·Clinical Research·

Reappraisal of the capsulorhexis: tearing angle in capsulorhexis

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Abstract

• AIM: To determine the tearing angle and tearing force, and effects of associated pressures in tearing of various materials and human lens capsule in continuous curvilinear capsulorhexis (CCC).

• METHODS: Tearing was done on different materials such as aluminum-laminated paper, different types of thin transplant plastics and human lens capsule with blunt tip needle. During the procedure, angle and direction of force were measured. Effects of increased underlying pressure on tearing of tearable materials and effect of anterior chamber depth and vitreous pressure on 24 postmortem human eyes with different ages (range from10 to 75 years), was evaluated.

• RESULTS: Tearing angle in every material was unique for that material. Angle and force of tearing was decreased reversely with increasing age (from 85 degree in a 10-years-old to 10 degree in older than 50 years). Increasing vitreous pressure and decrease in AC depth causes higher pressure on point of tearing. Safe methods in controlling CCC were discussed in the context.

• CONCLUSION: Understanding the physics and vector of forces during CCC is necessary in good performance and avoidance of radial tears. Change in capsular properties between different ages and different type of cataract causes different tearing angle and tearing force that should be considered during CCC.

• KEYWORDS: continuous curvilinear capsulorhexis; tearing; tearing angle; human lens capsule; capsulotomy

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INTRODUCTION

Continuous curvilinear capsulorheris is a standard cataract surgery technique that ossers many advantages [1]. It provides the cataract surgeon with a completely intact capsular bag for lens implantation. It is the only method of anterior capsulotoly which allows a complete operative and postoperative visual verification of "in the bag" placement of an implant; as the anterior capsular rim can be visualized for 360 degrees. However, those new to the technique find it difficult to perform. Poor control during capsulotomy can result in radial tears, which can cause complications such as posterior capsule rupture, or intra-operative or post-operative lens decentration. The configuration and size of an anterior capsulotomy significantly affect the outcome of the cataract operation.

One way to prevent such complications is proper training in the performance of CCC. It is well known that the lens capsule has elastic properties [2,3]. It is not clear, however, how much a tear force should and with which direction can be introduced to allow safe completion of the procedure while still avoiding tears and to take a round and large enough opening in capsule. Assia *et al* [4] studied the elastic properties of the lens capsule in capsulorhexis, and Krag *et al* [2] studied the stretching capacity of the capsule after capsulorhexis. We investigated the direction of the force for tearing; first in various tearable materials such as aluminum laminated paper and; second on different ages and cataract groups for obtaining a safe method in performing CCC.

MATERIALS AND METHODS

Subjects We studied on various materials that can be teared: aluminum laminated paper, different types of thin transplant plastics, and post-mortem human lens capsule. We obtained 24 post-mortem eyes from 24 patients. Mean age of the patients was 42.5±22.5 years (range, 10 to 75 years). The eyes were operated on 5-7 days after death. To study the tearing forces on different materials, we made a situation from sponge with similar shape to lens; that captured from periphery with a round metallic ring. To

produce similar vitreous effect on this material, we increased the mass of the sponge that causes to increase underlying pressure on inferior surface of these materials.

Methods After forming a flap on these materials similar to flap of CCC, tearing was completed as the same as CCC. During the procedure, we measured tearing angle with a goniometer. On the eyes that were for studying, the iris was excised down to its root, this permitted clear visualization of the entire anterior capsule, the anterior zonules, and the ciliary's processes. To show the effect of vitreous pressure 0.2mL normal saline was injected from pars plana in to vitreous in 5 eyes. During the procedure, AC was filled with viscoelastic. To show the effect of AC depth, in 4 patients we put it shallow. After making an opening with a blunt tip needle on center of capsule and forming a capsular flap, CCC was done with complete control and measurement of angle of traction for desired direction that introduced. This work was done on other materials that were noted above.

