

VOLUMETRIC THREE-DIMENSIONAL UPPER AIRWAY ANALYSIS IN PATIENTS WITH DENTO-FACIAL DEFORMITY FOLLOWING ORTHOGNATHIC SURGERY



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PURPOSE & BACKGROUND



- **3-D volumetric analysis is reproducible and accurate**
 - Schendel S, Hatcher D, Automated 3-D Airway Analysis by Cone Beam CT. *Journal of Oral and Maxillofacial Surgery*. 2010 March; 68(3):696-701
- **3-D upper airway volume in non OSA patients have been described**
 - Schendel S, Jacobson R. Normal Upper Airway Growth & Development. Presented at AAOMS Chicago 2010
- **MMA has a high success rate in treating patients with OSA**
 - Schendel S, Powell N, Jacobson R, Maxillary, Mandibular, and Chin Advancement: Treatment Planning Based on Airway Anatomy in Obstructive Sleep Apnea, *J Oral Maxillofac Surg*, 29:663:676, 2011.
 - Broujerdi J, Jacobson R, Schendel S, Volumetric 3D Upper Airway Analysis in Patients with OSA Following Maxillomandibular Advancement. The 3rd William H. Bell Lectureship: Accelerated Orthognathic Surgery and Increased Orthodontic Efficiency: A Paradigm Shift, 2011 March
 - Holty JE, Guilleminault C. Maxillomandibular Advancement for The Treatment of Obstructive Sleep Apnea: A Systematic Review and Meta-Analysis. *Sleep Med Rev*. 2010 Oct;14(5):287-97.
- **Evidence is lacking on airway volume changes after orthognathic surgery**
 - Mattos CT, et al. Effects of Orthognathic Surgery on Oropharyngeal Airway: a Meta-Analysis. *Int. J. Oral Maxillofacial Surgery*, 2011 July

Our Analytical Approach

Identify morphological & volumetric changes of the airway

Volumetric (cm³)

- **Upper Airway Space (UAS)**
 - Posterior of post-nasal spine to superior point of hyoid bone
- **Retropalatal Space**
 - Posterior of post-nasal spine to edge of the soft palate
- **Retroglossal Space**
 - Edge of soft palate to superior point of hyoid bone

Surface Area (mm²)

- **Choke Points**
 - Area of smallest surface area
 - Identified independently in Retropalatal Space and Retroglossal Space
- **PNS**
- **Occlusal Plane**
- **Hyoid**

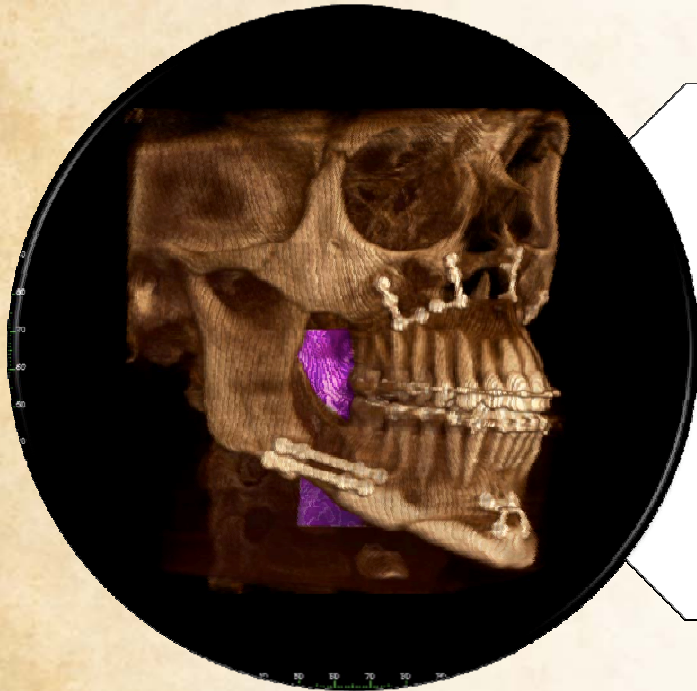
Length (mm)

- **2-Dimensional length parameters of the choke points**
 - Transverse Dimension
 - Anterior-Posterior Dimension
- **PNS – Tip of Soft Palate**
- **Mandibular Plane - Hyoid**

Height (mm)

- **2-Dimensional Height of the airway**
 - UAS height
 - Retropalatal height
 - Retroglossal height

