

# OCULUS - PENTACAM Show 2 Exams Topometric

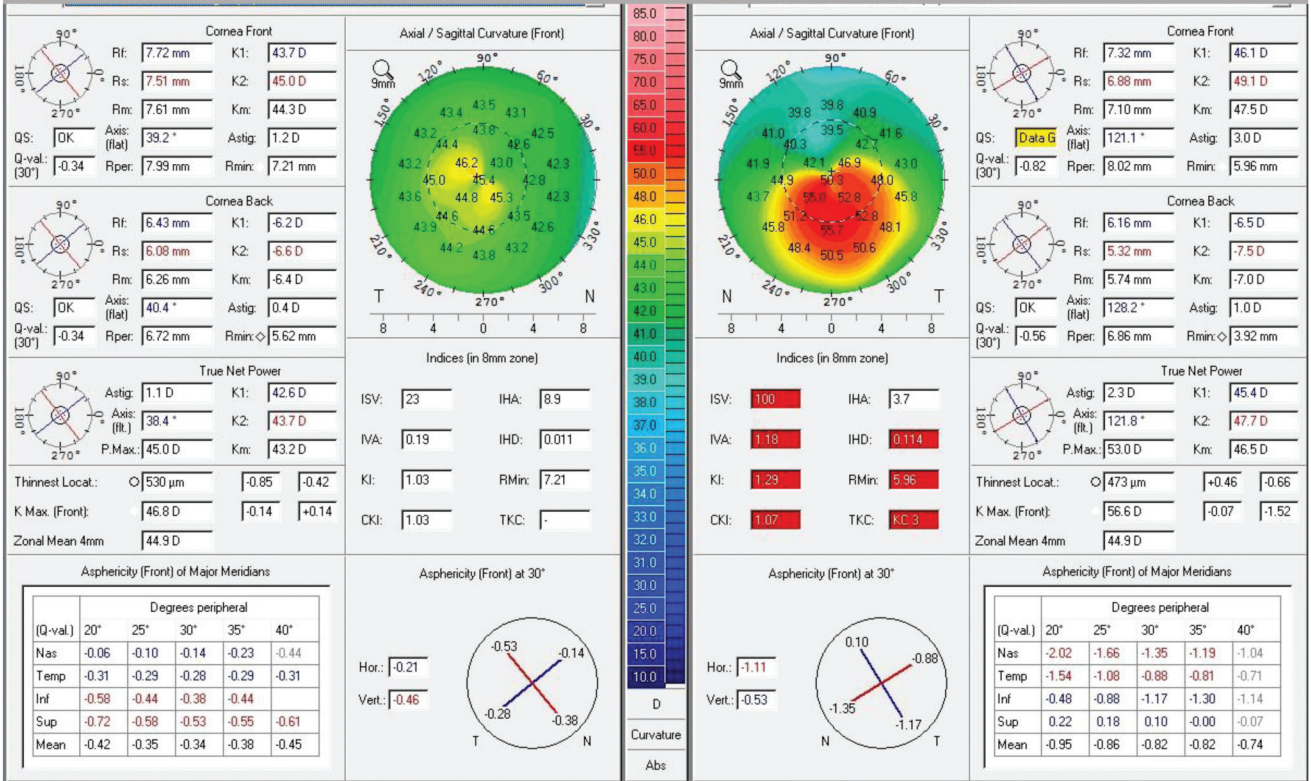


Figure A. Example of forme fruste keratoconus in the right eye.

