Development of a Classification System or Presbyopia Progression Based on Age and Near Visual Acuity

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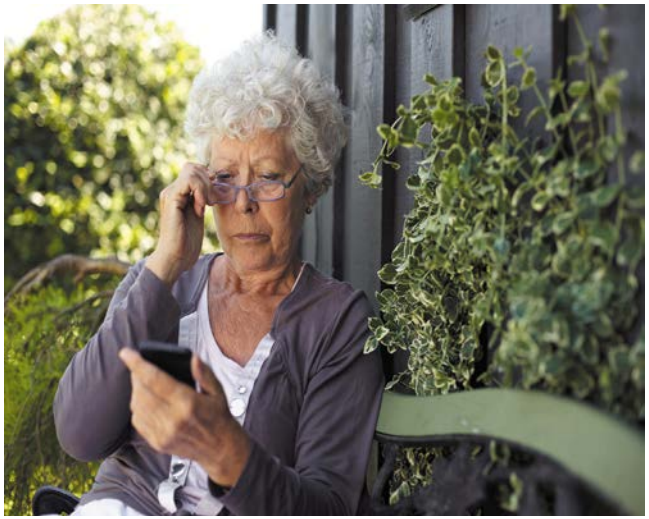
Background

- Despite a strong correlation of presbyopia with age, there is no standardized mechanism for classifying presbyopic stages.

- Such a standardized criterion could be vital to preventing age-induced progression of presbyopia and other ocular co-morbidities associated age

- Classification would also aid in treatment recommendations



Purpose:

Purpose: To develop an objective measurement tool for tracking presbyopia progress based on age and near visual acuity.

SYMPTOMS

- The need to hold reading material at arm's length.
- Blurred near vision
- Headache
- Fatigue
- Symptoms worse in dim light.

Setting:

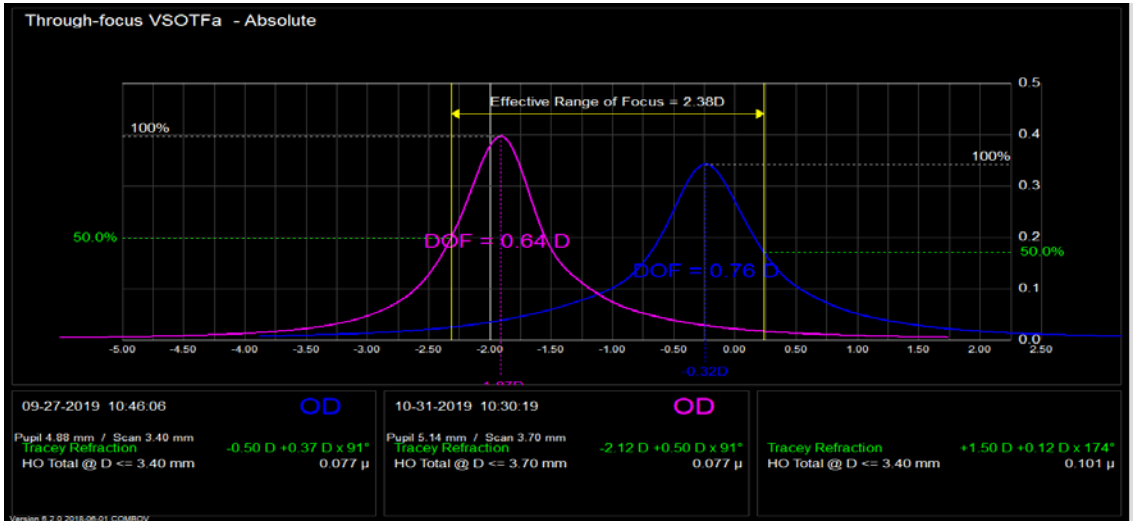
- Subjects were enrolled in an early feasibility study and separated into 4 categories based on disease progression.

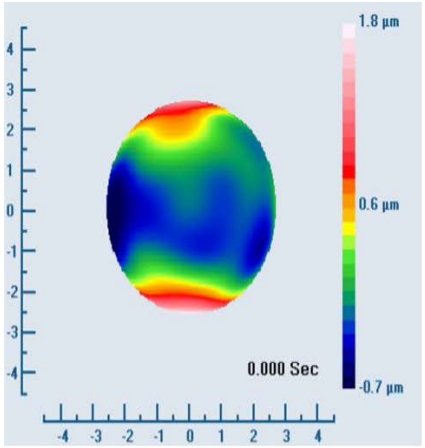
Method of Accommodation Measurement: Wavefront Aberrometry

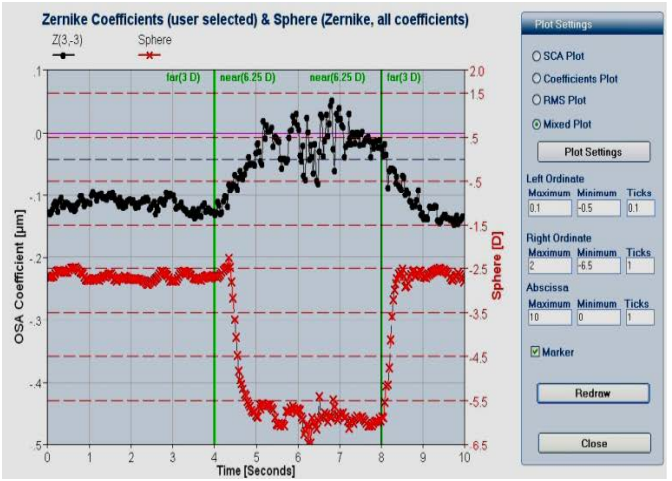
Objective Method to assess

accommodation:

