Research Article

Resistance to compression of the capsular tension ring over time

Abstract

Purpose: To evaluate the resistance to compression of commercially available capsular tension rings (CTRs) when submitted "*in vitro*" to a constant pressure over a period of time.

Setting: Research Unit. CHU Albacete. University of Castilla La Mancha. Spain.

Method: Four samples of 3 different CTR manufacturers were evaluated for resistance to compression over time while being exposed to a constant tension. The 13 millimetres CTRs were placed in a round rigid container with an 11 millimetres diameter and submerged in BSS at body temperature (37 degrees Celsius). CTRs were divided into two groups. Two samples of each model were introduced in the containers and removed and evaluated at 1 month, while the other two samples of each model were introduced in the containers and removed and evaluated at three months. Size and shape of the CTRs were measured at baseline, at 1 month and 3 months. Every measurement was repeated 3 times by two different observers.

Results: The mean decrease in CTRs diameter of the 1 month compression group was 1, 5 millimetres. The mean decrease in CTRs diameter of the 3 month compression group was 1, 63 millimetres. The differences in diameter between baseline and 1 month, as well as baseline and 3 months were statistically significant. There was no statistical significance when comparing the final size between the 1 month and 3 months groups.

Conclusion: All the commercially available CTRs studied have shown a decrease in diameter when exposed to a constant compression at body temperature. This could explain some of the published reports of capsular bag shrinkage or even dislocation of the entire IOL-CTR complex despite the implantation of a CTR.

Keywords: capsular tension ring, CTR, IOL, capsular phimosis, zonulolysis

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Introduction

Standard Capsular Tension Rings (CTR) are typically open-ended rings made of PMMA filament, with eyelets at either end, and are meant for capsular bag stabilization during and after cataract surgery. The first similar device was introduced by Hara in 1991.[1] It consisted of a silicon rod designed to maintain the circular contour of the capsular bag and prevent migration of cells into the posterior capsule. Several other properties have later been attributed to these rings, such as: better centration.[2] of premium IOLs generating less induced aberrations,[3] better predictability of refractive outcome,[4] prevention of posterior capsular opacification and prevention of capsular bag contraction.[5] The clinically desired tensional function of the device is generated by inserting a CTR with a diameter larger than the one of the patient´s capsular bag.

The CTR behaves as a spring and, in principle, follows Hooke´s law: the capsular bag will compress the CTR to a closer state diameter and in turn the CTR will exert an equal outward tension that will stretch and stabilize the capsular bag. As Hooke's law states: $F = -k\Delta L$. (F=force, k=spring constant of the material, ΔL=displacement), therefore, the force exerted by the CTR is directly proportional to the amount of compression. Hooke's law holds true for displacements within the elastic region of the material. Deformation outside the elastic region will cause permanent deformation of the material, according to Young´s modulus of elasticity (Figure 1). Despite the force exerted by the CTR, several cases of capsular bag shrinking have been published, some of them leading to capsular bag-IOL-CTR complex dislocations.[6–9] In this study we have measured the deformation of a CTR when submitted to a certain pressure "*in vitro*" and to ascertain if commercially available CTR's remain within the elastic region when the compression is maintained overtime.
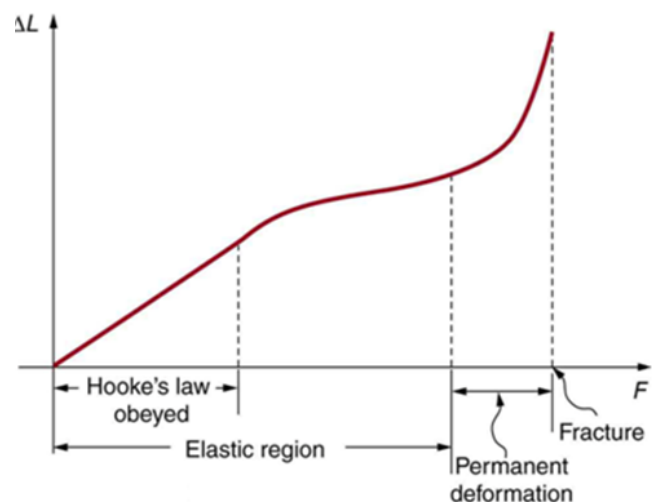

Figure 1 Hooke´s law and young´s modulus of elasticity.

