Hist. Ophthal. intern. 3, 347 – 381 (1985)

GLAUCOMA — HISTORY SINCE 1850

H. SAUL SUGAR, M.D.

Modern ophthalmology began with the invention of the ophthalmoscope by HERMANN VON HELMHOLTZ[1] in 1851. It was only then that an understanding of the relationship between elevated intraocular pressure and its effect on the optic nerves could begin. The first ophthalmoscopic observations were in error. When JAEGER[2] of Vienna first described the glaucomatous disc in 1854 he called it a "globular swelling." Even his student, VON GRAEFE,[3] made this error at first.

ALBRECHT VON GRAEFE (Fig. 1) was born in Berlin on May 28, 1828, the third son of CARL FERDINAND VON GRAEFE (Professor of Surgery at the Berlin University and founder of modern plastic surgery) and Augusta Alten. When he was ten, Albrecht started school at the French Gymnasium. He graduated from Berlin University in 1847 at the age of nineteen. Afterward he observed medical practice in Prague, Paris, Vienna and London. In 1850 he started ophthalmic practice in Berlin and worked at the Charité Hospital. In 1852 he was appointed to the medical faculty of the University of Berlin. In 1854 he founded the *Archiv für Ophthalmologie* which he edited until 1870; 2500 printed pages of his own works were included. In 1857 von Graefe was ap-

pointed Extraordinary Professor but he was not allowed to lecture in the university. The chair of ophthalmology was denied him until 1873, two years before he died at age forty-two. His private clinic became the largest on the continent. The reader is referred to Ullman's[4] excellent papers on this great ophthalmologist. A monument to his memory was unveiled in the garden of the Charité Hospital in Berlin in 1882. Von Graefe's first paper[5] described arterial pulsation in glaucoma. He knew that this pulsation could be elicited if great pressure were applied to the normal eye. He classified primary glaucoma and did the first visual field measurement, as well as the first iridectomy operation in 1856.[5] Prior to that paracentesis of the cornea or sclera had been advised by MACKENZIE (1854) since it afforded great relief of pain.[6]

In 1855, WEBER[7] demonstrated cupping of the optic nerve ophthalmoscopically. In 1858 HEINRICH MULLER[8] showed it in enucleated glaucomatous eyes.

A long with ophthalmoscopy, tonometry and perimetry form the diagnostic triad for glaucoma. In the field of tonometry the most important names are SCHIOTZ[9] and HANS GOLDMANN.[10] The instrument invented by Schiotz was the best until Goldmann invented the applanation tonometer. Historically, the two most important names associated with perimetry were JANNIK BJERRUM[11] (1851 – 1920), who introduced quantitative perimity and Bjerrum's sign, and HENNING RONNE[12] (1878 – 1947). Both men were Danish. The tonometry-related measure of the rate of fluid outflow (tonography) was first determined by MOSES and BRUNO[13] and developed by GRANT.[14] Goldmann's projection perimeter was introduced in 1946.[15]

The search for the cause of glaucoma led to theory after theory. VON GRAEFE[16] postulated the theory of serous choroiditis as the cause of elevated pressure. DONDERS[16] held similar views. BOWMAN[17] considered a disproportionately large crystalline lens to be the cause. PRIESTLEY SMITH,[18] in 1879, advanced the idea that a small eye and a relatively large lens were responsible. HENDERSON[19] claimed that sclerosis of the trabecular meshwork was the cause of obstruction to aqueous outflow. In 1873 LEBER[20] discovered that the ocular fluid drains from the ciliary processes to the sinus at the chamber angle. KNIES[21] and WEBER[22] observed obstructive adhesions in the angle in enucleated glaucomatous eyes. TAILOR[23] and DE VINCENTIIS[24] succeeded in reducing pressure by opening Schlemm's canal from the anterior chamber. These investigations led to further developments in surgical treatment which continue to this day.

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Acute angle-closure glaucoma

From our present point of view it is apparent that the recognized glaucomae in the early days of modern ophthalmology were those with symptoms, namely, acute angle-closure glaucoma and secondary glaucomas. The asymptomatic simple glaucomas were not recognized, certainly not early. ELLIOT[1] indicated that were was "no essential difference between the most chronic form of simple glaucoma and the most violent type of hemorrhagic affection."

