Can The Macula Be Attached If View is Obscured By A Bullous Retinal Detachment?

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NONE OF THE AUTHORS HAS ANY PERTINENT FINANCIAL DISCLOSURES

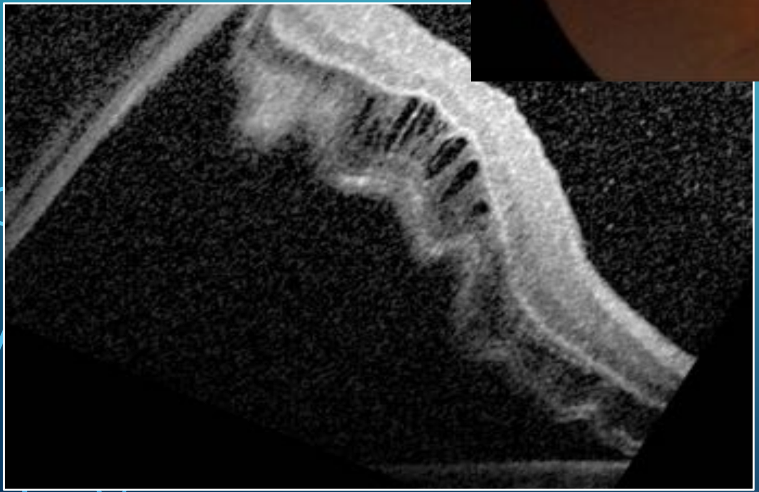
Summary: Can The Macula Be Attached If View is Obscured By A Bullous Retinal Detachment?

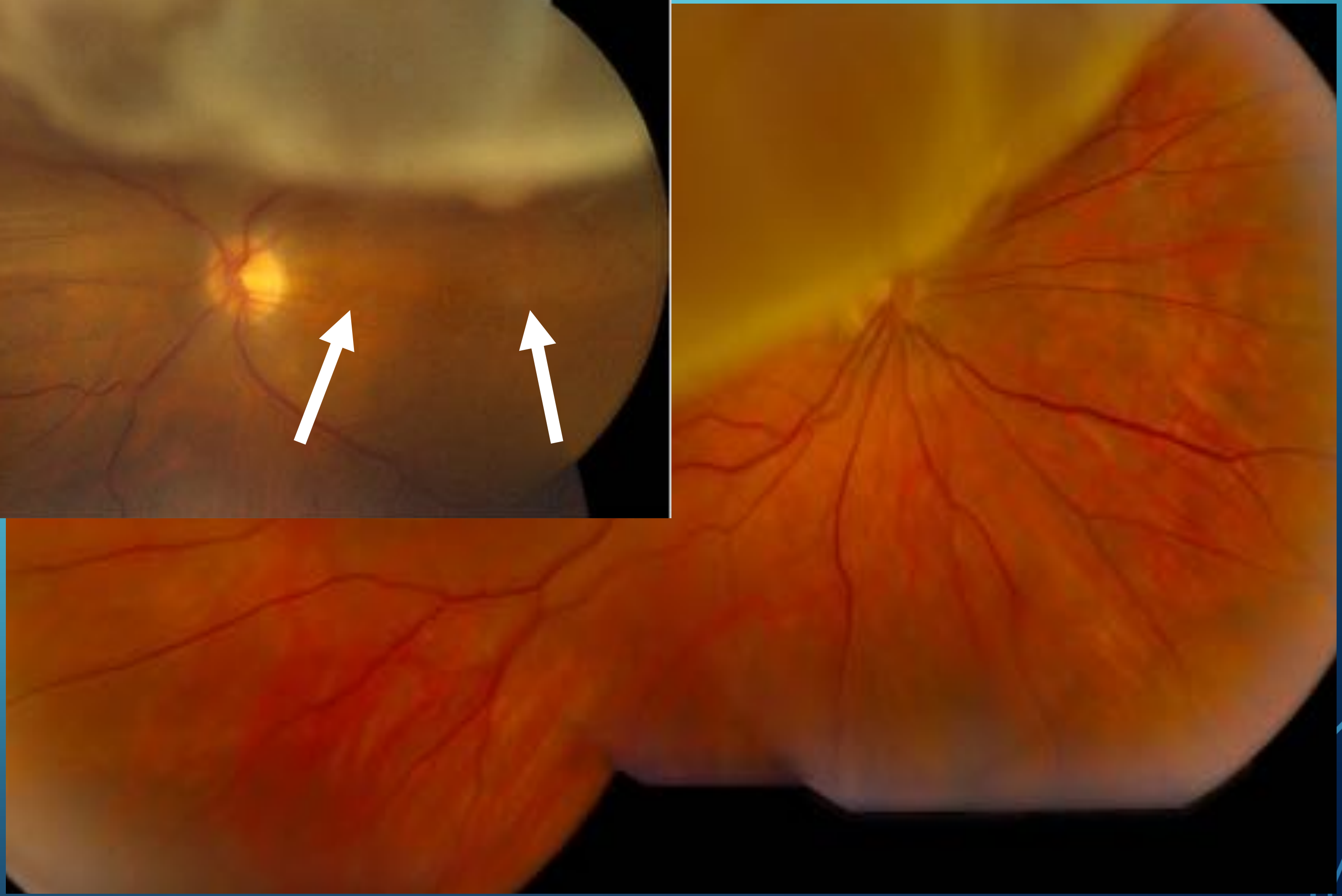
- Shape of retina modeled as oblate ellipsoid
- Sagittal section considered
- Retina hanging catenary
- Evaluated for various degrees of myopia
- Position of ora serrata estimated/measured
- Stretch of the retina probably not significant

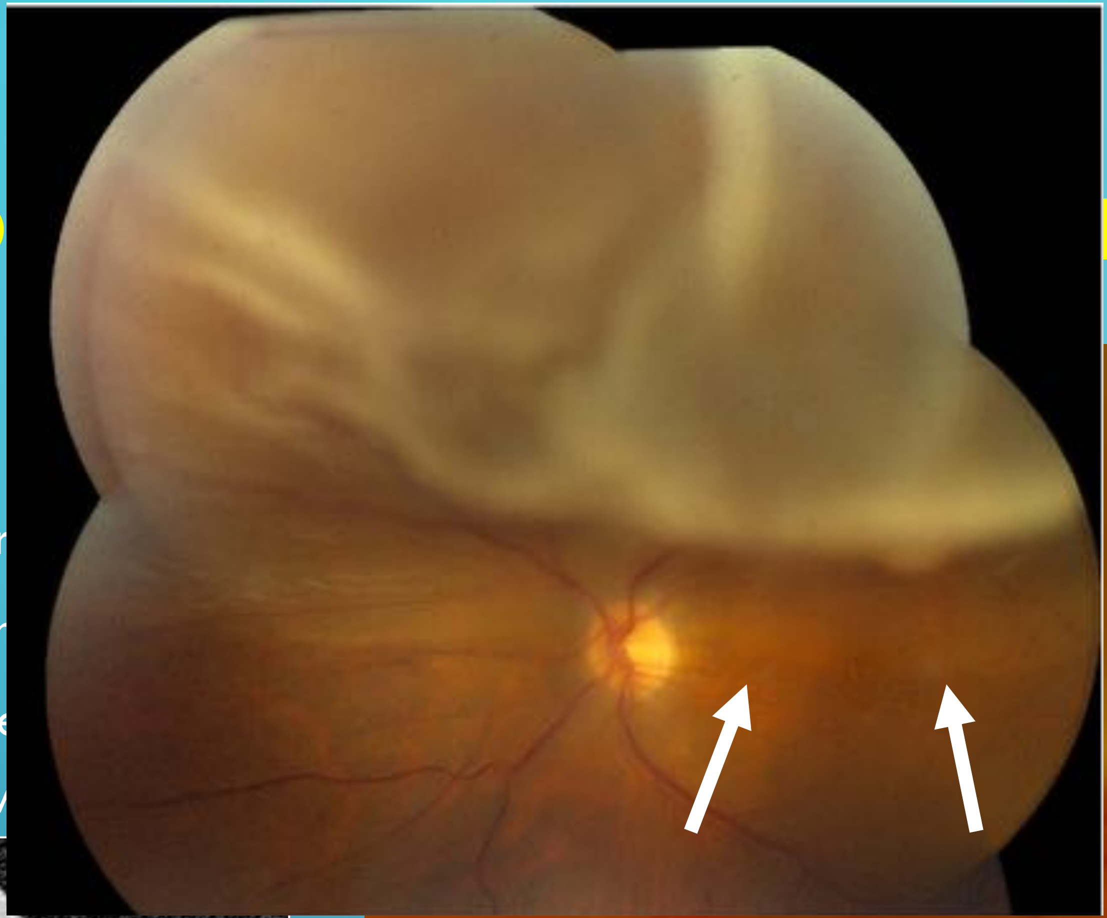
Maybe, but …

THE PRO locks View Of Macula

- Implications:
  - urgency of r
  - Visual progr
  - (of course ne
    for a shallov



