A GONIOSCOPICAL STUDY OF ANTERIOR PERIPHERAL SYNECHIÆ IN PRIMARY GLAUCOMA

AN ACADEMIC TREATISE

WHICH BY DUE PERMISSION

OF THE MOST EXPERIENCED FACULTY OF MEDICINE

AT UPPSALA

WILL BE PUBLICLY DEFENDED IN THE LECTURE ROOM
OF THE PHYSIOLOGICAL INSTITUTION
THURSDAY SEPTEMBER 1 1927 10 A. M.

FOR OBTAINING THE DEGREE OF DOCTOR OF MEDICINE

BY

T. W. THORBURN
LIC. MED. GBG

STOCKHOLM 1927
ISAAC MARCUS' BOKTRYCKERI-AKTIEBOLAG

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By T. THORBURN

I. Introduction

The solution of the question of etiology and pathogenesis of primary glaucoma is intimately connected with our knowledge of the chief channels of excretion for the intraocular fluid, that is the angle of the anterior chamber. Many investigations have been made in the last century on this part of the eye, but they all have had to be done on anatomical speciments or histological slides, as a clinical method for examining the angle of the anterior chamber has been lacking. It is only recently, that with help of the so-called contact glass it has been possible to get a good view of this area for examination, a method of observation, which has been called Gonioscopy.

Although we thus for some time have had a good clinical method of observation, it seems, as if the state of this part of the living eye, suffering from primary glaucoma, has not yet been the subject to systematic and sufficiently conclusive investigations; there further seems to be a good deal of uncertainty and confusion in the ideas, as to what degree the filtration channels may be possibly blocked by the root of the iris in primary glaucoma, and to what extent such a synechia, if any, between the root of the iris and the corneo-scleral wall may play some part as an etiological factor in primary glaucoma.

Only a few writers have published papers on the subject, giving their results from the gonioscopical method of observation, and as far as I am aware, there is no published record in the ophthalmological literature of any extensive series of goniscopical examinations of eyes suffering from various forms of primary glaucoma. These authors have described cases with a fully open angle, as well as cases, where the angle is more or less blocked by the iris, and they seem to be of the opinion, that at least in some classes of primary glaucoma the blocking of the excretion channels is the usual finding. Generalized conclusions, applicable to all forms of primary glaucoma, are not inferred.

It therefore seemed to me of great importance to undertake a series of gonioscopical investigations in primary glaucoma, as has also been emphasized by such an eminent author as Elliot, and it was with the view of elucidating these questions, that I planned this work at the suggestion of Dr J. W. Nordenson. As the question of glaucoma includes such an enormous number of interesting problems, it became necessary to limit the matter very strictly.

The questions I have chiefly tried to elucidate are:

1) Is in the majority of cases of primary glaucoma the angle of the anterior chamber blocked by a synechia of the root of the iris to the corneo-scleral wall?

2) Do in this respect any differences occur between various forms of primary glaucoma?

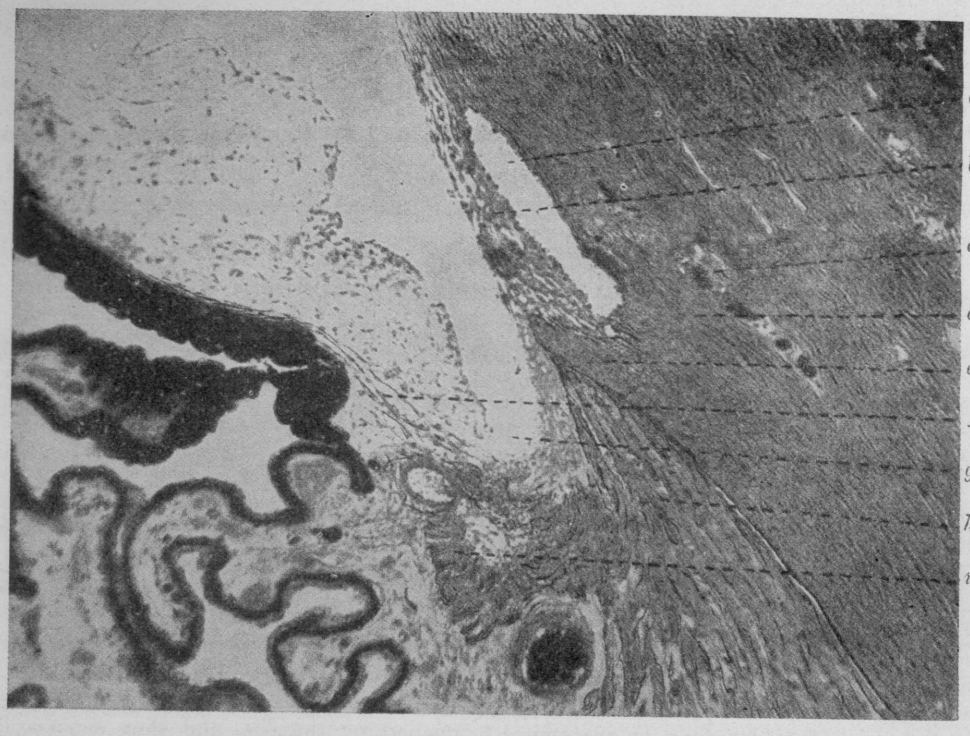

Fig. 1. The angle of the anterior chamber

a, Canal of Schlemm; b, trabecular tissue of pectinate ligament; c, scleral vein; d, dense scleral tissue; e, scleral process or spur projecting inwards and forwards from the sclera close behind the canal of Schlemm; f, radial muscular fibres of the iris extending outwards below the iridial angle; g, iridial angle; h, meridional fibres of the ciliary muscle; i, circular fibres of the ciliary muscle (By kind permission of Professor R. H. Elliot, and the Oxford Press)

II. General anatomical survey

The part of the eye the anatomy of which is of interest in gonioscopy, is the anterior chamber. This space is limited posteriorly by the iris and by that part of the anterior surface of the lens, which for the moment happens to be in the pupillary area. Anteriorly it is limited by the inner surface of the cornea. At the junction of the posterior and the anterior limitation, at the so-called angle of the anterior chamber, the ciliary body, covered by a network of connective tissue bundles, also takes part in bordering of the chamber.

As to the posterior wall of the chamber it is of interest to note, that the iris, the surface of which shows concentric as well as radiating folds, has the most peripheral of these concentric folds more developed than the others. This greatly affects the visibility of living eyes in regard to that part of the angle lying distally to this so-called last roll of the iris, as on account of its volume it may conceal parts of the angle, and thus simulate a synechia between the root of the iris and the anterior limit of the chamber.

Peripheral to the root of the iris comes the anterior surface of the ciliary body, to which the iris is fixed along a wavy line. The ciliary body is here mostly built up of fibres of the ciliary muscle. As its surface is doubly curved — not only aequatorially but also meridionally — the bottom of the angle is smoothed out, so that no sharp angle is formed, the posterior wall passing gradually over into the anterior.

Anteriorly the ciliary body is fixed to the sclera close to the scleral spur, the latter being a sligthly prominent in section triangular shaped ring of scleral tissue, forming the posterior border of the sulcus sclerae internus. This sulcus is a shallow groove, about 0.75 mm. broad, being gradually smoothed out in front. Outside the posterior part of this sulcus lies the canal of Schlemm, but the groove itself is filled out by a network of fibres, which continues to the sides, both covering the surface of the ciliary body and part of the sclera.

The canal of Schlemm is a flat furrow, often in some parts of its way round the periphery divided into 2 or 3 branches. It communicates with the venæ vorticosæ, but only in some diseased eyes it contains a little-blood; it is nowaday sconsidered normally to contain only aqueous, with perhaps a small quantity of much diluted blood. It is surrounded by scleral tissue on all sides, except towards the anterior chamber, where it is covered by the above mentioned network of fibres. There is, however, no direct communication with the anterior chamber, as the endothelium of the cornea extends into the angle and forms a delicate wall.

Just in front of the canal of Schlemm one finds the so-called »Grenzring» of Schwalbe, which is a narrow ring of flat bundles of scleral tissue. Then comes the sharply defined junction between the sclera and the cornea. This junction is seen in the section as an oblique line, so that the sclera at the outside of the eye extends further forwards and even closer to the axis of the eye, than at the inner side.

In some eyes may be seen threads of iris tissue bridging over the angle. The colour of these threads is determined by the pigmentation of the iris. They are white in poorly pigmented eyes, in more pigmented rather brown. They are mostly divided into branches. They can be seen as a direct continuation of the bundles of the iris, and to pass from the root of this membrane towards the scleral wall, where they become inserted at various distances forwards. They never occur in such great numbers as to form a real wall in the human eye, as is the case in some kinds of animals, where the pectinate ligament is formed by such threads.

The term pectinate ligament, however, is used in clinical ophthalmology for denoting a layer of tissue in the angle of the anterior chamber in the human eye. This layer consists of a network of threads, covering the ciliary body and part of the sclera at their surfaces facing the anterior chamber. Anatomically — macroscopically as well as microscopically — the network, however, may be divided into two separate portions, for if the iris is loosened from the ciliary body, the superficial bundles of this part stick to the iris, while the rest, forming the bigger portion, adheres to the ciliary body.

That part, which sticks to the iris, is called by Seefelder and Wolfrum ligamentum pectinatum or trabeculum uveale, while the other portion is called trabeculum corneo-sclerale. In a histological slide the threads may be seen to be covered by endothelium, which is a continuation of the endothelium on the inside of the cornea. The threads of the corneo-scleral trabeculum contain elastic fibres. They pass away in a mostly circular direction, so that the openings between the threads have their biggest extension in a course parallel to the surface of the iris. These threads are not so frequently divided into branches as the threads of the pectinate ligament, which are arranged in a more meridional direction, having bigger and more polygonal spaces between them. No elastic elements is to be found in the pectinate ligament.

The trabeculum covers the angle all the way from the root of the iris to the "Grenzring" of Schwalbe. It is thickest at the place corresponding to the canal of Schlemm, where it may be 15—20 threads in front of each other. From there it is getting thinner in each direction.

As normally most of the aqueous, when excreted from the anterior chamber, leaves the eye through the spaces of the trabeculum, the construction of this network has attracted great interest in several theories of glaucoma.

III. History of methods for examination of the angle of the anterior chamber

The difficulty or in many cases the impossibility of obtaining a view of the angle of the anterior chamber in the living human eye, depends on the considerable — in some parts total — reflexion, to which the beams of light, forming the image of this area, are subjected. Formerly it was possible to see this angle only in eyes with a pathologically deep anterior chamber, as in cases of high degree of myopia, hydrophthalmus etc. In eyes, suffering from primary glaucoma, it has been even more difficult than in healthy eyes, as a very common symptom of this disease is an abnormal shallowness of the anterior chamber.

A condition for obtaining a clear view of this recess, is a good illumination of it, even of its innermost parts. In order to reach right down to the bottom of the angle the beam of light must be thrown in at a wide angle to the axis of the bulb. The light, on its way out from the eye, as the image forming rays, hits the cornea at points far away from its apex, at points where the cornea is not spherical; it thus becomes astigmatic in character and makes a bad image. In consequence of the oblique direction of the imageforming rays, and the fact, that they pass from a medium with a higher optical index to a medium with a lower one, these rays become totally reflected in a very big area of the corneal surface, and thus do not form any image, observable outside the eye. The rays, not totally reflected, are those, the direction of which passes close to the surface of the iris, at an almost right angle to the axis of the eye. Naturally the major part of these rays is cut off by the iris, in the case of this being displaced forwards as in primary glaucoma.

In eyes, where the iris cuts the radius of the cornea in its foremost quarter, as seen from its apex, it is theoretically impossible to get a view of the angle of the anterior chamber, without the help of special arrangements.

If we assume the index of refraction of the cornea to be 4/3, and neglect the refraction at the inner surface of the cornea and the fact, that its peripheral parts are not spherical, and if, finally, we give the whole of the cornea the same radius as that temporal part of it, through which we can see the nasal section of the angle of the anterior chamber, we find the way of the illuminating and the image-forming rays by the following construction (indicated by Weierstrass, and quoted here from a paper by Salzmann in the Zeitschrift für Augenheilkunde 31/1914).

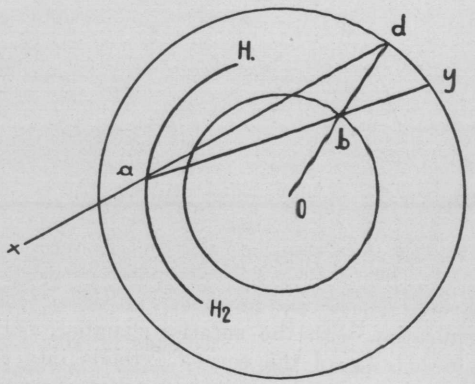

Fig. 2. Diagram of the refraction of the rays

We call the cornea H_1—H_2, its radius r, its the optical index n, and draw two concentric circles around the centre of the section of the cornea, the radius of the lesser circle being r/n, and that of the bigger r. n. The direction of the illuminating ray xa, is drawn from the point a, where it meets the cornea, to the point d, where it cuts the bigger circle. From d a radius is drawn to the common centre, and its intersection, b, with the lesser circle, is joined with the point, a, on the cornea, where the illuminating ray meets it. This last line, ay, shows the way of the ray, after being refracted at the surface of the cornea.

In observing the angle of the anterior chamber the question is not so much how the light enters the eye, but all the more how it leaves the eye to form the image. Its way may be found by reversing the

construction just mentioned. A point of light is thought to be situated at the angle of the anterior chamber (w), (Fig. 3) and the rays coming from it are considered. The

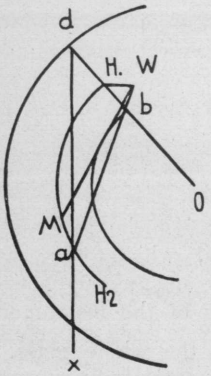

Fig. 3 Diagram of the refraction of the rays

direction of a ray, refracted in the cornea and coming from this point of light is found, if through the point, b, where it cuts the lesser circle, a radius to the bigger circle is drawn, and if further a line is drawn from the crossing-point, d, between this radius and the bigger circle to the point, where the ray meets the corneal surface, a. The continuation of this line outside the eye shows the direction of the ray, which comes from the angle of the anterior chamber, after having been refracted in the cornea.

As these rays come from a medium with a higher index, and enter a medium with a lower one, the case of a total refraction may occur. This is the case with the rays, which do not cut the lesser circle, namely in fig. 3 all the rays meeting the cornea between M. and H_2 which last point indicates the limitation of the translucence of the cornea. Thus only those rays, cutting the cornea between M and H_2, escape beeing totally reflected.

In a deep anterior chamber it is the junction between the translucent cornea and the non-translucent sclera, that forms the hindermost limit for image-forming rays. In a shallower anterior chamber it is the position of the iris membrane, that determines this hindermost limit for the rays, which can be used for getting a view of the angle, for, if the iris is moved forwards, some of the rays are cut off by it. In the extreme case, when the iris is placed altogether in front of the lesser circle, the very angle of the anterior chamber must be invisible, without special instruments or arrangements. Thus the foremost position of the iris, just making the observation of the angle impossible, is that when situated at the periphery of the lesser circle, the radius of which was $^3/_4$ of the radius of the cornea.