Before VON GRAEFE's introduction of iridectomy for glaucoma in 1856 he had used that procedure for relief of staphyloma of the cornea and noticed that the escape of aqueous resulted in marked regression of the staphyloma. Later he observed that the escape of aqueous was not of sufficient duration to explain the mode of action of iridectomy. He then advanced the view that the aqueous is partly or wholly secreted by the iris and that removal of part of the iris decreases the amount secreted. It is interesting to note the bitter opposition of WHARTON JONES and MACKENZIE[2] to VON GRAEFE's iridectomy. The operation was successful in the acute cases but not in the chronic ones in which it often led to the filtering scars which will be considered under filtering operations. The iridectomy was the sector type and was used until the early 1950's, even though PFLÜGER[3] had introduced peripheral iridectomy in 1893 and CURRAN[4] had introduced the iridotomy in 1920. Curran had concluded that the shallow anterior chamber often noted in glaucoma patients was due to obstruction of the angle by bulging iris. His peripheral iridotomy did not attract much attention. In 1938 BARKAN[5] recommended multiple peripheral iridectomy and CHANDLER,[6] in 1952, became the champion of a single peripheral iridectomy which has been the accepted procedure for acute angle-closure glaucome eversince. The change was probably produced by a combination of gonioscopic observations by BARKAN,[5], SUGAR,[7] and CHANDLER.

Non-surgical iridectomy was first described by MEYER-SCHWICKERATH[8] in 1956. He used a Xenon arc photocoagulator to produce iridectomies. Because of the corneal and lenticular opacities which developed he recommended that the procedure be done in aphakic eyes only. ZWENG[9] was able to produce iridectomy in brown-eyed rabbits with ruby laser energy. PERKINS[10] was successful in making laser iridectomies in patients with glaucoma. BECKMAN[11] was successful in brown eyes with the ruby laser. ABRAHAM[12] and POLLACK[13] used the Argon laser successfully to produce iridectomies.

In the late 19th century experience with mydriatics and miotics provided clues to the various types of glaucoma. In 1868 Dr. HASKET DERBY[14] protested against the use of mydriatics in glaucoma. He cited two cases in which acute glaucoma had supervened on the use of atropine. In 1876 LUDWIG LAQUEUR[15] introduced physostigmine for glaucoma. He certainly saved many eyes with this drug which had been used until the middle of this century, especially in acute glaucoma. It was in 1877 that pilocarpine was recommended by WEBER[16] for treatment of glaucoma. It has stood humanity in good stead for over a hundred years.

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Fig. 1: ALBRECHT VON GRAEFE

Fig. 2: ALEXIOS TRANTAS. Courtesy Dr. A. Dellaporta and Survery Ophthal. 20:137 – 149, 1975.

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Gonioscopy

Observation of the anterior chamber angle (gonioscopy) was made as early as 1892 by GALZOWSKI[1] but was put on a scientific basis in 1900 by TRANTAS[2] and SALZMANN,[3] respectively. Over the years these pioneers, along with others, described observations which led to the beginning of modern gonioscopy by TRONCOSO[4] in 1921 and its eventual establishment as an important part of the glaucoma examination. The best and most extensive historical paper on gonioscopy, one which has been an excellent source for part of this paper, is that of DELLAPORTA.[5]

ALEXIOS TRANTAS (fig. 2) was born in Konitsa, northern Greece, in 1867 and studied medicine at the University of Athens. He trained in ophthalmology in Paris and practiced in Constantinople until 1922 when he left for Athens because of political persecution. He practiced there until his death in 1961. He described his method of angle observation with the ophthalmoscope[6] and simultaneous compression of the retrolimbal area digitally. Later, he made

compression with LANGE's transilluminator.[7] He introduced the term "gonioscopy". He also observed that Schlemm's canal normally does not contain blood.[7]

The other great pioneer in this field, MAXIMILIAN SALZMANN (fig. 3), was born in Vienna in 1862. He graduated from the University of Vienna in 1887 and became an assistant to Professor Ernst Fuchs. In 1911 he became professor at the University of Graz and remained at this post until his retirement in 1932 at the age of seventy. He was a gifted painter, linguist, mathematician and botanist. He wrote the important *Anatomy and Histology of the Human Eye*, doing all the drawings himself. He died on April 17, 1954. Salzmann made observations of the angle by direct and indirect ophthalmoscopy[3] and later analyzed the problems of obtaining clear images. He realized that light reflected back from the angle of a normal eye underwent total internal reflection and therefore could not be received by the observer with an ophthalmoscope. He was able to see the angle in eyes with deep anterior chambers and prominent corneas where the internal reflection was incomplete. By using FICK's contact lens with an 8 mm corneal radius he was able to see better but the walls of angle were still blurred. He then had the Zeiss Company make a lens with a 7 mm corneal radius which improved the observations to some extent. SALZMANN made the first observation of blood in Schlemm's canal.

TRANTAS sought priority as the first to observe the chamber angle in a letter to the Zeitschrift für Augenheilkunde. SALZMANN[3] replied that each had made the same observations independently and credited TRANTAS with priority on the use of digital compression. He noted that although his own observations were first reported before the Medical Society of Styria in 1913,[9] he had made such observations as far back as 1900.