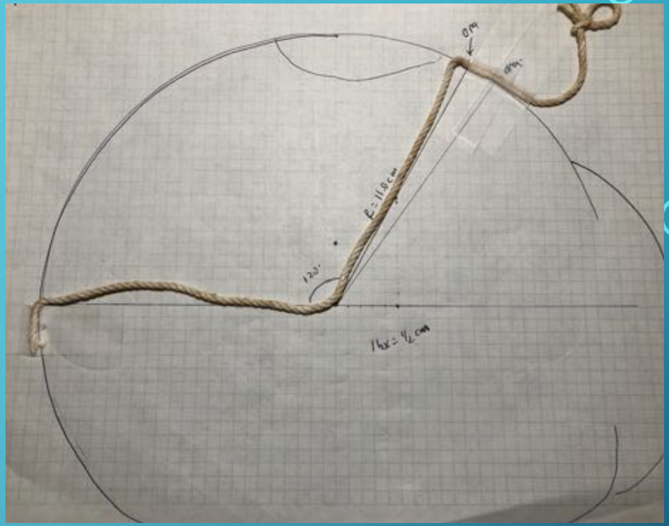


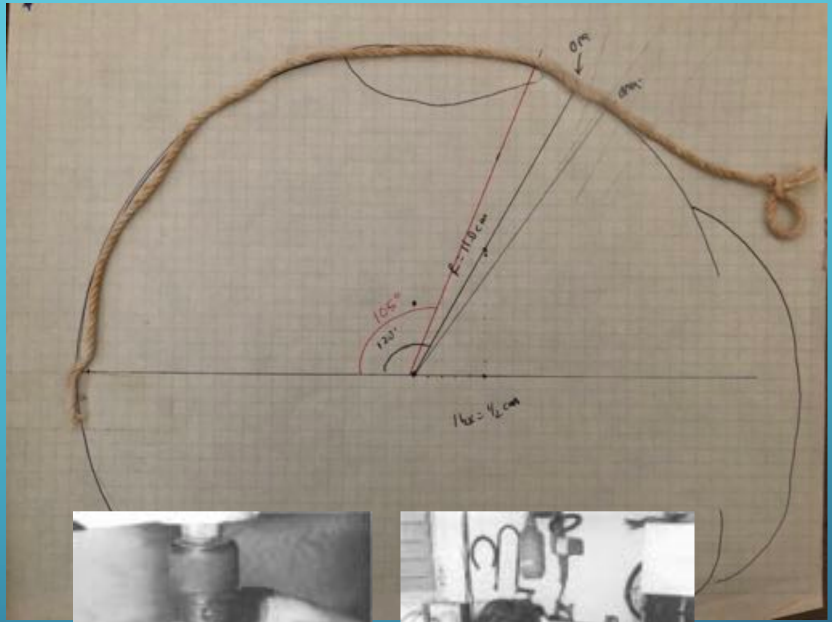


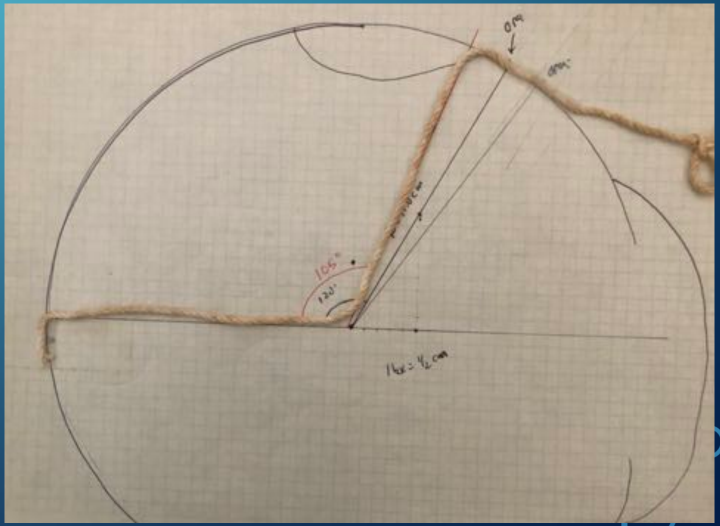
Courtesy of H Flynn, MD

1ST ITERATION: Retina Surface Forms A Sphere and Follows Legs

- Gullstrand's eye
  - R= 12.0 mm
  - When Is retinal arc length < 2 R?
  - **(arc angle/360°) (πR) > 2R**
  - so it <u>is</u> possible for the retina to hang over the optical axis if the ora is >115° from the fovea







BUT, the retina is not a sphere

The Shape Of The Retina Approximates An Ellipsoid

Atchison DA, et al. Invest Ophth Vis Sci 2005;46:2698

- MRIs of 21 emmetropic and 66 myopic eyes (to -12)
- Ellipsoid model (second iteration)
- $x^2/a^2 + y^2/b^2 + z^2/c^2 = 1$
- X-axis is transverse, width; Y-axis is sagittal, height; Z-axis is visual axis, length

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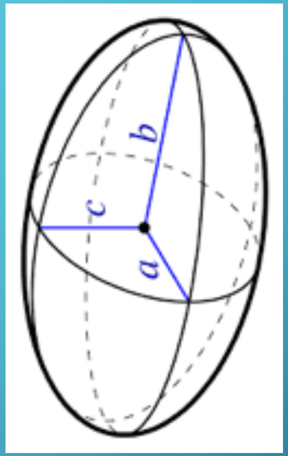
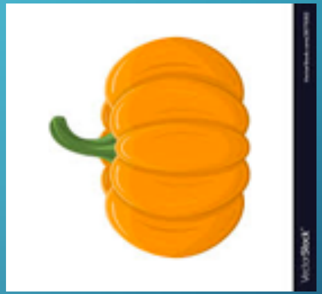
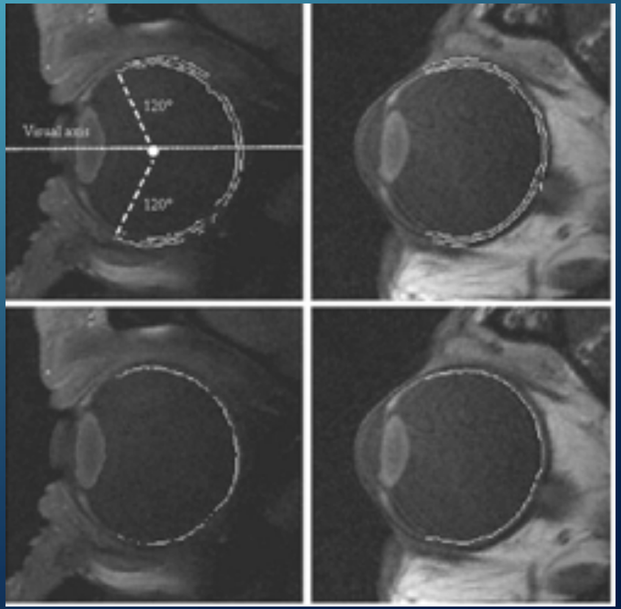
- Tilted 11° vertically (agrees well with macular tilt)
- Decentered 0.5/0.2mm nasally/inferiorly relative to fovea (ie negligibly)
- Problems: How fovea/ora ID'd not clear/MRI resolution only about 1mm