As the obstruction of the view of the angle, caused by the iris, depends upon the position of this membrane in relation to the radius of the cornea, the observation, in the case of equally deep chambers, is easier with a more curved cornea than with a flatter one, and in the case of the corneæ being equally curved easier with a deep than a shallow chamber.

Fuchs in the year 1900 made an attempt with another method to see the angle, especially the canal of Schlemm. He threw a very strong light through the limbus, where the sclera is very thin, and saw a grey band, which he thought to be the canal of Schlemm. Subsequent writers have in some respects been unable to verify the results thus gained by him. As far as I am aware, however, no series of observations of glaucoma eyes by this method have been published.

Trantas, in 1907, wrote a paper about a method, invented by him to make the angle of the anterior chamber visible for direct observation. Using the ophthalmoscope with a powerful convex lens inset, he observed the angle through the cornea in a very oblique direction to the axis of the eye, while at the same time making pressure with a finger at the limbus outside the point under observation. In eyes with deep anterior chambers he could thereby get a view of the anterior chamber in its peripheral parts, but owing to the pressure exerted on the limbus, its condition was an abnormal one. He published a description of the appearance of the region concerned in eyes, suffering from various diseases. In glaucomatous eyes, however, with their shallow anterior cham-

bers, the method is not suitable for solving the question as to the presence or not of synechiae between the iris and the corneo-sclera, as the pressure exerted upon the eye at the limbus may easily alter the mutual position of the different tissues, forming this part of the eye.

Even in a later paper (1918) Trantas does not seem to pay attention to this question.

The Japanese ophthalmologist, Missio, remarks, in 1913, that it is possible to see the very angle of the anterior chamber by ophthalmoscopy, if the conjunctival sack is filled with tears or some other fluid, but he has not published any systematically made observations of the angle in primary glaucoma.

It is not until the contact glass is invented, that a method useful for clinical observations is brought forth, and the name gonioscopy becomes appropriate.

Fick was the first one to use the contact glass. His glass was a concave-convex glass, 1 mm. thick, and with a radius of the convex surface of 8 mm. The object of using this instrument was to locate the refracting surface of the corneal system to the convex surface of the glass, thus making the part of the radius lying in front of the iris membrane appear longer. In the above mentioned construction the lesser circle is thus moved forward, and the areas in which the rays are totally reflected, are diminished. A larger amount of rays is thereby made imageforming. The glass was used so, that its borders were put under the lids into the conjunctival sac, and its concave excavation fitted closely to the corneal surface. There was always an interspace, however, between some parts of the cornea and the glass, and this vacuity had to be filled up with some fluid of about the same optical index as the cornea. This was effected by injecting saline solution into the interspace. By help of this contact glass and the ophthalmoscope Fick was able to get a view of the most peripheral parts of the anterior chamber, even in the case of this being abnormally shallow.

Salzmann, a German ophthalmologist, was the first to publish a case of gonioscopy in primary glaucoma with special attention to the question as to the presence or not of adhesions between the root of the iris and the corneo-sclera. For these observations he first used Ficks' contact glass, but he soon found, that this did not fit well to the cornea, and that the refracting surface was too flat, thus giving the image-forming rays a direction at too wide an angle to the axis of the eye.

The following year, 1915, he published a series of, among others, some cases of primary glaucoma observed by gonioscopy. For these observations he had constructed a new contact glass, which was divided into an optical zone and a supporting zone. The measurements of the instrument were:

Diameter	of	the whole glass.	= 17	mm.
„	„	optical zone	= 11.5	„
Radius	„	supporting zone	= 13	„
„	„	optical zone	= 7	„
Thickness	„	the glass	= 0.6	„

Although the radius of the optical zone in this contact glass of Salzmann was made 1 mm. shorter than in the glass of Fick, the line of vision in many cases is said to pass too close to the surface of the iris not to become interrupted by it.

In his book "Die Mikroscopie des lebenden Auges" Koeppe 1920 developed the theory of the possibility of seeing the angle of the anterior chamber. He also published the construction of a new contact glass, which like Salzmann's consists of an optical and of a supporting zone. The supporting zone is formed by the border of the glass, in which a groove is ground all round its periphery. The margins of the patient's lids were intended to rest in the groove, thus holding the glass in its place and pressing it tightly against the bulb. The diameter of this zone was 22 mm., a distance across which the rima palpebrarum of most patients can be made comfortably to gape.

The optical zone of the glass is a concave-convex lens. The concave surface has an opening of 12 mm. and a radius of 8 mm. The convex spherical surface, where the rays are refracted, when the glass is used, has an breadth of 8 mm. and radius of 10 mm.

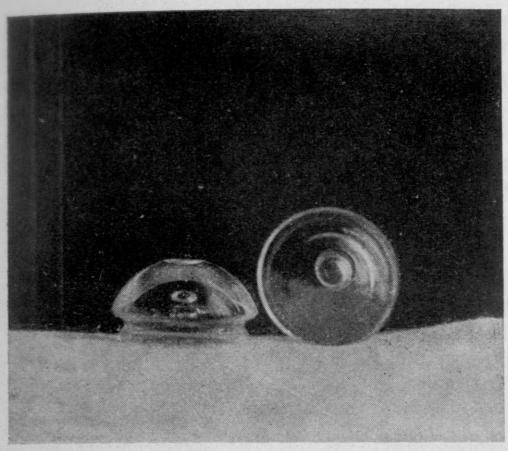

Fig. 4. The contact glass of Koeppe

At the vertex of the glass there is a small groove, which is intended to be the resting place for the tip of a bar, or the knot of a string for keeping the glass in position, without coming in collision with the observation-line. This contact glass gave 3 times magnification. Finding that the astigmatism, caused by this glass, was too great, Koeppe designed a new glass. The radius of the anterior surface of this was 13.5 instead of 10 mm. in the old one. Finding, that the glass was kept sufficiently in place by the pressure of the borders of the lids, no groove was made at the vertex of the glass.

Karl Ascher recently (1924) made a variation of Koeppe's glass by diminishing the opening of the supporting zone to only 12 mm., thus making it possible to apply the glass on patients with much lesser rima palpebrarum than the usual one.

In some of his investigations, Koeppe instead of the contact glass used a so-called "Vorschaltekammer", the principle of which is the same as that of the contact glass, namely to replace the refracting surface of the cornea by a more anteriorly situated surface of glass, thus lessening the amount of rays totally reflected. According to Koeppe, this instrument is a rounded glass chamber with a radius of 15 mm. and with a big opening on one side. The edges of this opening are ground to fit the surroundings of the eye, and are clothed with rubber. The space inside the chamber is big enough to allow the patient to twinkle without the risk of soiling it with the cilia. At the bottom of the "Vorschaltekammer" there was a tube for filling it with solution, and at the top another tube for the escape of the air. The "Kammer" was kept in position by a band, attached to metal bows and fixed round the head of the patient. This "Vorschaltekammer" is said to be less convenient in practice than the contact glass and not to give better views than the latter, so I have not tried it.

The question of illumination of the angle of the anterior chamber is a very important one, especially when observation instruments of great power of magnification are used. Various sources of light and different kinds of instruments have been used for throwing a sufficient beam of light into the eye, making gonioscopy possible.

At the beginning of the practice of gonioscopy the common ophthalmoscope was used and the light from an ordinary source directed to the angle of the anterior chamber with a concave mirror. It is Koeppe, who has developed the technique of using Gullstrand's slitlamp as source of light for gonioscopy. The instrumental outfit was the same as for corneal microscopy, with the slitlamp placed on a moveable stand and the aplanatic objective lens for the illuminating system placed close to the eye. As only an area of a few millimeters' width in the recess of the chamber was illuminated, and as the optical zone of the contact glass was of such small size, the rays of the illuminating and image-forming systems came to be very close to one another. To avoid a collision between the instruments for the illuminating and observing systems, Koeppe placed a little moveable silver mirror just distally to the objective lens, which altered the direction of the illuminating beam, thus allowing the source of light to be placed at a great angle to the observation instruments.

By this stationary instrumental arrangement, however, Koeppe found it difficult or even impossible to bring the upper and lower parts of the angle under observation,

especially as his patients were sitting during the gonioscopical observation.

Karl Ascher in a paper 1924 points out a way of getting over these difficulties. He has the patients in recumbent position on the operating table, and makes them bend their heads forwards in the examination of the lower parts, and backwards in the examination of the upper parts of the angle.

Even if thereby it was possible to get a view of the whole circumference of the angle, the technique was inconvenient, and the examination was tiresome to the patient. The greatest drawback of the method was the very limited area at the angle, that could be illuminated at anyone time and the consequent frequent moving of the source of light. In order to overcome these difficulties and to make the instrument more fit for clinical purposes Troncoso 1925 constructed his *gonioscope*, which he describes as follows:

"Hoping to obtain a clear, unobstructed view of the angle in all directions and a sufficient magnification, I have devised and perfected a new instrument, the gonioscope, which is a microscope and a periscope combined. It has been built by Bausch & Lomb Optical Co. with great care and accuracy.

The tube of a microscope with a length of 23 cm. revolves around its axis inside a looped band which is attached to the handle of the instrument. The handle is at right angles to the tube. Inside this handle a sufficient space for a dry a battery has been reserved. One end of the tube is conical and carries the objective lens and a square prism; the rays of light, coming from the angle and parallel to the surface of the iris, are totally reflected to the optical system in the tube, allowing the observer to place himself in front of the patient. Two interchangeable eyepieces give magnifications of 10 and 20 diameters. The rotation of the microscopetube around the eye brings into view the structures of the angle all around the limbus. This periscope arrangement gives the observer a much more comfortable position than the lateral view, which the use of the ophthalmoscope entails.

The illumination of the angle is made by a small electric lamp, carried in a tube and fastened alongside the conical end of the microscope. The lamp is provided with a condensing lens, and the rays of light are directed at right angles to the tube by means of a square prism, parallel and on level with the square prism of the microscope.

In order to keep electric contact when the gonioscope revolves the tip of the lamp carrying shaft, slides around a metallic plate connected with the dry battery.

Focussing was at first made by changing the distance between the objective and ocular, but we soon found that the slight movement transmitted to the instrument by sliding the ocular piece, caused a change in the place spotted and a blurring of the image, due to the displacement of the microscope. We then decided to have the ocular and object lenses stationary, and regulate the focussing by approaching or separating the tip of the gonioscope from the eye."

In 1926 Troncoso published some new arrangements, he had made, on his gonioscope. The source of light had been made more powerful and fitted to the ordinary electric current (of the house). The direction of the illuminating rays was better adjusted and the focal distance of the system was reduced in order to facilitate the examination of the temporal side of the angle, for which the tip of the instrument must be placed between the nose and the eye.

The total magnification of the image of the angle gained by this instrument, combined with Koeppe's, contact glass, was:

With	5	x eye-piece	13	times
„	7.5	x „	19.5	„
„	12.5	x „	32.5	„

Salzmann, Koeppe and Troncoso illustrate their papers with beautiful handdrawn pictures of the gonioscopical appearance of the angle, but, as far as I am aware, there is no photograph of it yet published. If a photograph of this region is obtainable, it ought to give a truer image than even the most artistically done handdrawings. Salzmann does also complain of the difficulty of making the drawings adequate, as he can

not draw in the same time, as he makes his gonioscopical observations, and thus only has to rely on his memory of the aspect.

IV. Technique employed in author's investigations

From the present day methods of excluding the total reflexion at the cornea of the rays coming from the angle of the anterior chamber, I have chosen the one developed by Koeppe, using his contact glass. The method of the »Vorschaltekammer» is said to be less convenient and not to give any better possibilities for getting a view of the area in question; the contact glasses of Fick and Salzmann are, as said in the foregoing chapter, not so well adapted to their purposes, as is the contact glass of Koeppe and hence I have used only his glass. In regard to the illuminating system, I have found the method of Koeppe rather inconvenient and have therefore made an alteration in that detail.

The great magnification obtained by the microscope, and even — according to Troncoso's statement in his last paper about gonioscopy — with his gonioscope, at least in using the most magnifying eyepieces, I have found quite unnecessary for diagnosing the presence or not of a synechia at the angle. The great magnification needs a particularly adequate focussing of the observation instruments, a thing which is very annoying as even a little movement of the patient's eye brings the view out of focus.

The patient is prepared for the gonioscopical examination by making the cornea and the conjunctival sac anaesthetic, so that the contact glass may be put in position without pains to the patient. This is easily done by instilling 2 drops of a 1 % solution of holocain hydrochloride into the conjunctival sack, an interval of 3 minutes being allowed to elapse between the drops. In glaucoma cases, where a dilatation of the pupil ought to be avoided, this form of anaesthesia may be used without risk to the patient.

As Ascher has pointed out, is it most convenient to have the patients lying down during the examination; this allows, when the instrumentary of Koeppe is used, a bigger area of the angle to be investigated as the upper and lower quadrants may be brought into sight, if the patients turn their heads to different directions. I have always had the patients lying on their backs on the operating table with their necks resting in a cupshaped supporter.

It is adviseable to wash out the conjunctival sack with saline solution just before the contact glass is put in position, as even small foreign bodies or mucus between the contact glass and the cornea greatly disturb the observation. For the same reason the contact glass itself must be kept absolutely clear and free from fat or dust, and is therefore best kept up in alcohol, when not in use.

Koeppe's contact glass is, as previously mentioned, supplied at the supporting zone with a groove, ground round the border. When the glass is to be put into position it is so placed, that the margin of the upper lid slips into this groove at one side of the glass, and then the upper lid is by help of the glass pushed upwards until the margin of the lower lid, being simultaneously pulled downward, glides into the corresponding part of the groove. The supporting zone of the glass is thus enclosed by the borders of the lids and so held in its proper place and pressed tightly against the bulb. Occasionally some patients complain of a slight feeling of strething in the angles of the lids, but this happens very seldom and may be avoided by using a glass with a smaller supporting zone, as is done by Ascher.

In the case of the rima palpebrarum being unusually wide, the grasp of the lids round the glass may not be steady enough, and the glass may then slip out and be broken against the floor. To avoid this accident the glass may be steadied in its place by a bar, the top of which rests in the excavation at the vertex of the optical zone of the glass. The bar itself is carried by a band round the head of the patient in the same way as the common front mirror is fastened. The bar does not disturb the examination of the angle, but in most eyes the glass is so well held by the lids, that it is an unne-

cessary precaution to use the bar, and in Koeppe's last construction no groove is made for this purpose.

When the glass is well put into position fluid must be injected into the interspace between the cornea and the concave surface of the glass. I have used saline solution for the injection of a temperature of about 18° Celsius, the optical index of which is about the same as for the glass and cornea. To facilitate the escape of the air in the interspace the patient's head is rotated laterally about 45°. A semicircular bent tip of a canule is then pushed round the border of the glass at the nasal side of it, and by means of a common syringe saline solution is injected, until the interspace is filled and every bubble of air has escaped. Often the last bubble of air will not get out by a simple injection of the fluid, but if the nasal side of the glass be lifted a little with the tip of the canule going round its border it will easily run away. Precautions must be taken to avoid the tip hooking up a fold of the conjunctiva and thereby hurting the patient.