# OCULUS - PENTACAM Show 2 Exams Topometric

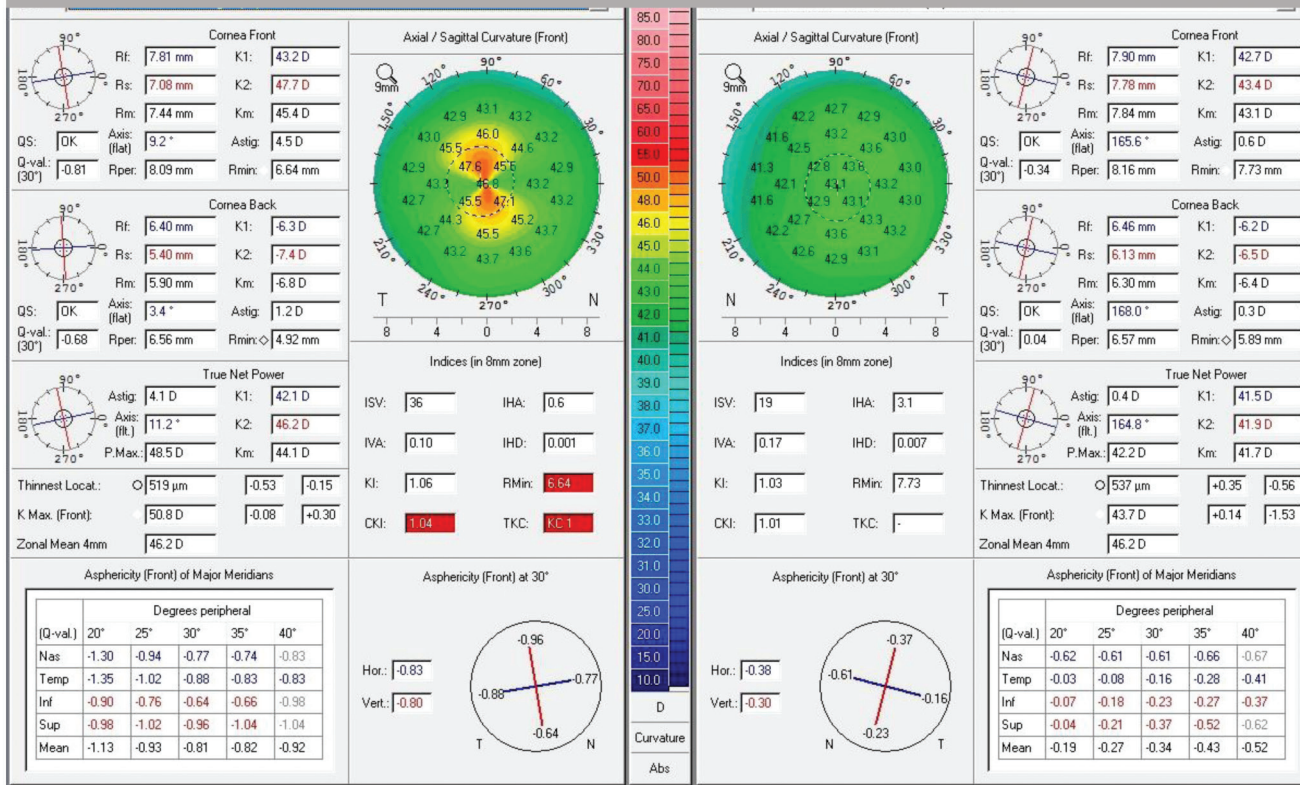
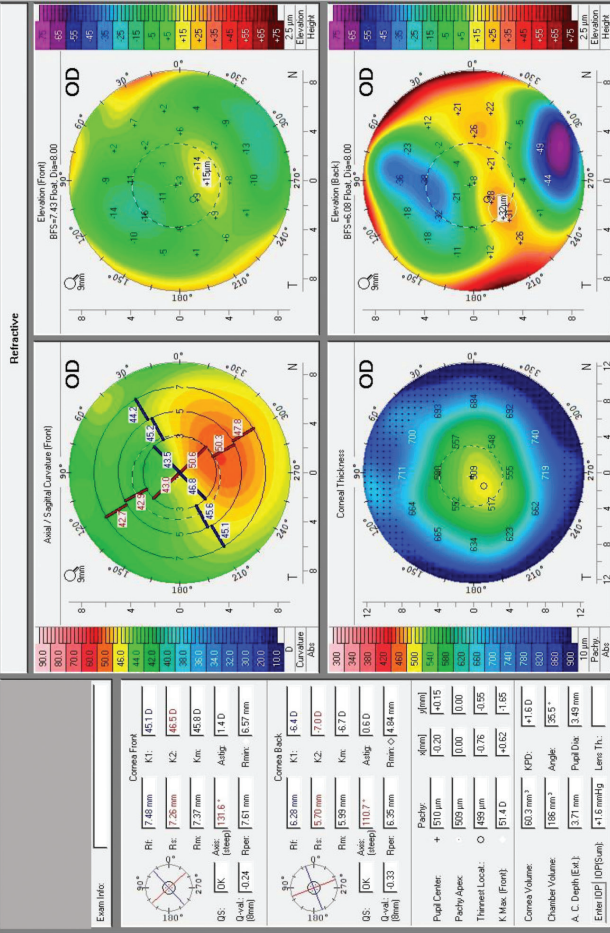


Figure B. Example of forme fruste keratoconus in the left eye.