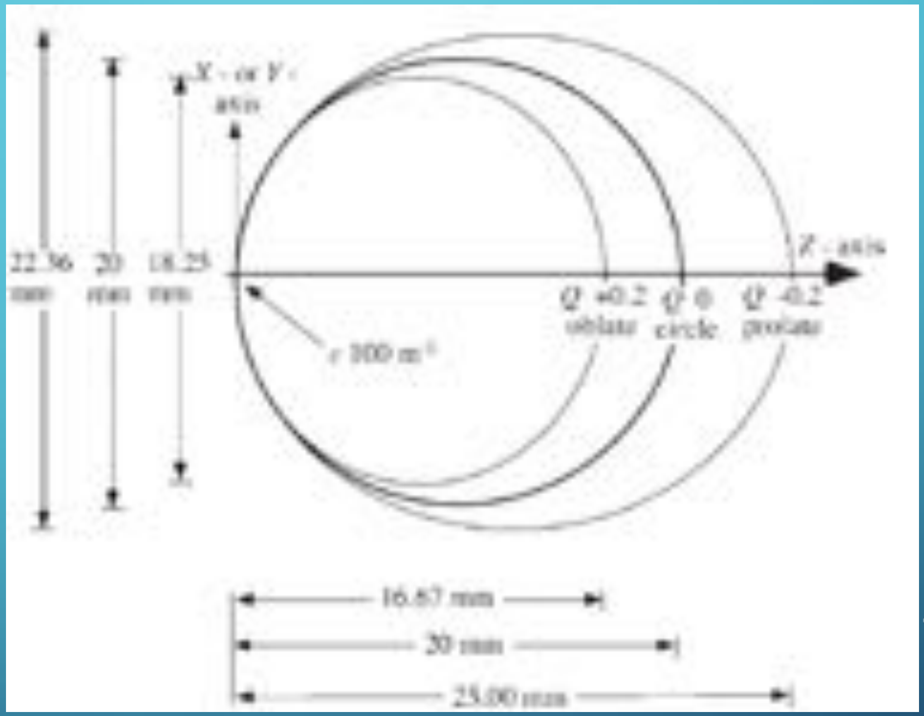


Oblate

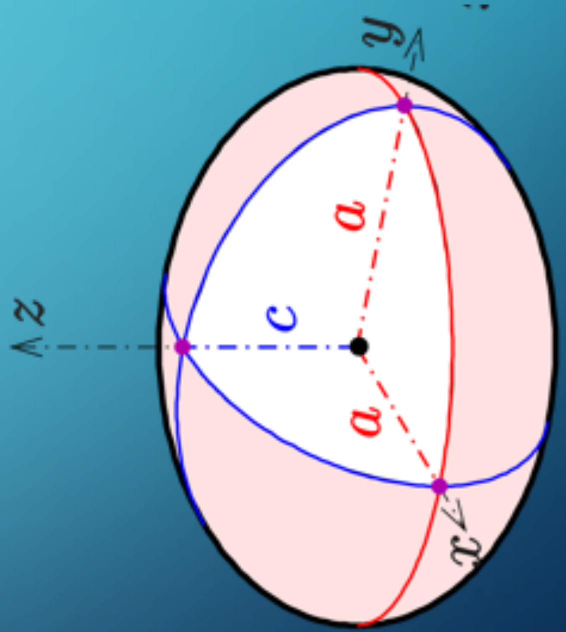


But we can consider just the sagittal (yz) plane

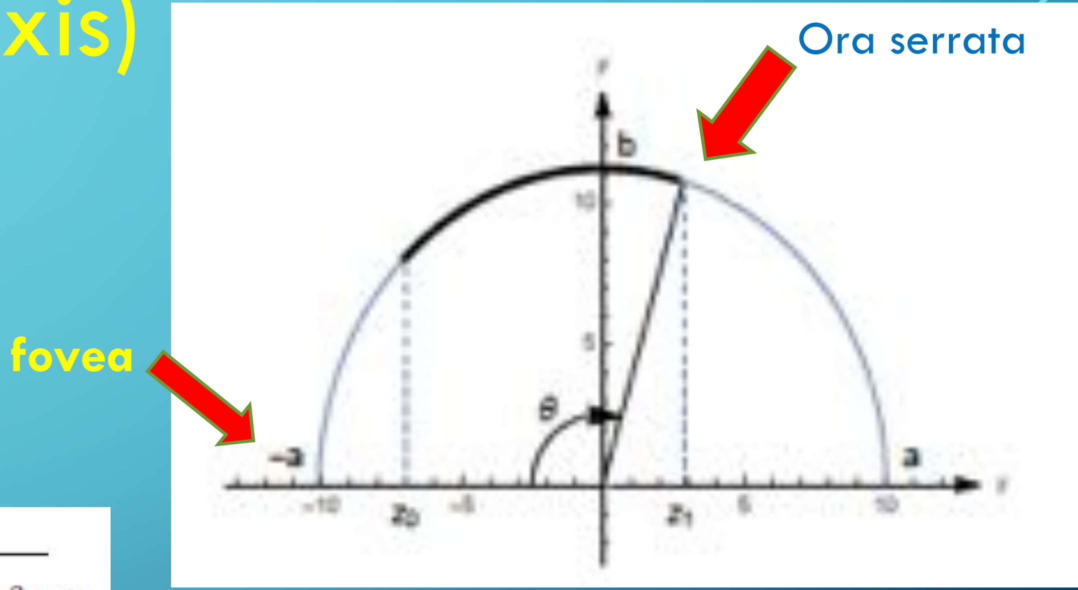
- R_x = 11.40 mm
- R_y = 11.18 mm
- R_z = 10.04 mm
- change (mm/diopter):
  - 0.04/0.09/0.16
- Q is measure of asphericity
  - Prolate (<0): football
  - Oblate (>0): pumpkin



Atchison, IOVS 2005



So how to measure arc length vs distance to obscure the visual axis (z-axis)



First, the arc length: z= R(θ) cos θ, y= R(θ) sin θ, but R changes, so need to parameterize:

x(t) = a cos t , y(t) = b sin t

$$L_e(z_1) = \int_{-a}^{z_1} \sqrt{1 + \left(\frac{df(z)}{dz}\right)^2}\, dz \underset{x=-a\cos t}{=} b \int_0^{\arccos(-z_1/a)} \sqrt{1 - \left(1 - \frac{a^2}{b^2}\right) \sin^2 t}\, dt\,.$$

$$L_e(z_1) = b\, E\left(\arccos\left(-\frac{z_1}{a}\right),\, 1 - \frac{a^2}{b^2}\right).$$

