Critique of:

AMERICAN ACADEMY OF OPHTHALMOLOGY®

The Globe's Eccentric Rotational Axis

Why Medial Rectus Surgery Is More Potent than Lateral Rectus Surgery

Robert A. Clark, MD,[1,2,6], Joseph L. Demer, MD, PhD[1,2,3,4,5,6]

Purpose: Tables typically recommend greater lateral rectus (LR) than medial rectus (MR) surgical doses for horizontal strabismus of any given magnitude, a difference unexplained by mechanical models that assume globe rotation about its center. We tested this assumption during horizontal ductions.

Design: Prospective observational study.

Participants: Eighteen adult subjects with normal binocular vision.

Methods: Surface coil magnetic resonance imaging at 390 or 430 μm resolution was obtained using 2-mm–thick contiguous axial planes while subjects fixated targets in central, right, and left gaze. Angular displacements of lines connecting the corneal apex through the minor lens axis to the retina were measured to approximate clinical ductions. Globe centers were calculated from their area centroids. Apparent lens and globe-optic nerve (ON) junction rotations around the globe center were then compared with clinical ductions.

Main Outcome Measures: Apparent angular rotations of lenses and globe-ON junctions during horizontal ductions.

Results: Globe-ON junctions appeared to rotate significantly less around globe centers than did lenses for abduction (20.6°±4.[illegible] vs. 27.4°±7.[illegible] ± standard deviation (SD), $P < 0.001$) and adduction (25.3°±6.7° vs. 31.9°±8.3°, $P < 0.001$). Both rotations differed significantly from clinical adduction (27.9°±8.3°, $P < 0.007$), but only in abduction was globe-ON junction rotation significantly less than clinical abduction (28.6°±9.4°, $P < 0.001$). The true geometric globe rotational center was 2.2±0.5 mm medial and 0.8±1.0 mm posterior to the geometric globe center and was displaced farther medially and posteriorly during adduction. This eccentricity imbues each millimeter of MR recession with approximately 30% more trigonometric rotational effect than equivalent LR recession.

Conclusions: The medial and posterior eccentricities of the normal ocular rotational axis profoundly influence horizontal rectus action. The proximity of the globe's rotational axis to the MR shortens its lever arm relative to the LR, explaining why mechanical effects of smaller MR recessions are equivalent to larger LR recessions. *Ophthalmology 2018;■:1–5 © 2018 by the American Academy of Ophthalmology*

No, That's Not Why MR Surgery Is More Potent Than LR Surgery

This paper is so riddled with misrepresentations, errors, and nonsense that it could be a hoax paper designed to ridicule the journal review process, but alas, Clark and Demer intend it seriously:

- The *raison d'être* of the study is a bad-faith misrepresentation of existing biomechanical strabismus models.
- Their "eccentric axis" hypothesis, based on naive and misleading biomechanics, is implausible on its face.

- The results of their study are invalid because their methodology is not what they describe, indeed it is nonsensical, yielding results having nothing to do with center of rotation.
- Their MRI measurements are obviously inaccurate.
- The discussion of their results is innumerate.

And yet, this travesty of science passed peer review at a top ophthalmology journal!

Correspondence to Ophthalmology

[This is the letter that led to Clark & Demer's paper being retracted – slightly expanded and edited for clarity]

To the Editor -

The recent paper by Clark and Demer [1] is based on incorrect characterizations of existing strabismus models, misleading biomechanics, and invalid measurements. Its results should not be relied upon for either scientific or clinical purposes.

The results are invalid. The authors proposed to find the eye's center of rotation by tracking angular movements of internal globe landmarks – the center of the lens and the middle of the globe-optic nerve junction – in horizontal MRI sections as the eye rotated horizontally, on the idea that these movements are equal only when measured from the center of rotation. But, as their Fig 2B shows, what they actually did was quite different: they drew straight lines between their landmarks before and after rotation, and asserted that their intersection was the center of rotation because both landmarks rotated about it by the same angle. This is nonsensical: the opposing angles of intersecting straight lines are always equal, and had different landmarks been chosen, those angles would also have been equal, although the lines would intersect at a different point. Their proposed "true axis of rotation" is simply an artifact of the features they chose to track.