### OCULUS - PENTACAM 4 Maps Refractive



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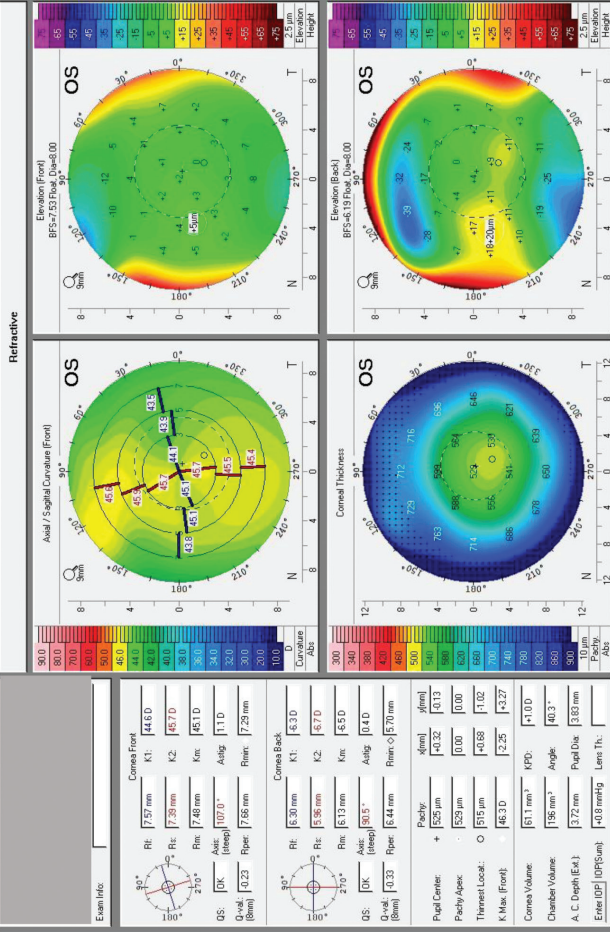


Figure C. Example of forme fruste keratoconus in the left eye.

TABLE A  
**Parameters From Corneal Tomography (Extracted From Oculus Pentacam HR)**

Parameter	Operation Definition	Interpretation
ISV	Standard deviation of individual corneal sagittal radii from the mean curvature	Expression of the corneal surface irregularity
IVA	Measurement of the mean difference between superior and inferior corneal curvature	The value of curvature symmetry, similar to commonly used inferior/superior ratio
IHD	Decentration of elevation data in the vertical direction	Provides the degree of decentration in the vertical direction
Enhanced BFS front	Variable of the anterior corneal elevation	Enhanced anterior best fit sphere
Enhanced BFS back	Variable of the posterior corneal elevation	Enhanced back best fit sphere
Elevation B BFS Apex	Variable of the posterior corneal apex elevation	Best fit sphere posterior of the corneal apex
Elevation B BFS Thinnest	Variable of the posterior corneal thinnest point elevation	Best fit sphere posterior of the corneal thinnest point
Elevation B BFS Max 4-mm Zone	Variable of the posterior corneal elevation	Best fit sphere of the posterior cornea outside 4-mm zone from thinnest point
Elevation B BFTE Apex	Variable of the posterior corneal apex elevation	Best fit toric ellipsoid posterior of the corneal apex
Elevation B BFTE Thinnest	Variable of the posterior corneal thinnest point elevation	Best fit toric ellipsoid posterior of the thinnest point
Elevation B BFTE Max 4-mm Zone	Variable of the posterior corneal elevation	Best fit toric ellipsoid of the posterior cornea outside 4-mm zone from thinnest point
BAD-D	Belin/Ambrósio display	The D values represent the mean deviation, representing the pachymetric progression
ART Max	Ambrósio relational thickness maximum	Division of the thinnest point by the RPI Maximum
ART Average	Ambrósio relational thickness average	Division of the thinnest point by the RPI Average
RPI Max	Relative pachymetric index maximum	The value of pachymetric progression is calculated by reference to the average curve. For each meridian, a maximum value that expresses pachymetric progression is calculated.
RPI Average	Relative pachymetric index average	The value of pachymetric progression is calculated by reference to the average curve. For each meridian, a maximum value that expresses pachymetric progression is calculated.