In the reply to Trantas' letter,[3] SALZMANN noted that ELSCHNIG had also succeeded in observing the angle recess with the help of tears accumulated in the lower cul-de-sac. In 1914 MIZUO[10] observed that "when one fills the lower cul-de-sac with water and the patient looks down, the structures of the lower quadrant of the angle can be visualized. The fluid apparently plays the same role as a contact glass."

Development of suitable gonioscopic contact lenses by KOEPPE[11,12] led to progress in interpretation of gonioscopic observations, largely through the work of TRONCOSO who may be considered the pioneer of modern gonioscopy.

MANUEL URIBE TRONCOSO (Fig. 4) was born in Toluca, Mexico in 1868. He received his medical degree from the University of Mexico in 1890. In 1898 he founded the *Anales de Oftalmologia* which merged with the *American Journal of Ophthalmology* in 1918. In 1907 he attended the *XIIth International*

Fig. 3: MAXIMILIAN SALZMANN. Courtesy Dr. A. Dellaporta and Survey Ophthal. 20:137 – 149, 1975.

Fig. 4: MANUEL URIBE TRONCOSO

Conference on Hygiene in Berlin and stayed in Europe for two years. On his return to Mexico he organized a department of student hygiene.

In 1916 TRONCOSO moved to New York City where he served as professor at the Postgraduate Medical School and Hospital. In 1921 he demonstrated the chamber angle with the Koeppe lens at the New York Academy of Medicine. In 1925 he devised a monocular gonioscope which is now in the *Bausch and Lomb Museum*; in 1942 he devised a binocular gonioscopic microscope. In 1932 he was appointed to the staff of the College of Physicians and Surgeons of Columbia University. TRONCOSO died at the age of 91 in 1951. I visited him not long before his death. He was almost totally deaf but still very alert.

TRONCOSO wrote one of the first comprehensive books on gonioscopy in 1947. Other early books were written by BUSACCA,[14] FRANÇCOIS[15] and FIEANDT.[1]

In 1927 THORBURN[16] of Sweden was the first to successfully photograph the chamber angle. CASTROVIEJO[17] and BOGART[18] made strides in obtaining better photographs. SUGAR[19] obtained good color photographs in 1941.

The most important development in glaucoma during the past half century has been related to gonioscopic separation of open- and narrow-angle glaucoma. CURRAN's[20] observations on iridectomy and, particularly, OTTO BARKAN's gonioscopic observations led to better understanding of the primary glaucomas. My own interest in gonioscopy was stimulated by Dr. RAPHAEL KOFF in September 1936 when he showed me a Koeppe lens and taught me to use it. At the time there was no one else in Chicago familiar with the technique. When I started the glaucoma clinic at the Illinois Eye and Ear Infirmary in 1939 we were able to take advantage of gonioscopic help. Unfortunately, I had just finished two years of residency and had not yet been able to acquaint myself with enough of the writings of BARKAN. When I read his material during that year I realized how correct his observations were. As a result the glaucoma clinic was able to help popularize the technique and spread information in the Midwest. CHANDLER did the same thing in the eastern states. When KRONFELD returned to Chicago in the latter part of 1939 he became interested in gonioscopy and did much to help its development.

OTTO BARKAN (Fig. 5) was born in San Francisco in 1887. He studied physiology at Trinity College, Oxford and medicine at the University of Munich where he graduated in 1914. He studied ophthalmology in Munich and Vienna and returned to San Francisco in 1921 where he was on the faculty of Stanford University. He used the Koeppe contact lens with a binocular microscope and introduced the term "*narrow angle glaucoma*". He devised the goniotomy technique for congenital glaucoma,[22] using a special knife and surgical contact lens and revived interest in the principle of the operation described by TAILOR[23] in 1891 and DE VINCENTIIS[24] in 1893.

HANS GOLDMANN did much to popularize gonioscopy in Europe by introducing his contract lenses to be used with the slitlamp.

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Fig. 5: OTTO BARKAN. Courtesy Dr. A. Dellaporta and Survey Ophthal. 20:137 – 149, 1975.

Fig. 6: LOUIS DE WECKER. Courtesy Dr. P. Kronfeld and Survey of Ophthal. 17:168 – 179, 1972.

Operations for congenital glaucoma

Although congenital and juvenile glaucoma respond to conventional filtering operations, especially subscleral procedures such as subscleral trephination, they respond most frequently to goniotomy[1,2] or cyclogoniotomy.[3] Goniopuncture, introduced by SCHEIE[4,5] in 1950 has had significant success.

Direct external goniotomy has been described for cases with cloudy corneas. URRETS-ZAVALIA,[6] in 1960, introduced such a procedure as goniotripsy. GALIN[7] described a technique for direct goniotomy in 1972.

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The Filtering Operations

The filtering operations had their beginning in 1869 when ALBRECHT VON GRAEFE noted cystoid cicatrices in over 20 percent of the eyes on which iridectomy had been performed. An excellent paper by KRONFELD[1] presents historic glimpses into the subsequent development of filtration surgery. The paper has been a valuable source of some of the material in this chapter.