- Wavefront aberrometry at distance and 40cm
- Affected by Pupil Size
- Light illumination







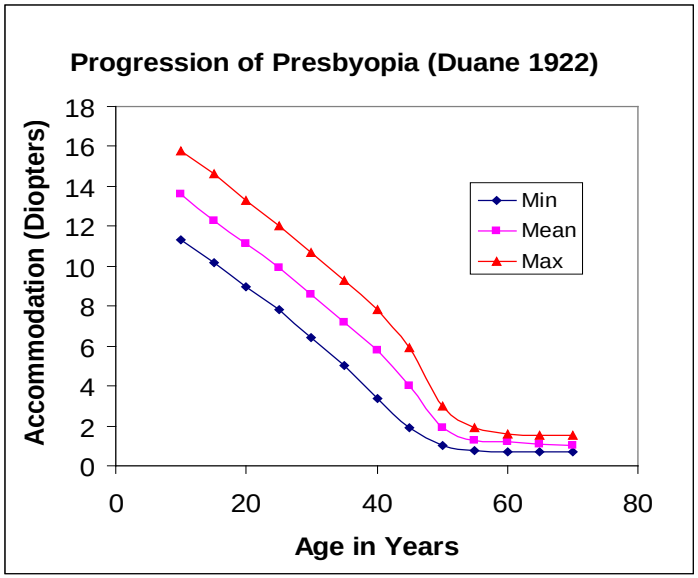
Method of Accommodation Measurement: Push up

- Push up method Increases Measured Accommodative Amplitude due to size magnification
- This report over-estimates level of accommodation due to erroneous testing methods.
- Residual Accommodation is often estimated:

(15-Age/4) = Diopters

But this estimate is *higher* than minus-lens testing results.

- Predicts Presbyopia progression as linear.



Approximate amplitude of accommodation relative to age

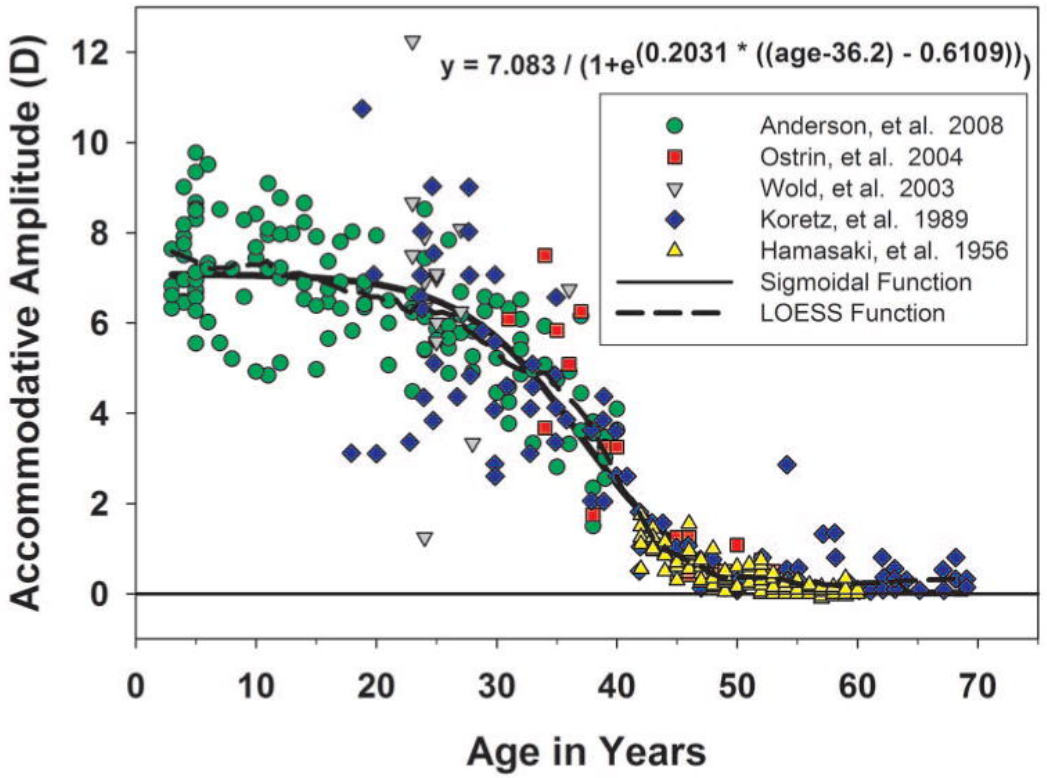
Age	Amplitude of accommodation (D)
45	3.5
50	2.5
55	1.75
60	1.00
65	0.50
70	0.025

Duane A. Studies in monocular and binocular accommodation with their clinical applications. American Journal of Ophthalmology. 1922 Nov 1;5(11):865-77.

Elements of refraction. 12/09/2014. Optician. https://www.opticianonline.net/cet-archive/30

Methods: Accommodation Measurement: Minus to Blur

- Minimal decline in accommodative amplitude throughout childhood.
- Rapid decline in amplitude from age 20 into the 50s.
- Amplitude reaches a level of 0.5 D and continues to decline slowly toward 0 by age 60
- Predicts Presbyopia progression to be Sigmoidal
- Authors used this method



Ostrin LA, Glasser A. Accommodation measurements in a prepresbyopic and presbyopic population. *J Cataract Refract Surg.* 2004;30:1435–1444.