RESULTS

First we describe our finding on tearing effects on aluminum laminated paper and different types of thin transplant plastics. After forming a flap on aluminum laminated paper (that covered sponge and creates a shape such as lens capsule), we saw that if direction of the vector of force was in align or continued with desired direction of tearing, tearing direction will be gone on a direction with an angle of 5-10 degree toward periphery (Figures 1, 2). After repeating this procedure on aluminum laminated paper and different types of thin transplant plastics we saw that this angle was related to the property of that material. For example in aluminum laminated paper, as noted this angle (or angle between the vector of force and direction of tearing) was 5-10 degree. Thus to maintain the desired direction of tearing, we must change vector of force or our direction of traction at the same degree toward central (Figure 1). Study on other materials that had elastic properties apposed to paper, showed that this angle will be increased with increasing the elastic property, for example in aluminum laminated paper, this angle was between 5-10 degree but, in different types of thin transplant plastics it was 40-45 degree that was related to the thickness and increasing the elasticity.

On studying the vitreous-like effect, we saw that increasing the underlying mass, causes to increase the pressure on lower aspect of this material, so that to maintain desired direction of tearing, this angle should be increased. On study on human lens capsule, the average dimension of capsular opening was 5.2mm (range 4.0 to 6.4mm). In pediatric age

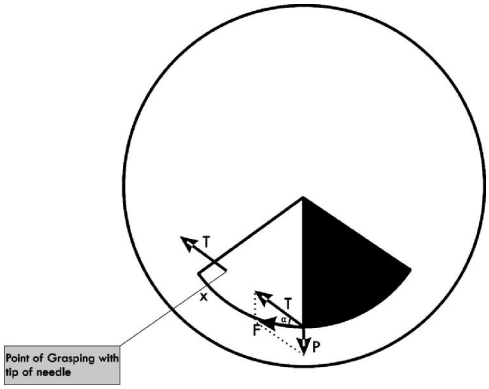

Figure 1 This figure defines the angle of tearing (α) or angle that forms vector of our traction on point of tearing with direction of tearing (*x*). *T* is the vector of our traction or force. *P* is the vector of force that is toward peripheral and is due to effect of underlying mass (such as reforming pressure of sponge) or traction effect of zonules on capsule. Then *F* will be Algebraic summation of *T* and *P* (*T*+*P*) and is the actual tearing force

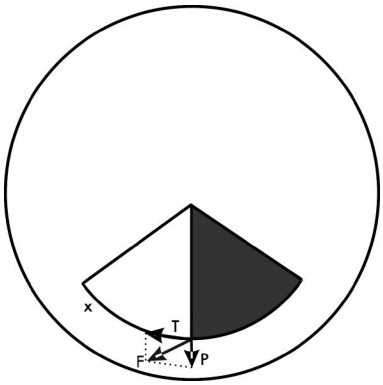

Figure 2 If the vector of traction or *T* be in direction of tearing (align with *x*), summation of *T*+*P* that is *F* and determines direction of tearing, will alter its direction toward peripheral

group eyes it was seen that the capsular elasticity was high. With increasing the age, this elasticity decreased. Tearing angle in 10-years old patient was 85 degree, in 16-years old was 50 degree, and in 25-years old it was 35 degree. After 50 years tearing angle seemed to be constant in different age patients (Figure 3). Two patients with ages 71, 75, had mature cataract, that capsular elasticity was lowest. On the other hand we saw that if point of grasping with needle was nearer to point of tearing we should alter the angle slightly vertical (Figures 4, 5). The effect of shallow AC depth and increased vitreous pressure were similar, so that at these situations, it needed to increase the tearing angle (Figure 6).

DISCUSSION

Numerous methods for capsulotomy have been developed. The most common of which are the can opener technique, linear (envelope) capsuotomy, and CCC[5]. Numerous other