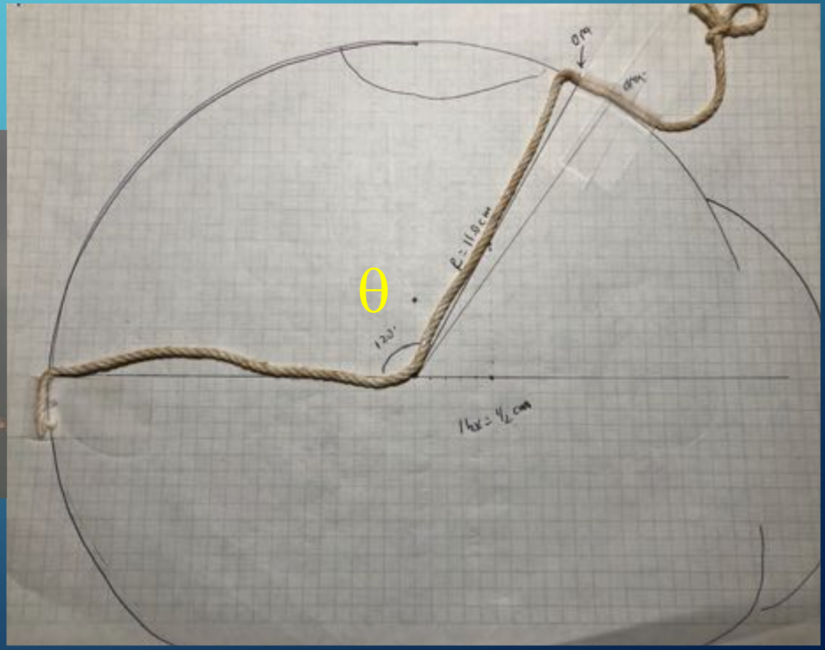
$$E(\phi, m) = \int_0^{\phi} \sqrt{1 - m \sin^2 t}\, dt,$$

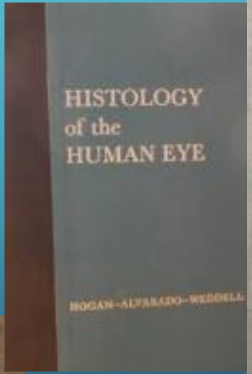
An "elliptic integral of the second kind"
Can't directly solve; use Mathematica to compute

Arc value from fovea to ora is not well established;Some calculations

- If assume R=12.0 mm, and superiorly arc length from the visual axis to the ora, s, is 8+7=15mm
- ½ C = 12 pi = 37.7 mm; then the arc length, S, from the fovea to ora is 22.7 mm
- Solving as if circle, θ =108
- If assume s= 14, then θ =113

- If assume R=11.0,
  - θ = 107 for s=15
  - θ =112 for s=14
- If adjust for arc length vs chord length, R=11.0, 7.7 and 6, then θ = is 105 (at the most)



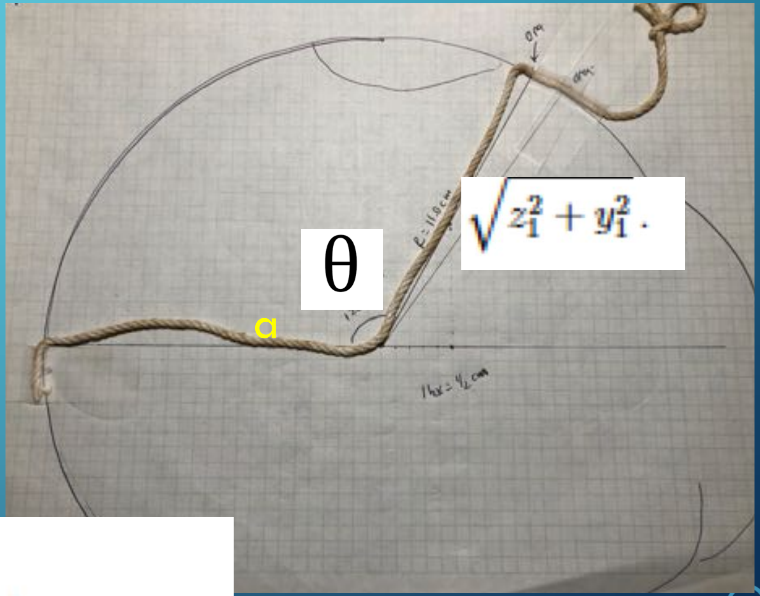


We need to calculate the maximal path the retina could hang down to obscure the visual axis

$$a(m) = 10.04(\pm 0.49) + 0.16\,m\,, \quad b(m) = 11.18(\pm 0.50) + 0.09\,m$$

$$L_{legs}(z_1) = a + \sqrt{z_1^2 + y_1^2}\,.$$

$$t = \arccos\left(-\frac{z_1}{a}\right)$$



So the quantity we are interested in is:

$$L_e(z_1) - L_{legs}(z_1) = b\,E\left(t, 1 - \frac{a^2}{b^2}\right) - \left(a + \sqrt{a^2\cos^2 t + b^2 \sin^2 t}\right)\,.$$

If this is >0 the the retina COULD hang down and obscure view to fovea

Does this vary with myopia degree? NO!

$$L(m,T) = (a + 0.16m) + [(a + 0.16m)^2 \cos^2(T) + (b + 0.09m)^2 \sin^2(T)]^{1/2}$$

- This plots values of m (refractive error) vs the difference of arc length vs length of legs: minimal variation with more myopia
- Conclusion: for all values of arc angle from fovea to ora <114° , the retina CANNOT obscure the view to the fovea and still be attached at the fovea
- BUT this assumes the retinal configuration along straight legs at center

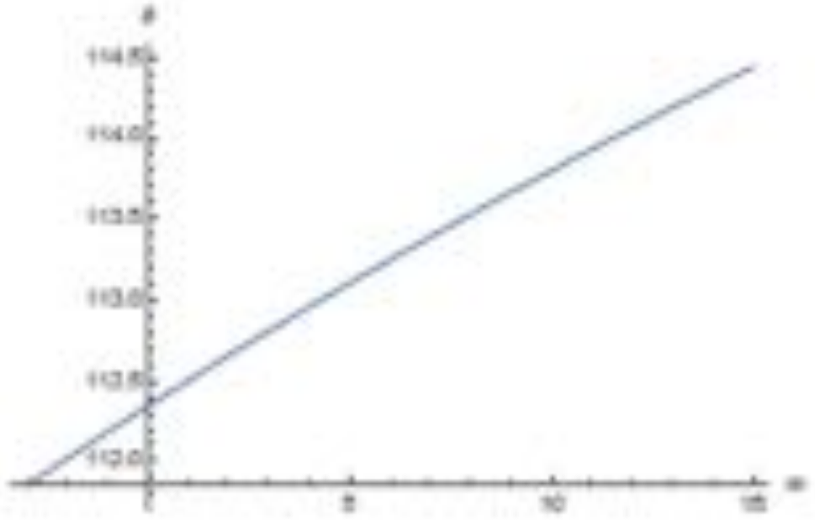
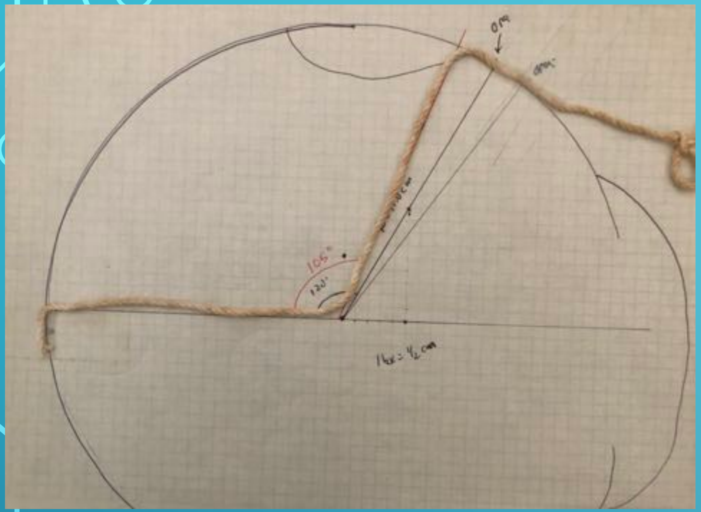
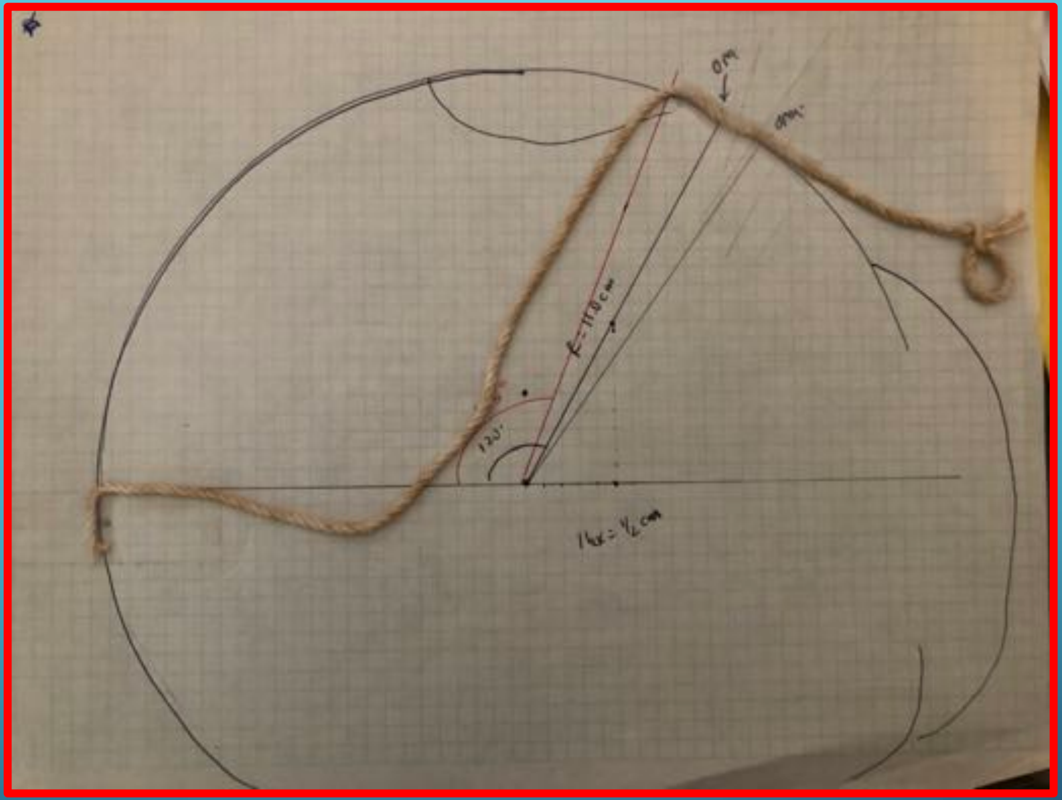