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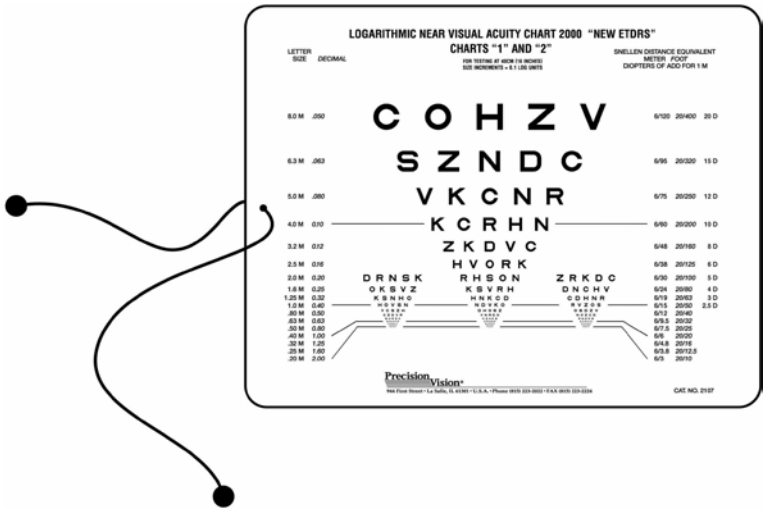
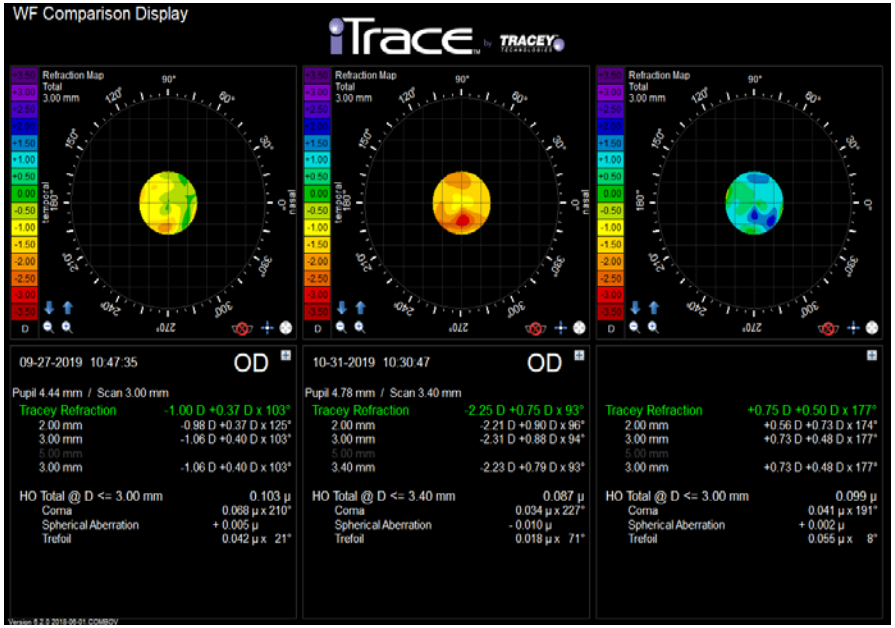
Koretz JF, Kaufman PL, Neider MW, Goeckner PA. Accommodation and presbyopia in the human eye-aging of the anterior segment. *Vision Res.* 1989;29(12):1685–1692.

Hamasaki D, Ong J, Marg E. The amplitude of accommodation in presbyopia. *Am J Optom Arch Am Acad Optom.* 1956;33(1):3–14.

Methods : Visual Acuity & Refraction

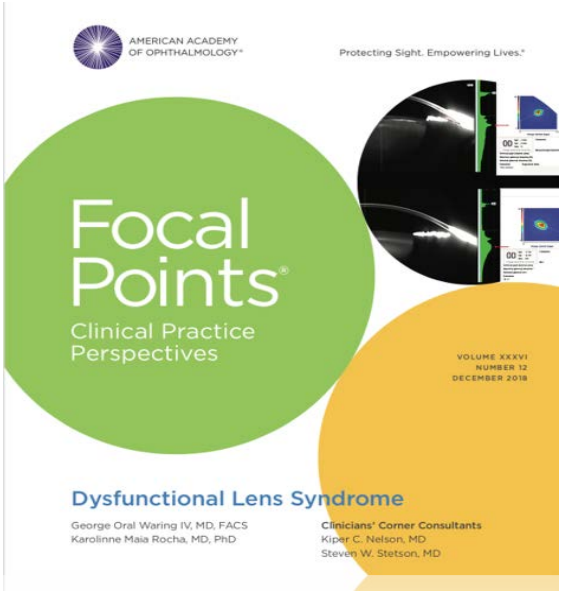




- Patients were over 40 years of age and showed loss of accommodative ability.
- Visual outcomes were assessed using the Early Diabetic Retinopathy Study (EDTRS) logMAR charts and wavefront aberrometry.
- Each patient was evaluated multiple times.