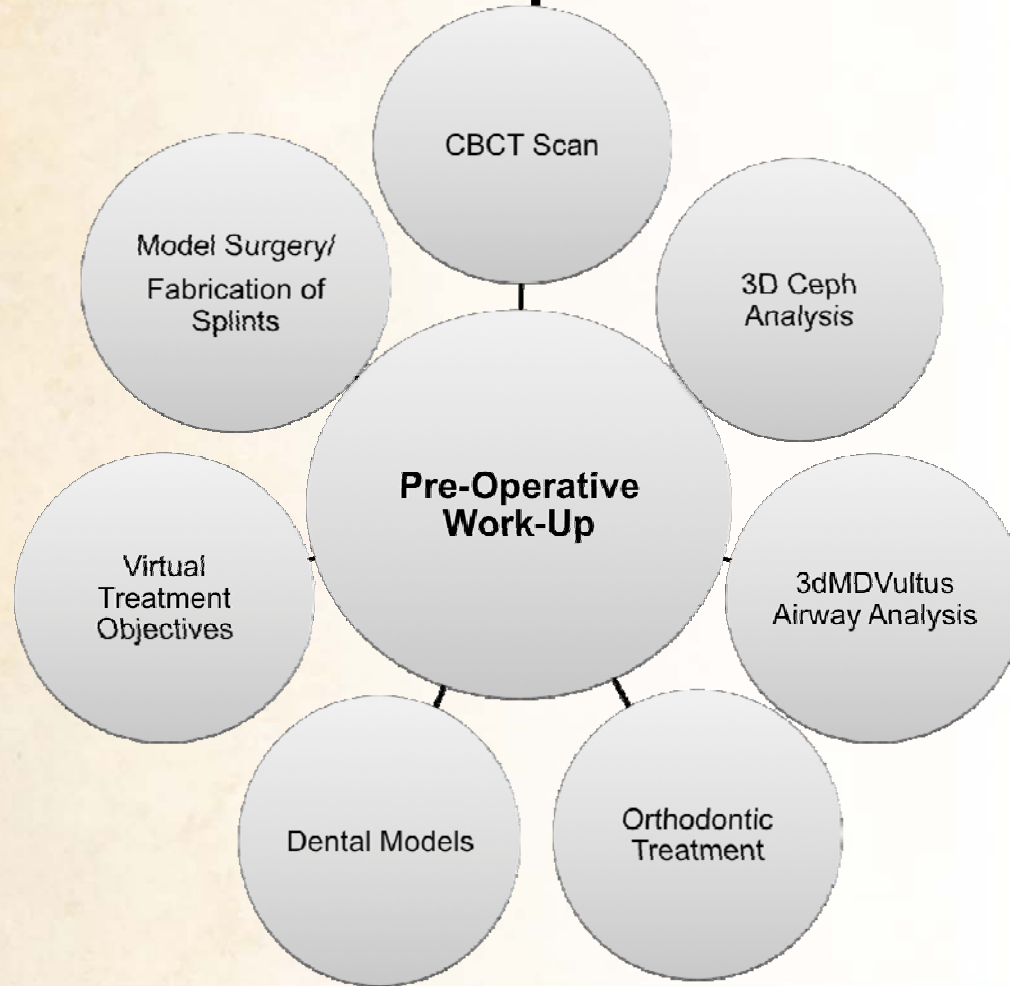
Clinical Experience



Patient Demographics

- **25 patients undergoing orthognathic surgery**
 - 9 Male
 - 16 Female
- **Age at time of Maxillomandibular Advancement**
 - 17-58 years old
 - Average 30.8 years old

Clinical Experience



Surgical Technique

- LeFort I Maxillary Osteotomy Advancement (+/- segmental) With Bone grafting
- Bilateral Sagittal Split Osteotomy of the Mandible Advancement
 - +/- Genioplasty

- Average Maxillary Movement: 6.5 mm
- Average Mandibular Movement: 12.3 mm
- Average Genio Movement: 6.4 mm



Post-Operative Care

Patients admitted to hospital for 2-4 nights



Discharged



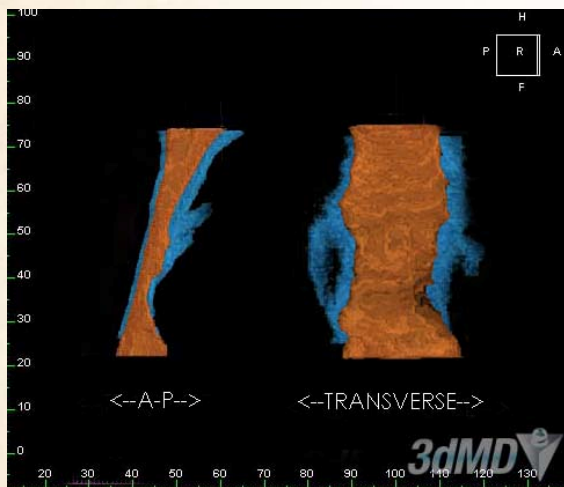
Weekly surgical and orthodontic follow-up



Post-operative CBCT scan obtained 3-6 months

Pre- & Post- Operative Volumetric Analysis

- Average UAS Pre 13.69 cm³
- Average UAS Post 19.44 cm³
- Average % Change UAS
 - 35.04%
- Average % Change RP
 - 44.65%
- Average % Change RG
 - 248.7%

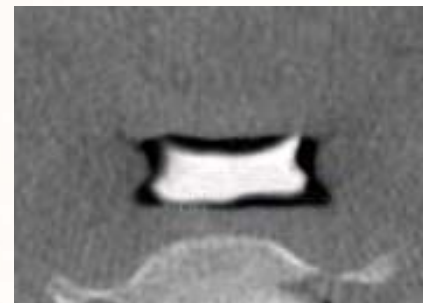


Patient Name	Pre-UAS (cm ³)	Post-UAS (cm ³)	Pre-Retropalatal Space (v cm ³)	Post-Retropalatal Space (v cm ³)	Pre-Retroglossal Space (v cm ³)	Post-retroglssal space (v cm ³)
JB	25.98	30.97	14.37	18.42	11.33	14.81
AB	14.81	20.03	12.16	16.7	3.26	4.7
LH	10.09	11.18	4.19	6.21	5.72	6.31
JS	23.88	28.49	10.37	13.37	12.73	13.25
IF	11.18	18.69	7.04	13.06	4.16	5.1
AV	21.47	23.81	13.64	16.69	6.22	4.31
RS	17.43	19.13	8.07	10.81	9.61	7.4
CD	8.35	11.16	5.97	7.66	2.47	3.98
DG	12.28	16.05	7.17	11.78	5.02	6.1
JBr	15.61	21.06	9.74	11.92	4.79	8.07
ED	5.95	18.92	3.7	9.8	2.82	7.61
MF	10	20.26	5.18	14.79	4.2	6.09
CJ	19.19	26.36	10.56	13.57	8.16	11.29
DC	14.75	15.03	9.98	10.33	4.31	5.01
NM	8.46	16.4	6.51	8.02	1.66	7.45
SP	15.86	21.41	10.02	13.21	5.41	7.56
RW	16.3	19.61	6.49	11.64	7.17	7.49
AW	8.64	10.1	6.04	6.92	2.33	2.98
KT	17.21	20.42	7.14	8.23	5.95	11.1
DL	8.45	18.16	5.48	11.28	3.31	6.49
EL	10.75	12.74	5.66	5.13	5.29	7.48
JE	15.67	17.17	10.33	10.89	4.22	5.58
HA	7.94	14.32	4.16	7.9	2.62	4.77
LV	20.83	27.23	9.3	17.12	9.14	9.21
TR	16.8	27.28	9.09	15.33	5.69	10.32

Pre- & Post- Operative Choke Point Surface Area Analysis

- **Average Choke Point RP Pre**
 - 184.11 mm²
- **Average Choke Point RP Post**
 - 286.91 mm²
- **Average % Change RP**
 - 55.84%
- **Average Choke Point RG Pre**
 - 157.46 mm²
- **Average Choke Point RG Post**
 - 213.29 mm²
- **Average % Change RG**
 - 35.45%
- **Location of Choke Pt Pre-Operatively**
 - 15 RG Pre-Op, 10 RP Pre-Op
- **Location of Choke Pt Post-Operatively**
 - 19 RG Post-Op, 6 RP Post-Op