Methods

Four samples of 3 different CTR manufacturers with an open state diameter of 13.0 millimetres were evaluated for deformation when exposed to a constant compression at body temperature. Capsular tension rings are usually described by an open state diameter and a closed state diameter.[10] The closed state diameter is the size of the capsular bag the CTR is intended for. All CTRs open state diameter were photographed and recorded under the microscope. The capsular tension rings were placed in separate containers with a diameter of 11.0mm, simulating the capsular bag. These containers were Plexiglas, machine made moulds with flat edges and a depth of 1 mm. The containers had an open top for easy insertion and extraction of the CTR without over-bending or stretching the CTR. The CTRs and containers were submerged in BSS at body temperature (37 degrees Celsius.) (Figure 2).
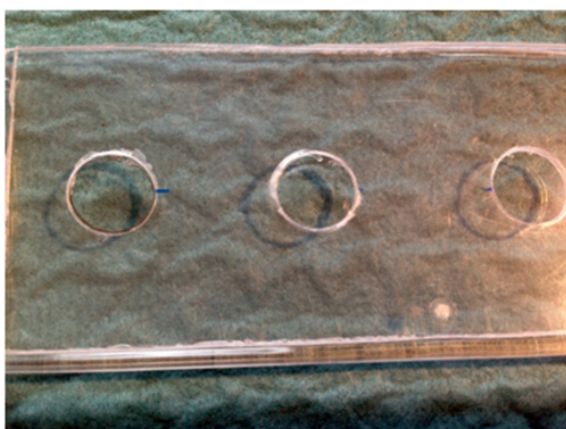

Figure 2 CTRs and containers at body temperature.

After one month, 2 CTRs of each manufacturer were removed from the simulated capsular bags, placed on a millimetric background and photographed under the microscope (Figure 3). The other 2 CTRs of each manufacturer remained submerged for a total period of 3 months before being removed and evaluated. During this study all manipulation of the CTRs were performed with forceps, sliding the CTR into and out of the containers without bending or stretching the CTR. All 24 photographs were then masked, coded and independently evaluated three times by two of the authors (JM and JV). Statistical analysis was performed with SigmaStat 4.0 software. The paired-t test was used to evaluate the differences between baseline and 1 month and baseline and 3 months ring´s sizes. The Student t test was used for comparison between the 1 and 3 months.
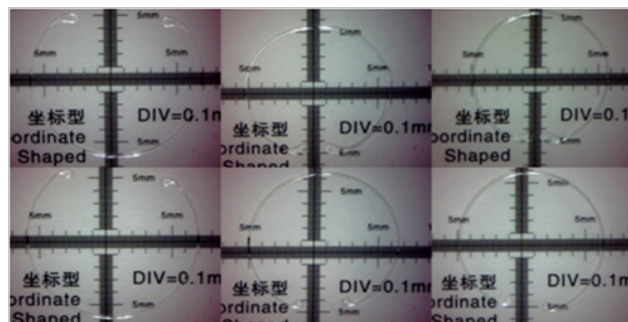

Figure 3 Open state diameter at baseline (Left), 1 (Middle) and 3 month evaluation (Right).

Results

Twelve CTRs, from 3 different manufacturers were evaluated. The manufacturers, in alphabetical order, were: CIMA Technology Inc. Pittsburgh, USA; Morcher GMBH Stuttgart, Germany and Ophtec BV Groningen, The Netherlands. All tested capsular tension rings had an initial open state diameter of 13millimetres (range 13.0-13.0; SD 0,00). The mean diameter, at 1 month evaluation, for all the CTRs was 11,492millimetres (range 11,25-11,7; SD 0,166). At 3 months, there was a further decrease in diameter to a mean of 11,367millimetres (range 10,85-11,65; SD 0,27). There was a statistically significant deformation of the CTRs at 1 month of 1.508 mm (p<0,001). No statistical significant difference was found between the deformation of the different manufacturers, neither was there a statistically significant deformation between the 1 and 3 months measurements (p=0.266) (Table 1).