*ISV = index of surface variance; IVA = index of vertical asymmetry; IHD = index of height decentration  
The Oculus Pentacam HR is manufactured by Oculus Optikgeräte, Wetzlar, Germany.*



TABLE B

**Variables Derived From the Signal of the Dynamic Bidirectional Applanation Device<sup>a</sup>**

Variable	Operation Definition	Interpretation
<b>Group 1</b>		
A1	Peak intensity of first applanation event	Maximum surface area achieving planarity during inward deformation
A2	Peak intensity of second applanation event	Maximum surface area achieving planarity during recovery
Applanation peak difference	A2–A1	Difference in maximum planarity between inward and recovery phases
Concavity min	Minimum applanation intensity between A1 and A2	Depth and irregularity (nonplanarity) of deformation
Concavity mean	Mean applanation intensity between A1 and A2	Depth and irregularity of deformation average
<b>Group 2</b>		
Average P1P2	(P1+P2)/2	Average of the pressures at the 2 applanation events
Pmax	Peak value of pressure signal	Force and time required to reach first applanation event
<b>Group 3</b>		
Concavity duration	Time lapse between A1 and A2	Temporal delay of deformation recovery between applanation events
Concavity time	Time from onset of applied pressure to A1	Time required to achieve maximum deformation from onset of impulse
Lag time	Time between Pmax and concavity min	Delay between peak applied pressure and maximum deformation
Applanation onset time	Time from onset of applied pressure to A1	Time required to achieve first applanation from onset of impulse
<b>Group 4</b>		
Slope up	Positive slope of the first applanation peak, from inflection point to peak	Rate of achieving peak planarity
Slope down	Negative slope of the first applanation peak, from inflection point to peak	Rate of loss of peak planarity
<b>Group 5</b>		
Hysteresis loop area	Area enclosure by pressure vs applanation function	Hysteresis aggregated over entire deformation cycle except concavity
<b>Group 6</b>		
Impulse	Area under pressure vs time curve	Air pressure intensity

<sup>a</sup>Data adapted from Hallahan KM, Sinha Roy A, Ambrósio R Jr, Salomao M, Dupps WJ Jr. Discriminant value of custom ocular response analyzer waveform derivatives in keratoconus. *Ophthalmology*. 2014;121:459-468.

TABLE C  
**Comparison of AUROC, Select Parameter Cut-off, Sensitivity, and Specificity for Variables Statistically Different Between Normal and FFKC Groups**