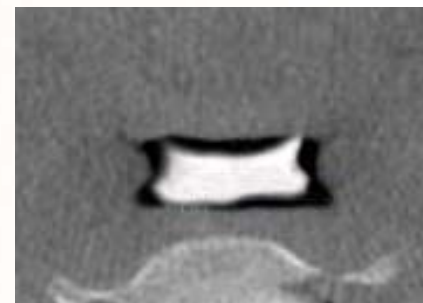
Patent Name	Pre-Choke point Retropalata (mm ²)	Post-Choke Point Retropalatal (mm ²)	Pre-Choke point Retroglossa (mm ²)	Post-chcke point Retroglossal (mm ²)
JA	357.47	552.72	225.08	374.09
AB	256.13	279.84	100.56	185.28
LH	67.36	157.77	85.6	157.32
IS	265.85	325.77	338.2	337.93
TP	117.63	236.91	155.36	154.89
AV	475.03	417.41	333.17	333.7
RS	227.73	296.08	163.62	167.4
CO	55.62	75.2	52.96	89.92
DO	132.93	131.28	161.44	181.6
JBr	295.43	508.65	170.01	155.2
EO	67.41	257.78	38.07	293.12
MF	109	153.92	89.38	110.56
CI	168.13	311.73	172.48	315.62
DC	255.08	237.6	183.2	176.32
NH	226.05	275.93	112.69	163.28
SP	224.32	228.59	193.8	167.13
ROV	194.89	335.79	244.34	260.77
AW	129.63	135.64	52.28	105.64
KT	123.2	254.56	134.1	184.8
DL	122.53	343.16	81.63	193.76
EL	139.95	229.76	144.27	186.38
JE	210.24	178.22	125.44	159.03
HA	81.19	239.46	57	144.99
LV	125.72	438.73	440.03	411.38
TR	173.92	454.09	181.78	327.53



Pre- & Post- Operative Surface Area Slice Analysis

- **Average PNS Pre**
567.83 mm²
- **Average PNS Post**
619.21 mm²
- **Average % Change PNS**
9.05%
- **Average OP Pre**
252.57 mm²
- **Average OP Post**
382.29 mm²
- **Average % Change OP**
7.39%
- **Average Hyoid Pre**
227.63 mm²
- **Average Hyoid Post**
272.14 mm²
- **Average % Change Hyoid**
19.55%

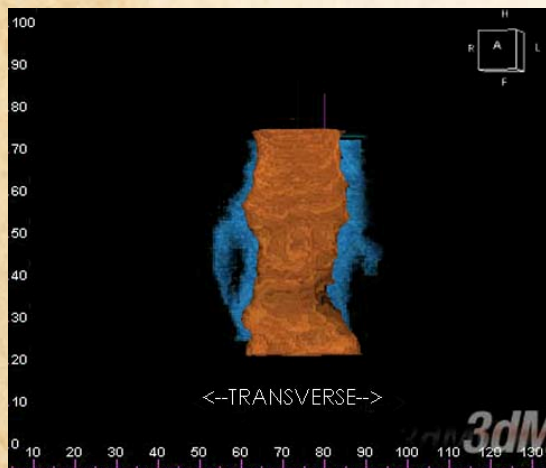
Patient Name	Pre-PNS (mm ²)	Post-PNS (mm ²)	Pre_OP (mm ²)	Post_OP (mm ²)	Pre-Hyoid (mm ²)	Post-Hyoid (mm ²)
JB	769.29	647.83	562.68	656.63	331.73	373.77
AB	714.31	884.3	466.38	491.21	150.13	216.64
LH	316.26	516.11	111.56	235.32	283.92	288.56
IS	545.3	688.22	270.89	456.97	519.37	517.77
TF	577.53	628.48	155.34	490.1	172.71	226.52
AV	803.79	712.57	520.9	737.51	318.38	224.95
RS	413.56	769.2	429.44	491.92	252.81	327.47
GD	564.64	644.39	110.06	122.86	85.6	165.12
DG	564.64	767.42	134.72	181.6	245.76	221.24
JR	555.53	607.03	337.94	383.61	246.59	200.48
ED	494.26	424.97	123.39	349.91	227.79	407.06
MF	785.44	893	126.69	185.92	136.81	172.32
GJ	898.51	1126.19	271.36	502.81	388.33	463.66
DC	592.86	507.29	362.25	191.53	287.28	269
NM	551.25	403.73	208.69	278.81	127.81	162.9
SP	533.29	536.75	229.12	310.85	193.36	258.36
EW	763.47	439.2	247.75	410.12	291.77	324.03
AW	489.38	433.34	187.44	173.73	53.84	116.65
KT	369.17	658.55	203.39	389.05	137.79	212.66
DL	576.44	694.03	31.63	432.71	150.88	239.57
BL	393.74	215.16	139.06	229.76	192.09	217.07
SE	581.44	699.79	285.77	279.82	148.83	159.83
HA	391.18	415.57	37.61	317.64	147.75	243.17
LV	555	675.49	457.72	534.68	314.54	425.15
TR	615.63	656.67	160.32	484.91	241.6	339.57



Pre- & Post- Operative Transverse Analysis

- Average mm change in the transverse dimension
 - Retropalatal Choke Pt:: 5.91 mm
 - Retroglossal Choke Pt: 2.98 mm
 - PNS: 2.70 mm
 - OP: 4.38 mm
 - Hyoid: .88 mm