Von Graefe believed that excision of iris was responsible for lowering of intraocular pressure after iridectomy and that filtering cicatrices were an undesirable complication of the operation.[2] He even advised that they be excised when thin or inflamed and were thus vulnerable to intraocular infection.

DE WECKER, in 1867 and 1871, introduced the idea of "anterior sclerotomy" in the chamber angle area with an overlying conjunctival bridge flap as a means of producing a filtering cicatrix through which the intraocular fluid might leave the interior of the eye.[3] He suggested the operation to Stellway who performed it the following year.[4] Quaglino reported successful results with this procedure in 5 cases.[5]

LOUIS WECKER was born in Frankfurt am Main in 1832. In 1866, when Frankfurt was incorporated under the state of Prussia, Wecker was granted Austrian citizenship. He was ennobled four years later and thus was able to add de before the Wecker when he moved to Paris. His clinic there was outstanding and extremely successful. He never held an official academic post. But to return to de Wecker's sclerotomy.

SNELLEN corroborated Quaglino's findings.[6] In 1894 de Wecker added iridodialysis to the sclerotomy.[7] In many cases the sclerotomy procedures were followed by digital massage and miotics but, in spite of these aids, use of the operation as a primary procedure declined and it was used by less than 15 percent of ophthalmologists in the first decade of the 1900's.[8] Successful results a year or more after the operation were few.

Observations on successful (at least temporarily) cases of iridectomy or sclerotomy led to observations of conjunctival and iris inclusions in the wound. These led to attempts to make fistulas through use of conjunctival infolding into the anterior chamber,[9] various setons and iris inclusion.

In 1907 HERBERT HERBERT introduced his small flap sclerotomy in which a rectangular trap door of sclera with its base attached to the cornea was formed.[10] Later (1913) he isolated a wedge of sclera attached only to conjunctiva to produce fistulization through shriveling of the isolated wedge.[11]

HERBERT HERBERT (Fig. 7) was born in Transmere, Cheshire and was educated at the University of Leeds. After entering the Indian Medical Serivce he became a professor of ophthalmology at Grant Medical College in Bombay. Following 20 years of Indian service he returned to England. He wrote "*The Operative Treatment of Glaucoma*" and was associated with the Nottingham and Midland Eye Infirmary. He died in 1942.

In 1906 FELIX LAGRANGE presented in "*his sclerecto-iridectomy*"[12] which became very popular and has been used to the present time, especially in Europe. A later study by MELLER of 11 eyes enucleated after the LAGRANGE operation indicated that successful filtration occurred when iris was incarcerated in the scleral wound.[13]

PIERRE-FELIX LAGRANGE (Fig. 8) was born in 1857 into the family of a village blacksmith in the Gascogne. He attained the professorship of surgery at the University of Bordeaux at the age of 26 by competitive examination. He was ordered to the Sino-French border war during 1883 – 85. Through systematic private study he became an ophthalmologist after he learned that he had been replaced at the university. In 1910 he was appointed professor of ophthalmology at Bordeaux. He was co-editor of the *Encyclopedic Française d'Ophtalmologie.*

Fig. 7: HERBERT HERBERT. Courtesy Dr. P. Kronfeld and Survey of Ophthal. 17:168 – 179, 1975.

Fig. 8: PIERRE-FELIX LAGRANGE. Courtesy Dr. P. Kronfeld and Survey of Ophthal. 17:168 – 179, 1972.

Ophthalmic surgeons continued to use the sclerectomy idea. As a matter of fact, we still do, with a long series of modifications of all kinds but with the ultimate goal of achieving a permanent fistula through which aqueous permeates the subconjunctival tissue and is absorbed or filtered through the epithelium.

SOREN HOLTH (1906) used a punch forceps to produce his sclerectomy.[14] Over the years modifications of the Lagrange type of operation were made (GRISCOM,[15] SPRATT's *"pocket flap iridectomy"*,[16] CURDY,[17] BEREN'S *"iridocorneosclerectomy"*[18]).

The first iris inclusion sclerectomy operation was introduced in 1857 by GEORGE CRITCHETT,[19] an associate of WILLIAM BOWMAN, as *"iridesis"*. It was defined as the formation of an artificial pupil by tying the iris. The operation was performed through the edge of the cornea. The iris was grasped and drawn out of the wound just enough to enlarge the pupil. A silk suture was tied over the prolapsed iris and removed the next day. Later, in 1882. CRITCHETT cautioned against iris inclusion because of the danger of sympathetic ophthalmia.