Table 1 Clinical and biochemical variables of individuals with overweight-obesity

Brand	Diameter t=0	Diameter t= 1 Month	Diameter t= 3 Months
CIMA 1	13	11,6	
CIMA 2	13	11,7	
Morcher 1	13	11,35	
Morcher 2	13	11,6	
Ophtec 1	13	11,25	
Ophthec 1	13	11,5	
CIMA 3	13		11,4
CIMA 4	13		11,45
Morcher 3	13		11,4
Morcher 4	13		11,65
Ophtec 3	13		10,85
Ophtec 4	13		11,45

SD, standard deviation; BMI, body mass index; WC, waist circumference; AC, abdominal circumference; HC, hip circumference; RER, respiratory exchange ratio; HR, hear rate

Discussion

Poly-methyl methacrylate (PMMA), also known as acrylic or Plexiglas is a lightweight, rigid, transparent thermoplastic. PMMA has a good degree of bio-compatibility and has been extensively used in ophthalmology for rigid IOLs, CTRs and rigid contact lenses. CTRs made of PMMA are known to be susceptible to damage during insertion, such as over-bending, stretching or even snapping. Furthermore, PMMA, being a plastic, is susceptible to "material creep". Material creep is defined as the permanent deformation of a material when exposed to mechanical stress. Creep is usually increased by temperature. Several studies have shown standard PMMA CTRs failing to prevent capsular bag shrinkage or late dislocation.[6–9] Capsular shrinkage and dislocation is known to be multi-factorial, being influenced by: progression of zonular damage, fibrous metaplasia of residual lens epithelial cells, IOL material and insufficient resistance to compression by the CTR. This lack of resistance to compression was already suggested in 1999.[11]

In our opinion, it is difficult to ascertain the effectiveness of a CTR, while not knowing, the capsular bag size for which it is intended nor the spring constant of the implanted CTR. We do know, however, that there is a great variability in spring constants (range 0.816-4.550mN/mm) between the different manufacturers.[12] In this study we show that PMMA will deform once implanted, decreasing the amount of contraction that it can prevent and the ability to redistribute the forces over the intact zonulae. According to Hooke's law: F=- k ΔL. (F=force, k=spring constant, ΔL=displacement). The force exerted by a CTR is directly proportional to the amount of compression. A reduction of the open state diameter of the CTR due to deformation will render a reduced displacement (ΔL). Since the outward force is equal to displacement (ΔL) multiplied by the spring constant (k), this will translate into a reduction in outward tension and hence a diminished resistance to capsular bag shrinkage.

The tested rings had an initial horizontal displacement (ΔL) of 2 mm (from 13 to 11mm) when placed in the containers. After 1 month of compression, the displacement was reduced to a mean 0,492mm, leading to a reduction of 75% of the initial outward force. This could explain some of the published reports of capsular contraction and late dislocations, despite the use of a PMMA CTR. The cease of deformation in this study is attributed to the decrease in mechanical stress once the CTRs has deformed. Inserting the deformed CTRs in a smaller container would have lead to further deformation. This implies that this PMMA CTR is not capable of preventing a slow progressive bag contraction. In this study we could not take into consideration the deformation generated during the insertion of the CTR during a cataract surgery, such as over bending and over stretching. In our opinion, this manipulation can weaken the material, possibly reducing its spring constant even more.

Several attempts have been made to increase CTR resistance, such as locking eyelets, suturing the eyelets together with Nylon 9-0 and even implanting several larger rings together. However, excessive shrinking can still distort the ring.[10] Further research is needed to evaluate the required tension and size of the CTR as well as exploration of other designs and materials capable of better resisting capsular compression. A rigid, closed CTR would be much less susceptible to this sort of deformations, providing a better resistance to contraction. However, implanting a closed PMMA CTR without enlarging the incision and selecting the best suitable size remains a problem.[13] Although most bag-IOL-CTR dislocations were observed 6 years after implantation,[14] capsular bag contraction is believed to occur mainly during the first 3 to 6 months post-operative.[15] Therefore it is important to know whether the implanted CTR will provide enough resistance to compression during this critical period. We believe that currently available CTRs are a great tool to help in cases of zonular weakness, but fail to be useful in other tasks, such as maintaining the shape and tension of the capsular bag when capsule contraction occurs.

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Conflicts of interest

Author declares that there is no conflict of interest.

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