The *raison d'être* of the study is the authors' claim that the LR-MR surgical difference is not explained by existing biomechanical models because all assume that the globe rotates about its geometric center. Both parts of this assertion are wrong. First, Orbit™1.8, the best known such model, does not assume globe rotation about its center or any fixed point [2, 3]. Instead it sums muscular and other forces in a model that reflects orbital geometry to compute both globe rotation and translation. Orbit's predictions of center of rotation are consistent with the literature [4], but not with Clark and Demer's theory. Second, Orbit does indeed predict the LR-MR surgical difference, largely as a consequence of the difference in horizontal rectus muscle lengths. Clark and Demer are welcome to criticize Orbit, but not misrepresent it.

The authors wrongly deprecate the relevance of muscle length (the relaxed, unloaded length of a muscle, eg, when freshly excised) by citing extremes over which muscles can be stretched or relaxed, which has little to do with calculating effects of surgery. They then propose that the real cause of the LR-MR surgical difference is that the LR

is farther from the eye's true center of rotation than the MR, and so, suffers a longer lever arm, but neglect to consider that even if this were so, the oculorotary effects of muscle length and force have opposite dependencies on lever arm, so tend to offset one another. An eye muscle is not like the bicycle chain in the authors' analogy.

Their Fig 2 raises other concerns. Whether you fit a circle to the globe, or simply place a ruler across its image, the geometric center of the globe pictured is not at the point marked "globe center", but about midway between that point and the one marked "axis of rotation". The distance between the two black dots (landmark separation before rotation) is different from that between the white dots (separation after), which cannot be correct unless the globe changed shape. The touted "sub-pixel resolution" of their MRI measurements is false advertising.

In discussing their results the authors argue that with recess-resect surgery the 30% stronger effect of MR surgery combined with the 30% weaker effect of LR surgery sums to a 60% effect, making their eccentric center of rotation seem very important indeed! But these are two ways of saying the same thing, not two independent effects that can be added. The authors have argued, in effect, that if John is 30% taller than Jim, and Jim is 30% shorter than John (itself arithmetically impossible, but never mind), the difference in their heights is 60%!

At the outset, then, there was no problem to solve: the LR-MR surgical difference is well-explained by muscle length. The authors nevertheless discard this explanation for no good reason, propose a weak lever arm alternative, and support it with incorrect and inaccurate measurements. Contrary to their assertions, the eye rotates about a point roughly at its center, which normally moves less than a mm or two, mostly posteriorly [3, 4]. In abnormal eyes, particularly co-contractive syndromes, larger translations can occur.

- Joel M Miller, PhD, Eidactics, San Francisco, CA, USA
- Alan B Scott, MD, Strabismus Research Foundation, San Francisco, CA, USA

Bibliography

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2. Miller JM, Robinson DA. A model of the mechanics of binocular alignment. Comput Biomed Res 1984;17:436-70.
3. Miller JM, Pavlovski DS, Shamaeva I. Orbit™ 1.8 Gaze Mechanics Simulation. San Francisco: Eidactics, 1999.
4. Carpenter RHS. Movements of the Eyes, 2nd ed. London: Pion, 1988; 114-6.

Dialog with Dr Demer

[We had a brief exchange on the issues in this paper, until Demer declined to continue – edited for clarity].

Fixing the Analysis

[JLD]: We have carefully read your correspondence, spent considerable time thinking about the issues and repeating analysis, and we thank you for pointing out an error in our original analysis. Your insight is valuable. While your criticism of our analytic method is valid, re-analysis of the data using a rigorous approach with an orbital coordinate system supports our original conclusion anyway, albeit with modestly different numbers. . . . The conclusion of the paper remains valid that the eye rotates about an eccentric point, and that this point is medial to globe center, and that this reduced the medial rectus and increases the lateral rectus arms.