When the saline solution has been injected, the head of the patient is rotated forwardly, and the patient is told to look straight in front and not to pinch with the eyelids. The patient can without discomfort look in different directions, when the glass is in position, which is of importance for the convenient examination of especially the upper and lower quadrants of the angle.

Naturally no arrangements need to be made for keeping the cornea moist, as it is kept so by the saline solution.

On bright days daylight is the best source of light, as it gives even without concentration a clear and homogenous illumination to the whole periphery of the angle. Working with out-patients, where it is of importance to carry out the examination quickly, the daylight is also the most convenient source of light. But in dark days and when working with observation instruments of greater magnification it may not be possible to concentrate the daylight sufficiently intensively to the innermost parts of the recess of the anterior chamber, and artificial light must then also be used.

The Nernst slit-lamp of Gullstrand, which was used by Koeppe (see page 7) gives very clear illumination of a small part of the angle but in consequence of the small area illuminated at one and the same time a frequent moving of the illuminating instrumentary becomes necessary. For the upper and lower quadrant of the angle this is very inconvenient. For photography or for a closer observation with instruments of greater magnification, as the corneal microscope, I have also used the technique of Koeppe, employing, however, a microarch-lamp instead of a Nernst-lamp. Mostly, however, I have used a small electric lamp, mounted in a cylindrical brass capsule with a condensing lens at the end. This little lamp was coupled to the main current of the laboratory through a resistance. It is worked by hand by the observer himself or by an assistent and thus easily directed to every place at the angle of the anterior chamber. The illumination was quite clear enough. to allow detailed examinations, even when using such a big magnification as that obtained by the corneal microscope.

Even in using a good light, well directed into the very depth of the angle, it was in some cases rather difficult to make sure of the presence or not of a synechia between the root of the iris and the cornea-scleral wall, owing to the limited illumination and to the somewhat similar appearance of the different zones. I haven often found much help in changing the direction of the illuminating rays so, that they pass through the thin sclera at the limbus instead of through the cornea and the anterior chamber. In so doing the translucent zones stand out clearly against the nontranslucent, that is the ciliary body and in cases of rich pigment deposition at the angle, to a certain degree the zone the Schlemm. In the case of a peripheral iris synechia being present this was easily seen with this direction of the rays. With the gonioscope, constructed by Troncoso, where the source of light is fixed

to the observation tube, this direction of the rays is not obtainable, without using another source of light than the one, for which the gonioscope is constructed.

As an observation instrument I have mostly used a binocular loupe, giving a magnification of 4 times and with a working distance of about 25 cm. This instrument gives a stereoscopic view, quite big enough to enable the observer to detect a peripheral synechia if present. As the line of vision from moment to moment has to be tilted to follow the small movements of the patient's eye, it is of great importance to have an observation instrument, allowing an easy movement, and one that does not necessitate a very accurate focussing. No trouble needs be experienced with the localisation as a bigger area of the angle is observed at one and the same time — a difficulty which is considerable, when using the corneal microscope. Previous writers on the subject, who have used the bigger magnification, do not seem to have had much use of this greater enlargement of the image.

The greatest simplification of the instrumentary by help of which the angle of the anterior chamber is brought into sight, is achieved by taking a common test-tube, which is cut about 2 cm. from its open end, and by placing the open end, the border of which is slightly outwards bent in the conjunctival sac, which previously is made anestetic. When saline solution is filled in the tube, a relatively good aspect of the angle is obtained. The aspect gained is sufficiently clear to allow a judgment of the presence or not of not too small a synechia between the iris and the corneo-sclera. As the instruments necessary for this examination are so very simple and cheap, that they can be got without difficulty by everyone, the method is mentioned here, especially as mostly no artificial source of light is necessary for the illumination. Even a moderately clear daylight is sufficient for illuminating the angle.

The limitation of the possibilities of seeing the angle of the anterior chamber by help of the gonioscopical method is essentially due to the opacity of the cornea. Unfortunately a diffuse haziness of the cornea is a very common symptom of glaucoma, where the intrabulbar tension is raised to a high degree. Even should the details thereby be made impossible of differentiation, it is generally possible in these cases to decide, whether there is a total synechia or not, because if the angle be open only to some degree, the mostly dark zone of the canal of Schlemm may be seen even trough a foggy cornea.

A macula corneae, situated in the line of vision, naturally makes the observation less exact or even impossible, according to the thickness and extension of the macula. As the zone in which the angle is clearly seen is very narrow, the macula need not be big for causing a considerable disturbance of the observation. In cases of hypopyon, blood or foreign bodies in the anterior chamber parts of the angle, of course, are excluded from gonioscopical investigation.

A question of very great importance is to what extent it is possible to decide by gonioscopy, whether a real anatomical synechia exists between the root of the iris and the corneo-scleral wall, or whether the deeper parts of the angle are only concealed by the mechanical pressure of the iris into the recess. If at a gonioscopical observation the white sclera is the only zone visible, it is impossible to judge, whether a real synechia with new formed connective tissue is present or not. It is only after some time's treatment of the eye with miotics and renewed gonioscopy, that the question in some cases may be solved. If the angle then is found quite free, the »synechia» must have been due only to mechanical pressure of the root of the iris to the wall, or the newly formed connective tissue must have been so thin as to have ruptured as a result of the miotics administered. If the angle in some parts of the circumference is found free, in other parts unaltered by the miotics, it is most probable, that a partial synechia is at hand, especially if the iris at the limit between the open and the closed part makes an abrupt elevation up to the level of the adhering part of it.

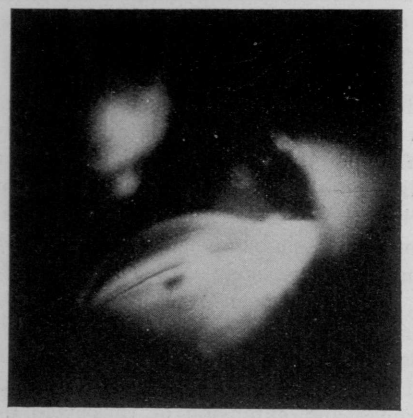

Fig. 5. Photo of normal angle of the anterior chamber

Where no change in the condition of the angle can be seen as an effect of the miotic treatment, it may be due either to an anatomical synechia too strong to be loosened by the miotics, or to the last roll of the iris being so prominent, that, although the iris being stretched by the miotics, it still conceals the zones of the deeper parts of the angle. In such cases gonioscopy can not solve the question of the possible presence of a total synechia but only make a real synechia very probable, especially if at the first gonioscopical examination the iris in its most peripheral, still visible area, made a smooth curve inte the angle, which curve at a second examination after miotic treatment is straightened out.

The question as to whether a synechia not loosened by miotics, is a real, anatomical one or not can only be solved by histological examination of the angle.

The difficulty in getting a good photograph of the angle is considerable, owing to the fact, that the region in question is sharply bent not only circurlarly but also radially. If one point is well focussed in the camera even its close neighbourhood is rather unclear, and thus only a very small area gives a really good view at one and the same time. A strong illumination must be used to allow a short time of exposure, as it is very troublesome to make the patient hold his eye fixed for even a very limited time. I have used the pointolite-lamp of Gullstrand as a source of light, when photographing. If that piece of the lamp, which is used for transilluminating the bulb, is unscrewed, leaving the lens in it at the lamp, a very suitable source of light is obtained, by which the time of exposure of the plates could be as short as 3—4 seconds.

To my disposal I had a camera for stereoscopical photographing, but it was impossible to get stereoscopical plates of the angle, due so its small extension, making a focussing of both plates at the same time impossible. I therefore had to be satisfied with focussing one of the plates. The focussing had to be minutely carefully done, if the excidingly little difference in colour between the zone of the canal of Schlemm and the scleral zone should be perceivable.

The magnification gained by the camera was 1.7 times.

V. The gonioscopical aspect of the anterior chamber in normal eyes

In order to judge whether anything pathological is to be seen in the angle of the anterior chamber in eyes suffering from primary glaucoma, one must, of course, be well aquainted with its aspect in normal eyes. The view, obtained by gonioscopy corresponds to what is to be expected from the anatomical structure of the part in question. Previous writers on the subject are, on the whole, agreed on the gonioscopical appearance of the angle in young normal eyes, although they do not agree in their opinion as to the frequency of some details. Salzmann, Koeppe and Troncoso give a detailed description of the appearance of the angle in living normal eyes, and I propose here to give a short survey of it, mentioning where my experience differs from theirs.

The various zones in the anterior chamber, that can be differentiated by gonioscopy in normal eyes, are:

1) The pupil.
2) The pupillary border of the iris.
3) The anterior surface of the iris.

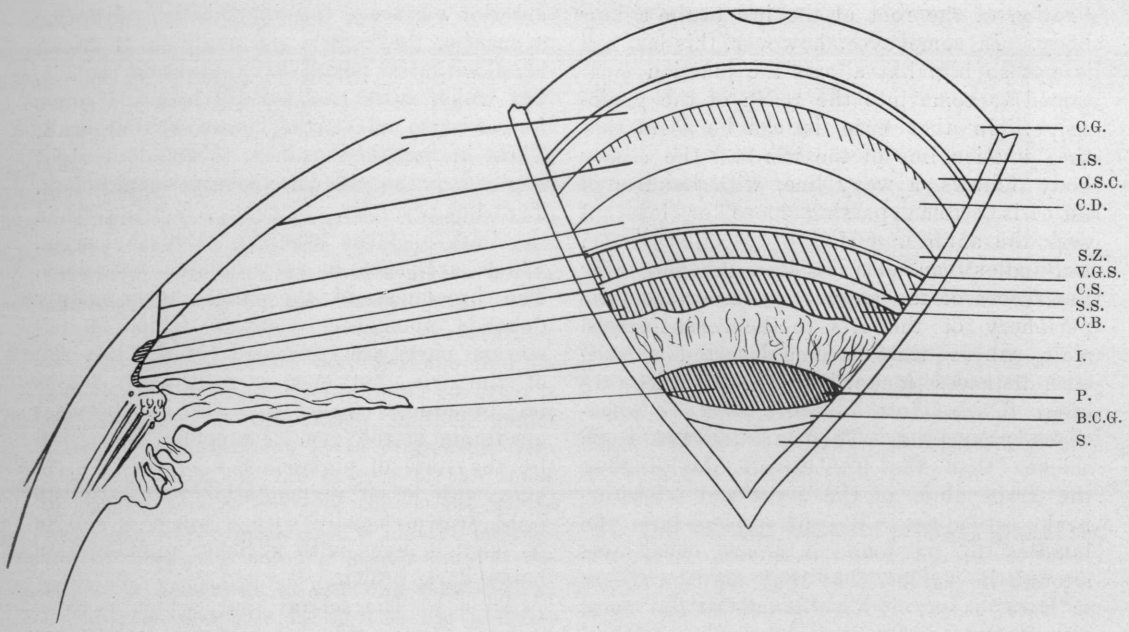

Fig. 6. Diagram of the angle of the anterior chamber and its gonioscopical correspondence.
C.G. = The contact glass. I.S. = Interspace between the contact glass and the cornea. O.S.C. = The optical section of the cornea. C.D. = The corneal dome. S.Z. = The scleral zone (inside of the limbus). V.G.S. = The Vordere Grenzring of Schwalbe. C S. = The canal of Schlemm. S.S. = The scleral spur. C.B. = The ciliary body. I = The iris. P. = The pupill. B.C.G. = The border of the contact glass. S. = The sclera outside the contact glass

4) The corneo-scleral and uveal trabeculum.
   4 a) The anterior surface of the ciliary body.
   4 b) The scleral spur.
   4 c) The canal of Schlemm.
   4 d) The »Vordere Grenzring of Schwalbe».
5) The limbus.
6) The concave dome of the cornea.
7) The optical section of the cornea.

Ad 1) In the pupil the lens may be more or less seen depending upon the degree of dilatation of the pupil. If a strong magnification is used, the structure may to a certain extent be differentiated.

Ad 2) The pupillary border of the iris shows various divisions. Hindmost one sees the margin of the black pigment layer at the posterior surface of this membrane. It is arranged in radiating folds causing its border to get a wrinkled appearance.

That part of the iris-stroma, lying between the very pupillary border and the place, where the circulus arteriosus iridis minor is situated, is built up of a network of white to gray or brown threads mostly in a radial direction, with more or less deep and broad crypts between them. These central parts of the iris are not so thick as the peripheral parts, a fact, causing an abrupt slope to be formed by the stroma to reach the level of the rest of the iris.

Ad 3) The stroma of the rest of the iris is formed by a similar network of bundles, which pass mostly in a radial direction and anastomose with each other. In irises of a lighter colour the bundles are white or gray, but in darker eyes they may contain pigment. The surface of the iris forms radiating as well as concentric folds, beautifully seen, when the pupil is dilated. The most peripheral of the concentric folds, the so-called last roll of the iris, forms in most eyes the most peripheral yet visible part of the iris, as it is generally bigger than the others, and big enough to conceal the very

fixation of the root of the iris to the ciliary body. In some eyes, however, this last roll is not so big, but allows the junction mentioned to come into the reach of the gonioscope. In that case it can be seen, that the junction line of the iris and the ciliary body follows a wavy line, with bundles of the iris stroma passing more or less out over the anterior surface of the ciliary body.

Bundles can also be seen bridging over the recess of the anterior chamber from the periphery of the iris to the corneo-scleral wall, where they become inserted at various distances forwards. The bundles are often divided into branches, and are sometimes pigmented. They are always much thicker than the fine threads, building up the trabeculum of the uveal and sclerocorneal reticulum. Koeppe considers the bundles to be found in almost every eye, altough he agrees, that they may be absent in rare cases; i have found several eyes, where they are undoubtedly absent and in my opinion they are not so often to be found in normal eyes, as believed by Koeppe.

Just behind the last roll of the iris one or more bright red arterial branches often peep out. Judging from their situation and direction, concentric to the periphery of the iris, the are probably branches of the circulus arteriosus iridis major.

Ad 4) Next zone visible in gonioscopy is that part of the angle, which is covered by the trabeculum corneo-sclerale and uveale, that is the ciliary body, the scleral spur, the canal of Schlemm and the »Vordere Grenzring of Schwalbe». As the trabeculum is partly very thin and greatly transparent, it allows the tissues behind it to come into sight. The colour of the trabeculum, as seen in the gonioscope, is determined by the colour of the underlying tissue. A fine meridional striation, caused by the trabeculum can be seen, especially in older patients, where some pigment often is deposited at the angle, making the spaces between the threads to stand out more clearly.

Ad 4 a) The most posteriorly placed zone, visible through the trabeculum, is the anterior surface of the ciliary body. It forms a surface, the central parts of which are on level with the peripheral sections of the iris, but which more peripherally makes a curve forwards to meet the corneo-scleral wall. Thus in parts it comes to stand at right angles to the line of vision in gonioscopy. The image of it, therefore, is truer, than the images of the other zones of the angle, which are seen in very oblique directions. The broadness of the ciliary body mainly depends upon the extent, to which its posterior parts are concealed by the last roll of the iris, but even in fully open angles its broadness varies a little in different quadrants of the eye. Its colour is decided by the state of pigmentation of the eye, in eyes with lesser pigmentation being gray to light brown, usually with a touch of red in it, and in eyes with a richer pigmentation being dark brown.

