Myopic Defocus from Catenary Optics

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Purpose: Studies have shown a strong dosage-dependent relationship with the myopia progression treatment effect, with the magnitude of relative plus/myopic defocus being the dose. [1-3] A contact lens design using catenary-like optics (Neurofocus Optics® Technology) to maximize the amount of relative plus power with minimal visual disturbance was evaluated for its optical characteristics, visual performance and impact on myopia progression management.

What matters for Myopia Progression Control?

1. Dosage: **Magnitude** dependence[1-3]
2. Location: **Eccentricity** dependence[5-7]
3. Duration/**Visual quality**: Wearing time[8]

Catenary Curve: A free hanging chain (Latin catena) will assume a shape of least potential energy which is a catenary curve. The surface of revolution of the catenary curve, the catenoid, has a minimal surface of revolution.[4]

Methods:

1. VTI's catenary-like optic was characterized with ray tracing on a model eye, focusing on the myopic defocus profile in relationship to the retina.
2. Visual performance against best corrected vision and peripheral refraction were performed on 20 children.
3. Retrospective data from progressing myopes who were fitted with these lenses were identified from 15 clinics (n=196, age 12.3±2.8).

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St. Louis arch image sourced from: https://www.smithsonianmag.com/history/story-st-louis-gateway-arch-180956624/

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US Indication: NaturalVue® (etafilcon A) Enhanced Multifocal Daily Disposable Soft Contact Lenses are indicated for daily wear for the correction of refractive ametropia (myopia and hyperopia), and/or presbyopia in normal eyes.
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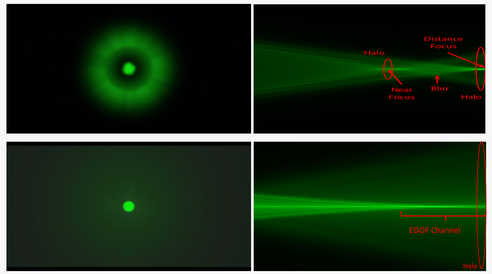
Results 1: Ray tracing of the catenary lens design on a model eye shows that the myopic defocus covers greater than ±30 degrees of retina. Compared to the conic surface, it tends to be spherical-like over a smaller central region but has a much higher level of peripheral steepening. It effectively extends the depth of focus while producing a gentle halo.

Bifocal optics
- Halo and ghosting could be obvious
- Defocus treatment area is limited

Neurofocus Optics® (Catenary)
- Halo evenly spread out, reduced intensity (<20% of +2D SA)
- Defocus treatment area significantly increased >±30°



Results 2: Ray tracing findings are supported by clinical data.

- **Visual Performances:** 20 subjects (age 14.5 ±1.5) with average refraction of OD -3.05 ± 1.56 and OS -3.14 ± 1.53. Compared with best corrected vision, children wearing these lenses experienced vision (including Stereopsis) not impacted by the defocus. Accommodative lag, a risk factor for myopia progression, was found to be both statistically and clinically better for the Test vs Control lens.

	Best Corrected	NVMF	p-value
Distance HCHI (VAR)	102.0 ± 3.1	102.2 ± 3.0	0.299
Intermediate HCHI (VAR)	106.9 ± 2.9	108.8 ± 3.7	0.524
Near HCHI (VAR)	104.6 ± 3.3	106.4 ± 3.1	0.101
Distance LCLI (VAR)	82.9 ± 3.4	79.3 ± 3.8	0.003
Intermediate LCLI (VAR)	97.0 ± 2.8	96.0 ± 4.9	0.372
Near LCLI (VAR)	95.0 ± 3.2	94.3 ± 3.0	0.412
Stereo acuity	23.8 ± 8.1	23.0 ± 5.5	0.675
Lag of Accommodation OD	0.61 ± 0.19	0.36 ± 0.24	0.002
Lag of Accommodation OS	0.58 ± 0.20	0.38 ± 0.21	0.014

- **Peripheral Refraction:** 20 subjects (age 14.5 ±1.5) [9, 10]