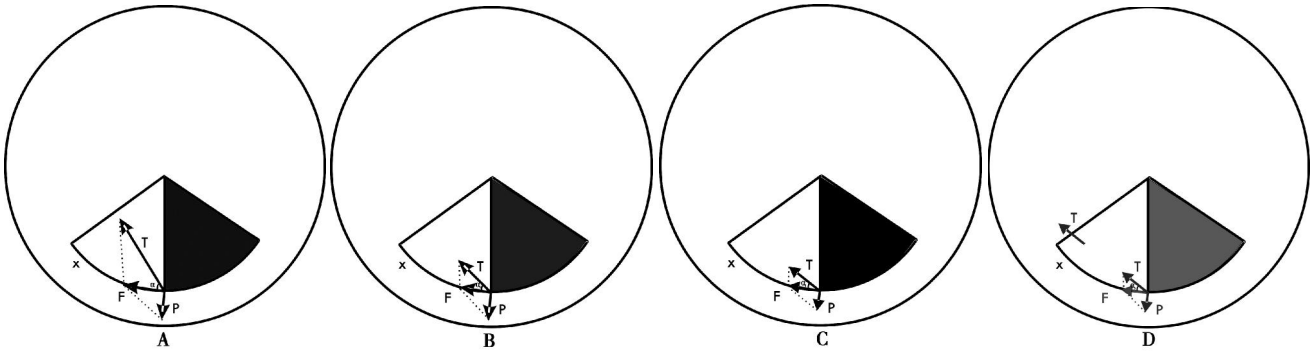

Figure 3 Angle and force of tearing in different ages A: In 10-years-old patient, angle (α) is 80 degree. Due to higher elasticity of capsule, traction (T) and force (T) for tearing is high; B: In 25-years-old patient angle is 40 degree and force is lower than former; C, D: In 45 and 58 years old patients this angle and force decreased

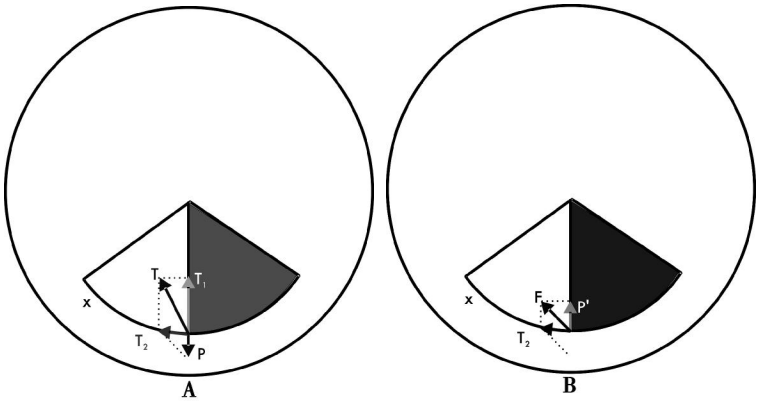

Figure 4 A: If your grasping point to be closer to point of tearing, its direction of traction should be toward center of circle with a higher angle (α). In this situation, vector of traction (T) will analyze to $T1$ and $T2$. $T1$ is toward center of circle and cause to decrease the effect of P to $P1$. Algebraic summation of $P1$ and $T2$ determine direction of F (actual direction and force of tearing). If $P1=0$, then direction of tearing will not alter. If $P < T1$, then direction of tearing will go more peripheral, but if $P < T1$,tearing will go inward of circle with direction of F; B: This figure shows with best form that how changing the angle of traction toward central, when our capsulotomy going toward peripheral, will help us in its controlling and avoidance of radial tear