Ad 4 b) The scleral spur, which is covered by a very thin layer of the trabeculum looks like a shining white very narrow band, sharply limited at both sides from the surrounding zones.

Ad 4 c) The zone corresponding to the canal of Schlemm comes immediately anterior to the scleral spur. In young normal eyes this zone is often difficult to differentiate from the white zone of the scleral spur and the »Grenzring of Schwalbe» on each side of it. If transscleral illumination is used it is often more easily distinguished, as the sclera at this line is thinner than at its immediate surroundings, and thus more translucent. Usually it can be seen as a light gray ring, sometimes with a very light red touch in it. In diseased eyes I have had the opportunity of seeing this zone more red, evidently depending on diluted blood in it, but it has never been bright red. As the trabeculum here is at its thickest a pigment deposition in the spaces gives the zone more of a dark brown colour as compared with the other zones. A branching of the canal of Schlemm, which is said to have been anatomically found, I have never been able to observe.

That this zone of the canal of Schlemm

is very difficult to see in some cases, is understood from the fact, that Salzmann in his paper of 1914 says: »Vom Schlemmschen Kanal habe ich nie etwas sehen können», a statement, which he corrects in a paper of 1915, giving a description of the actual gonioscopical appearance of the zone.

Troncoso also states, that the gray zone of the canal of Schlemm is very often non-existing, and that the white sclera begins immediately outside the ciliary body.

The incompleteness of the observations of the named authors may perhaps find its explanation in their having used so great a magnification of the image in their gonioscopical investigations as to render the delicate variations in the colours of the zones of the hindmost parts of the corneo-scleral wall less easily observed; a clearer conception is obtained, when a bigger area of the angle is observed at any one time. Even if the microscope is used, it is not possible to differentiate these zones by anything else than their colour.

Ad 4 d) The concentration of scleral tissue, called the »Vordere Grenzring of Schwalbe», at the boundary between the sclera and the cornea has an exceedingly thin layer of trabeculum in front of it, as the trabeculum here passes over into the membrane of Descemet. The white colour of this zone is generally very intense, but its breadth being very small, it may easily be overlooked.

Ad 5) The inside of the limbus forms a gonioscopical zone, usually called the scleral zone. It is white in colour, but as the cornea is fixed to the sclera in an oblique line, going most posteriorly at the inner side, the cornea becomes thicker the more forwards one comes, the colour of the sclera getting blueer in the anterior parts. The anterior limit of the sclera forms a forwardly convex line, according to the line of vision in gonioscopy.

In the anterior half several branches of blood-vessels are seen passing meridionally and disappearing round the outer limbus, A pigment deposition, which may be seen even in rather young eyes, is usually arranged in lines, which, although being mostly wavy, pass concentrically to the border of the cornea: I have seen such a line even in a man of 30. This pigmentation is by Koeppe considered as being a senile sign, which is also often found in cases of glaucoma simplex.

Ad 6) The concave dome of the cornea shows a homogenic zone of watercolour. Depending upon from which point the observation is made it looks like a smaller or bigger crescent.

Ad 7) The last zone observeable in gonioscopy is formed by the optical section of the cornea, which, looks like a blue-gray equally broad band, going in a semi-circle from side to side.

VI. The various forms of primary glaucoma

The great symptom-complex, called primary glaucoma, includes several forms of the disease. It is of very great importance to keep the various subdivisions well apart, and to be quite clear about the differential diagnosis between them. This is all the more necessary as a pathogenesis common to all forms is unknown, and it is not impossible, that the state of the angle of the anterior chamber may vary with different forms of primary glaucoma, and that its part played as an etiological factor may vary.

Several attempts have been made to unite all the different types of the disease under one form, and one sign or symptom after the other has been considered common to all cases.

It was von Graefe, who urged, that the raised intrabulbar tension should be a sign sine qua non. He thereby excluded all those cases of simple glaucoma, where no hypertension could ever be found.

Another sign, which was considerad present in every case of primary glaucoma, was the cup-shaped papilla. If that should be the common ground for classification, almost none of the acute cases could be included, as in those cases there is generally no cup-shaped papilla to be found at least in the beginning of the acute attack.

Nor is the way in which the contraction of the field of vision comes on or the secondary amaurosis a symptom sufficiently uniform in all cases of primary glaucoma to serve as a common factor, by which all the types could be characterized.

As no sign or symptom is absolutely certainly found in every case of glaucoma, confusion naturally arises in the classification and terminology of these cases.

The following is the special classification I have used:

Irritative glaucoma { acutum / chronicum
Simple glaucoma
Absolute glaucoma
Partner.

The great class of secondary glaucoma, where a cause of the disease can be found, is not being discussed in this paper, as the question is limited to gonioscopy in primary glaucoma, nor is the end-state, the degenerative glaucoma mentioned, as it is lacking in gonioscopical interest.

By the *acute irritative glaucoma* is meant that form, which is characterized by an acute, attack-like onset of symptoms. One of the most prominent signs is the raised tension, which rises to rather a high degree. The haziness of the cornea in the majority of the acute cases is thus very pronounced, which also is the case with the irritation of the eye, wide, curly veins being seen. In most cases there is a considerable shallowing of the anterior chamber. The iris is discoloured, and the pupil dilated. The cupping may be entirely absent. As a result of the haziness of the cornea the ophtalmoscopical examination of the fundus is much restricted, but if the tension be soon brought down, the cornea clearing up, and the observation of the disc being again possible, generally no excavation of it can be seen in acute cases. During the attack the vision is strongly diminished. Intense pains accompany the attack.

The attack usually passes in a short time, sometimes leaving the tension a little raised, and the vision somewhat obscured. After some time — a few days to some weeks — a new attack comes on. In rare cases the eye may be damaged at the first attack, making it amaurotic.

The *chronic irritative glaucoma* may develop from the acute form, where the attacks are becoming so frequent as to cause the irritation to become chronic, or it may develop from a simple glaucoma, or be from the beginning chronic.

This irritative form of glaucoma is characterized by a chronic state of irritation, which is clinically evidenced by the dilated, curly veins and the deep pericorneal injection. The pathological signs here are more localized to the anterior parts of the eye, than it is in the simple glaucoma cases. The fogginess of the cornea and the anestecia of it is pronounced, the anterior chamber is shallow. The iris is discoloured, with venous stasis, the pupil somewhat dilated, slowly reacting. Cupping of the disc can sooner or later be found in every case of irritative glaucoma. The tension is as a rule rather highly raised, and the vision is, partly on account of the fogginess of the cornea more affected than in simple glaucoma. A certain amount of pain is usually felt by the patient.

The *simple glaucoma* begins insidiously without any allarming symptoms. Irritation of the eye is fully absent, as the pathological changes are limited mostly to the hinder parts of the eye, where a cupping of the disc always sooner or later can be found. In the anterior part of the eye the glaucomatous signs in the simple cases are never well developed. A pericorneal injection is not present, the haziness of the cornea very little, if any, the shallowness of the anterior chamber is not obvious, and the pupil is not pathologically dilated. The tension is in most cases of glaucoma simplex just a little raised above the normal. In some cases, however, it may reach a rather high elevation, but in other cases on the other hand it may be totally absent during the whole time of the disease. The field of vision by and by becomes contracted, but the central vision mostly remains good for a long time. There is often found a nor-

nal central vision in patients, who for years have suffered from simple glaucoma, but the simple glaucoma has a tendency — though slowly — to get worse, and if one eye is affected by the disease its partner is also very likely to get the same trouble sooner or later, a fact characteristic, however, also for irritative glaucoma.

By *absolute glaucoma* is meant a condition when the eye is blinded by any form of the disease in question, whether an irritative or a simple form. The classification is here only based on the vision, and in this group may be found eyes of a very different clinical condition. A fact often found in these eyes is that the anterior chamber has regained its normal depth.

Eyes, which show no signs or symptoms of glaucoma, but which have their fellow-eyes suffering from primary glaucoma, are here called *partners*. They are, as experience shows, nearly always bound to sooner or later develop the disease themselves. It is therefore of great interest to carry out gonioscopical investigations of these eyes as well, as signs of glaucoma, if any, before the disease has developed, may perhaps be detected.

VII. General survey of glaucoma theories of interest in gonioscopy

That the raised intraocular tension is the chief — though not indispensable — factor in primary glaucoma, and that most of the other symptoms can be deducted from it, is a very widely accepted opinion among the ophthalmologists of today. The cause of the raised tension, however, has not been incontrovertibly explained. The hypothesis concerning the pathogensis of primary glaucoma — or as they are usually called the glaucoma theories — may be divided into secretion and retention theories.

The secretion theories assume a hyperfunction of the secreting organs in the eye, that is to say chiefly the ciliary processes which are considered to produce most of the intraocular fluid. The theories of this group have not been verified either anatomically or experimentally, and as the region, observed by gonioscopy is of very little interest in connection with those theories, they will not be further mentioned here.

To the retention theories may be reckoned those, which assume the pathogenesis to be sought in a changed physical or chemical state of the tissues, forming the eye especially the vitreous body. By some change in the colloid state, in the acidity or in the permeability of the tissues, a retention of fluid should follow, causing a raised tension with all its consequences for the eye. Although it seems very possible, that an alteration in these respects may play a considerable part in the development of glaucoma, it has not yet been shown, that the origin is hidden in any process of that kind, and experiments in vitro, made in order to verify the theory, are far from conclusive.

Of greater interest in relation to gonioscopy are some of those retention theories, in which an obstacle to the outflow of the aqueous from the eye is supposed to be the cause of primary glaucoma. It has been shown by several authors, that only a small amount of the aqueous leaves the eye by the way of the sheaths of the optic nerve, and that the main part (it is said 98 %) escapes at the angle of the anterior chamber. Thus the chief part of the fluid from the vitreous body has to pass through the anterior membrane of the vitreous, round the border of the lens, between the fibres of the zonula Zinnii, behind the iris and out through the pupil: passing the anterior chamber it arrives to the trabeculum at its recess, through which it is brought over to the canal of Schlemm, and from there it proceeds into the veins.

Glaucoma theories have been published, in which obstruction to the outflow is supposed to be present in almost any part of the excretion channel. Of all those theories, those which place the obstacle in question at the angle of the anterior chamber, naturally possess the greatest interest in gonioscopy, and I therefore here mention examples of them, desisting from describing all

of them, as they can be found in the handbooks.

It is a priori clear, that a stoppage here in the chief channel for the excretion fluids, must result in a raised intraocular tension, if no other regulating factors come in. This stoppage, if any, may be brought about in several ways. So did Knies in 1876 publish a theory, inferring that the pathogenesis of primary glaucoma was an indurative inflammation in the surroundings of the canal of Schlemm, and that the subsequent adhesion of the iris-root to the corneo-scleral wall blocked the excretion channels. Already before the publication of Knies' theory, the observation had been made several times on histological slides, that the peripheral zones of the iris were pressed against the wall, but it was considered a secondary mechanical effect. It was Knies, who first poinsed out the possible etiological importance for primary glaucoma of this synechia, which in most cases he found to be a real, anatomical adhesion, formed by fresh connective tissue.

Independently of the work of Knies, Weber in the same year, 1876, published a somewhat similar theory, in which the mechanical obstruction of the angle of the anterior chamber was thought to be brought about by inflammatory swelling of the ciliary processes, pressing the iris forewards against the corneo-scleral wall.

In the same year Czermak also published a paper on how the obstruction of the angle of the anterior chamber was brought about by the iris when an acute attack of glaucoma set in. He said, there was no inflammation at the angle and no real anatomical synechia, but only a mechanical pressure of the root against the wall. In the shallow anterior chamber of the glaucomatous eye the anterior surface of the iris, comes to lie against the corneo-scleral wall at a line corresponding to the hind limit of the membrane of Descemet, when the pupil is dilated, and thus an interspace at the bottom of the angle is formed, where the hind wall is formed by the ciliary body. The outflow of the aquous to this interspace from the anterior chamber is more or less checked by the iris, and when this stoppage is absolute, the tension in the interspace must rapidly get much lesser than in the chamber, and consequently the iris must be squeezed into the bottom of the angle.

The strong contraction of the sphincter pupillæ, brought about by the eserine instillation, sometimes is powerful enough to pull the iris out from the angle, thus again allowing a free excretion, and break the attack.

A great many histological examinations of the angle in primary glaucoma were undertaken in those years by different investigators; Poyla, for instance, has collected a series of 438 eyes, suffering from various kinds of primary glaucoma, in which, according to the account of de Vries, the angle was found blocked in 350 cases, partly free in 25 cases, fully free in 38 cases.

In a paper, published 1907, Henderson hypothetically located the cause of primary glaucoma in the trabeculum of the angle of the anterior chamber, which he said, was undergoing sclerosis. By this sclerosis the excretion of the aqueous from the eye was supposed to be rendered more difficult and thereby the intraocular tension increased. In acute cases, (which he calls inflammatory cases), the attack should be precipitated by mydriasis or by a generally or locally raised blood-pressure, caused by physical or mental strain, which would bring about an increased amount of aqueous. The raised blood-pressure should also increase the difficulty for the venous return and make the iris swollen and oedematous. As a result of this condition the iris should become attached to the pectinate ligament and so block the outlet for the intraocular fluid.

In cases of chronic glaucoma the sclerosing process of the pectinate ligament should be so slow and lengthy, that the drainage should for years be sufficient to obviate a congestive attack, with subsequent adhering of the iris-root to the wall, but not be ample enough to prevent an increase of the tension, by which the finer tissues in the eye would gradually be destroyed.

It is a well known fact, that in primary glaucoma an abnormal deposition of particles of pigment in the angle of the anterior chamber is a common finding. Levinsohn was the first one to realise the possible connection between this fact and the pathogenesis of primary glaucoma. He observed on histological slides a reaction of the tissues in the form of leucocyte infiltration around the lumps of pigment in the spaces of the trabeculum, and considered this to cause a blocking of the excretion channels for the aqueous.

A glaucoma theory, based on the function of the scleral spur, was published in 1911 by Thomson. As said in the anatomical survey, the scleral spur is a rim of condensed scleral tissue, which on section appears triangular in shape with one angle pointing inwards-forwards and which forms the posterior limit of the sulcus scleræ internus, containing the canal of Schlemm. Thomson draws attention to the fact, that the scleral spur can be bent inwards and backwards by the meridional strokes of the ciliary muscle, fixed to its posterior surface, and be pulled back to its anterior position by the elastic threads of the trabeculum. By these movements, he says, the lumen of the canal of Schlemm must be changed, as it lies immediately anteriorly to the scleral spur and is separated from the anterior chamber only by the moveable wall, formed by the trabeculum. The ciliary muscle as well as the sphincter pupillæ, brought into play by the act of accomodation, thus very frequently, when the patient is awake, acts on the scleral spur, and thereby on the canal of Schlemm. When the scleral spur is pulled backwards, the lumen of the canal must be enlarged and the aqueous be sucked into the canal, as some arrangement seems to be present by which the inflow of venous blood is checked in normal eyes. Thomson declares, that he has seen on histological slides channels going from the anterior chamber to the canal of Schlemm, which channels are so arranged as to keep open, when the scleral spur is pulled backwards, and shut, when the spur is in its anterior position.