COCCIUS,[20] in a thesis in 1859 in which he noted that von Graefe's iridectomy and paracentesis were often only temporarily successul, advised that during iridectomy only a small part of the iris be removed and the larger part be left lying in the wound as an iridencleisis. Iridencleisis was used by BADER[21] in 1881 and in 1903 by HERBERT[22] who called the operation *"subconjunctival prolapse of the iris"*. In 1906 HOLTH (Fig. 9), who had the advantage of using newly available Schiotz tonometry, reported on the procedure he called "iridencleisis antiglaucomatosa",[23] which was based on the premise that effective conjunctival covering over the iris was essential to preserve the integrity of the eye. He made his scleral keratome incision through a sub-Tenon's tunnel with the conjunctival opening some 8 – 10 mm distant from the scleral wound which was 1 mm from the corneolimbal junction. The iris sphincter was drawn into the wound and a meridional cut made through it on one side of the forceps. In spite of a high success rate (86 percent), professional opposition to the operation led HOLTH to use a modified LAGRANGE sclerectomy in which a punch instead of scissors was used for the sclerectomy.[24] Later he again returned to the iridencleisis operation.

In 1911 BORTHEN introduced a modification of the iridencleisis operation in which the iris was incarcerated but the sphincter remained uncut. This procedure was called "iridotasis".[25] Apparently the operation was first used in the United States by HARROWER.[26].

An important variation in the iridencleisis operation technique was that introduced by WEEKERS in which the prolapsing iris is torn between two iris forceps and the two iris tongues are incarcerated into the respective ends of the limbal incision.[27]

ELLIOT[28] condemned all iris-inclusion operations, as did BERENS.[29] An interesting historical review of the iris inclusion operations is that of ALLEN, published in 1944.

A type of sclerectomy which was well received and shared popularity with Scheie's thermal sclerotomy (which will be described), was the posterior lip sclerectomy described by Iliff and Haas.[31] A punch forceps was used to excise the posterior lip of the sclerotomy, producing much the same result as the Holth sclerectomy.

The final modification of the early sclerectomy operation came im 1909 with the introduction of the trephining operation by FREELAND FERGUS[32] and ROBERT HENRY ELLIOT.[28] A one-twelfth inch corneal trephine had been used by ARGYLL ROBERTSON in 1874[30] to make a fistula through the pars plana. The operation was only used on four eyes with inconclusive results.

FERGUS has never received adequate credit for his pioneer work, overshadowed as he was by ELLIOT. At any rate, Fergus introduced his operation in January 1909.[32] He prepared a large conjunctival flap and then used a 3 mm Bowman's trephine to make a sclerectomy as close to the cornea as possible. He claimed that "the operation does not involve the ciliary body at all but lays it bare". He modified the technique to add introduction of the point of a fine iris repositor through the sclerectomy into the anterior chamber, thus causing ELLIOT[35] to describe the modified Fergus operation as a combination of trephining and cyclodialysis. Elliot's emphasis on the cyclodialysis was, in my opinion, incorrect since it is doubtful that a true separation of the ciliary body insertion was obtained. Fergus accepted[34] the designation of a portion of the operation as a cyclodialysis but his own descriptions indicate that the concept of cyclodialysis held at that time differed from that which in held today.

ELLIOT introduced his trephining operation in August 1909 and described its use in 50 cases.[35] He prepared a large triangular flap based at the limbus and used a 2 mm trephine placed as close to the corneolimbal junction as possible. An iridectomy was made in about a fifth of the cases. In subsequent operations Elliot greatly modified his procedure into the corneoscleral trephining.[28] He made the flap large with the conjunctival incision running concentric with the limbus 8 mm from the limbus. It was continued into the cornea by splitting the latter for a distance of 1 mm. The 2 mm trephining was thus half in cornea and half in limbus. An iridectomy was usually made and the flap was then replaced and sutured. ELLIOT stressed the importance of removing a complete disc of Descemet's membrane and not involving the trabecular area.

ROBERT HENRY ELLIOT (Fig. 10), the son of a British army colonel, was born in India in 1864. He was educated in England at St. Bartholomew's. He entered the Indian Medical Service in 1892, first serving on the northeast frontier. Later he was appointed superintendent of the Government Ophtalmic

Fig. 9: SOREN HOLTH. Courtesy Dr. P. Kronfeld and Survey Ophthal. 17:168 – 179, 1972.

Fig. 10: ROBERT HENRY ELLIOT. Courtesy Dr. P. Kronfeld and Survey of Ophthal. 17:168 – 179, 1972.

Hospital in Madras. He became professor of ophthalmology at the Madras Medical College. Elliot retired from the Indian Medical Service in 1913 and returned to England where he practiced and taught. He died in 1936.

The Elliot operation became the most popular antiglaucoma operation in the world until about 1940 when, because of relatively high incidence ob bleb rupture and late infection, its use began to decline. In 1913, when iridectomy was still being used in chronic glaucoma, trephining was done in 47 percent of operations in England. In 1931, at the Illinois Eye and Ear Infirmary in Chicago, the Elliot procedure was used in 60 percent of operations for chronic simple glaucoma. In 1945 its use had dropped to 5 percent [36] while iridencleisis increased to 62 percent and continued to be popular until about 1957.