Assessment : Presbyopia and DLS

- Assessment of presbyopia was historically measured optically in the strength of required reading addition and considered an entirely refractive and nonpathological entity.
- Dysfunctional Lens Syndrome (DLS) has essentially combined the pathology of presbyopia and cataracts, increasing interest in staging visual dysfunction.
- Attempt to characterize and standardize a triad of aging changes of the crystalline lens: Presbyopia, Higher order aberrations and Lens opacities

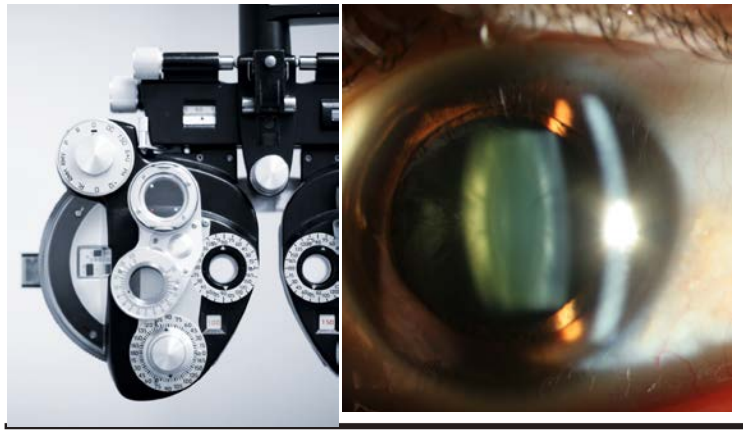


Waring, George & Rocha, Karolinne. (2018). Characterization of the Dysfunctional Lens Syndrome and a Review of the Literature. Current Ophthalmology Reports. 6. 10.1007/s40135-018-0190-3.

Assessment: Dysfunctional Lens Syndrome

Assessment of Presbyopia, Higher order aberrations and Lens opacities

- LOCS III
- Ocular Scatter Index
- Dysfunctional Lens Index
- Aberrometry (whole eye and combined)
- Refraction at chosen working distance



STAGES OF DLS

STAGE 1

42 TO 50 YEARS OF AGE

- Crystalline lens starts to stiffen and loses focusing power
- Loss of near vision
- Development of higher-order aberrations

POTENTIAL TREATMENT OPTIONS

- Corneal laser monovision or blended vision
- Corneal inlays

STAGE 2

50 YEARS OF AGE OR OLDER

- Loss of accommodation
- Light scatter formation and degrading vision
- Decreased contrast and night vision

POTENTIAL TREATMENT OPTIONS

- Refractive lens exchange
- Corneal laser monovision or blended vision

STAGE 3

65 YEARS OF AGE OR OLDER

- Full cataract
- Poor visual quality
- Nucleus of the lens yellows, affects color perception
- Opacity with degraded vision

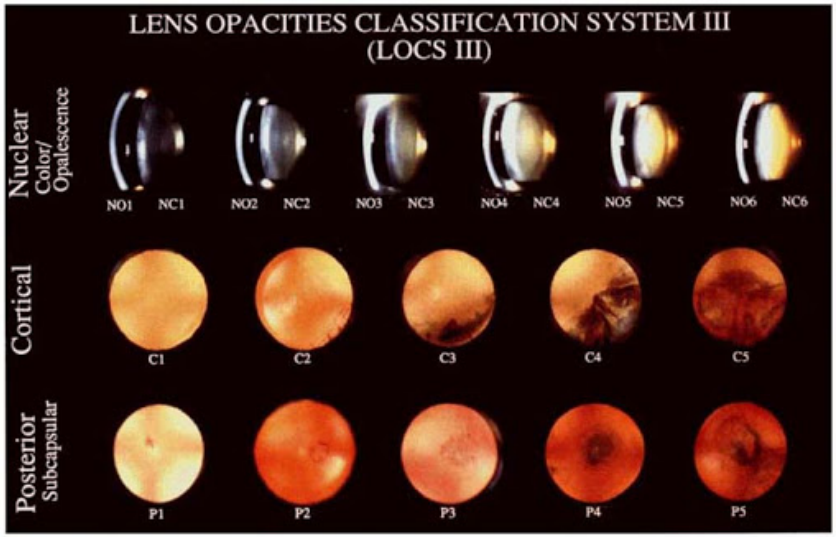
POTENTIAL TREATMENT OPTIONS

- Cataract surgery with implantation of monofocal or premium IOL

Waring IV GO, Rocha KM. Characterization of the Dysfunctional Lens Syndrome and a Review of the Literature. Curr Ophthalmol Rep. November, 2018.

Assessment: Lens Opacities Classification System III (LOCS III)

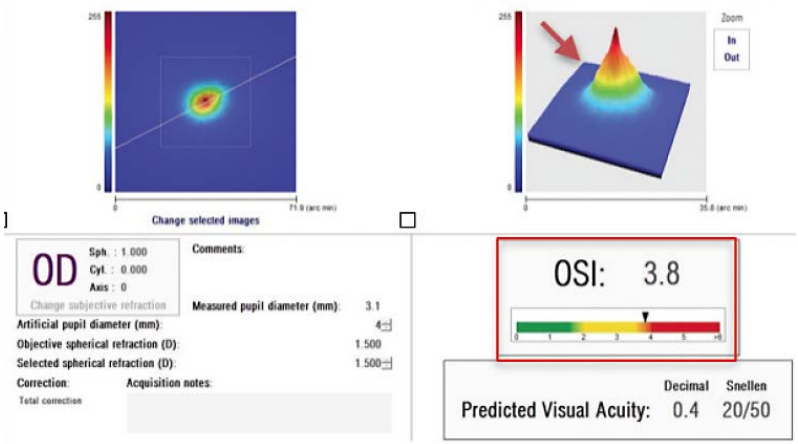
- Cataract severity is graded on a decimal scale.
- The standards have regularly spaced intervals on a decimal scale.
- Grading includes:
  - Nuclear Opalescence (NO)
  - Nuclear Color (NC)
  - Cortical (C)
  - Posterior Subcapsular(P)



Chylack, L & Wolfe, J & Singer, D & Leske, M & Bullimore, Mark & Bailey, Ian & Friend, J & McCarthy, D & Wu, Sheng-Yong. (1993). The Lens Opacities Classification System III. The Longitudinal Study of Cataract Study Group. Archives of ophthalmology. 111. 831-6. 10.1001/archopht.1993.01090060119035.