Patient Name	Pre-Choke Point Retropalatal Transverse (mm)	Post-Choke Point Retropalatal Transverse (mm)	mm difference	Pre-Choke Point Retroglossal Transverse (mm)	Post-Choke Point Retroglossal Transverse (mm)	mm difference	PNS Transverse	PNS Transverse	mm difference	OP Transverse	OP Transverse	mm difference	Hyoid Transverse	Hyoid Transverse	mm difference
JB	26.3	44	17.7	33.6	32.8	-0.8	46.5	43.6	-2.9	41.4	44.4	3	35.7	32.8	-2.9
AB	33.25	31.2	-2.05	22.5	23.2	0.7	34.75	33.6	-1.15	40.75	39.2	-1.55	27	25.6	-1.4
LH	17.6	22.6	5.2	16.4	23.1	6.7	25.2	31.8	6.6	19.2	24	4.8	26	26.1	0.1
IS	27	29.2	2.2	24.6	25.6	1	33.3	39.6	6.3	23.7	32.8	9.1	36.9	38	1.1
TF	21.6	27.6	6	19.8	24.3	4.5	35.7	38.7	3	25.2	30	4.8	24.9	22.8	-2.1
AV	33.6	30.9	-2.7	28.2	27.6	-0.6	42	41.4	-0.6	38.1	39	0.9	28.8	28.8	0
RS	27.6	31.2	3.6	21	20.4	-0.6	31.25	37.2	5.95	42	44.1	2.1	28.75	30.9	2.15
CD	12.8	14.8	2	17.6	14	-3.6	28	29.6	1.6	18	16	-2	24	25.6	1.6
DG	23.2	21.6	-1.6	20.8	21.6	0.8	28.8	27.6	-1.2	24	24.8	0.8	31.2	29.6	-1.6
Jbr	24	27.6	3.6	24.6	24.4	-0.2	30.9	30	-0.9	29.4	28.8	-0.6	27.9	24	-3.9
ED	20.4	34.8	14.4	8.6	39.9	31.3	39	29.4	-9.6	27	35.4	8.4	30.9	33	2.1
MF	22.5	27.2	4.7	25	29.2	4.2	31.5	35.2	3.7	23.5	28.8	5.3	30.5	32.4	1.9
CJ	26.4	30.6	4.2	27.2	31.5	4.3	29.6	34.5	4.9	23.6	40.5	16.9	36	37.8	1.8
UC	36	38.8	2.8	29.2	26.4	-2.8	40.4	37.29	-3.11	37.2	35.2	-2	29.2	30.4	1.2
NM	20.5	26.4	5.9	18.75	24	5.25	27.5	32.7	5.2	23.5	29.1	5.6	21.75	24.3	2.55
SP	18.4	27.6	9.2	13.6	19.8	6.2	26	31.2	5.2	27.6	30.6	3	35.6	32.4	-3.2
RW	24.9	35.7	10.8	29.1	30	0.9	30	36.6	6.6	28.2	35.1	6.9	30.9	31.5	0.6
AW	22.25	21.9	-0.35	19	21.9	2.9	32.25	35.1	2.85	26	28.2	2.2	19	34.2	15.2
KT	19.2	28	8.8	24.6	28.4	3.8	19.5	25.2	5.7	29.7	35.2	5.5	19.2	29.2	10
DL	19	32.4	13.4	15.25	23.4	8.15	30	39	9	15.25	33	17.75	28.5	32.7	3.2
FL	20.1	24.9	4.8	22.6	24.9	2.3	24.9	24.3	-0.6	20.1	24.9	4.8	26.7	26.4	-0.3
IE	19.6	21.6	2	28	26.7	-1.3	32.8	36	3.2	20.8	25.8	5	30.8	28.2	-2.6
HA	22.25	41.4	19.15	18.75	27.3	8.55	25	30.6	5.6	25	33	8	30.5	30.6	0.1
LV	37.8	37.8	0	41	28.8	-12.2	35.4	38.4	3	46.2	36	-10.2	29.4	27.9	-1.5
TR	21.2	35.2	14	34	39.2	5.2	31.2	40.4	9.2	21.2	33.2	12	41.2	39.2	-2



Pre- & Post- Operative A-P Analysis

- Average mm change in the A-P dimension
 - Retropalatal choke pt: 1.80 mm
 - Retroglossal choke pt: 2.67 mm
 - PNS: 2.44 mm
 - OP: 2.41 mm
 - Hyoid: 2.12 mm

Patient Name	Pre-Choke Point Retropalatal AP (mm)	Post-Choke Point Retropalatal AP (mm)	mm diff	Pre-choke pt retrogl ossal AP (mm)	post-choke pt retrogl ossal AP (mm)	mm diff	PNS Pre-A-P	PNS Post-A-P	mm diff	OP Pre-A-P	OP Post-A-P	mm diff	Hyoid Pre-A-P	Hyoid Post-A-P	mm diff
JB	10.2	16.4	6.2	6.6	16.8	10.2	23.7	25.7	2	27.3	11.2	-16.1	13.5	16.8	3.3
AB	5.75	8.4	2.65	9.75	14.8	5.05	23.25	26	2.75	5.5	10.4	4.9	12.5	14.4	1.9
LH	1.6	3.6	2	3	3.6	0.6	10	10.8	0.8	2	3.3	1.3	0.8	8.7	-0.1
IS	12.6	12	-0.6	16.5	14	-2.5	22.5	24.6	2.1	14.1	18.1	4	22.2	20	-2.2
TF	3.9	10.2	6.3	7.2	14.4	7.2	18.3	20.1	1.8	4.2	11.1	6.9	6.6	15.8	9.2
AV	21.6	15	-6.6	13.5	15.3	1.8	25.8	22.8	-3	23.7	26.7	3	15	6.3	-8.7
RS	8.1	7.2	-0.9	8.7	8.4	-0.3	13.75	18.9	5.15	7.75	7.8	0.05	8.75	11.4	2.65
CD	4	4.8	0.8	4	5.6	1.6	19.6	26	6.4	4.8	5.6	0.8	6.8	7.2	0.4
DC	4	8.4	4.4	8	8.4	0.4	17.6	18	0.4	4	6	2	10	8.8	-1.2
JBr	11.4	12.8	1.4	10.2	10	-0.2	22.5	32.08	9.58	11.1	13.6	2.5	12.9	10	-2.9
ED	1	2.7	1.7	1	3.3	2.3	17.7	18.3	0.6	1.8	6.3	4.5	9.6	16.2	6.6
MF	4.25	4	-0.25	3.75	5.2	1.45	19.5	26.4	6.9	4.5	4.4	-0.1	6	7.2	1.2
CJ	5.2	8.4	3.2	7.6	7.8	0.2	24.4	16.5	-7.9	10	20.7	10.7	15.6	16.8	1.2
DC	6	7.6	1.6	6	8.8	2.8	18.4	17.6	-0.8	6.4	18	11.6	13.6	14	0.4
NM	4.5	10.2	5.7	7	4.5	-2.5	23.75	18.9	-4.85	6.5	10.2	3.7	5.25	4.8	-0.45
SP	9.6	9.6	0	10	8.7	-1.3	12.8	18.9	6.1	9.6	10.5	0.9	12	13.8	1.8
RW	9	9.9	0.9	12.3	13.8	1.5	10.8	19.2	8.4	17.1	13.5	-3.6	13.5	14.7	1.2
AW	6.5	6.3	-0.2	2.5	6.3	3.8	18.75	15.9	-2.85	7.5	6.3	-1.2	2.5	6	3.5
KT	5.1	10	4.9	9.9	12.4	2.5	15.9	25.2	9.3	16.2	13.2	-3	6.9	13.2	6.3
DI	8	11.4	3.4	4.75	8.7	3.95	23	27.5	4.5	4.75	11.4	6.65	6.5	8.1	1.6
EL	5.4	7.5	2.1	8.1	9.3	1.2	21	23.7	2.7	5.4	7.5	2.1	7.8	11.4	3.6
IE	19.25	8.7	-10.55	4.4	5.4	1	18.4	19.8	1.4	10.8	24	13.2	7.6	9	1.4
HA	2.75	7.8	5.05	3.25	5.7	2.45	15.5	19.5	4	3.5	8.1	4.6	6.75	12.6	5.85
LV	12	18.3	6.3	11.4	20.1	8.7	18.6	22.5	3.9	17.4	13.5	-3.9	13.8	19.8	6
TR	7.2	12.8	5.6	5.6	20.4	14.8	18	20.8	2.8	7.2	12	4.8	10	20.4	10.4