Parameter	AUROC	SE <sup>a</sup>	P <sup>b</sup>	Sensitivity	Specificity	Cut-off	CI 95% <sup>c</sup>
FECTB	0.953	0.0237	< .0001	85.71	98.68	> 0.4653	0.890 to 0.986
BAD-D	0.91	0.05	< .0001	90.48	82.89	> 0.96	0.835 to 0.959
B BFTE Th	0.872	0.05	< .0001	85.71	78.95	> 0	0.789 to 0.931
ART Maximum	0.863	0.06	< .0001	85.71	78.95	≤ 435	0.778 to 0.924
RPI Maximum	0.841	0.07	< .0001	80.95	97.37	> 1.29	0.753 to 0.907
B BFS Th	0.839	0.06	< .0001	85.71	75	> 3	0.751 to 0.906
ART Average	0.838	0.06	< .0001	80.95	75	≤ 557	0.749 to 0.905
RPI Average	0.836	0.06	< .0001	80.95	75	> 0.95	0.747 to 0.904
B BFTE 4Z	0.779	0.06	< .0001	71.43	67.11	> 7	0.684 to 0.857
p1area1	0.717	0.07	.0009	71.43	63.16	≤ 1,237.5	0.617 to 0.804
p1area	0.707	0.07	.0014	66.67	65.79	≤ 2,885.188	0.606 to 0.795
HLA	0.688	0.07	.0059	66.67	71.05	≤ 49.903	0.586 to 0.778
h1	0.663	0.07	.0213	61.9	68.42	≤ 319.688	0.560 to 0.756
h11	0.663	0.07	.0213	61.9	68.42	≤ 213.125	0.560 to 0.756
Impulse	0.650	0.07	.0323	66.67	67.11	≤ 4,401.975	0.546 to 0.744
dive1	0.649	0.07	.0297	61.90	63.16	≤ 279	0.545 to 0.743
Pmax	0.648	0.07	.0325	61.90	61.84	≤ 414	0.544 to 0.742
BFS Fr	0.646	0.07	.0267	61.90	63.16	≤ 7.86	0.542 to 0.740
B BFTE Ax	0.645	0.08	.0582	57.14	67.11	> -1	0.541 to 0.739
Ele B BFS 8-mm Apex	0.645	0.0764	.0582	57.14	67.11	> 1	0.541 to 0.739
uslope2	0.642	0.08	.0646	57.14	69.74	≤ 65.5	0.538 to 0.736
aspect2	0.630	0.0809	.1072	57.14	67.11	≤ 13.425	0.526 to 0.726
slew2	0.629	0.08	.1040	61.90	63.16	≤ 274.125	0.525 to 0.725
h2	0.629	0.0796	.1040	52.38	67.11	≤ 262.688	0.525 to 0.725
h21	0.629	0.0796	.1040	52.38	67.11	≤ 175.125	0.525 to 0.725
uslope1	0.627	0.0753	.0928	61.90	53.95	≤ 54.714	0.522 to 0.723
CRF	0.622	0.0742	.1012	61.90	68.42	≤ 8.9	0.517 to 0.718
dslope2	0.622	0.0830	.1432	52.38	69.74	≤ 16.732	0.517 to 0.718
mslew2	0.622	0.08	.1432	61.90	52.63	≤ 20.733	0.517 to 0.718
uslope21	0.622	0.0824	.1402	52.38	75.00	≤ 46.583	0.517 to 0.718
mslew1	0.622	0.0727	.0930	57.14	64.47	≤ 89	0.518 to 0.719
Aindex	0.620	0.0738	.1050	66.67	61.84	≤ 9.384	0.515 to 0.716
A1	0.617	0.0750	.1171	57.14	60.53	≤ 525	0.513 to 0.714
aspect21	0.617	0.0752	.1184	52.38	72.37	≤ 16.563	0.513 to 0.714
aspect1	0.614	0.0729	.1176	57.14	60.53	≤ 15.694	0.510 to 0.711
w2	0.613	0.0811	.1629	61.90	59.21	> 19	0.509 to 0.710
path1	0.610	0.0828	.1830	52.38	67.11	> 23.29	0.506 to 0.708
Enh BFS Back 8 mm	0.610	0.0689	.1094	61.90	61.84	≤ 6.49	0.506 to 0.708
CH	0.607	0.0766	.1633	57.14	51.32	≤ 9.9	0.502 to 0.705
dslope21	0.604	0.0740	.1598	61.90	52.63	≤ 30.65	0.500 to 0.702
Slope down	0.604	0.0742	.1609	57.14	57.89	> -92.74853801	0.500 to 0.702

TABLE C (cont'd)

**Comparison of AUROC, Select Parameter Cut-off, Sensitivity, and Specificity for Variables Statistically Different Between Normal and FFKC Groups**