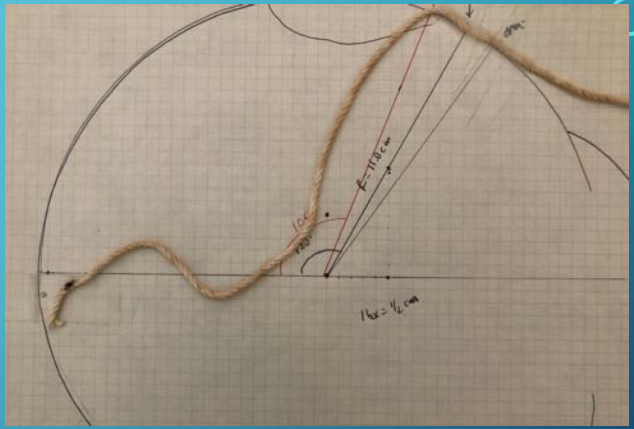
Figure 2: Arc length equals legs length

But straight "legs" is not actual (string model is sphere)…



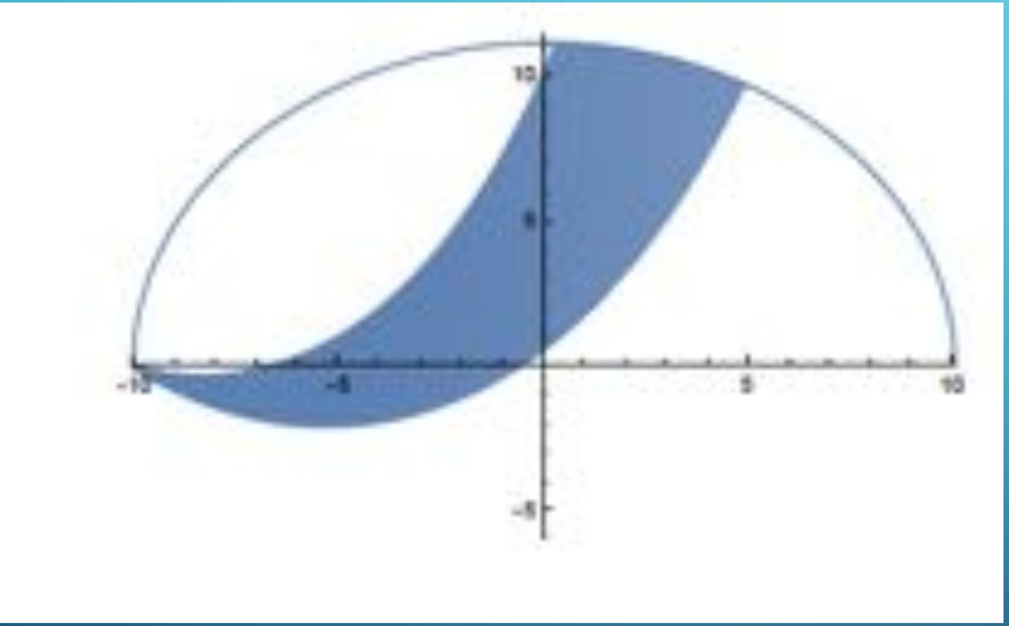


Retina can take a "short cut"



Other less than maximal, but more common instance

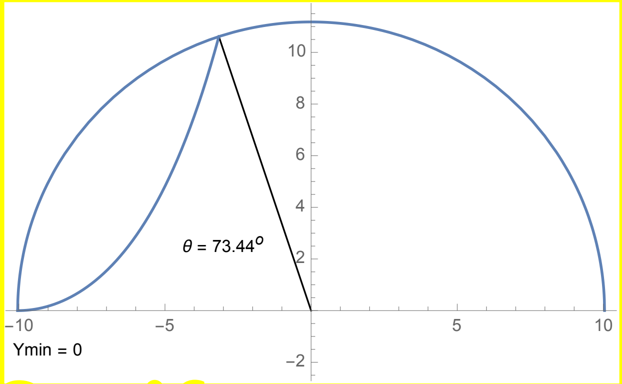
3rd iteration: The retina does not hang as 2 legs, more of a catenary. What is impact on intersection with the optical (z) axis?