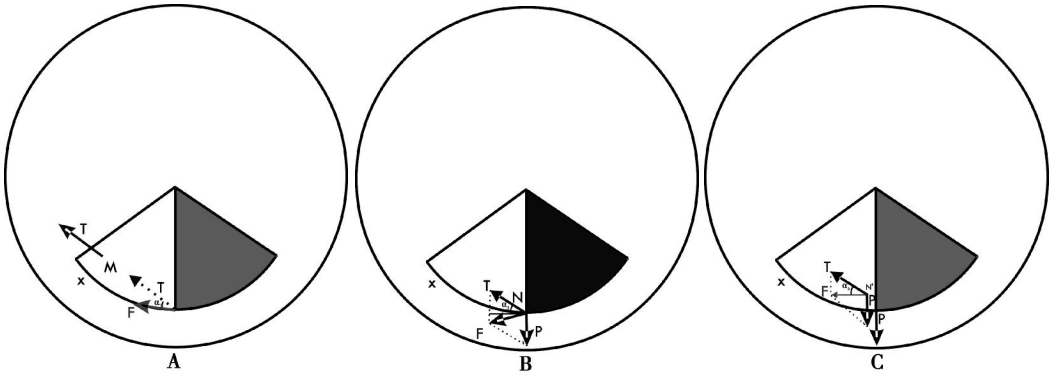

Figure 5 Point of grasping A: It is better that point of grasping with tip of needle to be 2-3 hours farther relative to point of tearing (M). In this situation vector of traction and direction of tearing form an angle that is 10-20 degree; B: If point of grasping be closer to point of tearing (N), its effective vector of (F) will be unpredictable, and may alter its direction toward peripheral (1, 2); C: Thus in closer point of grasping to the point of tearing direction of traction should be more toward central or with higher angle (3)

techniques are used, which generally are variations of one of these three categories [6]. Capsulotomy can be done with using various devices. Such as capsular forceps, diathermy, and blunt needle tip. Blunt rough capsulotomy needle technique allows more controlled performance of the anterior capsule tear [7]. CCC is a surgical skill which can be demanding. An opening with an intact edge and near circular dimensions to eliminate weak spots, and with

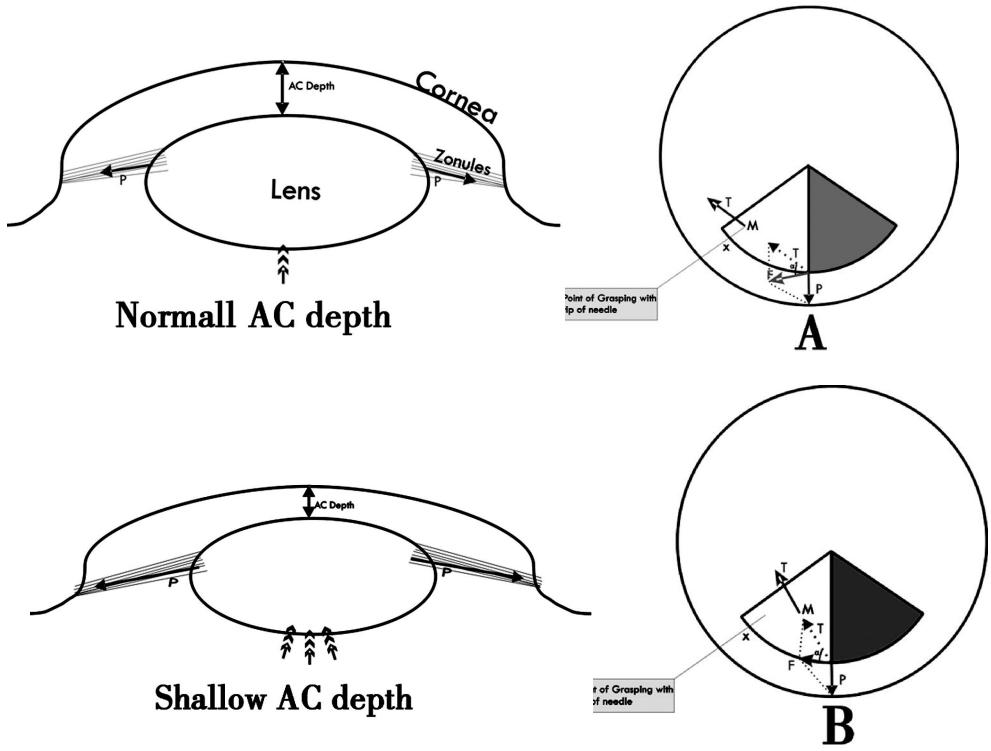

Figure 6 Vitreous pressure and AC depth A, B; If vitreous pressure increase or AC depth decrease, traction of zonules on capsule will increase, and *P* will be higher than normal. In this situation if our direction of traction (*T*) to be in the same direction as normal AC depth or normal vitreous pressure, vecteral summation of *T* and *P* will go toward peripheral. Thus it is better to increase angle of traction and so point of grasping be closer to the point of tearing to limit the effect of *P*1 (as shown in Figure 5)

enough size is desirable.