Parameter	AUROC	SE <sup>a</sup>	P <sup>b</sup>	Sensitivity	Specificity	Cut-off	CI 95% <sup>c</sup>
A2	0.601	0.0793	.2033	61.90	60.53	≤ 457	0.496 to 0.699
dslope1	0.599	0.0723	.1711	66.67	48.68	≤ 26.393	0.495 to 0.697
IHD	0.599	0.0663	.1369	57.14	67.11	> 5	0.494 to 0.697
p2area	0.597	0.0755	.1981	57.14	60.53	≤ 2,013	0.493 to 0.695
Aplhf	0.589	0.0702	.2035	57.14	61.84	> 1.3	0.485 to 0.688
Applanation onset time	0.588	0.0690	.2022	66.67	50.00	≤ 7.65	0.484 to 0.687
bindex	0.587	0.0764	.2545	52.38	59.21	≤ 9.656	0.483 to 0.686
Concavity min	0.586	0.0800	.2798	61.90	55.26	> 48.33333333	0.482 to 0.686
w11	0.585	0.0788	.2834	47.62	63.16	≤ 10	0.480 to 0.684
AvgP1P2	0.584	0.0725	.2486	57.14	51.32	≤ 172.5	0.479 to 0.683
Slope up	0.580	0.0779	.3070	61.90	44.74	≤ 77.84313725	0.475 to 0.679
Concavity mean	0.570	0.0831	.3982	52.38	57.89	≤ 113.0817204	0.466 to 0.670
p2area1	0.566	0.0730	.3631	57.14	55.26	≤ 884.5	0.462 to 0.667
path21	0.564	0.0721	.3756	61.90	47.37	≤ 35.025	0.459 to 0.664
w21	0.559	0.0738	.4275	57.14	44.74	> 8	0.454 to 0.659
slew1	0.558	0.0762	.4445	61.90	53.95	≤ 56.357	0.454 to 0.659
uslope11	0.557	0.0790	.4705	52.38	46.05	≤ 57	0.453 to 0.658
ISV	0.555	0.0669	.4149	61.90	52.63	≤ 19	0.450 to 0.655
Ele B BFS 8-mm max 4-mm zone	0.554	0.0746	.4729	52.38	59.21	> 13	0.449 to 0.655
dive2	0.554	0.0830	.5136	57.14	46.05	≤ 230.75	0.450 to 0.655
aspect11	0.540	0.0860	.6411	61.90	46.05	≤ 23.778	0.436 to 0.642
aspect11	0.540	0.0860	.6411	52.38	52.63	≤ 22.693	0.436 to 0.642
IVA	0.533	0.0718	.6467	47.62	51.32	≤ 0.16	0.429 to 0.635
w1	0.530	0.0735	.6822	61.90	51.32	≤ 21	0.426 to 0.632
Concavity time	0.529	0.0720	.6856	57.14	50.00	≤ 12.975	0.425 to 0.631
Lag time	0.522	0.0684	.7449	52.38	46.05	≤ .675	0.418 to 0.625
path2	0.505	0.0736	.9457	42.86	46.05	≤ 25.232	0.402 to 0.608
Applanation peak dif	0.505	0.0823	.9544	57.14	52.63	≤ -112	0.401 to 0.608
Concavity duration	0.501	0.0767	.9935	52.38	43.42	> 10.8	0.397 to 0.604
dslope11	0.501	0.0814	.9877	47.62	44.74	> 35.208	0.398 to 0.604

AUROC = area under the receiver operating characteristic curve; FFKC = forme fruste keratoconus; SE = standard error; CI = confidence interval; FECTB = function enhanced combined tomography and biomechanics; BAD-D = Belin/Ambrósio display; B BFTE Th = elevation B best fit toric ellipsoid thinnest; ART = Ambrósio relational thickness; RPI = relative pachymetric increase; B BFS Th = enhanced best fit sphere thinnest; B BFTE Ax = elevation B best fit toric ellipsoid apex; B BFTE 4Z = elevation B BFTE maximum 4-mm zone; HLA = hysteresis loop area; Pmax = pressure; BFS Fr = enhanced BFS front; CRF = corneal resistance factor; CH = corneal hysteresis; IHD = index of height decentration; ISV = index surface variation; IVA = index of vertical asymmetry

<sup>a</sup>Data adapted from DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*. 1988;44:837-845.

<sup>b</sup>Area = 0.5.

<sup>c</sup>Binomial exact.