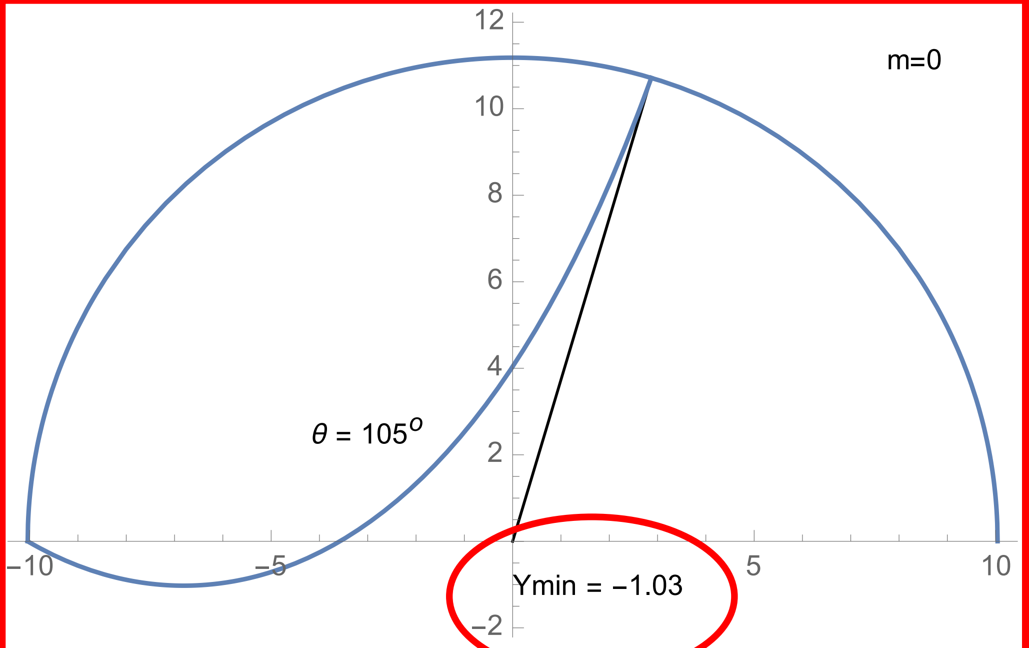


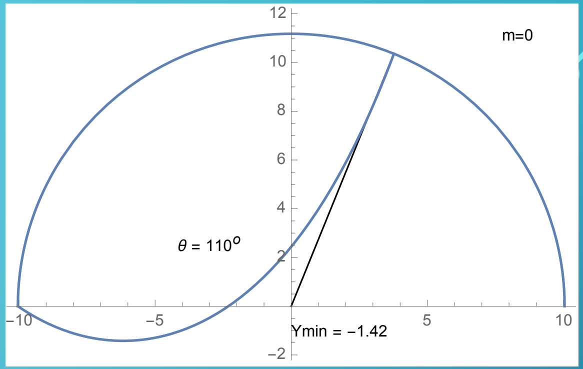
The retina as a hanging cable (catenary)

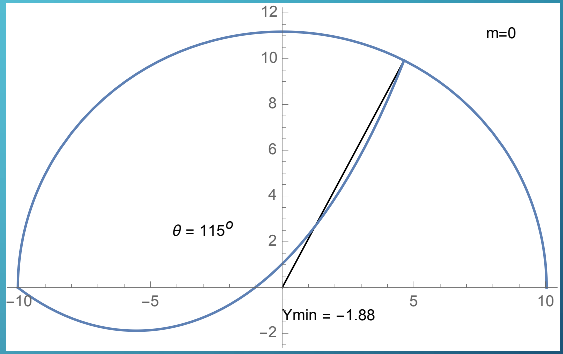
$$y(z) = -\lambda + s\cosh\left(\frac{z+\alpha}{s}\right)$$

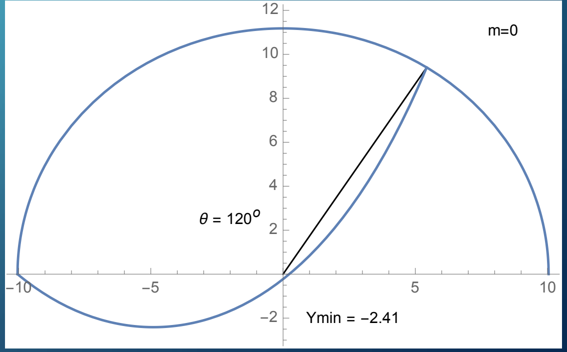
$$L_{cat}(z_0, z_1) = s\left[\sinh\left(\frac{z_1+\alpha}{s}\right) - \sinh\left(\frac{z_0+\alpha}{s}\right)\right]$$







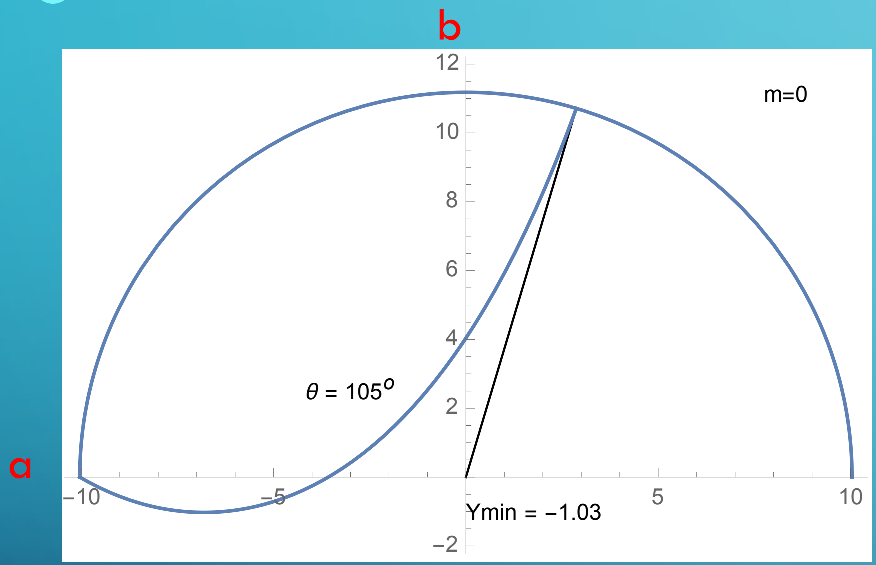


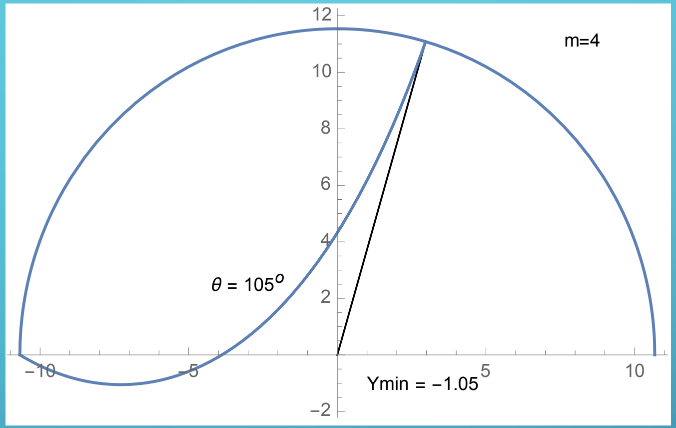


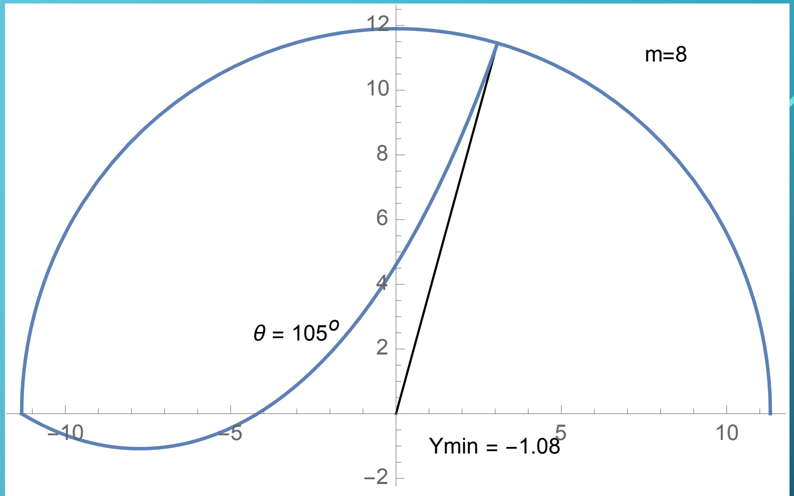
So if cannot see to within 1dd of the fovea, it <u>might</u> be attached