[JMM]: Joe, your specious analysis is more than a mere blemish. You described a reasonable method, and then employed a similar-seeming but nonsensical one that yielded an eccentric point having nothing to do with center of rotation. You are now claiming that a rigorously correct analysis happens to produce essentially the same results as the one that was artifactually determined by your choice of landmarks. This sort of serendipity requires very close scrutiny.

Mischaracterizations of Orbit™

[JMM]: Contrary to your assertion, Orbit does not assume that the globe rotates about its geometric center, or about any fixed point. And Orbit does indeed predict the LR-MR surgical difference, largely as a consequence of the difference in muscle lengths.

[JLD]: While you are correct that Orbit does not assume that the globe rotates about its exact geometric center, the account of translation of the globe predicted for the normal eye by Orbit is very small, and compatible with quantitatively negligible eccentricity of the ocular rotational axis. We would be happy to acknowledge our mathematical imprecision in this regard. From a practical standpoint, however, the behavior of Orbit does not meaningfully differ from our statement.

[JMM]: Joe, you're confusing two completely different things: [1] A model incapable of predicting non-central rotation axes with [2] A model that carefully calculates translation, compatible with published measurements but different from your theory. Are you trying to mislead credulous readers, or are you actually this confused?

[JLD]: The prediction of the LR-MR surgical difference in Orbit does not guarantee that the rationale for this prediction is correct. It is possible to get the right result for the wrong reasons, as you know. We are not out to bash Orbit gratuitously; however, it is a couple of decades old and you know that it does not incorporate the new anatomical and physiological findings since your wrote the model. We'd love to see an update to Orbit. It is still a beautiful work.

[JMM]: Having now admitted that Orbit does indeed predict the LR-MR surgical difference, you've shifted to generalized Orbit-bashing, based mainly on it not embodying your own dubious claims of the past 10 years (more about which in future).

Naive & Misleading Biomechanics

[JMM]: You wrongly discounted the importance of muscle length by confusing it with path length. You ignored muscle force with a misleading "bicycle chain" model. Such specious arguments do nothing to advance clear thinking in our field, which is a value I would like to think we share.

[JLD]: I do not see how you or anyone else can confidently determine the rest (zero tension) length of an extraocular muscle, which is what you need to make a convincing argument here. How would you know the length of a human muscle under zero load and with zero innervation? Regardless of muscle length, lever arm is still a major contributor to oculorotary torque.

[JMM]: Excising and abutting a ruler would be one way to measure resting length. You could also estimate lengths from MRI assuming reasonable primary position stretch ~8%. There are other ways. You are denying a well-verified empirical length difference and obfuscating elementary mechanical concepts. And, yes of course, a given force exerts more torque on a long arm. That was <u>my</u> point, against yours! <u>Your</u> point was that the muscle on the longer lever arm was relatively <u>disadvantaged</u>, requiring more surgery for the same oculorotary effect. Your arguments are shifting and incoherent.

Obviously Inaccurate MRI Measurements & Innumeracy

[JMM]: Whether you fit a circle to the globe, or simply place a ruler across its image in your Fig 2, the geometric center of the globe pictured is not at the point marked "globe center". The distance between the two black dots (landmark separation before rotation) is different from that between the white dots (separation after), which cannot be correct unless the globe changed shape.

[JLD]: Our MRI images are generally excellent, but the human eyeball does some odd things during actual horizontal duction. An additional source of noise may be dynamic deformation of the globe during duction, but our raw axial images leave no doubt that human horizontal duction is eccentric.

[JMM]: So, you like our theory that the globe changed shape? Would you then say Fig 2 is representative of your MRI measurements? Finally, would you also defend your calculation that the 30% stronger effect of MR surgery combined with the 30% weaker effect of LR surgery sums to a 60% effect?

[Demer declined to continue the discussion.]