Pre- & Post- Operative Height Analysis

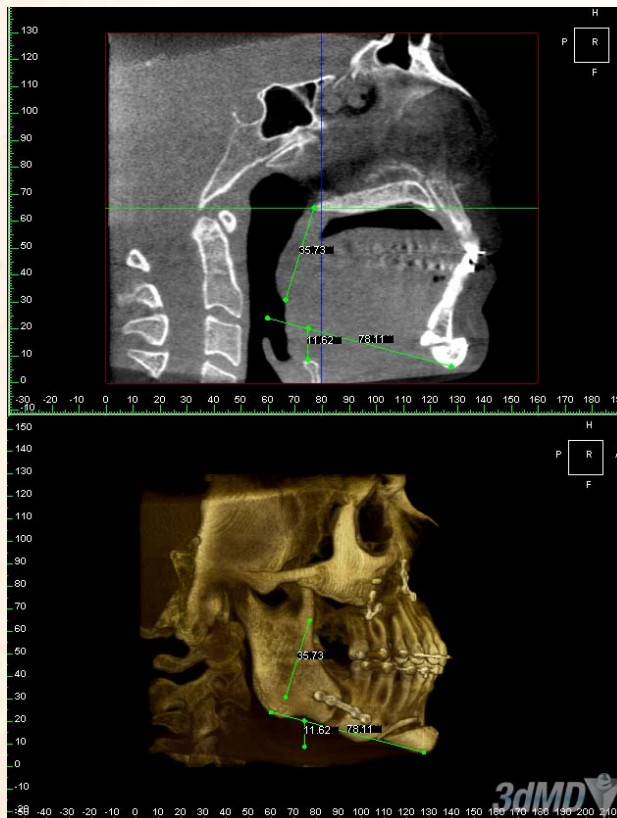
- Average Change in UAS height
 - -.48 mm
- Average Change in RP height
 - +1.44 mm
- Average Change in RG height
 - -1.92 mm

Patient Name	UAS height before	UAS height after	UAS mm diff	RP height before	RP height after	RP mm diff	RG height before	RG height after	RG mm diff
JD	69	57	-12	38	30	-8	30	27	-3
AD	60	57	-3	33	36	3	27	21	-6
LH	60	57	-3	30	30	0	30	27	-3
IS	63	66	3	24	33	9	38	33	-5
TF	60	54	-6	30	33	3	30	21	-9
AV	45	54	9	27	33	6	18	21	3
RS	69	72	3	30	33	3	38	39	1
GD	72	66	-6	38	42	4	33	24	-9
DG	63	66	3	45	51	6	18	15	-3
JBr	94	57	-37	21	27	6	33	30	-3
LD	57	63	6	36	38	2	21	21	0
MF	66	75	9	39	42	3	27	33	6
GJ	70	70	0	38	36	-2	34	34	0
UC	54	54	0	33	33	0	21	21	0
NM	57	54	-3	33	38	5	18	15	-3
SP	75	72	-3	33	30	-3	42	42	0
RW	54	54	0	21	30	9	33	24	-9
AW	57	51	-6	33	27	-6	24	24	0
KT	72	69	-3	39	36	-3	33	33	0
DL	54	60	6	24	30	6	30	30	0
EL	63	60	-3	33	21	-12	30	30	0
IE	60	60	0	33	33	0	27	27	0
HA	60	54	-6	30	30	0	30	24	-6
LV	57	60	3	30	36	6	27	24	-3
TR	66	60	-6	36	33	-3	30	27	-3