The elastic properties of the lens capsule are well known and have been the subject of several studies [2-4,8]. Fisher[3,8], and Fisher and Wakely *et al*[9] thoroughly investigated the elastic constants of the human lens capsule and showed that the modulus of elasticity decreases significantly with age, as we observed in our study. The thickness of the capsule increases until the sixth decade and slightly decreases thereafter. The loss of elasticity is therefore accompanied by a loss of thickness during the aging process. Assia *et al*[4] showed that elastic properties of the capsule were not affected by the time interval after death, probably because the lens capsule is a membrane and does not contain any living structure. They showed that the elasticity of the capsule was higher in younger ages (younger than 55 years) compared to older eyes. In patients older than 60 years, however, age did not alter capsular elasticity. In our study, this change was seen after 50 years.

In this study, our approach was on tearing angle and effect of traction on different direction on direction of tearing. First we worked on tearable materials and saw that in every material the tearing angle is unique for that material. In addition to this finding, we observed that in materials that have elastic property, increasing elasticity, causes to increase direction of force (or angle) to maintain our desired direction. If we assume our traction force and its direction as *T*, the traction or pressure from zonules (or underlying pressure on inferior aspect of materials that we studied) as *P*, and the tearing force or actual needed force for tearing as *F*, *F* will be the algebraic summation of *T* and *P*(*F*=*P*+ *T*). As you see in Figure 2, if direction of our force (*T*) be in continuous with direction of tearing (*x*), then vector of algebraic summation of *T*+*P* will go toward periphery. This angle between *T* and *F* is known as tearing angle. If we want to save direction of tearing, then *F* should be align or continuous with tearing direction (*x*). In this situation because *F* is summation of *T* and *P*, then *T* vector will go toward center of circle with an angle that is equal to tearing angle (Figure 1).

In one capsule that will be teared with angle of 15 degree, if we increase the angle, *T* should be increased. In this situation vector of *T* will be analyzed on two vectors (*T*1, *T*2) (Figure 4). *T*1 is perpendicular to tearing direction or in alignment with opposed direction with *P*. In this position effect of *P* will be decreased (*P*1=*P* - *T*1), and finally algebraic summation of *T*2 (that is on direction of tearing)

and $P1$ determine direction of tearing. If $T1=P$, then $P1=0$, and direction of tearing will be on line x or desired direction. If $P<T1$, then direction of tearing will go peripheral, and if $P<T1$, then $P1$ will be toward central that causes direction of tearing changes toward inward. The last situation is helpful in control of peripheral tearing when our CCC goes peripheral.

As noted above, elasticity of capsule changes with increasing age. We observed that in up to 25 years, this elasticity was high, so that this angle was 45-80 degree (Figure 3). In patients with 25- 48 years, the elasticity was moderate, and the tearing angle was 15-35 degree, after 50, we observed that elasticity and tearing angle was equal between patients with different ages, but in mature cataract this was very low. As was noted on other materials, increasing the underlying mass that is similar to increasing vitreous pressure and decrease in AC depth causes more traction on point of tearing (or P will be increased). Thus for saving the direction of tearing toward x, angle of our traction (T) and following amount of T should be increased (Figure 6).

On summary, to achieve an ideal sized, round capsulorheris with intact capsular edge, we should: (1) Take in mind that tearing angle in every material in unique for that material. (2) Notice to age of patient is very important: in lower ages to maintain desired direction, direction of our traction should be toward center more than older patients. This angle will decrease until 50 years. After that it seams to be equal in older patients. (3) To obtain desired direction of tearing, point of grasping with needle should be 2-3 hours farther to point of tearing and 1-2mm central to border of flap. This work provides an angle of 10-20 degree (Figure 5). (4) To neutralize or decrease the effect of vitreous pressure or shallow AC depth on zonulla, depth of anterior chamber should be deep enough (Figure 6). The authors believe that consideration of this finding would help the best to maintain integrity of the capsular bag, and extension to peripheral will be limited.

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