Assessment :Ocular Scatter Index (OSI)

- Double-pass technique
- Examines the forward-scattered light
- This causes degradation of retinal images in eyes with cataract
- OSI Cataract stages:
  - Normal (non-cataractous) (<1.0)
  - Early (from 1.0 to 2.9)
  - Mature (from 3.0 to 6.9)
  - Severe (≥7.0)

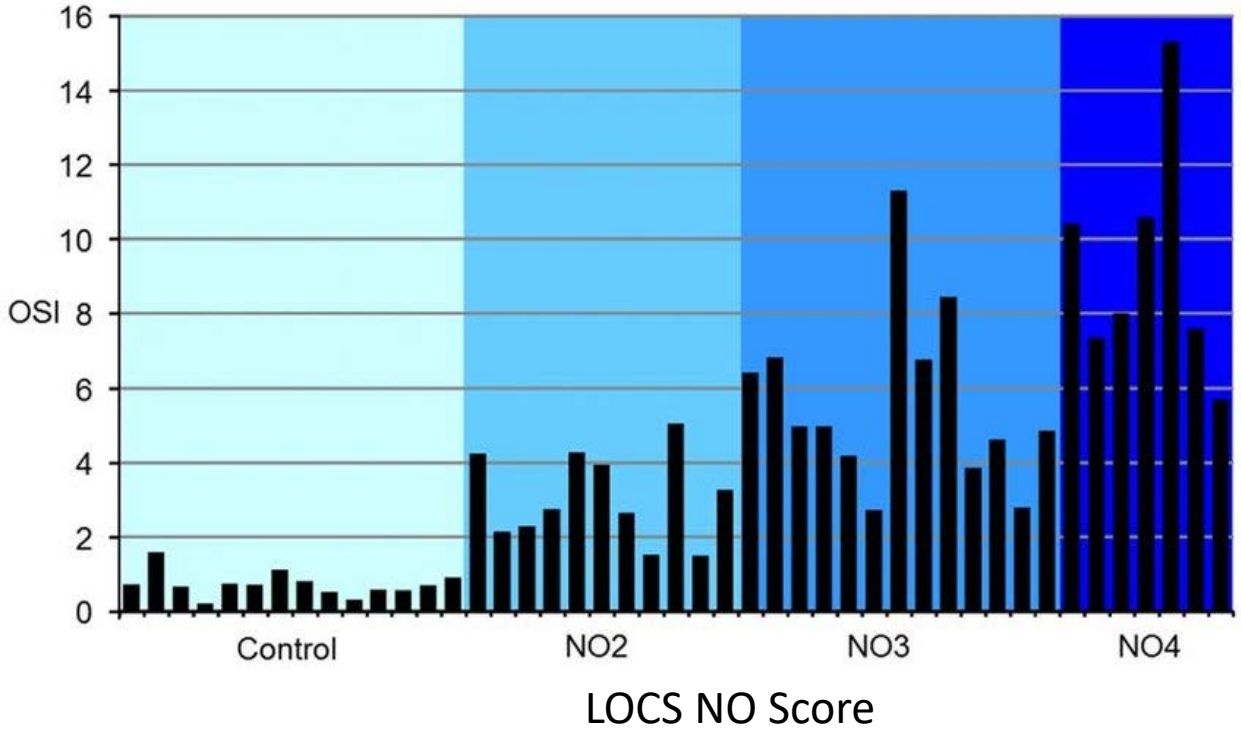


	CDVA	3 cpd	6 cpd	12 cpd	18 cpd	OSI
Control (52 to 65 years) [4]	−0.10	1.69	1.92	1.51	0.93	0.67
LOCS III (grade 1)	0.03	1.56	1.81	1.41	0.99	1.56
LOCS III (grade 2)	0.18	1.52	1.70	1.29	0.81	3.47
LOCS III (grade 3)	0.31	1.43	1.57	1.12	0.80	5.88
LOCS III (grade 4)	0.59	1.31	1.30	0.90	0.46	10.23

Fernández J, Rodríguez-Vallejo M, Martínez J, Tauste A, Piñero DP. From Presbyopia to Cataracts: A Critical Review on Dysfunctional Lens Syndrome. *J Ophthalmol*. 2018;2018:4318405. Published 2018 Jun 27. doi:10.1155/2018/4318405

Assessment: Cataracts, OSI, and LOCS III

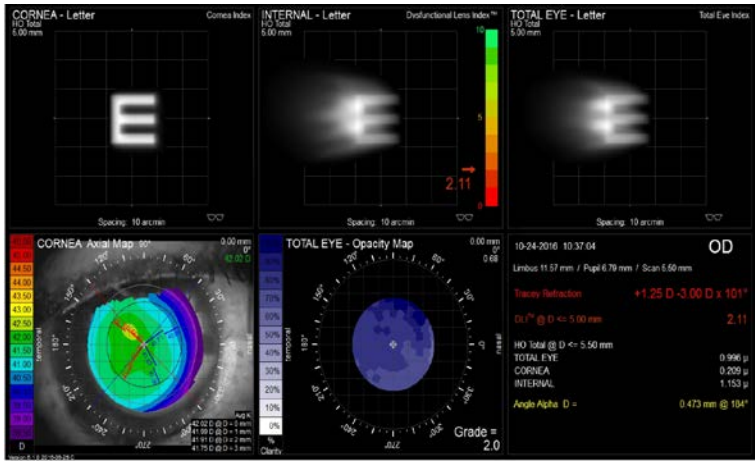
- Grading of NS relative to OSI is variable
- Increasing nuclear sclerosis increases scatter