TABLE D  
**Comparison of All ORA Variables**

Parameter	Normal Group Mean $\pm$ SD (Range)	FFKC Group Mean $\pm$ SD (Range)	P <sup>a</sup>
p1area1	1,412.29 $\pm$ 447.54 (554.25 to 2,686.5)	1,085.19 $\pm$ 363.43 (553.5 to 1,762.38)	.0024 <sup>b</sup>
p1area	3,331.25 $\pm$ 910.23 (1,402 to 5,606.06)	2,644.83 $\pm$ 746.93 (1,450.13 to 4,008)	.0037 <sup>b</sup>
HLA	5,501.00 $\pm$ 15,339.15 (8,853 to 97,693)	43,614.55 $\pm$ 18,597.56 (-11,656.5 to 78,052)	.0086 <sup>b</sup>
h1	377.05 $\pm$ 103.64 (218.62 to 640.87)	319.06 $\pm$ 102.74 (168.75 to 563.62)	.0228 <sup>b</sup>
h11	251.37 $\pm$ 69.09 (145.75 to 427.25)	212.70 $\pm$ 68.49 (112.5 to 375 .35)	.0228 <sup>b</sup>
Impulse	4,536.22 $\pm$ 323.30 (3,775.35 to 5,314.08)	4,402.86 $\pm$ 418.84 (3,796.58 to 5,807.36)	.0363
dive1	323.77 $\pm$ 117.79 (38.75 to 614.5)	266.39 $\pm$ 115.82 (19.5 to 561.75)	.0375
Pmax	423.74 $\pm$ 35.49 (344 to 505)	408.43 $\pm$ 45.09 (348 to 557)	.0391
mslew2	127.75 $\pm$ 56.57 (25.75 to 326)	97.08 $\pm$ 51.35 (19.25 to 173)	.0421
uslope2	85.99 $\pm$ 43.24 (14.67 to 239.12)	62.14 $\pm$ 45.55 (3.27 to 138.75)	.0478
slew2	86.40 $\pm$ 42.63 (17.5 to 239.12)	63.70 $\pm$ 44.10 (6.66 to 138.75)	.0487
aspect11	24.42 $\pm$ 9.85 (10.11 to 55.70)	25.29 $\pm$ 16.21 (9.37 to 75.15)	.5751
aspect2	18.15 $\pm$ 8.99 (4.62 to 55.02)	14.54 $\pm$ 11.03 (1.76 to 42.44)	.0685
h2	304.57 $\pm$ 90.38 (153.56 to 605.25)	252.13 $\pm$ 120.12 (72.18 to 466.87)	.0705
h21	203.04 $\pm$ 60.25 (102.37 to 403.5)	168.09 $\pm$ 80.08 (48.12 to 311.25)	.0705
uslope1	63.29 $\pm$ 31.77 (23.22 to 187.16)	49.71 $\pm$ 25.17 (18.13 to 112.35)	.0768
mslew1	106.28 $\pm$ 39.59 (53.5 to 239.5)	89.58 $\pm$ 30.31 (40.75 to 163.25)	.0876
CRF	9.75 $\pm$ 1.78 (6 to 148)	9.10 $\pm$ 1.99 (5 to 13.8)	.0893
dslope2	23.63 $\pm$ 12.93 (5.58 to 83.21)	19.51 $\pm$ 14.99 (2.58 to 57.71)	.0893
uslope21	68.73 $\pm$ 31.87 (13.91 to 157)	54.66 $\pm$ 42.13 (1.73 to 137.62)	.0893
Aindex	9.24 $\pm$ 1.05 (5.34 to 10)	8.59 $\pm$ 1.52 (4.95 to 10)	.0943
A1	582.36 $\pm$ 148.06 (358 to 916)	519.00 $\pm$ 160.57 (279 to 860)	.1005
aspect21	26.23 $\pm$ 14.16 (4.56 to 69.9)	20.85 $\pm$ 15.21 (2.18 to 62.25)	.1005
aspect1	17.98 $\pm$ 6.19 (8.33 to 39.31)	15.34 $\pm$ 6.19 (6.75 to 31.31)	.1109
w2	18.58 $\pm$ 4.57 (10 to 34)	22.67 $\pm$ 9.02 (11 to 42)	.1139
path1	22.45 $\pm$ 3.98 (15.29 to 36.43)	24.96 $\pm$ 6.05 (16.18 to 36.43)	.1232
CH	10.15 $\pm$ 1.62 (6.2 to 14.1)	9.27 $\pm$ 2.16 (6 to 13.1)	.1353
dslope21	40.85 $\pm$ 26.15 (5.79 to 135.12)	32.25 $\pm$ 24.35 (3.30 to 104.87)	.1459
Slope down	-105.20 $\pm$ 36.41 (-249.56 to -55.47)	-93.03 $\pm$ 38.26 (-181.99 to -40.32)	.1459
A2	476.96 $\pm$ 128.73 (256 to 807)	418.38 $\pm$ 174.69 (141 to 737)	.1585
dslope1	26.06 $\pm$ 8.89 (11.60 to 52.81)	23.25 $\pm$ 9.42 (9.85 to 45.1)	.1664
p2area	2,183.22 $\pm$ 550.90 (1,163.43 to 3,829.81)	1,928.98 $\pm$ 597.38 (447.5 to 2,909.63)	.1746
Aplhf	1.32 $\pm$ 0.31 (0.8 to 2.4)	1.55 $\pm$ 0.84 (0.9 to 5)	.212
Applanation onset time	7.69 $\pm$ 0 .43 (6.6 to 8.6)	7.66 $\pm$ 0.77 (6.75 to 10.65)	.2185
bindex	9.34 $\pm$ 1.08 (4.90 to 10)	8.42 $\pm$ 2.32 (1.80 to 10)	.2234
Concavity min	48.84 $\pm$ 9.88 (15.33 to 78.33)	51.87 $\pm$ 12.44 (23.66 to 167.33)	.2268
w11	11.00 $\pm$ 2.45 (5 to 17)	10.05 $\pm$ 3.25 (5 to 16)	.237
AvgP1P2	176.00 $\pm$ 22.23 (129 to 235.5)	179.43 $\pm$ 55.85 (140.5 to 411.5)	.2423
Slope up	76.83 $\pm$ 25.59 (33.70 to 148.92)	66.57 $\pm$ 30.08 (17.26 to 121)	.266
Concavity mean	119.83 $\pm$ 21.32 (81.88 to 185.03)	117.94 $\pm$ 44.04 (71.91 to 279.63)	.3266
p2area1	927.63 $\pm$ 274.63 (486 to 1,868)	831.18 $\pm$ 277.80 (206.5 to 1,316.5)	.3532
path21	36.04 $\pm$ 9.34 (14.58 to 66.56)	34.00 $\pm$ 8.43 (21.34 to 52.54)	.3716
w21	9.01 $\pm$ 3.05 (4 to 23)	10.67 $\pm$ 5.31 (5 to 24)	.4128
slew1	64.82 $\pm$ 31.25 (19.37 to 187.16)	56.41 $\pm$ 25.13 (19.5 to 112.35)	.4153
uslope11	62.02 $\pm$ 31.59 (14.5 to 181.37)	56.78 $\pm$ 31.67 (13.83 to 1,443.37)	.4254
dive2	235.69 $\pm$ 84.44 (87.5 to 551.25)	209.27 $\pm$ 111.58 (20 to 409)	.4487