In 1960, as a result of dissatisfaction with the procedures then in use, I decided that if corneal splitting were avoided and the conjunctival-Tenon's capsule junction at the limbus were left intact the trephining operation might serve well as a safe, reproducible filtering procedure.[37] While surveying the literature I discovered that in 1921 SOBHY BEY stated [38] that by studying eyes which had been operated according to Elliot's technique he found

> *. . . the splitting or the cutting of the cornea during the operation (to be) unnecessary and the hole could have been in the right place without it . . . I was always tempted to stop the corneal dissection in my technic for Elliot's trephining and owing to the lack of experiments . . . I dared not stop it and feared touching the ciliary body by being so peripheral.*

I introduced a non-corneal-splitting trephining technique as limboscleral (later as limbal) trephining, with modifications to limit the fistula to 1 sq mm and to make possible final evaluation of the patency of the fistula and the leak-proofness of the conjunctival flap. The results in 317 limbal trephinings observed up to 16 years were better than I had experienced with other procedures in older adults with chronic open-angle or chronic angle-closure glaucoma.

In 1958 SCHEIE introduced a filtering operation which was the most popular between that time and the present period of trabeculectomy popularity.[39] The operation is based on use of thermocautery to form a fistula on a line parallel to the limbus and 1 mm behind it. After making a conjunctival flap and starting the cautery a scratch incision is made through this area and cautery is applied again until the anterior chamber is entered. After a peripheral iridectomy the conjunctival flap ist sutured.

A direct cautery type of filtering operation had been described previously by PREZIOSI in which the cautery point was applied obliquely to enter the anterior chamber after preparation of a conjunctival flap.[40]

The trabeculectomy operation is the present surgical fad; it is proving to be a popular procedure. It was started with the intention of producing a direct opening from the anterior chamber into two open ends of Schlemm's canal. The first procedure describing a scleral lamellar flap and trabeculectomy was described by me in 1961 as "experimental trabeculectomy".[41] The scleral flap was carefully sutured to prevent filtration; it failed. Another description of trabeculectomy was written in Greek by CORYLLOS in 1967.[42] A paper by CAIRNS[43] reported such good results that use of the procedure became widespread but its effectiveness was then attributed to filtration. I have found it best in all younger individuals below 55 to 60 years of age.

The technique includes an 8 mm conjunctival flap which is reflected back onto the cornea. A half-thickness lamellar corneoscleral flap (5 x 5 mm rectangle or 4 – 5 mm triangle with its base at the cornea) is dissected toward the limbus and 1 – 1 1/2 mm into the cornea. The deep layer ist then incised as far forward as possible and the area of the trabecular wall is excised. I prefer a triangular flap and a 2 mm trephining of the deep layer, much as has been described by FRONIMOPOULOS,[44] DELLAPORTA[45] and STILMA[46]. The scleral flap is replaced and sutured loosely at the corners or apex and then the conjunctiva is closed with a running silk suture. In all filtering procedures the use of a Wheeler knife incision in the lower temporal quadrant of the cornea permits filling of the chamber with balanced salt solution after the operation, as well as ascertaining the patency of the fistula and the leakproofness of the conjunctival flap.

It is likely that the ultimate filtration procedure will continue to be sought after. We have, however, come a long way since von Graefe's observations a little more than a century ago.

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Seton Operations

Another filtering procedure which was used in the early days of glaucoma surgery and much less in recent years is the seton procedure. In 1876 DE WECKER[1] described the insertion of a gold wire through the sclera in cases where iridectomy was unsuccessful. WALKER[2], in 1894, reported on the use of various seton substances, including muscle tissue.

In 1907 ROLLET[3] reported use of a horsehair seton in painful absolute glaucoma. Silk thread setons were used in 1912 by ZORAB[4] and MAYOU[5], independently, and by WOOD[6] and VAIL[7] in 1915, and WOLFE and Blaess[8] in 1936. WEEKERS[9] in 1922 and STEFANSSON[10] in 1925 returned to the use of a gold seton. WOLKOWITZ[11] used gold leaf. Platinum wire was used by MULDOON[12] in 1951. Tantalum was used by BICK[13] in 1949 and STONE[14] in 1958. Glass was used by BOCK[15] in 1950. QUADEER[16] used an acrylic plate in 1954. In 1955 LAVAL[17] used gelfilm. EPSTEIN[18] (1959) and ILLIG[19] (1959) used polyethylene. ELLIS[20] (1960) used silicone and STRAMPELLI[21] (1956) used Supramid. Supramid was also used in the latest seton by KRUPIN[22]. The Supramid was sealed to a Silastic tube with a slit valve. Polyvinyl tubes were used by LAROCCA[23] in 1958.