PRE & POST-OPERATIVE SOFT PALATE & HYOID LENGTH ANALYSIS

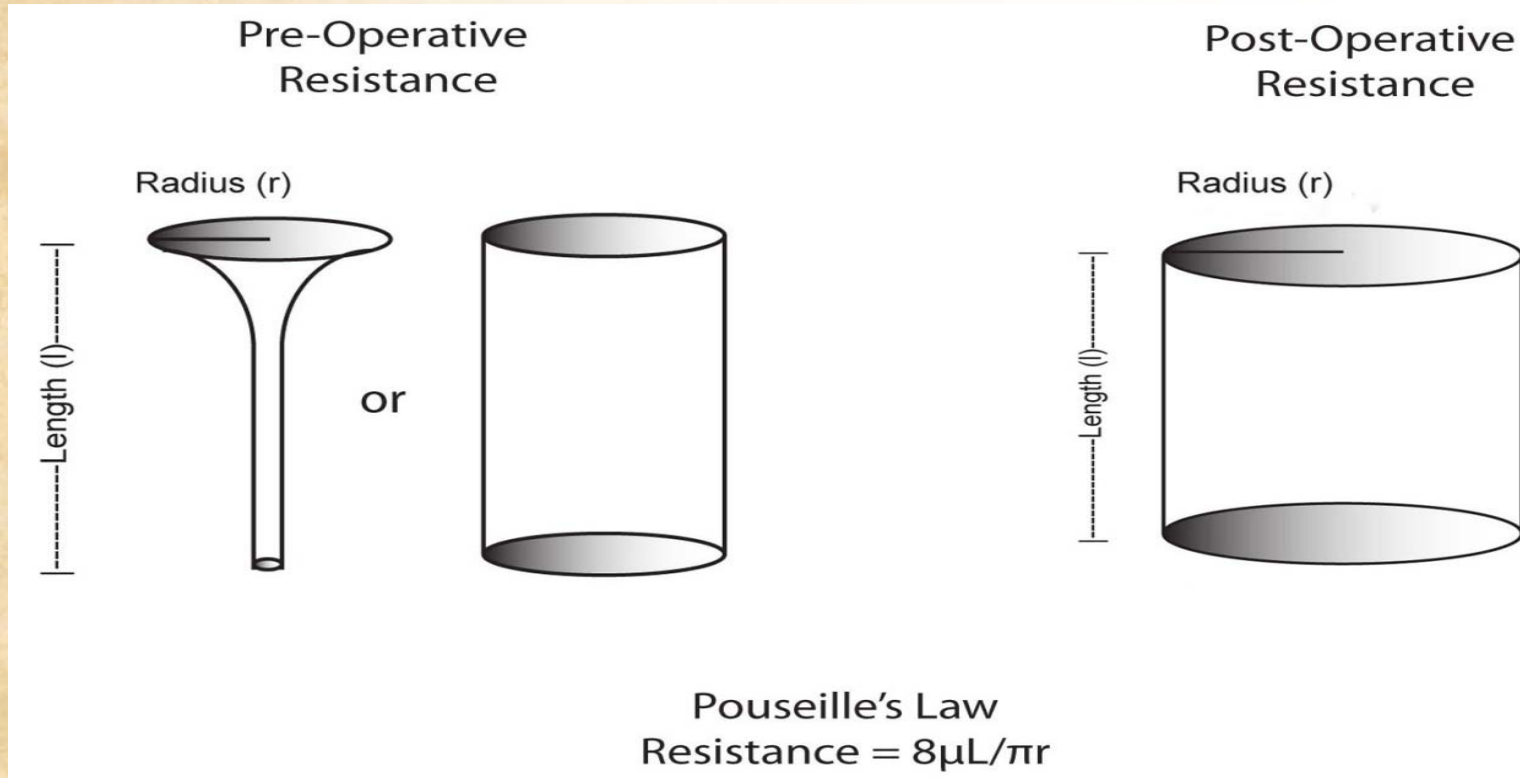
- Average Change in Soft Palate Length
 - -0.87 mm
- % change in Soft Palate Length
 - -2.29%
- Average Change in Mandibular Plane –Hyoid Length
 - -1.97 mm
- % change in Mandibular Plane – Hyoid Length
 - -10.32%



Patient Name	Soft Palate Length Before	Soft Palate Length After	mm diff	M-Hy Before	M-Hy After	mm diff
JB	47.01	30.38	-17.56	19.96	7.16	-12.8
AR	41.37	40.93	-0.44	18.25	17.59	-1.34
LII	37.99	35.92	-2.07	18.18	14.03	-4.15
IS	37.6	39.27	1.67	24.39	22	-2.39
TF	35.07	34.67	-0.4	10.83	10.19	-0.64
AV	32.57	36.07	3.5	5.1	14.71	9.61
RS	34.64	35.71	1.07	17.7	21.7	4
GD	44.29	48.98	4.67	18.43	18.33	-0.1
DG	49.4	53.62	4.22	18.62	16.77	-1.85
JBr	29.32	35.82	6.5	14.03	16	1.97
ED	37.15	38.36	1.21	13.68	14.06	0.38
MF	45.49	36.48	-9.01	26.68	30.19	3.51
GJ	41.79	36.22	-5.53	24.78	14.98	-9.8
DC	34.88	32.78	-2.1	13.31	11.43	-1.88
NM	37.12	40.58	3.46	10.2	17.85	7.65
SP	38.45	36.72	-1.73	21.3	19.36	-1.94
RW	29.18	32.6	3.42	23.8	18.5	-5.3
AW	33.03	33.44	0.41	22.92	16.58	-6.34
KT	41.32	39.33	-1.99	25.52	25.52	0
DL	38.21	33.32	-4.89	29.60	19.46	-10.4
EL	30.4	29.11	-1.29	22.11	16	-6.11
IE	37.66	37.06	-0.6	26.21	13.21	-13
HA	34.94	34.66	-0.28	21.28	19.37	-1.91
LV	33.58	38.32	4.74	16.06	19.65	3.59
TR	41.87	33.25	-8.62	16.03	13.36	-2.67

POUSEILLE'S LAW

- As radius increases and height decreases, the resistance of flow decreases



Results

- **Volume**

- The UAS enlarged significantly
- The shape of the UAS changed from a funnel to a tube like shape
- The retroglossal space increases in volume more than the retropalatal space

- **Surface Area**

- The surface area at the choke point in the retroglossal space increases by a greater percent change than the retropalatal space
- The location of the choke point is generally post-operatively in the retroglossal space, however, the retroglossal space increases the most as does the hyoid surface area slice
 - Indication of normalizing the airway and eliminating any bottlenecking/funneling
- The airway enlarges in a rectangular fashion