Straylight and Visual Quality on Early Nuclear and Posterior Subcapsular Cataracts - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Mean-and-SD-values-of-age-CVA-Ct-logs-and-OSI-of-groups-NO1-NO2-P1-P2_tbl1_290442189 [accessed 27 Jun, 2021]

Assessment: Aberrometry and Topography

- Lenticular aberrations = Whole eye – Corneal wavefront (Raytracing/ Hartman–Shack).
- Internal aberrations = lenticular changes



- Corresponding cutoff values for medically necessary cataract surgery:
  - DLI 5.7 = OSI 2.9, corresponding to a LOCS III of NO/NC 2+ or 3.
  - NO increases; DLI decreases; OSI increases

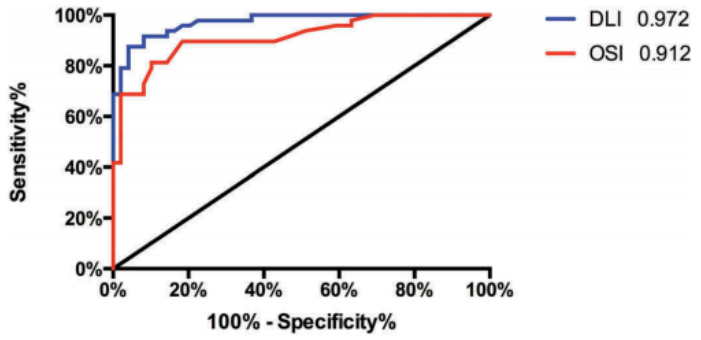
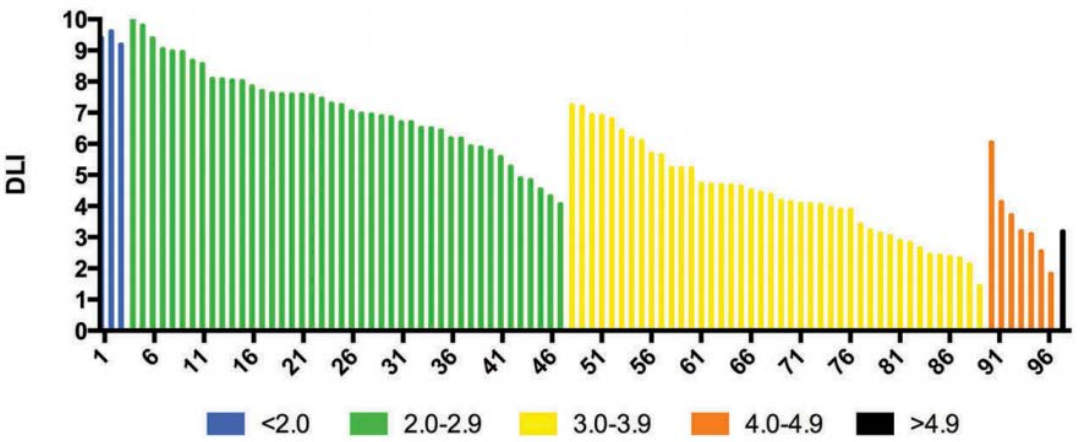


Figure 4. The ROC curve corresponding to the value of DLI and OSI from the Surgical group and the Non-Surgical group. The AUC of the DLI was higher than that of the OSI (DLI = dysfunctional lens index; OSI = objective scatter index; AUC = area under the receiver operating characteristic curve).

Zhangliang Li, Yun-e Zhao, Pingjun Chang, Yinying Zhao, Xixia Ding; Dysfunctional lens index serves as a novel surgery decision maker for age-related cataracts. *Invest. Ophthalmol. Vis. Sci.* 2018;59(9):4791.

Relationship Dysfunctional Lens Index (DLI), OSI, LOCS III

- Objective lens performance metric derived from internal higher order aberrations (HOAs), pupil size, and contrast sensitivity data.[1]
- DLI value decreased as the NO grade increased.[2]
- Stages:
  - Normal = 10 (not cataract)
  - DLS = 9-5.8 (not visually significant cataract)
  - < 5.8 (visually significant cataract)



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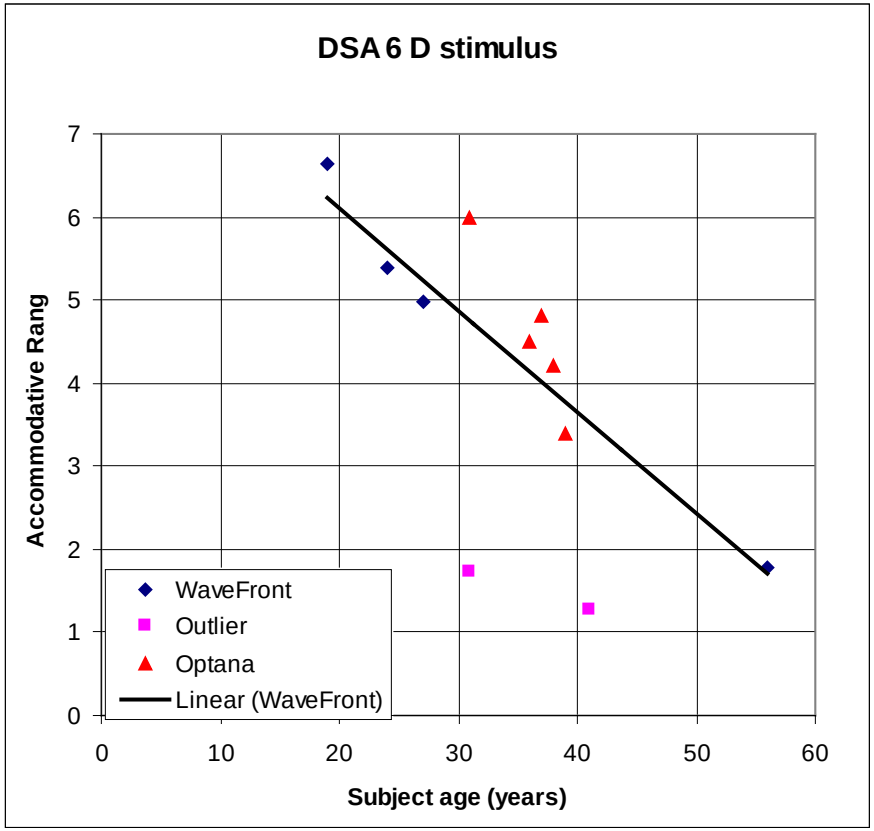
2. Li Z, Yu L, Chen D, Chang P, Wang D, Zhao Y, Liu S, Zhao YE. Dysfunctional Lens Index Serves as a Novel Surgery Decision-Maker for Age-Related Nuclear Cataracts. Curr Eye Res. 2019 Jul;44(7):733-738. doi: 10.1080/02713683.2019.1584676. Epub 2019 Mar 1. PMID: 30822168.