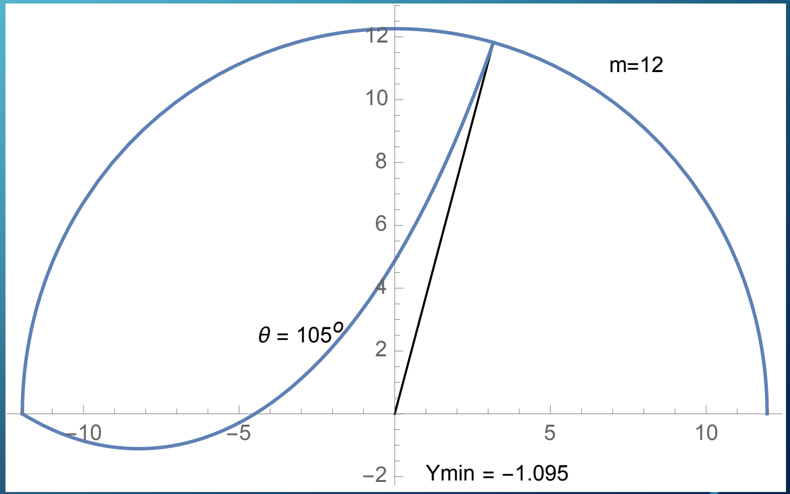
$$L_e(z_1) = b\,E\left(\arccos\left(-\frac{z_1}{a}\right),\, 1 - \frac{a^2}{b^2}\right).$$

How does this vary with increasing myopia? (For 105°)