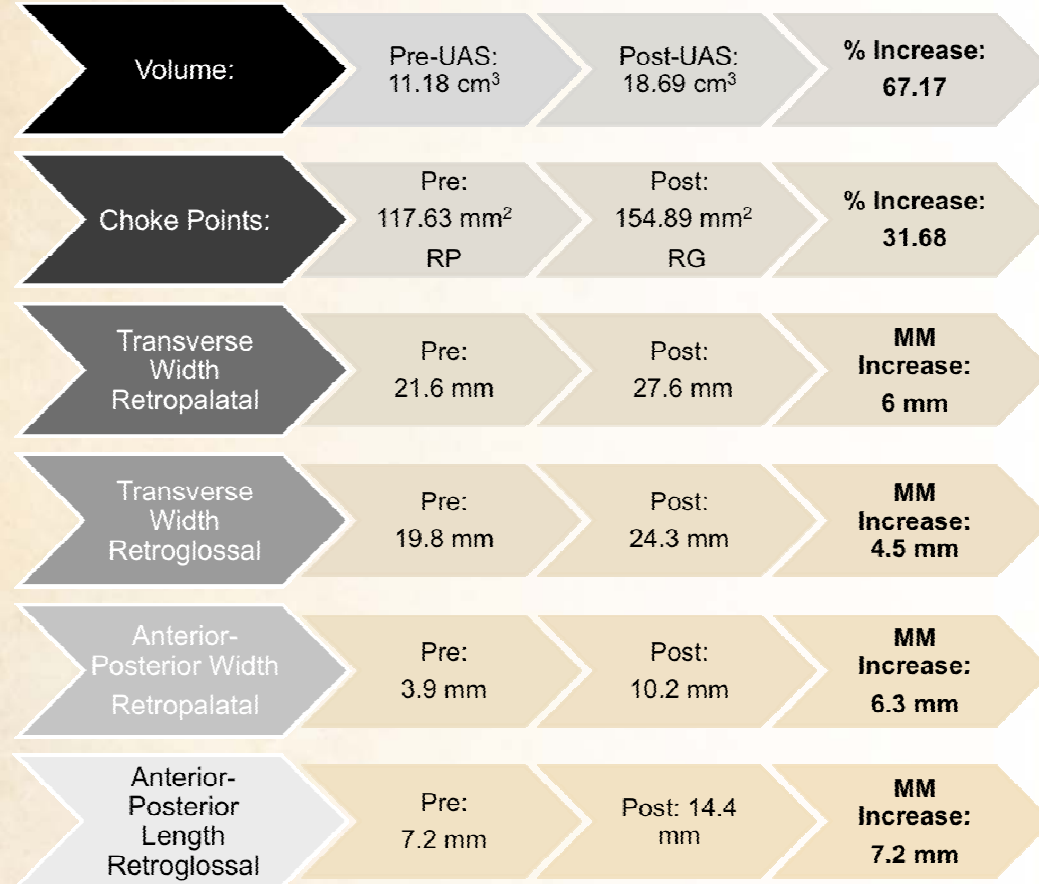
- **Width**

- The transverse dimension increases more than the A-P dimension in millimeter change
- The A-P dimension increases more than the transverse dimension in percent change
- The retropalatal space increases more in the transverse and A-P dimensions than the retroglossal space does

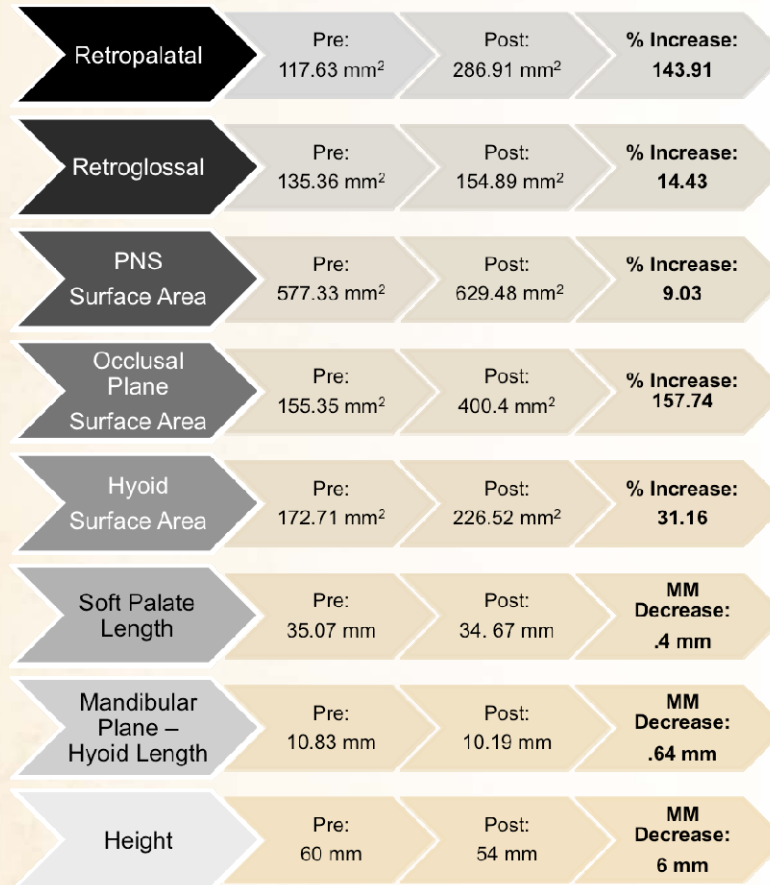
- **Height**

- The height of the airway measured from the posterior of the post nasal spine to the superior tip of the hyoid bone generally decreases post-operatively
- The height of the airway was pre-and post- operatively longer in the retropalatal space than the retroglossal space
- The height of the retropalatal space increase on average and the height of the retroglossal space decreases
- The height of the mandibular plane to the hyoid bone decreases

Case I



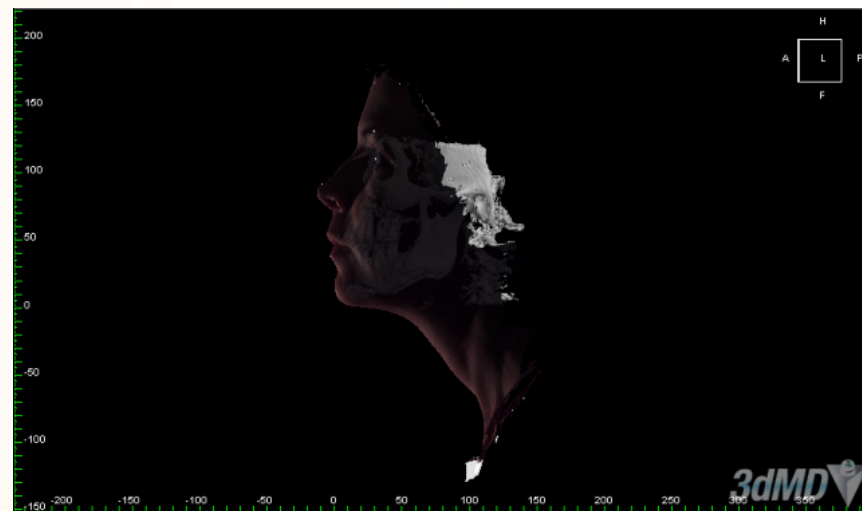
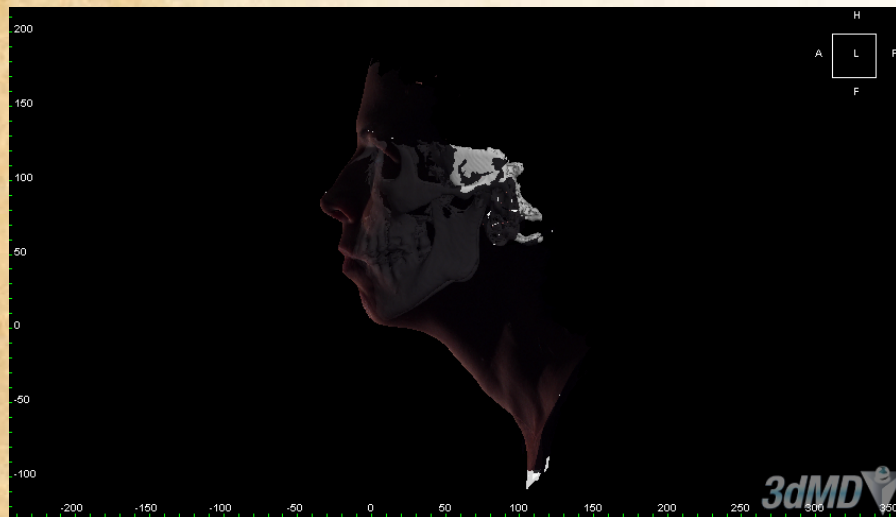
Case I