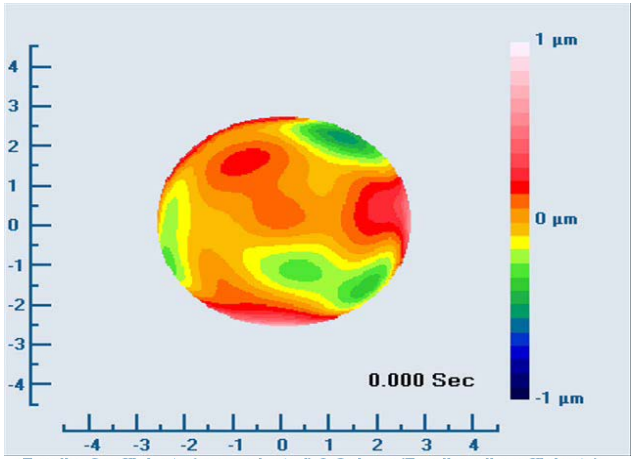
Objective measurement of true accommodation – 30-YEAR-OLD Eye

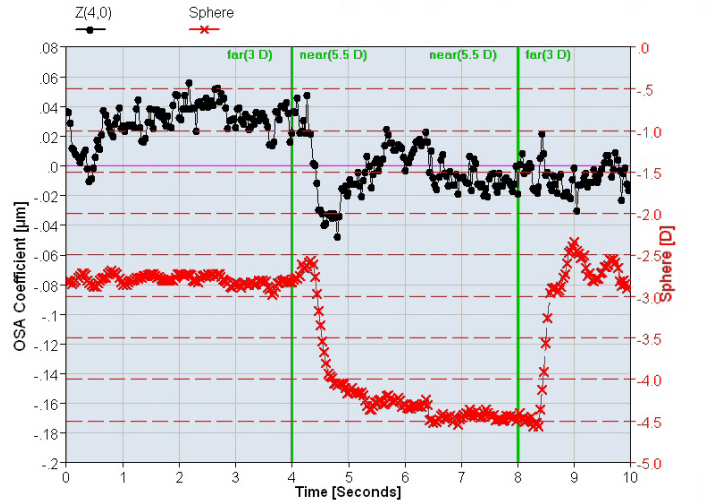
- The iTrace (Houston, TX) objectively measures refraction and HOAs.
- A refractive difference between distance and near refraction demonstrates true accommodation.

Study Results

Normal emmetropes follow the typical accommodation trend*







*outliers possibly due to patient variability for mono-vision and/or multi-focality

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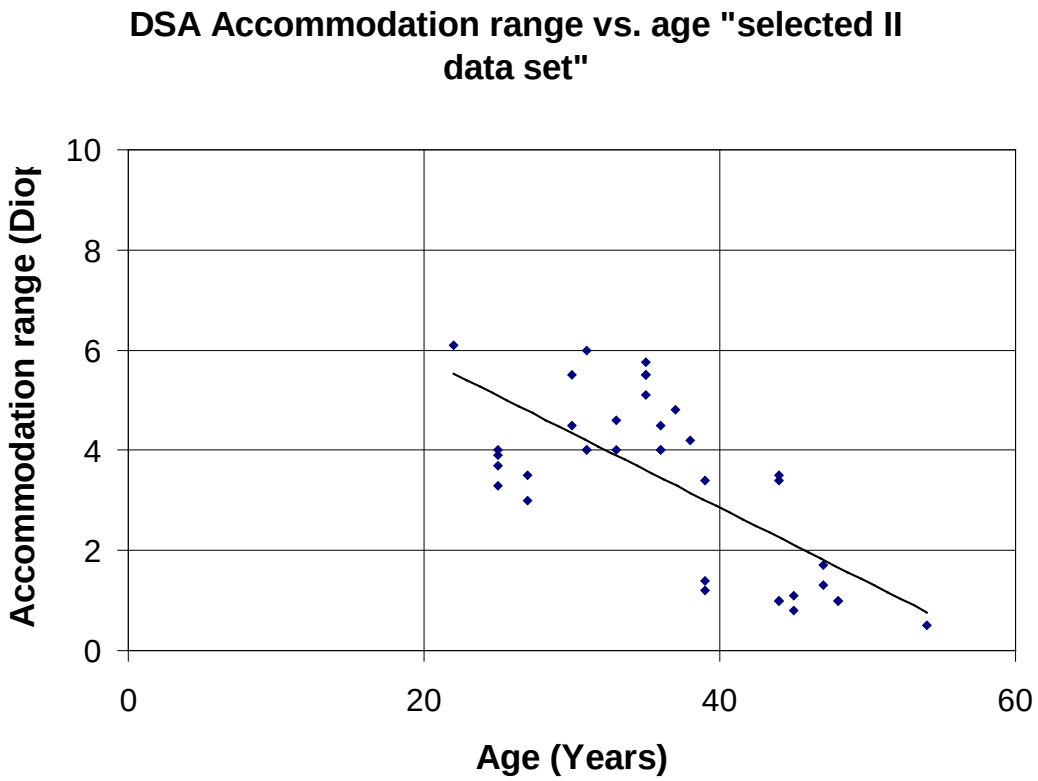
Results