The use of vortex venous transplants into the limbus was described by STRAMPELLI and VALVE[24] (1967) and a vortex vein connected to the anterior chamber by way of a silicone tube was used by LEE and SCHEPENS (1966)[25].

The most complete monograph on the setons was written by KREJCI[26] in 1974.

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Trabeculotomy and Laser trabeculopuncture

Although BARKAN[1] was able to achieve internal trabeculotomy (goniotomy) in 1936, it was not successful in adults. External trabeculotomy in which Schlemm's canal is entered was introduced by SMITH[2] in 1960. He inserted a nylon thread into Schlemm's canal through two or more external incisions. The filament was then drawn taut so as to cut through the inner wall of the canal into the anterior chamber. BURIAN[3] introduced a metal probe into the canal. Modifications of the probe had improved the technique.

Laser trabeculopuncture was first described by HAGER[4] in 1972 as perforation of the trabecular meshwork from within the eye by means of a laser beam, usually Argon or the Q switched "*modulated ruby*" (KRASNOV[5]). WORTHEN described his procedure as *Argon laser trabeculectomy*.[6]

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Cyclodialysis

The first operative procedure to form a communication between the anterior chamber and the suprachoroidal spaces was that of HANCOCK[1] in 1861. He performed an intraocular ciliary myotomy. The operation was modified by HEIBERG.[2] In 1900, QUERENGHI[3], who attributed glaucoma to a lack of

communication between the suprachoroidal space and the anterior chamber, described a similar procedure which he called sclerocyclotomy or sclerochorotomy.

CHIBERT[4], in 1897, described an operation which he called sclero-cyclo-iridic puncture in which an incision was carried from the sclera 3 to 4 mm behind the limbus through the anterior portion of the ciliary body into the anterior chamber, finally spearing the iris.

HEINE's[5] cyclodialysis procedure was based on the observations of FUCHS and AXENFELD. FUCHS[6] had noted low intraocular pressure in patients with choroidal detachment following both cataract extraction and iridectomies for glaucoma. AXENFELD[7] noted the 10 percent incidence of choroidal detachment after iridectomy, sclerotomy and incision in the chamber angle. He attributed it to a tear in the angle tissues permitting aqueous to enter the suprachoroidal space. DEMARIAN in Axenfeld's clinic, actually demonstrated such a tear in the ciliary body insertion following iridectomy for glaucoma. Heine's operation was deliberately intended to produce such a communication so that aqueous could be slowly absorbed in the suprachoroidal space. ELSCHNIG[8] believed that the cyclodialysis operation acted by straightening of angulated veins in the iris root. He found clinical evidence of the cyclodialysis cleft in an eye of a patient who had a successful cyclodialysis fourteen years before. Gonioscopic corroboration was first made by VANNAS[9] in 1935, BARKAN, BOYLE and MAISLER[10] in 1936 and SUGAR[11] in 1939.

Many modifications have been made in cyclodialysis technique. BLASKOVICS[12], GUYTON[13], O'BRIEN and WEIH[14], SWAN[15] and GALIN[16] made important changes.

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Cyclodiathermy, Cyclocryotherapy and related operations

Cyclodiathermy was introduced into glaucoma therapy by WEVE[1] in 1932 after he had noted that the intraoculuar pressure frequently remained low after extensive surface diathermy for anterior retinal dialysis. He used surface diathermy in treating cases of infantile glaucoma. In 1936 VOGT[2] used penetrating diathermy for glaucoma and later changed to a partial penetrating technique because of the resulting complications. Both methods were used extensively. CASTROVIEJO[3] advised application of 8 to 16 perforating diathermy applications through the conjunctiva and sclera with a 11/2 mm electrode 6 mm from the limbus, evenly distributed around the eye, each application lasting for 10 seconds. BERENS[4] found more serious complications after cyclodiathermy than after cycloelectrolysis which he considered safer.

In 1950 BIETTI[5] introduced the use of solid carbon dioxide to the ciliary body. This was the earliest cyclocryotherapy. POLACK[6] and DE ROETTH[7] and MC LEAN and LINCOFF[8] pioneered in this work in the United States, as did KRWAWICZ and SZWARC[9] in Poland. Cyclocryotherapy is currently a popular antiglaucoma procedure, especially in glaucoma immediately after keratoplasty.

Transcleral ruby laser irradiation of the ciliary body is a technique which has given good results and has been useful in intractible cases where standard procedures have been unsuccessful. It was introduced by BECKMANN in 1972.[10]

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Secondary Glaucomas

Only a few of the secondary glaucomas with historic aspects will be discussed.

1. The exfoliation syndrome

The exfoliation syndrome is clinically important only because a high percentage of patients develop chronic glaucoma.