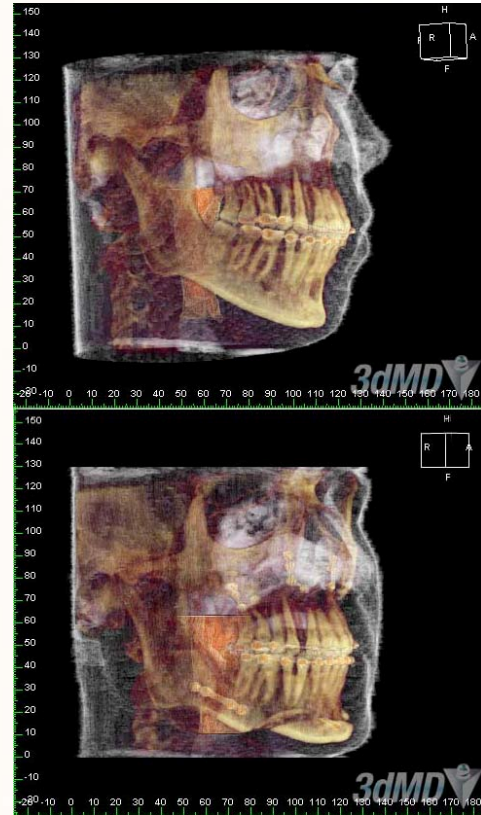
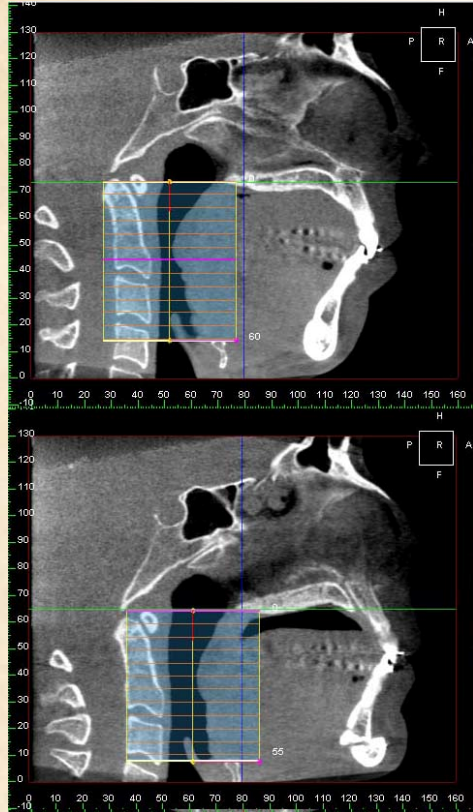
CASE I

Pre-Surgical

Post-Surgical



Case I



Case I

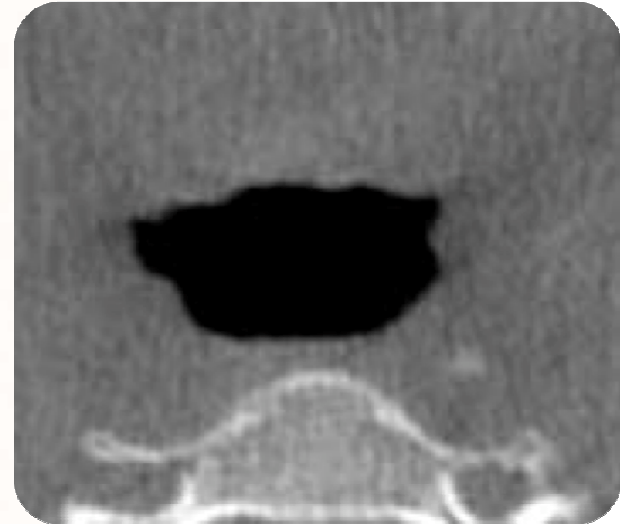


Case I

Pre-Surgical



Post-Surgical



Conclusions

- 3-Dimensional airway analysis indicates that orthognathic surgery for dento-facial deformities positively increases the patients airway by increasing tension and changing the position of the palatal and pharyngeal muscles. As a result:
 - Airway volume increases
 - Shape of airway changes
 - Bottleneck to cylinder
 - Height of airway decreases
 - Resistance decreases
 - Radius of the airway increases
 - Height of the airway decreases

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2. Broujerdi J, Jacobson R, Schendel S, *Volumetric 3D Upper Airway Analysis of Patients with OSA after Maxillomandibular Advancement*. The 3rd William H. Bell Lectureship: Accelerated Orthognathic Surgery and Increased Orthodontic Efficiency: A Paradigm Shift, 2011 March
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4. Mattos CT, et al. *Effects of Orthognathic Surgery on Oropharyngeal Airway: a Meta-Analysis*. Int. J. Oral Maxillofacial Surgery, 2011 July
5. Schendel S, Hatcher D, *Automated 3-D Airway Analysis by Cone Beam CT*. Journal of Oral and Maxillofacial Surgery. 2010 March; 68(3):696-701
6. Schendel S, Jacobson R, Normal Upper Airway Growth & Development. Presented at AAOMS Chicago 2010, pre-publication.