Accommodation range measurements reflect the subject's visual condition*



*outliers possibly due to patient variability for mono-vision and/or multi-focality

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Results

- We classified patients into 4 stages based on disease progression.
- Stage I Early Presbyopia (38-42 years): difficulty reading 20/40 (J5) or better at near but not wearing ADD/reading glasses
- Stage II Acute Presbyopia (43-48 years): need reading add to see 20/40 (J5) or better at near (40 cm)
- Stage III Chronic Presbyopia (49-55 years): Dependent upon minimum +1.25D ADD and progressive increase of 0.25 D reading ad every year.
- Stage IV Stable Presbyopia (55+ years): inability to read 20/100 (J10) without reading ADD.
- These stages had good correlation with the stages in dysfunctional lens syndrome (DLS).

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Discussion: Predicted Amplitude of Accommodation Based on Linear Progression:

- Norms Badal Optometer, minus lens push down method
- Duanels curve references
- But this estimate is *higher* than minus-lens testing results.
- Predicts Presbyopia progression as linear.

Expected Reading Addition with Age

Age (years)	Expected amplitude (D)	Near addition (D)	Lines of Vision Lost
20	10	-	
30	8	-	
40	6	-	
45	4	0.00 – 1.00	0-4
50	2	1.00 – 1.75	4-7
55	1	1.50 – 2.25	6-9
60	1	1.75 – 2.50	7-10

*Table Modified from: Rabbetts, R. Clinical Visual Optics, Butterworth-Heinemann, 1998. Table 7.1, p119

Stages of Classification for Presbyopia Progression

Age	Predicted Amplitude of Accommodation (D)[1]	Reading Add to read 20/20 @ 40cm (D)	Emmetrope's ETDRS UNVA @ 40cm	DLI Value[2]	DLS Value[3]	OSI Value[4]	LOCS III NO/NC Value[5]
35	4.19	0.00	20/20	10.00	Stage 0	0	gr 0
40	2.43	0.00	20/20	10	Stage 1 (42-50 yo)	< 1.0	gr 0
45	1.13	1.37	20/25	10	Onset of presbyopia, scatter is mild, progressive loss of accommodation.	< 1.0 normal	gr 0-1
50	0.46	2.04	20/30	7	Stage 2 (50 to 65yo) some lens opacification with onset of aberrations or change of refraction,	Early ≥1.0-2.9	Grade I
55	0.17	2.33	20/50	6	Not yet meeting the insurance-based criteria for a cataract--but affecting daily life	≥3.0	Grade 2
60	0.06	2.44	20/60	>5.8	Late state 2: Minimal affect on Snellen VA but subjectively reduced VA	Visual significant > 3.0	Grade 2+
65	0.02	2.48	20/100	< 5.8	stage 3: cataract signficantly affecting vision	5.88	Grade 3
69	0.01	2.49	20/100	3	stage 3: cataract signficantly affecting vision	10.23 (Severe > 6.9)	Grade 4

1. Anderson HA, Hentz G, Glasser A, Stuebing KK, Manny RE. Minus-lens-stimulated accommodative amplitude decreases sigmoidally with age: a study of objectively measured accommodative amplitudes from age 3. *Invest Ophthalmol Vis Sci*. 2008;49(7):2919-2926. doi:10.1167/iovs.07-1492.
2. Li Z, Yu L, Chen D, Chang P, Wang D, Zhao Y, Liu S, Zhao YE. Dysfunctional Lens Index Serves as a Novel Surgery Decision-Maker for Age-Related Nuclear Cataracts. Curr Eye Res. 2019 Jul;44(7):733-738. doi: 10.1080/02713683.2019.1584676. Epub 2019 Mar 1. PMID: 30822168.
3. Defining dysfunctional lens syndrome, by Dr med Omid Kermani. Ophthalmology Times. April 1, 2017. https://europe.ophthalmologytimes.com/view/defining-dysfunctional-lens-syndrome.
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5. Chylack LT Jr, Wolfe JK, Singer DM, Leske MC, Bullimore MA, Bailey IL, Friend J, McCarthy D, Wu SY. The Lens Opacities Classification System III. The Longitudinal Study of Cataract Study Group. Arch Ophthalmol. 1993 Jun;111(6):831-6.

Conclusions

- There is clinical value to classify the prevalence & incidence of age-related ocular decline with the progression of presbyopia.
- This novel classification system has the potential for stage related treatment intervention, including LSM, topical miotics, bifocal contact lenses, and refractive lens exchange.
- Relating LOCS III, OSI, DLI values with presbyopia allows better guidance for medical management of visual needs
- Our results corroborate presbyopia progression is sigmoidal and not linear.
- Age is not the best predictor of loss of accommodation. Multifactorial assessments (OSI, DLI, LOCSIII) are more reliable predictors.