Primary glaucoma, according to Thomson, may by caused by:

1) sclerosis of the trabeculum, which thereby looses its elasticity and capability of pulling the scleral spur forwards;

2) atrophy or paresis of the ciliary muscle, by which the posterior traction of the scleral spur is made insufficient;

3) hypertrophy of this muscle, which then keeps the scleral spur in such a state of retraction, that the elastic fibres in the trabeculum are unable of replacing it to its anterior position. In these ways an equilibrium can be established in the tension of the anterior chamber and the canal of Schlemm, and no aqueous is then excreted.

It is of interest to note the experiments of Heine, in which the effects of eserine and atropine are studied. He has shown, that in monkey eyes, histological slides of eyes treated with eserine just before death have a much more open canal of Schlemm, than eyes under the same conditions treated with atropin and that the angle of the anterior chamber in the eserine eyes is much wider than in the atropin eyes. This indicates a possible way, in which miotics may act in those frequent cases, where their tension lowering effect is undoubted, and where this can not be explained by any opening up of a blocking, if any, of the excretion channels by the root of the iris, which should be stretched by the miotics. Barret and Orr have puplished such a case, where an upper and lower iridectomy for glaucoma had been undertaken, but where the tension nevertheless became raised. Eserine treatment immediately lowered the tension, but no trace of miosis could be seen on the remaining parts of the iris.

Koeppe, who considers a good deal of the aqueous to be excreted through the sponge-like tissue of the iris, has with help of the corneal microscope been able to see a fine dust of pigment in the very stroma of the iris, of the aqueous of the anterior chamber and at the angle of this, evidently emanating from the destroyed pigment layer at the posterior surface of the iris. He suggests that the fine lymphatic vessels and small

veins become filled up and blocked by this pigment and the intraocular tension thereby raised. He says, that the pigment is found in almost every eye with primary glaucoma and that he has seen it in several »normal» eyes, which subsequently after a shorter or longer time, have undoubtedly been the seat of primary glaucoma. These eyes he calls pre-glaucomatous eyes. The alteration of the pigment condition of the glaucomatous eye, he says, is a preliminary process to a narrowing of the angle of the anterior chamber. The root of the iris is by and by creeping up on the corneo-scleral wall in the developed glaucoma, but a true synechia of anatomical foundation, Koeppe says, he is not quite sure of having detected by gonioscopy in these eyes. Sclerosis of the trabeculum he thinks is often present, being a senile sign, but a real glaucoma is not established until the pores in the spongelike iris tissue are blocked by the pigment dust.

That a peripheral synechia is considered by several authors to be the usual finding in primary glaucoma, is seen by the following quotations from prominent authours.

Salzmann says in 1915, in writing about the state of the angle of the anterior chamber in primary glaucoma: "Vollständige synechie wie es in schweren Fälle von Glaucoma meistens der Fall ist . . ."

Elliot says about eyes blinded from primary glaucoma although the angle was fully open: "1) In some of the eyes it is suggeted, that an albuminous fluid unfit for filtration has replaced the normal aqueous. 2) In others the closure of the angle, which existed during life, has been broken down in the course of the preparation of the specimen (for histological examination)." Further he says: "Closure of the filtration angle is a cause, not a consequence of glaucoma. To the writer's mind, the evidence, though circumstancial, is overwhelming."

In a lecture before the Clinical Congress of the American College of Surgeons Verhoff said 1924: "In cases of primary glaucoma, with elevation of pressure, there is almost constantly found an obstruction of the filtration angle by the root of the iris. In a few early cases, in which this has not been found, it is probable, that the root of the iris has separated from the ligament in the preparation of the specimen for examination", and further, "Since we know, that in practically all, if not all, cases of primary glaucoma, peripheral anterior synechia exists, and we know, that except in special cases, obstruction of the filtration angle leads to inceased intraocular tension, we must conclude, that peripheral anterior synechia is one of the constant causes of glaucoma."

VIII. Previously published results of gonioscopy in primary glaucoma

The observations of the angle of the anterior chamber and especially of the condition of the canal of Schlemm, made by Fuchs, who used the transscleral illumination, did not deal with the question of the possible presence of a synechia of the root of the iris to the corneoscleral wall in glaucoma. Neither did Trantas turn his interest to this question, when he made his investigations of the angle of the anterior chamber in living eyes, by help of his previously mentioned method.

It was not until the contact glass began to be used in clinical work that this question was more closely considered.

As a consequence of the relative novelty of this method of examination the terminology of the different conditions of the angle, as seen in gonioscopy, has not yet been uniformly settled. Salzmann declares in 1915, that by a peripheral synechia between the iris and the corneo-scleral wall he means every adherence between them, not observeable by the ordinary oblique examination, but only by ophthalmoscopy of the angle of the anterior chamber. According to their extension synechiæ may be divided into various forms. For the different circular extensions of a synechia Salzmann does not give any distinct names, but meridional varieties he divides into complete and incomplete synechiæ.

As *complete* synechiae he considers those, where the adhesion of the iris-root to the wall extends as far forewards as to the po-

...of border of the cornea, and by *incom-* ..., those, in which the foremost limit of ... adhesion lies more posteriorly than the posterior border of the cornea.

A synechia, however, may reach the bottom of the angle or not, just as a symblepharon posterius or anterius may or may not reach the bottom of the conjunctival sac Salzmann says, it is very difficult te determine which of the two possibilities is present in each case, but if the synechia has a small circular extension, and the bottom of the angle can be seen completely up to both sides of it, it is most probable, that the angle behind it is free and that the synechia is comparable to a symblepharon anterius.

A form of synechia with a very short circular extension, he calls »zipfelförmige» or »umschriebene».

Troncoso objects to the terminology of Salzmann, saying that the terms may be mistaken as referring to the circular extensions of the synechiae, and he suggests instead the names *narrow* or *trabecular* and *broad* or *scleral peripheral synechiae*. »When the ciliary body and a part of the Schlemm's zone only are concealed», he says, »it may be called a narrow or trabecular synechia. If the border of the iris encroaches upon the scleral zone, coming near or even up to the insertion of the cornea, we speak of a broad or scleral peripheral synechia».

As to the circular extension of the adhesions, a short, only a bridgelike one, is called by Troncoso a *restricted peripheral synechia*, a somewhat broader he calls a *partial peripheral synechia*, and when the iris all the way round the periphery is fixed to the wall, he speaks of a *total* or *annular peripheral synechia*. This terminology of Troncoso is used in this paper; the word peripheral, however, being left out.

As far as I am aware, it is only Salzmann, Koeppe and Troncoso, who have published cases of gonioscopy in primary glaucoma.

Among the cases, including several diseases of the eye, which Salzmann describes in his paper of 1914, there is only one case of primary glaucoma. In that case he finds a peripheral synechia, concealing the ciliary body all the way round the periphery. On account of a gray shadow the other zones could not be differentiated, but as the ciliary body was concealed, it must have been at least a total trabecular synechia. The tension was 30 mm.

In Salzmann's paper of the following year, 1915, he describes the gonioscopical aspect of 8 eyes, suffering from primary chronic glaucoma, and one eye, being the partner to one of the chronic glaucoma eyes. In these two last eyes the ciliary body was visible all round the periphery; that is to say that the angle was fully open. In the remaining 7 eyes a certain degree of synechia was found, the extension of which Salzmann estimates to about one quadrant in each eye, but the tension was a high as 60 mm. in one of the eyes.

Salzmann says, that a total scleral synechia is such a common condition of the angle in irritative glaucoma, that he does not take the trouble to publish any series of descriptions of such cases. He thus seems to be of the opinion, that the total scleral synechia is the one usually found in irritative glaucoma.

Koeppe describes several cases of slit lamp examination of the angle in primary glaucoma, but he turns his interest mostly to the question of the presence or not of pigment deposits in the iris and at the angle, and gives no distinct statements whether the angle is blocked or not by the root of the iris. His cases are therefore not discussed here.

Troncoso describes in his publications in 1925 and 1926 on gonioscopy, among eyes suffering from various diseases also a number of eyes with the diagnosis primary glaucoma, of which 13 were glaucoma simplex, 4 irritative (chronic congestive), 2 acute, 1 incipient and 1 prodromal. Two eyes (No. 13/1924) were not absolutely certain to be primary glaucoma, as synechiae were found between the anterior lens-capsule and the iris. In cases No. 10 (1925), 11 (1925) and 2 (1926) it is not quite certain,

that a pure primary glaucoma is present, as the patients also suffered from syphilis with definite eye symptoms in one case. The 3 last cases, however, are included in the eyes considered here.

In 8 of the eyes a *total scleral synechia* was found. Of these 5 were simplex, 2 irritative and 1 an acute case. It is of interest to note that the other acute case could not, on account of the haziness of the cornea, be gonioscoped before the tension was lowered by miotics, and that then a total trabecular synechia was found The tension in these eyes with a total scleral synechia varies between 100 mm. and 21 mm. and 5 of the eyes had tension below 35 mm. Only 2 of the eyes with a total scleral synechia were observed before an anti-glaucomatous operation had been performed.

In 9 eyes a *certain degree of synechia* was found. Of these eyes 5 were simple, 2 irritative and 1 acute. Tension varies in the different eyes between 45 mm. and 22.5 mm. As far as I can see, only 3 of these eyes were examined before an anti-glaucomatous treatment was set in.

In 4 cases there was found a fully *open angle,* of which 3 were simple and 1 a prodromal case. The tension varies between 22.5 mm. and 31 mm. All the eyes, except the prodromal one, seems to have been treated for glaucoma before the examination.

Troncoso thus found in the simple cases no synechia in 3 eyes, a partial synechia in 5 and a total scleral synechia in 5 eyes. The numbers of irritative cases are respectively 0,2,2, and of acute cases 0,1,1.

One case, which Troncoso mentions in both his papers (No. 15/1925 and 4/1926) seems to be of special interest. A woman was suffering from glaucoma simplex in both eyes, and had, when first examined by Troncoso, a vision in the right eye of 20/30 and in the left 20/20, the tension being in the right eye 30 mm. and in the left eye 35 mm. A deep cupping of the disc was observed in both eyes. Gonioscopy showed a total scleral synechia in both eyes. After one week's treatment with eserine gonioscopy of the right eye showed no alteration of the angular condition, but in the left eye a fully free angle was found, showing that the »synechia» must have been due only to mechanical pressure of the iris against the wall, or to such a delicate anatomical connection, that it could be torn by the eserine treatment. The tension in the bulbs at the time of this gonioscopy, are, however, not mentioned.

As in spite of faithful use of miotics the tension went up to 45 mm., and the field of vision was more and more contracted, a trephining operation was done on the right eye, with the result of immediate decrease of tension. Half a year later gonioscopy still showed a free angle in the left eye.

After about another six months the patient was again examined. The vision was then in the right eye 20/40 and in the left 20/25. The tension was in the right eye 15 mm. and in the left 30 mm. The gonioscopical aspect Troncoso describes thus: »In the left eye, where the angle was free all round, it now is open only above and a little inward. On the nasal side scleral synechia, temporally and below trabecular synechiae, with a gray Schlemm zone above. In the right eye, where the trephining and iridectomy was done, the angle is open temporally and nasally, trabecular synechia below. In the coloboma the ciliary processes appear small and discoloured. The whole of the trephine is visible as a dark gray spot in the narrow scleral zone.» Troncoso says about this case: »The case shows, how the angle gradually closes with the progress of the disease, even under the action of miotics. That continued hypertension is probably the principal cause of the closing is established by the fact, that the right eye, where the trephining lowered the tension in a permanent way, the angle has continued open in part...»

It is of interest to compare the extension of the synechiae in these two eyes with the degree of intrabulbar tension. In the right eye there is a slight increase of the tension, 30 mm., although, according to gonioscopical examination, there seems to be a real, total, scleral synechia present, which does not loosen by prolonged miotic treatment, only by

iridectomy. In the left eye, on the contrary, the tension is raised to 35 mm., although the »synechia» is opened up by miotic treatment, leaving the angle fully free. Unfortunately there is no statement as to the tension at the time of the second gonioscopy after one week's miotic treatment. If no other regulation of the tension comes in, than the outflow at the angle of the anterior chamber, and if the secretion is undiminished, it is very strange, that the tension in the left eye, without any real synechia, should be higher, than in the right eye, where the synechia was unaffected by miotics.

Another case of those described by Troncoso in the paper of 1926, (No. 6), is of great interest. A lady had suffered severe pains in her right eye, which was operated on without result, the eye now being blind. The left eye, also failing in vision, was operated on a short time before Troncoso saw the case, when examination showed broad colobomas after iridectomy in both eyes. Vision of the right eye was perception of light, of the left eye 20/50. Tension in the right eye was 25 mm., in the left eye 21 mm. Deep cupping of the discs on both sides. Gonioscopy showed a total scleral synechia in both eyes, but in the left the root of the iris was left in the coloboma. There was a solid thread covered with black pigment, going from the edge of the iris in the temporal part to the scar of the inner part of the sclera.

Troncoso says: »In this case the result of the iridectomy has been quite different. The right eye is blind and degenerated, the operation probably being performed too late. In the left eye the strip of the iris-root does not seem to have any bad consequences even in the presence of annular synechia. Vision is fairly good and tension lower».

Troncoso finally describes a case of total scleral synechia without any signs of glaucoma. Cases of a partial synechia are mentioned in other diseases of the eye by Troncoso as well as by Salzmann. The intra-vital examinations of primary glaucoma eyes made by Troncoso thus include cases with a very different condition of the angle of the anterior chamber, but in most eyes he found anterior peripheral synechiæ.

It is thus seen, that previous writers on gonioscopy in primary glaucoma have found a synechia being present in the majority of the cases. This result I have been unable to verify, as I have found the angle to be open much more frequently, especially in the simplex cases.

IX. The material

The patients, on whom the gonioscopical examinations were made, were out-patients as well as in-patients of the eye-department at the Academic Hospital of Uppsala. A few patients were from the Garrison Hospital of the Fortress of Boden, and a few from the Sabbatsberg Hospital in Stockholm.

There were 32 men and 24 women. The age of the patients has varied between 40 and 83 years. Only 4 patients were younger than 60 and only 2 older than 80 years.

Three of the patients had one of their eyes suffering from another disease, not allowing the diagnosis of primary glaucoma and have not therefore been included among the cases.