LINDBERG[1] first described the exfoliation syndrome in 1917 but it was more clearly defined in 1925 by VOGT[2] whose description included pupillary-margin flakes, capsular changes, and precipitates of exfoliated material on the posterior corneal surface. In 1926 Vogt described the presence of exfoliated material in the chamber angle and considered blockage of aqueous flow by this material to be responsible for the glaucoma. He later named the glaucomatous phase glaucoma capsulo-cuticulare.[3] In 1928 BUSACCA[4] suggested that the capsular material was not an exfoliation but a deposit of an unknown substance on the normal capsule. In 1954 DVORAK-THEOBALD,[5] following Busacca's view, named the condition *"pseudoexfoliation of the lens capsule"*, a name which subsequently was adopted by most clinicians. When electron microscopy by BERTELSEN[6] in 1964 and ASHTON[7] in 1965 revealed that there actually was involvement of the lens epithelial cells and capsule and, possibly, the pigment epithelium of the iris, use of the term *Pseudoexfoliation syndrome* took on an ambiguous meaning. Today several authors refer to the exfoliation syndrome or the capsular exfoliation syndrome to indicate the presence of exfoliative material in the anterior segment of the eye without relation to its origin and without reference to the presence or absence of glaucoma.[8]

Today we can accept the idea that there are two components of the exfoliative process, first exfoliation of the zonular lamellae or pericapsular membrane and second a deposition on the surface of the zonular lamellae in the area in contact with iris.

Considering the source of the fibrillar material according to the theory of BERTELSEN and his associates,[6] the epithelial cells in the anterior periphery of the lens are stimulated by pathophysiologic factors to form new incomplete basement membranes and a substance which, at least when fixed, appears as fibrils which enter the fibrillar layer of the capsule as clefts containing granules and then become fibrillar again on reaching the lens surface where brush-shaped excrescences appear.

SUGAR described a case[9] of exfoliation syndrome in an eye with an eccentric pupil in which the granular material was present on the capsule only where the iris was in contact with it, including the central area of the capsule surface. This finding, together with evidence of continuing deposits after intracapsular cataract extraction suggested that the granular material is deposited from the iris and ciliary body epithelium and that the material formed by the lens epithelium remains within the lens capsule.

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II. Pigmentary glaucoma

Pigmentary glaucoma was first mentioned by SUGAR in 1940[1] when discussing a patient who was later described when a second patient was observed.[2] The subject was reviewed in 1966[3] at which time observations compiled from 128 cases in the literature and 19 private patients were summarized. The glaucoma was described as the end result of the pigment-dispersion syndrome which has a characteristic clinical picture. Because of the long interval between the onset of pigment dispersion and development of glaucoma, not all patients develop glaucoma; however, this interval allows greater opportunity to diagnose the glaucoma early.

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III. Corticosteroid Glaucoma

The first case of corticosteroid glaucoma was described by FRANÇOIS[1] in 1954. In 1977 FRANÇOIS[2] distinguished between acute and chronic corticosteroid glaucoma. The acute form is seen after intensive systemic corticotherapy while the chronic form appears within a few weeks up to 12 months and usually follows topical instillations.

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IV. Pupillary-block glaucoma

In spite of Bowman's recognition of pupillary-block glaucoma following cataract extraction as early as 1865,[1] it remained a rarely recognized entity for a long time. CHANDLER and JOHNSON in 1947[2] and later CHANDLER,[3-5] SHAFFER,[6] SUGAR,[7,8] and SWAN,[9] discussed various aspects of this important complication of cataract extraction. Recognition and understanding of this condition and its relationship to other forms of interchamber block have salvaged a growing number of involved eyes and, even more important, in many instances have led to prevention of pupillary block.

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V. Aphakic Obstructive Glaucoma

BOWMAN,[1] in 1865, first recognized the occurrence of postoperative glaucoma after extraction or discission of cataract. CZERMAK,[2] in 1897, showed histologically that the angle was closed and the iris adherent to the corneal periphery. SUGAR[3] proved this gonioscopically in 1940. KRONFELD and GROSSMAN[4] corroborated Sugar's findings and added significantly to our knowledge of the subject.

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VI. Rubeosis iridis glaucoma

Rubeosis iridis was first described well by SALUS,[1] in 1928, who called it rubeosis iridis diabetica. Since then a whole series of conditions have been recognized as causes of the ischemia which results in rubeosis and secondary glaucoma. Ocular vascular diseases include central retinal vein thrombosis and central artery occlusion, as well as syphilitic retinal vasculitis and diabetes mellius. The angle is open during the first weeks but is soon zippered closed in its entirety. The early angle findings were described by KURZ[1] in 1937, SUGAR[2] in 1941 and TRONCOSO[3] in 1946. The first central artery occlusion followed by glaucoma was reported in 1927 by OPIN.[4]

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