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Quantification of long anterior lens zonules and their resulting zonule free zone sizes

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Long anterior lens zonules (LAZ) are characterized by zonular fibers, often pigmented, that extend more central than usual on the anterior lens capsule, sometimes causing marked reduction in the zonule-free zone (ZFZ) (Fig. 1).⁽¹⁾ One LAZ variety occurs with genetic mutation and late-onset macular degeneration.⁽²⁾ Another type, which may have a prevalence near 2%, has unknown etiology and association with age >50 years, female gender, hyperopia, shorter axial length, and persistent pupillary iris strands.⁽³⁾ LAZ have received attention due to possible association with open- and narrow-angle forms of glaucoma⁽⁴⁾ and due to concern that their cutting may cause capsular tearing following cataract surgery.⁽¹⁾

To further characterize the LAZ trait, we quantified LAZ and their ZFZs using subjects from a prior study who had extensive testing and standardized documentation that included post-dilation retro-illumination photos (16x) of the anterior capsule.⁽⁴⁾ To view the entire intra-pupillary lens without obscuration, photos were taken with light beams just inside the temporal and nasal pupil borders. We then developed a custom program (MATLAB® 6.1, The MathWorks, Inc., Natick, MA, USA) to merge unobstructed image halves and enhance LAZ for mapping (Fig. 1).

One observer (CM), masked to subjects, reviewed randomized images and marked the anterior tip and peripheral tip of each LAZ fiber, which was often limited by the pupil border (Fig. 1). Two other observers (TN, DKR) reviewed tracings before acceptance. Fiber counts and meridians were then calculated. For all subjects who had acceptable lens optic section photos at the time of the retro-illumination photos, ZFZ diameters were estimated from “pupil to visible iris diameter” ratios in relation to different diameter assumptions, i.e.,

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11.5, 12.0, and 12.5 mm.⁽⁵⁾ Three sizes were used in order to provide sensitivity analysis. Another masked observer (SF) determined the ratios using software (EyeCap™ SL, V3) provided with the Haag-Streit BX900® photo slit lamp (Haag-Streit AG, Koeniz, Switzerland).

Our analyses found that number of LAZ varied greatly, with many subjects having relatively few LAZ (Table 1). We also found a predilection for superior quadrants (Fig. 2). Mappings highlighted a propensity for fibers to extend more centrally in some clock-hours than others, and estimations indicated that 50% of eyes had ZFZs ≥ 3.0 mm in diameter. We didn't detect any relationship between ZFZ size and number of LAZ, age, or refractive error ($P>0.1$). Number of LAZ number also didn't vary significantly with age or refraction (Fig. 2). Although we didn't find the highest number of LAZ in the oldest subjects, it is interesting that we have rarely detected LAZ in people <50 years of age.⁽⁴⁾ The reason for this remains unknown, and since LAZ are often non-pigmented, better visibility from pigmentation doesn't adequately explain their detection in later years. Since we did not find significant variation of ZFZ with age, this also suggests that ZFZ size might be established early after LAZ become clinically apparent.

The tracings highlighted a peculiar feature of LAZ, i.e., a “segmental” appearance in which fibers end abruptly without visible extension all the way peripherally (Fig. 1). Why this happens remains unexplained, but determining its reason might improve knowledge of lens/zonule physiology. In total, these data help further characterize the LAZ trait, which remains understudied given its suggested prevalence, potential relationship to glaucoma and macular degeneration, and importance relative to cataract surgery.

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Figure 1.

Normal zonules vs. LAZ (Top Left). Retro-illumination images of pupil with different light positions and example lens optic section photo used to calculate ratio of pupil diameter to visible iris diameter (Top Right). LAZ tracing of nasal/temporal halves of intra-pupillary lens, and halves merged and overlaid onto the pupil zone for illustrational purposes. ZFZ borders are based on tip of most anterior extending zonule. Final ZFZ is based on smaller half circle (Bottom Left). Number of LAZ plotted against ZFZ size. Plot includes least squares regression lines with 95% confidence limits (Bottom Right).

Figure 2.

Graph showing LAZ predilection for superior quadrant (SUP=superior, NAS=nasal, INF=inferior, TEMP=temporal) (Top Left). Number of LAZ and ZFZ size plotted against age. Plots include least squares regression lines with 95% confidence limits (Top, Bottom Right). Histogram showing distribution of ZFZ diameters (Bottom Left).

Table 1
[†]Long anterior zonule subject characteristics

TOTAL SUBJECTS*			
^{††} N=59 (54 female, 5 male)			
[‡] Mean Age = 70.6 ± 9.0 yrs (53-91 yrs)			
RIGHT EYES		LEFT EYES	
N=51 (47 female, 4 male)		N=51 (48 female, 3 male)	
Mean Age = 70.7 ± 9.1 yrs (53-91 yrs)		Mean Age = 70.5 ± 9.7 yrs (53-91 yrs)	
^{‡‡} SR = +2.14 ± 2.09 D (-1.88 to +8.38 D)		SR = +1.43 ± 2.46 D (-10.38 to +7.38 D)	
Median Number (Range) LAZ Per Eye		Median Number (Range) LAZ Per Eye	
52 LAZ (5-207)		62 LAZ (8-267)	
Median Number (Range) LAZ by Quadrant / Clock hours		Median Number (Range) LAZ by Quadrant / Clock hours	
24 LAZ (1-79)	Superior / 10:30-1:30	28 LAZ (0-107)	Superior / 10:30-1:30
9 LAZ (0-61)	Nasal / 1:30-4:30	9 LAZ (0-77)	Nasal / 7:30-10:30
7 LAZ (0-54)	Inferior / 4:30-7:30	6 LAZ (0-110)	Inferior / 4:30-7:30
3 LAZ (0-50)	Temporal / 7:30-10:30	4 LAZ (0-61)	Temporal / 1:30-4:30
Right Eyes with ZFZ Estimates		Left Eyes with ZFZ Estimates	
N=42 (38 female, 4 male)		N=41 (38 female, 3 male)	
Mean Age = 71.1 ± 9.0 yrs (53-91 yrs)		Mean Age = 69.6 ± 9.4 yrs (53-91 yrs)	
SR = +2.15 ± 2.27 D (-1.88 to +8.38 D)		SR = +1.38 ± 2.54 D (-10.38 to +7.38 D)	
Iris Diameter Assumption	Median ZFZ Diameter	Iris Diameter Assumption	Median ZFZ Diameter
11.5 mm:	2.9 mm (1.8-5.6 mm)	11.5 mm:	3.0 mm (1.5-6.6 mm)
12.0 mm:	3.0 mm (1.9-5.8 mm)	12.0 mm:	3.1 mm (1.6-6.9 mm)
12.5 mm:	3.2 mm (2.0-6.0 mm)	12.5 mm:	3.2 mm (1.6-7.2 mm)

[†] For study purposes the criterion for LAZ was zonular fibers present >1.0 mm central to the normal zonule insertion zone, and to insure definitive cases, only eyes with >5 LAZ fibers were included.

^{††} Abbreviations: D, diopters; LAZ, long anterior zonules; mm, millimeters; N, number; SR, subjective refraction; Yrs, years; ZFZ, zonule-free zone.

[‡] Analyses conducted using The SAS® System, 9.3 for Microsoft Windows® (SAS Institute, Inc., Cary, NC, USA)

^{‡‡} Spherical equivalent refractive error.

* Institutional Review Board approval was obtained for the investigation.