The so far clinically healthy fellow-eye to a glaucomatous eye has been counted here as one number under the name of *partner*. Such eyes are, as the ophtalmological experience shows, very likely sooner or later to develop glaucoma themselves, and they are included im my series, in the hope of gaining some interesting information concerning the pathogenetic rôle, if any, played by the angle of the anterior chamber in primary glaucoma. In none of the partners did one find any traces of glaucomatous signs or symptoms. I regret, that I have not come across any case, which at the first examination showed no signs of glaucoma, but where at a later examination such had developed. It would of course have been of special interest to compare the condition of the angle of such an eye in its different glaucomatous stages, and it is desirable, therefore, that further investigations should be made on partners. *(Contin. see p. 28.)*

X. Clinical Cases

Number	Tension mm.	Vision	Treated before the gonioscopy	Gonioscopy	Treatment	Tension after treatment	Later gonioscopy	Partner to number	Notes
					Glaucoma simplex				
1	32	F. c. 4 m	Miotics	T. s. s.	Miotics	27	Idem	—	Partner chronic iritis.
2	20	6/36	Elliot	P. s. s	»	18	»	4	Canal of Schleman visible nasally, else s. s. Coloboma to the root.
3	40	6/36	Miotics	»	»	18	»	9	S. s. only upwards. Seen with six months interval. Coloboma to the root.
4	20	6/18	Elliot	»	»	20	»	2	S. s. except nasally, where it is T. s.
5	40	6/18	Nil	»	»	32	P. t. s.	12	S. s. on 3 mm temporally, else t. s. After miotics O. a. nasally, else T. s.
6	37	6/24	Miotics	T. t. s.	»	—	—	98	Only seen once.
7	12	6/60	»	»		—	—	11	» » »
8	22	6/6	Elliot	»		—	—	99	» » »
9	40	6/36	Miotics	P. t. s.	»	18	Idem	3	T. s. only upwards on one quadrant.
10	32	6/12	»	»	»	38	»	22	T. s. except down.
11	26	6/36	»	»		—	—	7	Nasally T. s., else narrow O. a.
12	40	6/12	Nil	»	»	30	O. a.	5	At first gonioscopy T. s. in the upper half.
13	27	F. c. 1/2 m.	»	»	»	16	Idem	20	T. s. only on one quadrant nasally.
14	37	6/6	Miotics	O. a.	»	17	»	15	Generally narrowed angle.
15	23	6/6	»	»	»	30	»	14	Narrow angle down.
16	27	6/8	»	»	»	23	»	17	Generally narrowed angle.
17	37	6/12	»	»	»	27	»	16	» » »
18	45	6/6	»	»	»	35	»	19	Nasally narrow angle
19	45	6/6	»	»	»	35	»	18	
20	16	6/24	Nil	»	»	16	»	13	
21	37	6/6	Miotics	»	»	20	»	68	Temporally narrow angle.
22	45	6/8	»	»	»	26	»	10	
23	35	6/8	»	»	»	27	»	24	Generally narrowed angle.
24	35	6/8	»	»	»	23	»	23	» » »
25	25	6/6	»	»	»	20	»	67	
26	32	6/6	»	»	»	20	»	27	Junction between the iris and the cil. body visible.

No.	Age	Vision	Treated before the gonioscopy	Gonio-scopy	Treatment	Tension after treatment	Later gonio-scopy	Partner to number	Notes
					Glaucoma simplex (contin.)				
27	25	6/6	Miotics	O. a.	Miotics	20	Idem	26	Junction between the iris and the cil. body visible.
28	37	H. m.	»	»	»	24	»	29	
29	37	6/6	»	»	»	26	»	28	
30	23	6/6	»	»	—	—	—	31	Narrow angle. Only seen once.
31	32	6/6	»	»	—	—	—	30	» » » » »
32	20	—	»	»	—	—	—	33	Only seen once.
33	17	—	—	»	—	—	—	32	» » »
34	27	6/18	Miotics	»	—	—	—	35	» » »
35	23	6/12	»	»	—	—	—	34	» » »
36	20	6/24	»	»	—	—	—	107	» » »
37	37	6/24	Iridect	»	—	—	—	89	Narrow coloboma to the root. The cil. proc. not swollen.
38	23	H. m.	Miotics	»	—	—	—	39	Only seen once.
39	23	6/18	»	»	—	—	—	38	» » »
40	44	6/18	»	»	—	—	—	106	» » »
41	22	H. m.	Nil	»	—	—	—	42	Narrow angle. Only seen once.
42	22	F. c. 2 m	»	»	—	—	—	41	» » » » »
43	20	F. c. 4 m	»	»	—	—	—	44	Only seen once.
44	35	F. c. 5 m	»	»	—	—	—	43	» » »
45	30	6/24	Miotics	»	Miotics	26	Idem	53	Macula corneæ.
46	26	6/18	»	»	»	17	»	74	Incipient cataract.
47	27	6/18	Nil	»	»	25	»	100	
48	27	6/24	Miotics	»	—	—	—	—	Generally narrowed angle. Only seen once. Partner too big a macula corneæ.
49	15	6/8	Elliot	»	—	—	—	64	Narrow coloboma not to the root. Iris-rest blocking to angle. Only seen once.
50	12	6/18	Miotics	»	—	—	—	55	Incipient cataract. Only seen once.
51	47	F. c. ½ m	»	»	—	—	—	102	Only seen once.
52	22	6/18	Iridect.	»	Miotics	17	—	85	Iridectomy to the root, else idem.
53	30	6/8	Miotics	»	»	26	Idem	45	
					Glaucoma irritativum acutum				
54	70	H. m.	Miotics	T. s. s.	Iridect.	20	—	93	Coloboma to the root, else idem.
55	12	6/18	»	P. t. s.	—	—	—	50	The canal of Schlemm visible in the wavetroughs all the way round.

Number	Tension mm.	Vision	Treated before the gonioscopy	Gonioscopy	Treatment	Tension after treatment	Later gonioscopy	Partner to number	Notes
				Glaucoma irritativum chronicum					
56	75	F. c. 1 m	Nil	T. s. s.	Miotics	60	Idem	95	Operation declined.
57	52	H. m.	Miotics	»	Iridect.	24	»	92	Coloboma to the root.
58	52	6/12	Nil	»	Miotics	26	S.s.down else O.a.	94	» » » »
59	52	H. m.	Miotics	P. s. s.	Elliot	7	—	61	Temporally canal of Schlemm visible
60	100	»	»	»	—	—	—	65	Canal of Schlemm visible temporally along 1 mm.
61	47	6/24	»	T. t. s.	Miotics	37	Idem	59	Coloboma to the root.
62	62	F. c. 2 m	»	»	Iridect.	17	»	105	Ciliary proc. not swollen.
63	52	6/60	Nil	»	Miotics	17	»	103	
64	72	H. m.	Miotics	»	—	—	—	49	Only seen once.
65	12	6/18	»	»	—	—	—	60	» » »
66	63	6/24	»	P. t. s.	Miotics	40	Idem	104	Temporally-upward a narrow t. s. else O. a.
67	70	F. c. 2 m	»	»	»	35	O. a.	25	At first gonioscopy O. a. down, else T. s.
68	59	6/36	»	»	»	40	Idem	21	O. a. down. Generally narrowed angle.
69	52	H. m.	Nil	O. a.	Iridect.	14	»	108	Coloboma to the root.
70	52	F. c. 4 m	»	»	Miotics	35	»	86	
71	32	»	»	»	—	—	—	96	Only seen once.
72	65	F. c. 3 m	Miotics	»	Elliot	10	Idem	77	Narrow coloboma to the root.
73	44	6/6	»	»	Miotics	25	»	88	
74	60	H. m.	»	»	Elliot	17	?	46	The angle not visible due to bombé of the i iris.
75	50	»	Iridect.	»	—	—	—	76	Iridectomy to the root. Only seen once.
76	20	6/12	Miotics	»	—	—	—	75	Only seen once.
77	58	6/6	»	»	Miotics	26	Idem	72	Generally narrowed angle.
78	50	6/18	»	»	»	26	»	79	Generally narrowed angle, especially upwords.
79	30	6/6	»	»	»	27	»	78	
80	42	6/24	»	»	—	—	—	81	Only seen once.
81	37	6/18	»	»	—	—	—	80	» » »
				Absolute glaucoma.					
82	45	Amauros.	Nil	T. s. s.	Enucleatio	—	—	91	Irritative type. Only seen once.
83	85	»	»	»	»	—	—	109	» » » » »
84	60	»	»	P. s. s.	Miotics	26	T. t. s.	—	Irritative type. S. s. only nasally on one quadrant. Partner phthisic.

Number	Tension mm.	Vision	Treated before the gonioscopy	Gonioscopy	Treatment	Tension after treatment	Later gonioscopy	Partner to number	Notes
				Absolute glaucoma (contin.)					
85	27	Amauros.	Iridect.	P. s. s.	Miotics	18	Idem	52	Coloboma not to the root. Rest of iris blocking the angle. Canal of Schlemm visible only nasally. Irritative type.
86	63	»	Nil	T. t. s.	»	54	»	70	Irritative type.
87	52	»	Miotics	P. t. s.	»	37	Narrow O. a.	101	Irritative type. T. S. upwards on one quadrant. The zone of the ciliary body broader after miotics.
88	47	»	Iridect.	O. a.	»	42	Idem	73	Irritative type. Iridectomy not to the root. Iris-rest lying straight into the chamber.
89	45	»	Nil	»	»	15	»	37	Simple type.
90	47	»	»	»	»	35	»	97	» »
				Partners.					
91	17	6/18	Nil	T. s. s.	Miotics	14	Idem	82	Choroiditis.
92	14	6/6	»	P. s. s.	»	17	»	57	S. s. upwards only on one quadrant, to the other sides T. s.
93	17	»	»	»	»	17	»	54	S. s. temporally only along a few mm. T. s. to the other sides.
94	15	»	»	O. a	—	—	—	58	
95	20	»	»	»	—	—	—	56	
96	17	»	»	»	—	—	—	71	
97	24	»	»	»	—	—	—	90	
98	26	»	»	»	—	—	—	6	Only seen once.
99	17	»	»	»	—	—	—	8	» » »
100	17	»	»	»	—	—	—	47	
101	18	»	»	»	—	—	—	87	» » »
102	20	»	»	»	—	—	—	51	» » »
103	24	»	»	»	—	—	—	63	» » »
104	24	»	»	»	—	—	—	66	
105	25	»	»	»	—	—	—	62	
106	17	»	»	»	—	—	—	40	» » »
107	17	»	»	»	—	—	—	36	» » »
108	25	»	»	»	—	—	—	69	» » »
109	24	»	»	»	—	—	—	83	» » »

Abbreviations

T. s. s. = Total scleral synechia.
P. s. s. = Partial scleral synechia.
T. t. s. = Total trabecular synechia.
P. t. s. = Partial trabecular synechia.
O. a. = Open angle.
H. m. = Hand movements.
F. c. = Finger counting.

The diagnosis has been made in each case after a clinical examination, carried out as completely as circumstances allowed. A record was kept of the history as well as of the present state of the eye. The intrabulbar tension was measured on in-patients almost every day and on out-patients as often as they called at the Hospital. The measurements were made with Schiötz's tonometer. As a control several measurements were made from time to time with different speciments of the instrument of that construction.

From time to time the field of vision was registrered by perimetry.

In most cases a measurement of the depth of the anterior chamber was undertaken. It was mostly done with Lindstedt's instrument, an instrument by which it is possible to determine the distance from the anterior surface of the lens to the cornea in one single focussing. However, such measurements are rather complicated, and it is especially difficult in patients with one eye blind, as they find a great difficulty in keeping the eyes fixed, when the examination is done in the seeing eye. The measurements I found correspond well to the depth of the anterior chamber, found by Lindstedt and others. As I have no reason to discuss the depth of the anterior chamber, nor the field of vision, these subjects will be left out here, and i have restricted myself to mentioning the tension and the vision in the table of the cases.

Except the 19 partners there are 18 eyes, which had not been treated for glaucoma previously to my gonioscopical examination of them. All the other eyes in my series had been subjected to some sort of anti-glaucomatous treatment. From the point of view of investigating the pathogenetic rôle, if any, played in primary glaucoma by the angle of the anterior chamber, the previous treatment of the eyes is naturally a drawback, but as most of the eyes in spite of the treatment have a pathologically raised tension, the cause of which is unknown, they still must be said to suffer from various forms of primary glaucoma, wherefore a gonioscopical examination of them is of almost equally great interest as of those not previously treated.

XI. Results of author's investigations

My series of gonioscopical examinations of eyes suffering from primary glaucoma consists of 109 eyes, including the so far healthy partners to diseased eyes.

There are 53 simplex, 2 acute irritative, 26 chronic irritative, 9 absolute glaucomas and 19 partners.

Glaucoma simplex

Total scleral synechia	=	1
Partial » »	=	4
Total trabecular »	=	3
Partial » »	=	5
Open angle	=	40

Among the simplex cases there was only one eye, where a *total scleral synechia* was found (1). In this case the synechia was as a later gonioscopy showed not ruptured by miotic treatment but the tension was lowered to normal. The partner of this eye is not included in the series, as it had posterior synechiæ, indicating a previous disease, and the case can therefore not incontrovertibly be said to be a primary glaucoma. No signs of a previous iritis could be detected in the glaucomatous eye.

In 4 eyes a *partial scleral synechia* was found. In 2 (2, 4) of them the synechia extended over almost the whole perifery, leaving only a small area at the nasal side so much open that the zone of the canal of Schlemm could be gonioscopically seen. Elliot's operation was made in both eyes, the small colobomas extending to the root. In the third (3) eye the scleral synechia was only found upwards but the angle was generally narrow, just allowing a narrow band of the zone of Schlemm's canal to come into sight when the line of vision was carefully directed to the bottom of the angle. In the fourth eye (5) a narrow scleral synechia was found temporally; to the other sides trabe-

cular synechia at the first gonioscopy. Miotics loosened the temporal and scleral synechia.

A *total trabecular synechia* was found in 3 eyes. None of the eyes I have had the opportunity of seeing more than once. I cannot therefore say what effect an intense miotic treatment has on the synechiæ but as 2 (6, 7) of the eyes had been under miotic treatment for a considerable time and the third (8) had been subjected to a trephining operation it seems very probable that the synechiæ were real ones and not only due to mechanical pressure of the root of the iris against the corneo-scleral wall.

A *partial trabecular synechia* was also found in 5 eyes. In one of these eyes (9), with a tension of 40 mm., the angle was generally narrowed. Upwards over about one quadrant only a narrow band of Schlemm's canal and to the other sides a narrow ciliary body were visible. That a real synechia was present here, was made likely by the fact that strong eserine doses did not change the gonioscopical aspect of it,. The tension was, however, lowered to 18 mm. In 2 of these eyes (11, 12) there was found a trabecular synechia only over one quadrant nasally, but the angle was generally narrowed. The third (10) of these eyes had a more extended trabecular synechia, leaving only the down quadrant free. Miotics did not open the angle or lower the tension. In the remaining eye, having a trabecular synechia in the upper half, miotics liberated the angle all the way round the periphery. The eye had never been subjected to miotic treatment before.

Out of the 53 simple glaucoma eyes examined not less than 40 had no synechiæ at all at the angle of the anterior chamber, that is to say there is a so called *open angle*. The angle was in 13 of these eyes generally or partially narrower than normal, but the ciliary body was visible, if the line of vision was carefully directed to the bottom of angle.

From the simplex cases with some degree of synechia, there were 3 (5, 12, 13), that had not been treated previously to the gonioscopical examination and one of these eyes had only a trabecular synechia of about one quadrant extension at the nasal side of the angle. An Elliot-operationen had been performed in 3 of the cases with synechia and simple glaucoma, the coloboma in all cases involving the root of the iris.