TABLE D (cont'd)

**Comparison of All ORA Variables**

<b>Parameter</b>	<b>Normal Group Mean <math>\pm</math> SD (Range)</b>	<b>FFKC Group Mean <math>\pm</math> SD (Range)</b>	<b>P<sup>a</sup></b>
aspect11	24.42 $\pm$ 9.85 (10.11 to 55.70)	25.29 $\pm$ 16.21 (9.37 to 75.15)	.5751
w1	21.57 $\pm$ 2.70 (15 to 28)	21.71 $\pm$ 3.51 (17 to 31)	.6742
Concavity time	12.92 $\pm$ 0.86 (10.42 to 14.62)	12.83 $\pm$ 0.87 (11.1 to 14.4)	.6838
Lag time	0.79 $\pm$ 0.55 (0.1 to 2.32)	0.74 $\pm$ 0.50 (0.075 to 2.25)	.7558
path2	25.61 $\pm$ 6.63 (11.57 to 51.14)	25.33 $\pm$ 6.05 (15.28 to 36.86)	.9441
Applanation peak dif	-105.39 $\pm$ 126.27 (-433 to 168)	-100.62 $\pm$ 169.75 (-353 to 199)	.9476
dslope11	40.62 $\pm$ 17.45 (14.10 to 104.06)	44.78 $\pm$ 27.95 (1,434 to 121.62)	.986
Concavity duration	10.91 $\pm$ 0.45 (9.9 to 12.15)	10.69 $\pm$ 1.14 (6.15 to 11.625)	.993

ORA = Ocular Response Analyzer (Reichert Ophthalmic Instruments, Depew, NY); SD = standard deviation; FFKC = forme fruste keratoconus; HLA = hysteresis loop area; Pmax = pressure; CRF = corneal resistance factor; CH = corneal hysteresis

<sup>a</sup>Mann-Whitney U test.

<sup>b</sup>Statistically significant difference after Bonferroni correction.