.H., 1943.
42. Obrig T.E., 1942; Maisler S., 1939; Town AE., 1940: Presented at the Convention of the American Academy of Ophthalmology and Otolaryngology, Chicago Oct. 10, 1939. - Kerr's dental wax is manufactured by the Detroit Dental Manufacturing Company.
43. Weeks C., 1939. Read on September 26th, 1938 before the Los Angeles Ophthalmological and Otolaryngological Society; Anderson A.L., 1945a.
44. Chisholm J.F. Jr., 1940; Kauhl M.H., Hummel D.G., 1947.
45. Albastone and Calestone of Amalgamated Dental Company Ltd.
46. Hartinger H., 1930b, 1932a, b; Amsler M., 1930; Fischer F. P., 1928, 1932b, Berg F., 1930.
47. Bonnet R., Cochet P., 1960; Cochet P., Amiard H., 1966; Soper J.W. Sampson W.G., Girard L.J., 1962; Sampson W.G., Soper J.W., Girard L.J., 1965; - For PEK of W-J, see chapter 27 §4.4.1 & Fig 27-18. –"Corneopter" of Scientific Advances Inc., Columbus OH: Bitonte J.L, Keates R.H., 1967.
48. Csapody I. v., 1929a; Biffis A., 1935; Strebel J., 1932, 1937; Nissel G., 1939.
49. See chapters 20, 21 & 22.
50. Heydt R.v.d., 1932.
51. Ehrlich P., 1982; Müller F.E., 1920; Fischer F.B., 1929b; Heydt R.v.d., 1932; Obrig T.E., 1938b (see chapter 22, §5); Neill J.C., 1940 (see chapter 25, §3.17 and figure 25-31); Barkan O., 1941; Wies F.A., 1941; Hague E.B. 1940; Greenspoon R., 1939 (Lecture given before Academy of Los Amgeles County Association of Optometrists. April 20, 1939).
52. Fischer F.P., 1931a, b, 1932a, b; Krämer R., 1923a,b; Schnaudiegel O., 1922; Strebel J., 1931, 1932, 1938.
53. Sattler C. H. 1931, 1935, 1938a; Feldman J.B., 1937.
54. See chapters 24, 25, 26; Conlogue J.B., 1947a.
55. See chapter 27.
56. Wichterle O., 1965, 1967; Wichterle O., Lim D., 1956, 1960; Becker W.F., 1962.