Only 6 of the 40 eyes with the angle free from synechia had not been treated previously. The rest were subjected to a miotic treatment except 3, which were operated upon. In 2 eyes (37, 52) an iridectomy had thus been performed, the coloboma extending to the root, and in one eye (49) an Elliot's operation had been performed. In this eye there could now be seen a very small coloboma, in which a rest of the iris was left and which now was lying against the corneo-scleral wall concealing the different zones in an area of about 1 mm. upwards. In spite of this fact I have registered the eye as one with an open angle. This is done because the small synechia is evidently a sequel to the operation, as it is situated just in the coloboma and the angle is fully open quite up to it, which never is the case in synechiæ found in primary glaucoma.

As seen from the previously mentioned quotations, the opinion is widely accepted by prominent ophtalmologists of to-day, that the angle of the anterior chamber in glaucomatous eyes is blocked by the root of the iris. This opinion is partly founded on the results of histological examinations of the area in question, which examinations have been mostly done in the last quarter of the passed century. It is clear, that mistakes, depending on the method of investigation, may be easily done, when the complicated histological method is used, working as it is with dead material, which in the course of preparation might undergo rather deep-going changes especially concerning the mutual position of the tissues. A shrinking of the eye during the preparation cannot possibly be fully avoided, a fact, which has great influence on the topographical situation of the tissues in the angle of the anterior chamber, where the iris may easily

be moved from its normal position. Doubt has even been expressed in recent years by men as Elliot and Verhoeff as to the thrustworthiness of the histological examinations of the anterior peripheral synechia in primary glaucoma. They accept the examination in those cases, where the angle is blocked by the root of the iris, but object to the reliability of it in those cases, where the angle is found open, saying that it might have been liberated in the course of preparation of the slides. They are convinced that the angle of the anterior chamber in nearly all cases of primary glaucoma is obstructed by the root of the iris and that this is one of the chief causes of the production of glaucoma.

The gonioscopical examination of glaucoma eyes is so new and so seldom done, that the results gained by Troncoso, Salzmann and Koeppe are too few to allow a full break with the old opinion, that the angle is blocked in glaucoma, although this method gives truer results than the histological method, working as it is with living eyes.

The conclusion drawn from my gonioscopical examinations in this group is:

In the great majority of glaucoma simplex cases the angle of the anterior chamber is not at all blocked by adhesions from the root of the iris to the corneo-scleral wall.

Glaucoma irritativum acutum

The eyes with an acute attack of glaucoma are only 2 in my series. One of these eyes (54) had gone through at least 2 certain attacks. The patient, a man of 62, gave the history, that he since may 1926 now and then had had pains in the right eye for short periods. November 27 he called in for an ophtalmologist because his vision was dimmed. His vision was then, according to the statement of the doctor, 0.9, the intraocular tension 21 mm., field of vision not contracted and the ophtalmoscopical aspect of the disc normal in the right eye, The tension in the left eye was 17 mm. and the eye was clincally normal. The right eye was on account of the attacks of pains treated with miotics.

On December 17 the patient came back with a tension of 60 mm., a vision of 1/60 and redness of the eye. Strong miotics were ordered and on December 18 the eye was pale, tension 25 mm. and vision 5/60. On the 19th the patient had a new attack and was sent to the Academic Hospital at Uppsala.

When the patient came to the Hospital (20/12) his right eye was very irritated with wide tortuous veins on the sclera. The cornea was so hazy, that the deeper part of the eye could not be examined, nor could the depth of the anterior chamber be measured, but it looked very narrow on inspection, The pupil was in state of medium dilatation, the iris discoloured, slowly reacting. Vision was hand movements, and tension was 70 mm. Left eye was without clinical changes.

Gonioscopy of the right did not succeed on account of the haziness of the cornea. When the contact glass was reapplied after eserine treatment, which brought down the tension to 36 mm., one could not see any zone behind the scleral on the whole way round the periphery. The bombé of the iris was not pronounced.

On December 23 and iridectomy was performed in the right eye. Repeated gonioscopical examinations afterwards showed a narrow coloboma to the root of the iris, but a total scleral synechia to every other side of the angle.

It is of interest to note that on gonioscopy of the fellow eye (93) a synechia was detected, which was extending as far forwardly on the temporal side as to the scleral zone, concealing the zone of the canal of Schlemm on this side. To all the other sides the dark band of the Schlemms canal could be seen in the wave-troughs of the border of the iris.

The other acute glaucoma eye (55) belonged to a woman of 74 years. She had for some month observed dimness of vision in the right eye, and seen coloured halos around lights. Now and then she had had attacks of pain and redness of the right eye. On June 21 1927 her vision was hand mo-

vements, and the tension was 70 mm. in the right eye and in the left eye vision was 6/18, refraction + 2.5 and tension 17 mm. (Beginning senile cataract.)

Eserine was ordered and the tension went down to 20 mm. When I saw the patient (5/7 1927), there was some dilatation of the scleral veins, the cornea was clear, the anterior chamber was shallow but no sure cupping of the disc could be seen. Refraction was + 2.5, vision 6/18 and the tension was now only 12 mm.

Gonioscopy of the right eye showed a rather pronounced bombé of the iris. The peripheral border of the iris made big waves, the tops of which went as far forwardly as upon the zone of Schlemms canal, which in the valleys could be seen as a dark brown band. The pigment deposition was very poor.

Gonioscopy in the left eye, being a simple glaucoma case, showed a total trabecular synechia to the anterior half of the canal of Schlemm.

The number of acute irritative glaucoma eyes is to small to allow any generalized conclusions. It is desirable that further gonioscopical examinations on such cases should be done and it would be of special interest to examine such eyes during the acute attack and at the free intervals, an examination, which I have not had the opportunity of doing, as no such case has come my way, where one could wait for the attack to subside, without jeopardising the patient's vision and health.

In both my cases of acute irritative glaucoma, treated with miotics previously to my gonioscopical examination of them, a rather pronounced degree of anterior peripheral synechiae was found.

Glaucoma irritativum chronicum

Total scleral synechia	= 3
Partial „ „	= 2
Total trabecular „	= 5
Partial „ „	= 3
Open angle	= 13

Among my 26 eyes with chronic irritative glaucoma there were 3 in which a *total scleral synechia* was found. In one of them (56) the cornea was so foggy, that the view of the angle was not as clear as usual, but, however, clear enough to allow the judgment that the peripheral border of the iris was projecting as far forwardly as to the scleral zone. Intense miotic treatment lowered the tension from 75 to 60 mm and slightly cleared the cornea, but did not change the goniscopical aspect of the angle. As the patient did not agree to an operation, there was no opportunity of lowering the tension further and thereby to make the cornea sufficiently clear for a detailed diagnosis to be made.

Miotics had another effect in the next one of my chronic irritative cases with total scleral synechia (57), as the tension was brought down to normal and the angle was opened up so widely, that the ciliary body could be seen on all sides except on about one quadrant down.

The third (58) of these cases had a tension of 54 mm, which was not sufficiently brought down by miotics and an iridectomy therefore was performed Later gonioscopy showed, that the iris had been taken to the root in the coloboma and that the rest of the angle showed no change, a total scleral synechia still being found.

In the first (59) of my irritative eyes, where a *partial scleral synechia* was found, the brown zone of the canal of Schlemm was visible all the way round the circumference only in the wavetroughs, but the tips of the waves of the last roll of the iris were extended as far forwards as to the beginning of the scleral zone. In this eye miotics brought down the tension to normal, but an Elliot's operation was nevertheless made. Later gonioscopy showed, that the iris in the coloboma had been taken to the root, but on account of blood in the anterior chamber the lower parts of the angle could not be inspected.

The other one (60) of the partial scleral synechia eyes had the blocking of the angle by the iris root extended over almost the whole periphery, as there was an area of only about 1 mm broadness at the temporal

side, in which the zone of the canal of Schlemm was visible.

The fellow-eye (61) to n:o 59 was also suffering from an irritative chronic glaucoma and had also a synechia, going as far forwards as to the anterior parts of the zone of Schlemm's canal with the tips of the waves of the last roll of the iris, leaving a broader area of this zone free in the wave-troughs, thus being a *total trabecular synechia.*

Not less than 5 of the chronic irritative eyes had a total trabecular synechia. That is to say, the root of the iris was extending so far forwards that the ciliary body could nowhere be brought into sight, but the zones anterior of the zone of the canal of Schlemm could possibly be seen. The visible part of this zone was of different broadness. In none of the cases could any alteration of the condition of the angle be seen as an effect of even intense miotic treatment, although the tension in most cases was strongly reduced. Even in the eye (62), where an iridectomy was performed, the angular state was the same as before the operation except at the liberation of the angle in the coloboma.

A *partial trabecular synechia* temporally-upwards was found in the case n:o 66. The state of the angle was not influensed by miotic treatment, but the tension was lowered though not to normal.

In the 2 other cases (67, 68) with a partical trabecular synechia it concealed the ciliary body only on an area of a few mm in each eye, and these small synechiæ were in n:o 68 opened up by miotic treatment, indicating that they were probably not anatomically founded by a union between the root of the iris and the corneo-sclerel wall. The rest of the angle was generally narrowed, without however concealing the ciliary body.

Among the chronic irritative glaucoma eyes not less than 13 were found having the angle *entirely free from synechia.* In 2 of the eyes (77, 78) there was as obvious general narrowing of the angle. In 3 (69—71) of the eyes with open angle the effect of antiglaucomatous treatment had not been investigated.

The conclusions drawn from my gonioscopical examinations of the eyes suffering from primary chronic irritative glaucoma are:

1) *In several such cases the angle of the anterior chamber is not at all blocked by the root of the iris adhering to the corneo-scleral wall.*

2) *There is a greater number of chronic irritative eyes with blocking of the angle of the anterior chamber by the root of the iris than found in simple cases of glaucoma.*

Glaucoma absolutum

Total scleral	synechia	= 2
Partial	"	= 2
Total trabecular	"	= 1
Open angle		= 4

Of the 9 eyes of absolute glaucoma, there were 7 of an irritative type with wide tortous veins, pronounced fogginess of the cornea and other glaucoma signs in the anterior parts of the eye. Of the absolute glaucoma eyes 2 were of a more simplex type and the tensions here were not so high as in most of the irritative eyes.

The gonioscopical view of the 2 eyes (82, 83) with a *total scleral synechia* was not so clear as usual, but it was sufficiently clear to allow the diagnosis of total scleral synechia to be definitely made. On account of pains in the eyes both were enucleated, as miotic treatment had not a sufficiently lowering effect on the tension. One of them (83) was histologically examined and the diagnosis of a total scleral synechia verified, as the root of the iris had united with the corneoscleral wall all the way forward to the beginning of the membrane of Descemet. Fresh connective tissue could be found joining the iris and the lateral wall of the angle as far forwards as to the inside of the limbus.

There were 2 cases with a *partial scleral synechia.* In one (84) of them the peripheral parts of the iris were extending as far forwards as to the middle of the zone of the canal of Schlemm, except over about

one quadrant on the nasal side where it extended still further, concealing even this zone. Miotic treatment, lowering the tension from 60 to 26 mm, brought the zone of the canal of Schlemm into the reach of the gonioscope, but left the other sides of the angle untouched.

A very interesting case is the second one (85) of my 2 cases of absolute glaucoma, where a partial scleral synechia was found. Unfortunately I had not the oportunity of seeing the patient before he was operated on, iridectomy in his left eye being done, but according to the statement in the clinical report he had since 1919 been suffering from glaucoma in both eyes, the tension being at the time of operation in the left eye 80 mm and the vision: amaurotic. On January 26 1926 an iridectomy was performed in this eye with complete success, as the tension being lowered to 17 mm. as measured a fortnight later.

On June 14 1926 I gonioscoped the patient's left eye and found a scleral synechia to every side except over a small area at the nasal side, where the zone of the canal of Schlemm peeped out a little in front of the border of the iris, thus being a partial scleral synechia. But the interesting finding was that the iris had not been taken to the root, but was adhering to the corneoscleral wall, concealing all the different zones posterior to the scleral one. The tension was then 27 mm and vision of course still amaurotic.

A strong dose of eserine was instilled and after 2 hours the tension was 18 mm, but no change in the state of the angle could be detected, when the contact glass was reapplied.

It is possible, that the small area at the nasal side of the angle, where the synechia is not a total scleral one had been opened up by the pulling of the iris at the operation, but it seems very doubtful, that such small area of the angle, which was freed here, should be sufficient to allow such a good drainage of the anterior chamber, that the tension was kept almost normal for 6 month. That the very cutting of the iris tissue should have a prominent tension-lowering effect, as urged by Troncoso, has not ben verified experimentally or anatomically, as far as I am aware.

Only one eye (86) had a *total trabecular synechia*, and in this eye the diagnosis was not quite certain on account of the haziness of the cornea. A brown band could be seen at the angle, and it was considered to be the zone of the Schlemm's canal, but it might have been the ciliary body; anyhow the angle was not blocked further than to the canal of Schlemm.

The only case (87) with a *partial trabecular synechia* had had no ciliary body visible over about one quadrant upwards. After miotic treatment the ciliary body was brought into sight even here and was broader towards the other sides, than before the treatment and the eye is therefore reckoned as one with an open angle.

Of the absolute glaucoma eyes 4 had an *open angle*. One of them (88) had been treated with an iridectomy, which however, had not taken the very root of the iris, but the rest of the iris was not blocking the angle, as it was lying straight into the anterior chamber. Immediatly nasally to the coloboma there could be seen a synechia about one mm. broad, going as far forwards as to the scleral zone. In spite of this I have registered the case as one with an open angle, because I consider the synechia being artificially produced, a sequel to the operation. The angle was fully open up to the synechia, and the iris did not pass up to the level of it gradually, as it usually does in the synechiæ found in primary glaucoma.

The tension was, accordning to the clinical record of the patient, 70 mm. at the time of the operation and I will not deny the possibility of a synechia being then present, extending as far forwards as indicated by the still existing small synechia, but it seems very unlikely, as the appearance of it was not the usual one of such synechiæ. That the hypertension of 47 mm., which was now found, was due to the small synechia just mentioned is not likely, as the

tension was lowered by miotic treatment to 42 mm. without any gonioscopically visible alteration of it.

The other 3 eyes (87, 89, 90) with an open angle had a tension of 52, 45 and 47 mm respectively and 2 of them were of a simplex type, that is to say the glaucomatous signs were not well developed in the anterior parts of the eyes, the third being the previously mentioned case no 87.

As said in chapter VI the classification of the absolute glaucoma cases is based upon the vision only, and eyes of a simplex or an irritative type may thus be found among them. In my series 2 of the 4 eyes with an open angle were of a simplex type, the remaining 2 being of an irritative type. All the eyes, where a certain degree of anterior peripheral synechia was found, were of the irritative type. *The findings in this group are thus in favour of the opinion, that anterior peripheral synechiæ occur less frequently in the simplex type, than in the irritative type.*

Partners

Total	scleral synechia	=	1
Partial	„ „	=	2
Open angle		=	16

I have examined 19 eyes, so far healthy partners to different types of glaucomatous eyes. None of the patients, to whom the eyes belonged, have given any history of definite glaucomatous attacks, which would make the diagnosis of prodromal glaucoma adequate. No signs of glaucoma have been found in these eyes, but although no hypertension has thus been found, a synechia at the angle of the anterior chamber has been found in not less than 3 cases.