	Spherical Component (mean diopter ± SD)				Cylindrical Component (mean diopter ± SD)				Spherical Equivalent Component (mean diopter ± SD)			
	BL		NVMF		BL		NVMF		Control		NVMF	
	OD	OS	OD	OS	OD	OS	OD	OS	OD	OS	OD	OS
N30	-1.39 ± 1.30 *(n=19)	-1.09 ± 1.50 *(n=19)	1.05 ± 1.69	1.29 ± 2.16 *(n=18)	-1.02 ± 0.64	-0.97 ± 0.57	-2.50 ± 1.84	-2.46 ± 1.86	-1.90 ± 1.37	-1.58 ± 1.58	-0.20 ± 2.39	0.06 ± 2.81
N15	2.74 ± 1.93	-2.65 ± 2.00	0.59 ± 0.97	0.45 ± 0.92	-1.00 ± 0.43	-0.88 ± 0.39	-1.34 ± 0.94	-1.55 ± 0.90	-3.24 ± 1.91	-3.10 ± 1.98	-0.08 ± 0.80	-0.33 ± 1.16
Central	-3.24 ± 1.61	-3.12 ± 1.91	0.32 ± 0.50	0.32 ± 0.50	-0.42 ± 0.33	-0.40 ± 0.33	-0.57 ± 0.47	-0.49 ± 0.32	-3.45 ± 1.66	-3.32 ± 1.94	0.04 ± 0.42	0.10 ± 0.24
T15	-2.60 ± 1.65	-2.80 ± 1.89	0.35 ± 0.91	-0.23 ± 0.36	-1.17 ± 0.69	-0.70 ± 0.43	-2.35 ± 1.62	-1.34 ± 0.70	-3.19 ± 1.54	-3.15 ± 1.86	-0.82 ± 1.45	-0.90 ± 0.46
T30	1.62 ± 1.14 *(n=13)	-1.84 ± 1.66 *(n=17)	0.13 ± 1.78 *(n=10)	0.33 ± 1.51 *(n=16)	-2.28 ± 1.04	-3.21 ± 1.42	-4.04 ± 3.17	-4.93 ± 3.55	-2.76 ± 1.02	-3.45 ± 1.55	-1.90 ± 2.99	-2.14 ± 3.06

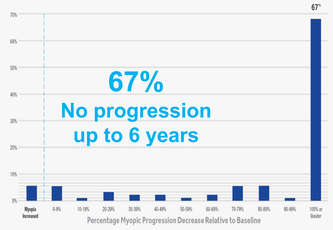
- Peripheral refraction at temporal and nasal 30° was unable to be measured for some participants, possibly due to non-dilated pupils during the procedure. This also applies for Cyl and SE data.

Visual quality: Minimal image disturbance results in easy neuroadaptation[9-11]
- ➔ preserves visual quality (VA, CS, PREP)
- ➔ preserves stereopsis
- ➔ reduces accommodative stress

Peripheral Myopia: focuses peripheral light rays from both meridians in front of the retina to reduce peripheral hyperopia[9, 10]

Results 3: Myopia Progression

A Retrospective cohort study (n=196) of NaturalVue® Multifocal (Neurofocus Optics®) on myopia management up to 6 years.[12] There were no reports of discontinuation of lens wear due to visual quality. No Adverse events were reported. Baseline age was (Mean±SD) 12.3±2.8 years, Spherical Equivalent Refraction (SER) -3.60±2.00D, and Axial Length (AL) 25.05±1.50mm, progression was -0.98±0.78D/yr.



Annual axial elongation (mm/year) as a function of age predicted by the OLSM and SCORM

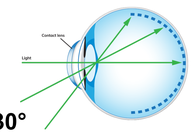
Age	Myopes OLSM	Myopes SCORM[1]	Emmetropes OLSM	Emmetropes SCORM
8	0.28	0.39	0.15	0.14
9	0.25	0.31	0.13	0.11
10	0.30	0.25	0.09	0.09
11	0.22	0.20	0.07	0.08
12	0.20	0.17	0.06	0.06
13	0.19	0.14	0.06	0.06
14	0.18	0.12	0.05	0.05
		AVG 0.09		0.08

Age and Ethnicity Matched Virtual Control Group Axial Elongation (mm)[1-5]				
Baseline	Y1	Y2	Y3	3 Yr Cumulative
0.20	0.25	0.22	0.20	0.67
Actual Observed Axial Elongation with NaturalVue Multifocal (mm)				
Baseline	Y1	Y2	Y3	3 Yr Cumulative
0.33	0.08	0.07	0.08	0.23

All values are in mm. OLSM, Orinda Longitudinal Study of Myopia; SCORM, Singapore Cohort Study of the Risk Factors for Myopia.
[1]For the SCORM cohorts, equations for vitreous chamber depth elongation were used

Summary:

The Neurofocus Optics® technology (Catenary-like curve)



- **Magnitude:** generates an extremely high magnitude of myopic defocus; 6-8D ADD at pupil margin
  - Effectively reduces peripheral hyperopia
- **Eccentricity:** the defocus smoothly distributed **over ± 30°**
- **Visual quality:** Visual functions preserved
- **Myopia Management:** real world data demonstrated significantly reduction in myopia progression.

Conclusions: Contact lenses with catenary optics provide a high magnitude of myopic defocus, with minimal optical disturbance, and reduces peripheral hyperopia. A cohort study using real world data demonstrated high acceptability, safety and effectiveness. A multi-centered, randomized, double-masked, 3-year prospective study has since been initiated which is designed to rigorously quantify the NaturalVue® Multifocal safety and effectiveness profile.

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