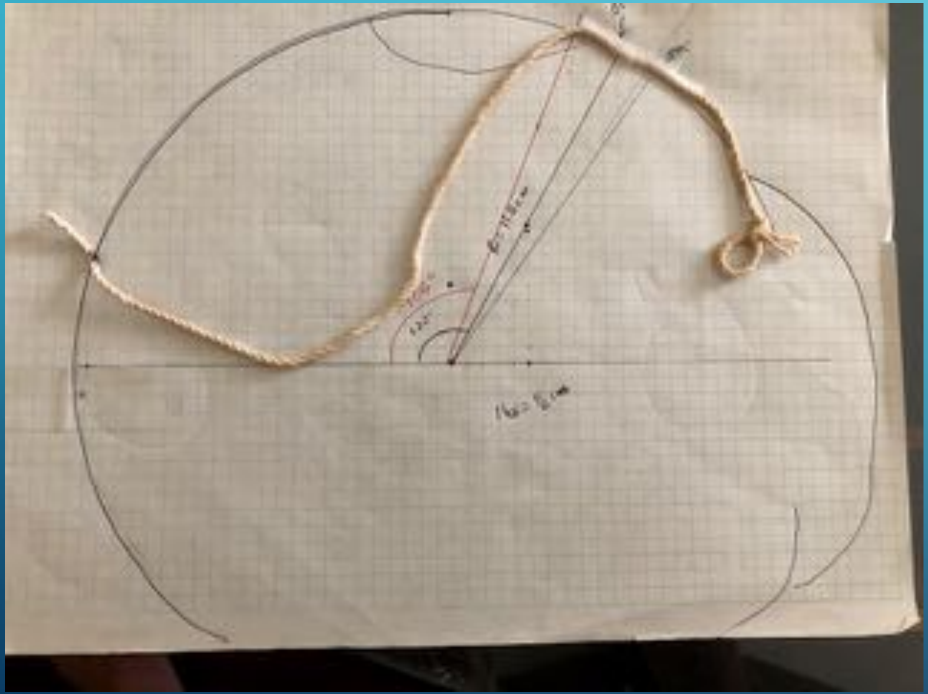
$$a(m) = 10.04(\pm 0.49) + 0.16\,m\,,$$

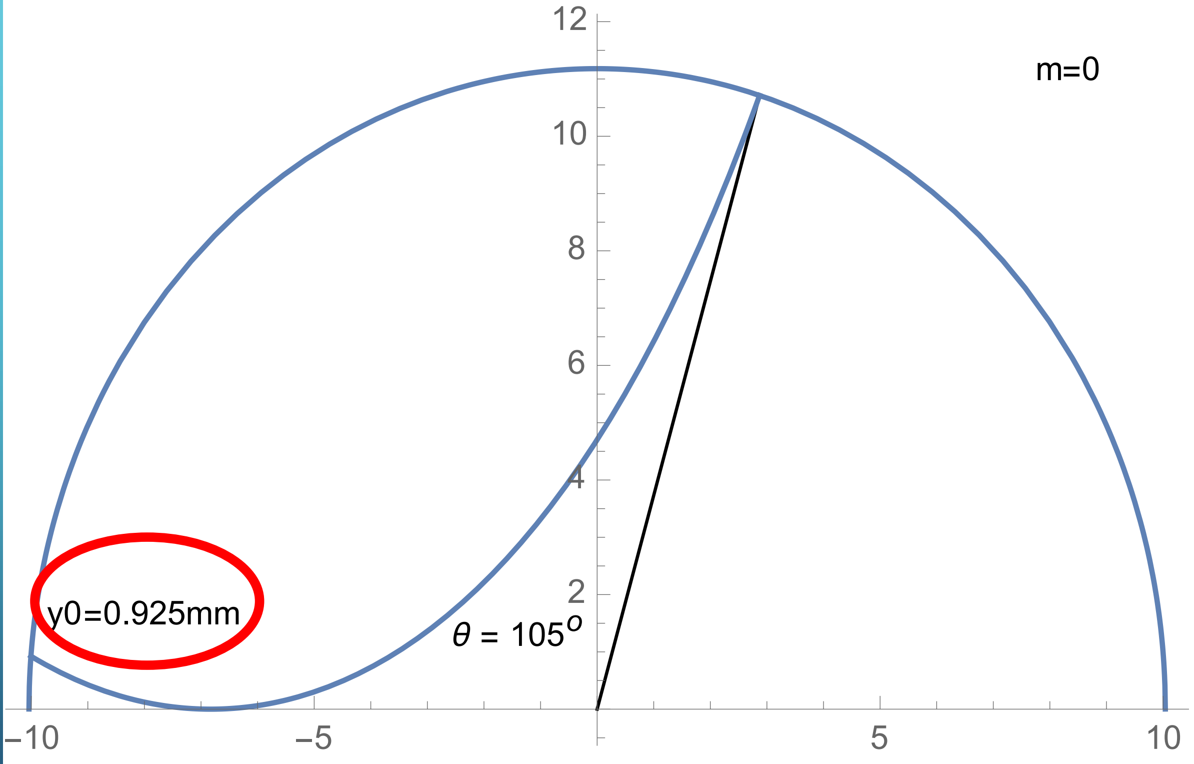
$$b(m) = 11.18(\pm 0.50) + 0.09\,m$$

<u>Not that much</u>, since whole eye expands only slightly asymmetrically

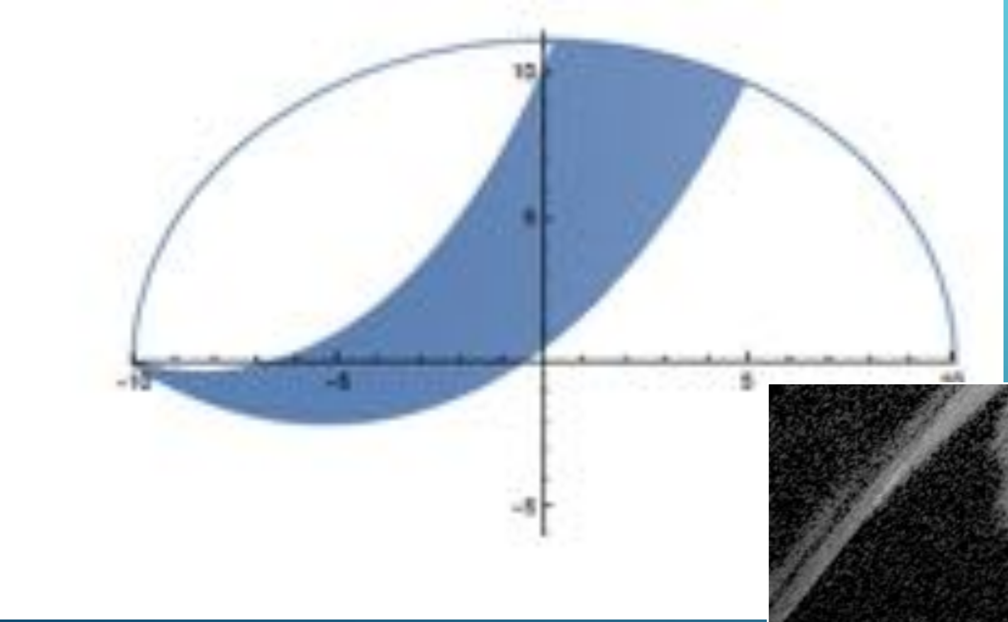
From Atchison, IOVS 2005

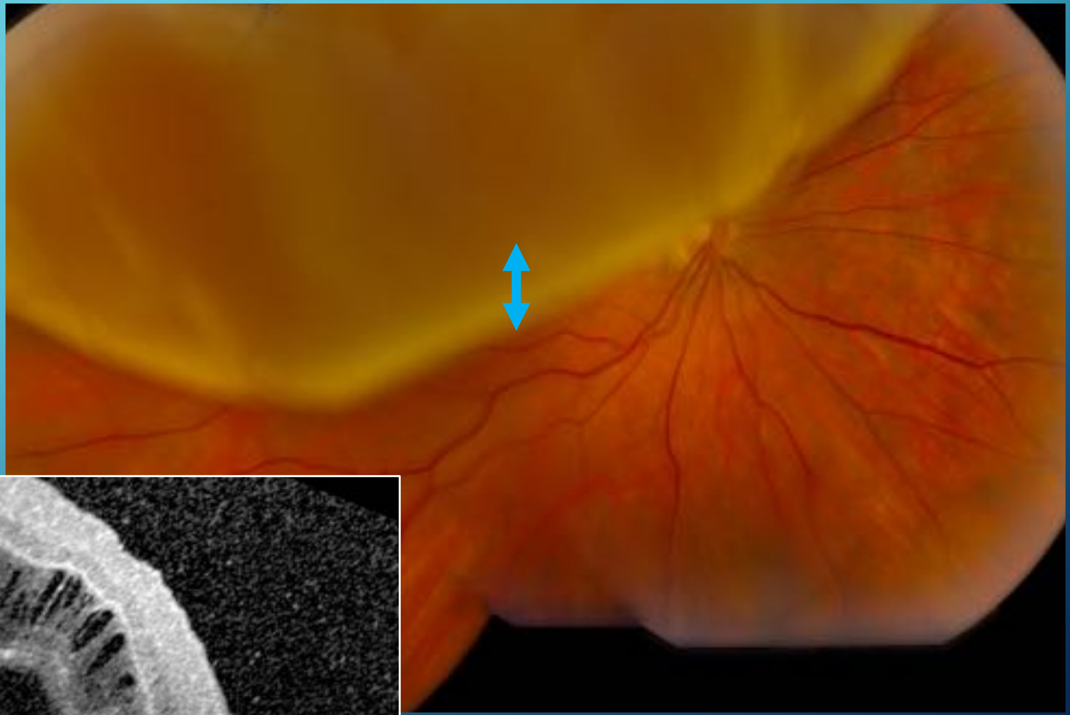
So how above the macula would a mac on tether point have to be to just reach the optical axis?

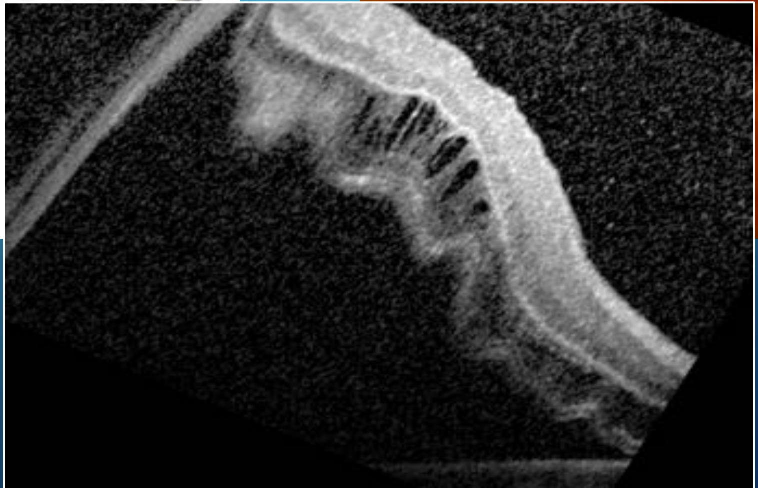




If we can see a certain (extrapolated) distance below the fovea, how might that strengthen our assertion that the macula must have become detached?





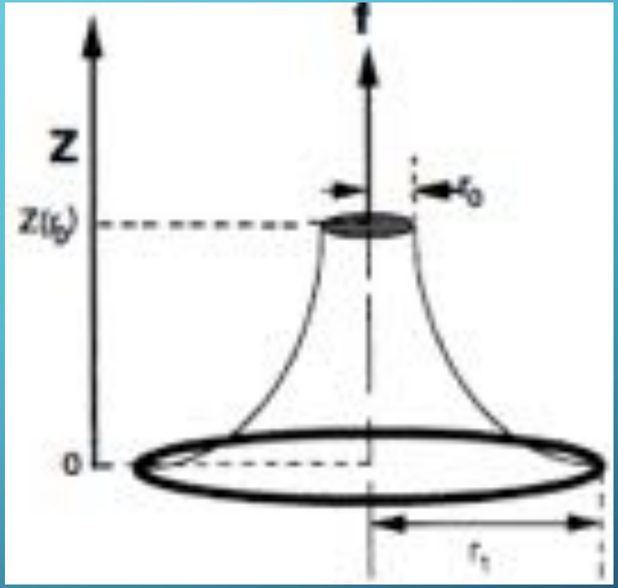


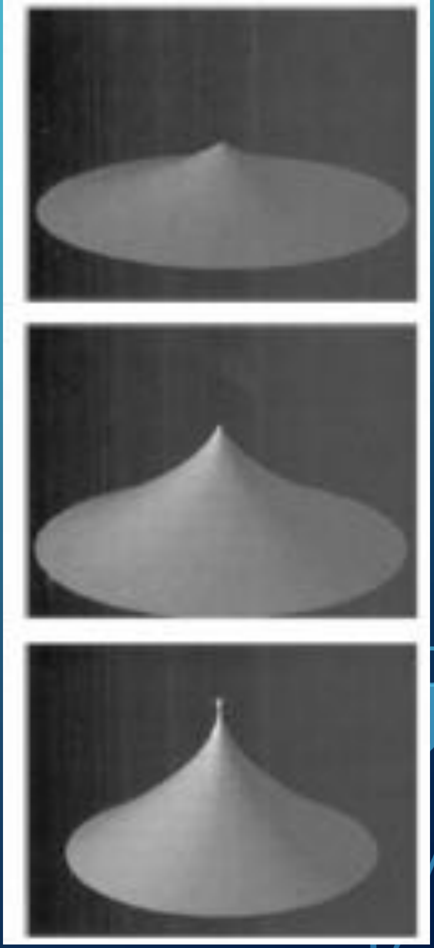
What about retinal stretching? Young's Modulus of the retina

F depends upon specific gravity of SRF vs vitreous; depending upon chronicity, this gradient is minimal

$$E \equiv \frac{\sigma(\varepsilon)}{\varepsilon} = \frac{F/A}{\Delta L/L_0} = \frac{F L_0}{A\,\Delta L}$$

- Bovine retina, excised, glued to end of suture at center of mounted specimen
- Concluded: Young's modulus, 2×10^4 Pa which is about 100X sheet of typical rubber
- But retina is not homogeneous, etc but assumed weak incompressible solid, sigma = 1/2





Jones IL, et al. Eye 1992;6:556-559

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- Evaluated for various degrees of myopia
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- Stretch of the retina probably not significant

Maybe, but …

Conclusions:

- If the retina is blocked >1 dd from center it is detached
-Otherwise, it <u>may</u> be attached
-myopia has a minimal effect on this