In one of these cases (91) a *total scleral synechia* was present. The tension in the eye was 17 mm. and the vision 6/18. Yet on the fundus were found signs of a choroiditis.

To try the effect of miotics on the synechia, pilocarpin was instilled for some days, but no opening could be found at any side of the angle.

It is naturally possible, that the patient had an iridocyclitis at the time, when the choroiditis was acute, and that the synechia was a sequel to this hypothetical iridocyclitis, but whatever the cause to the synechia was, it doe not seem to have had any fatal consequenses on the intraocular tension, this being only 17 mm. That the synechia was of such a type, that bridges over the bottom of the angle (comparable with a symbleparon anterius) and that there was some small opening of the synechia through which the aqueous was excreted, is very possible.

In his paper of 1926 Troncoso described a case similar to the one just mentioned, where he to his surprise found a total scleral synechia in an eye, where no trace of glaucoma could be found, but as in my case signs of a choroiditis were detected at the fundus. In Troncoso's case, however, the fellow-eye was not glaucomatous.

The 2 cases (92, 93), where a *partial scleral synechia* was detected, had a tension of 14 and 17 mm respectively. Miotic treatment had no influence on the extension of the synechia. In both of the eyes the major part of the circumference showed a trabecular synechia, allowing a narrow band of the canal of Schlemm to come into sight. Only along a few mm in one eye (93) and in about a quadrant in the other eye (92) is the synechia a scleral one.

In no less than 16 of the partners was *the angle found open.* In several of these eyes a rather rich pigmentation was found and it was commonly of the same degree as in the glaucomatous eyes, to which they were partners.

It is of great interest to compare the conditions of the angular state in the eyes, the fellow-eyes of which are so far healthy, with that in the so called partners, as some conclusions may thereby be drawn as to the rôle, if any, played by the synechia in the pathogenesis of primary glaucoma.

Among the 16 partner-eyes, where the angle was found open, there were not less than 7 where no difference could be found, in comparison with their glaucomatous fel-

low-eyes in which therefore the angle was also found open. All these eyes were of a simple type except 2, one of which had a tension as high as 52 mm. and was of a chronic irritative type. In these cases the hypertension can of course not have been caused by the blocking of the excretion channels by the root of the iris as such a blocking was totally absent. No pathological changes except deposition of pigment in the angular tissue could be gonioscopicaly detected.

A slight difference in the angular condition was seen in 2 eyes (101, 104) in comparison with their glaucomatous fellow-eyes (87, 66), as only a trabecular synechia extending over a small area was gonioscopicaly detected in the last named eyes.

In the remaining 7 glaucomatous eyes, the partners of which had an open angle, a more pronounced difference was found as to the presence or not of synechia as 4 of them had a total trabecular and 3 had a total scleral synechia.

A slight difference was also found in the extension of the synechia in those eyes, where the partner showed a partial scleral synechia (92, 93) compared with their glaucomatous fellow-eyes, and no difference in the eye (91), where a total scleral synechia was found in both eyes of the same patient.

The conclusions drawn from the gonioscopical examination of this group of so called partner eyes are:

1) *In the great majority of cases there is no synechia between the root of the iris and the corneo-scleral wall.*

2) *In rare cases such a synechia may be found more or less extended, in spite of no clinical evidence of any hypertension or any other signs of glaucoma.*

XII. General conclusions

In all then it may be said that an angle without any anterior peripheral synechia is a very common finding in most classes of primary glaucoma, but that in several cases of the disease such synechiae may be found, extending over a bigger or smaller area of the anterior chamber.

It should be of interest to compare the extension of the synechia, when found, with the degree of hypertension in the same eye. If the excretion of the major part of the aqueous chiefly takes place through the trabeculum of the angle of the anterior chamber, as shown by Leber and others, and no other regulating factors come in and if further the secretion be not decreased and the hypertension be caused by increased difficulty for the excretion, established by the blocking of the angle by the adhering root of the iris, it seems most probable, that a more extended blocking of the angle would bring about more pronounced elevation of the tension than would be caused by a less extended blocking. Thus the eyes with a total scleral synechia ought to have the most raised tensions. This supposition is not supported by my investigations, as it includes cases with a total scleral synechia without any hypertension at all as well as cases with only slightly raised tension.

Neither are the cases in which a certain degree of synechia was found in favour of this supposition, as there were eyes with a very limited synechia, in which the hypertension was rather high, and eyes with a very widely extended synechia, though not totally scleral, with a very slight increase of tension, at least at the time of observation.

In several of the retention theories of glaucoma the blocking of the angle by the root of the iris is the cause of the hypertension. If no such blocking can be found, there ought not to be any hypertension. In my series may be found several eyes without any such blocking at all, but in spite of this a tension raised as high as 50 mm. and even more the tension in one eye reaching 65 mm. Such cases, gonioscopically observed, are described by Salzmann as well as by Troncoso, but these authors seem to consider them as being very rare cases and have not drawn any general conclusions from the observed fact.

It is clear, therefore, that the extension of

the synechia does not correspond to the degree of hypertension in eyes affected by primary glaucoma.

It is also of interest to compare the area of the angle liberated from adhesion of the iris by an iridectomy, undertaken with the aim of decreasing the tension in a glaucomatous eye, with the area left open in most glaucomatous eyes, in their relation to the intraocular tension. Even by a broad artificial coloboma, there is not as much as one quadrant of the angle liberated from synechia, but in most of the eyes i have gonioscoped a considerably greater proportion of the circumference of the angle is not blocked to any degree by synechiae. That the tension-lowering effect of an iridectomy is undoubted and lasting for a very long time in most cases where the operation is done, is a well known fact, but the way in which it works is not incontroversibly explained. Elliot says, that an iridectomy may act in several ways. Of one of the ways he says: »in early cases, before the angle of the chamber is irreparably sealed, the removal of a sufficient piece of iris mechanically opens up the filtering area in the neighbourhood of the base of the excised portion, and thus permits the escape of a sufficient quantity of fluid to maintain the correct balance between secretion and excretion».

That this is not the case in all such operations is seen by the case n:o 85, where the iris was not taken to the root at the iridectomy but was left in the coloboma, where it still blocked the angle and concealed the different zones, of which the zone of the canal of Schlemm on the nasal side came into the gonioscopical view. It is possible that this part of the angle was liberated at the operation, but this is not proved; at any rate the angle was still blocked in the coloboma, although the tension was greatly decreased for months.

Such a case, where the tension was lowered in a permanent way in spite of the angle of the anterior chamber still being blocked by the iris not having been taken to the root at the operation, is described by Troncoso.

The way in which the iridectomy works, is not by opening the angle in my case n:o 69, as the angle in this eye already previously to the operation was fully open. In spite of this the tension before the operation was as high as 59 mm. and was lowered by the iridectomy to 14 mm. By gonioscopy a coloboma to the root was found after the operation as well as a still open angle all the way round the periphery of the anterior chamber.

That miotics, instilled into the conjunctival sac of eyes, have an undoubtedly lowering effect on a pathologically raised tension, is a fact that has been very well known for many years. The effect of it is thought to be brought about by the contraction of the sphincter iridis, by which act the peripheral parts of the iris are drawn from the angle of the anterior chamber, where they in glaucoma are supposed to block the excretion ways for the aqueous, thereby producing an intraocular hypertension. Another explanation of the effect of miotics is, that the stretching of the iris by the contraction of the sphincter iridis increases the surface of the iris, which is supposed by some authors to absorb the aqueous. A third attempt to explain the effect of miotics is, that they cause the ciliary muscle to contract and that thereby the trabeculum of the angle is strected and so allows a better outflow of the intraocular fluid.

That the explanation, saying that the miotics act by liberating the angle of the anterior chamber from an obstructing iris, is not according to fact in most cases of primary glaucoma, can be seen in my series of observations of the actual condition of the angle in the living eye before and after instillation of miotics. In the great majority of cases, where a certain degree of anterior peripheral synechia was found, the miotics had a pronounced decreasing effect on the intrabulbar tension, in spite of the synechia not being loosened. In all those cases, where there was no anterior peripheral synechia present, the tension-lowering effect was also pronounced and in those cases it is obvious therefore that the miotics did not

bring about their therapeutic effect by any alteration of the mutual position of the iris and the trabeculum at the angle of the anterior chamber.

A case, in which miotics brought about a lowering of the tension without causing liberation of the angle, is probably the previously mentioned case of Barret and Orr, where the writers suppose, that no stretching of the iris took place, as the pupil did not contract at all. They did not, however, observe the angle of the anterior chamber by gonioscopy and thus their supposition of a blockage of it by the root of the iris has not been verified.

The conclusion, that in most cases the mode of action of miotics is not by liberation of the angle, is in distinct opposition to a widely accepted idea of the way, in which the miotics act.

Several of the retention theories of glaucoma, as those of Knies, Weber, Czermak and Henderson, suppose that the raised tension, at least in most cases, is caused by the blocking of the angle by the root of the iris. This blocking of the angle may be brought about in different ways, but the very blocking, which they consider being an almost constant fact in primary glaucoma, plays a very great rôle for the actual elevation of the tension. The other pathological changes at the angle, whether an inflamation, a sclerosis or a hyperaemia of the iris or the ciliary body, they only consider to be a predisposing phenomenon.

The gonioscopical examination of primary glaucoma eyes shows, that the obstruction of the excretion channels by the root of the iris is not at all necessary, and that in most cases, especially in simplex cases, hypertension is found although the filtration channels are quite free from such blocking by the iris.

But thereby is not said, that the blocking of the angle by the root of the iris cannot be a cause of raised tension. That it most probably is the actual cause of hypertension in some glaucomatous cases, is seen from the well known fact, that a mydriasis in such eyes as a rule brings about an abrupt rise of the tension. That the mydriatic drugs may act in another way than by dilatation of the pupil, whereby the iris is thickened in its peripheral parts and thus obstructs the excretion channels, must be considered; the fact, however, that the dilatation of the pupil, coming on when the patient is placed in a dark room, also in many cases has such an increased tension in sequel, points to the possibility of the real cause of the hypertension, being an actual blocking of the excretion channels by the iris.

The effect of mydriasis in an eye, being a so far clinically healthy partner to an irritative chronic glaucoma eye, was studied in case n:o 95. The tension in the partner eye was 20 mm., and the ciliary body was visible all the way round the periphery of the anterior chamber. No signs of glaucoma could be found in this eye. In the conjunctival sac drops of homatropine were instilled (2 drops of a 2 % solution of homatropine hydrochloride during 3 days). The pupil was thereby moderately dilated, but no elevation of the tension could be measured, until the morning of the 4th day, when it was 82 mm. The patient complained of pains in the eye, which had the scleral veins dilated and the cornea a little foggy. Gonioscopy then showed no zones behind the white scleral one. The patient was immediately put under eserine treatment and the following day the tension was 15 mm. and the eye was pale. By renewed gonioscopy a fully open angle was detected as before the mydriasis. A clinical examination of the eye could not reveal any signs of glaucoma.

The possibility cannot be denied, that in this eye the root of the iris actually did block the excretion channels, when the pupil was dilated, and that this blocking could be the cause of the abruptly raised tension, but the possibility of the mydriatics also acting in another way must be considered. That an even more pronounced dilatation of the pupil, than in the case just described, brought about by mydriatics in eyes, not suffering from glaucoma or not being partners to glaucomatous eyes, only in very rare cases causes such an abrupt elevation of

the tension indicates, that it is not only the iris, thickened in its peripheral parts by the dilatation and probably blocking the filtrating area, which is the single cause of the established hypertension. It thus seems most probable, that there exists another, yet unknown pathological change in the glaucomatous eyes and their partners, and that the effect of mydriatics upon this pathological change is such, that the balance of the intraocular tension becomes so greatly disturbed.

The statements of Koeppe and Troncoso, that the angle gradually gets blocked, by the root of the iris, creeping up at the corneo-scleral wall, I cannot agree with. In my series there are cases, where the angle was gonioscopically found fully and widely open, in spite of that the patient had been suffering from primary glaucoma for as long time as 10 years, according to the patient's own statements and to the records of the hospital, where they had been treated for the disease for such a long time. The objection may be made, that it was due to the treatment, that the angle was still open, but at least Troncoso argues that the gradual blocking of the angle occurs in spite of miotic treatment.

On the other hand I have found several eyes, where a general narrowing of the angle was undoubtly present without any synechiae. The estimation of the degree of such a narrowing of the angle without any synechiae is very difficult as the wideness of the opening of the angle looks vere different, according to the accuracy, by which the line of vision is directed to the bottom of it. No lines suitable for landmarks for this estimation are obtainable, as the different zones at the lateral wall of the recess are in the estimation of the extension of anterior peripheral synechiae, and thus the estimation must be rather subjective.

The absolute absence of any bombé of the iris in spite of even a great extension of synechia was very frequently found in those eyes, I had the opportunity of examining with the gonioscope. This may be a fact in favour of the opinion, that synechiae at the angle of the anterior chamber are brought about by the iris being pushed against the corneo-scleral wall by the ciliary processes which by some authors are supposed to be swollen in cases of primary glaucoma. In the cases, where I have had the opportunity of seeing the ciliary processes, namely those eyes in which an iridectomy had been made, the ciliary processes have not been swollen enough to reach the posterior surface of the iris; these observations, however, have, of course been made rather a long time after the operation so that the processes might have had time to get rid of the swelling. The pathogenesis of anterior peripheral synechiae in primary glaucoma has not been explained in a convincing way.

XIII. Summary

1. The gonioscopical metod of examination is not much used in ophthalmological practice, but it is a method by which important information on the condition of the angle of the anterior chamber can be gained. It ought therefore to be included in the routine examination of every glaucomatous eye.

2. It is not necessary to use the microscope as an observation instrument as a loup with 3 – 4 times magnification is enough to give a clear view of the angle. The contact glass may be substituted by a simple aqueous chamber.

3. To the first question, which this work tries to elucidate, »Is in the majority of cases of primary glaucoma the angle of the anterior chamber blocked by a synechia of the root of the iris to the corneo-scleral wall?», the answer is, that in the great majority of cases of primary glaucoma there is no such synechia present.

4. The second question, »Does in this respect any difference occur between various forms of primary glaucoma?» can be thus answered, in cases of simple glaucoma the angle of the anterior chamber is more fre-

quently free from such synechiae than in the irritative type of primary glaucoma.

5. The raised tension in primary glaucomatous eyes can be reduced by miotic treatment and by iridectomies, although the condition of the angle in respect of anterior peripheral synechiae is not affected.

6. The gonioscopical examinations of primary glaucoma eyes here accounted for do not exclude the possibility of a blocking of the exretion channels at the region of the angle of the anterior chamber and that this hypothetical blocking may be the cause of the hypertension, but in the great majority of primary glaucoma eyes it is not formed by the adhesion of the root of the iris to the corneo-scleral wall.

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