SURGICAL MANAGEMENT OF OBSTRUCTIVE SLEEP APNEA SYNDROME

Peter D Waite MPH DDS MD FACS

ENDOWED CHARLES MCCALLUM PROFESSOR

PROFESSOR AND CHAIR DEPT OF ORAL AND MAXILLOFACIAL SURGERY

OUTLINE

- History of Sleep
- Medical problem
- Surgical results
- Technique
- Evaluation of the airway.

HYPNOS SLEEP MYTHOLOGY

- Greek god or spirit of Sleep, opium horn
- Nyx (night) was his mother
- Somnus was the Roman equivalent
- Thanatos (peaceful Death) was his brother

MORPHEUS

- Greek god of dreams
- Son of Nyx
- Brother and attendant to Hypnos
- Could take any shape and appear in dreams.

H

- Ondine the immortal nymph fell in love with a German Knight who pledges “my every waking breath shall be my pledge of love and faithfulness to you. She finds him with another lover and, while snoring curses, “for as long as you are awake you shall breath. But should you ever fall into sleep that breath will desert you”

THE POSTHUMOUS PAPERS OF THE PICKWICK CLUB
(ALSO KNOWN AS THE PICKWICK PAPERS) IS THE FIRST NOVEL BY CHARLES DICKENS 1837

MEDICAL PROBLEM

OBSTRUCTIVE SLEEP APNEA
OSA

- “Picwickian syndrome” Charles Dickens, *Posthumous papers of the pickwick club*, 1837
- Burwell, 1956 1st published case
- Day time fatique, EDS
- Sleep deprivation
- 10 sec cessation of airflow
- RDI or AHI, events/hr

SLEEP DISORDERS

- 1979: First official classification of sleep disorders
- Estimated 40% of adults experience some form of sleep disorder
  - Sleep apnea
  - Narcolepsy
  - Insomnia
- Estimated cost: $16 billion

SLEEP DISORDERED BREATHING

- Snoring
- Upper Airway Resistance Syndrome (UARS)
  - Sleep disturbance without desaturation
- Sleep Apnea
  - Central
  - Obstructive
  - Mixed

OSA : INCIDENCE

- 1-3 % of adult population: conservative
- Higher in industrialized countries
- Middle age males: 1-16%
- Elderly males: 18-67%
- Middle age females: 1-5%
- Elderly females: 20-54%

OBSTRUCTIVE SLEEP APNEA PATHOPHYSIOLOGY

- Maximal relaxation during REM sleep
- Most cases: multiple sites of obstruction

OBSTRUCTIVE SLEEP APNEA
CARDIOPULMONARY CHANGES

- Pulmonary
  - Pulmonary Hypertension
  - Polycythemia
- Cardiac
  - CHF
  - Systemic Hypertension
  - Arrhythmias
  - Decreased cardiac output

CARDIO VASCULAR DISEASE IN OSA

- HTN correlates to OSA even when other factors are controlled
- Ventricular arrhythmia
- Brady-tachy syndrome most common
- PVCs increase in OSA
- Decrease in CO = bradycardia, BP, neg pressure
- MI= BP surge, plaque fracture, vasospasm more common in AM assoc with REM

  Sleep Heart Health Study, Young, Jama

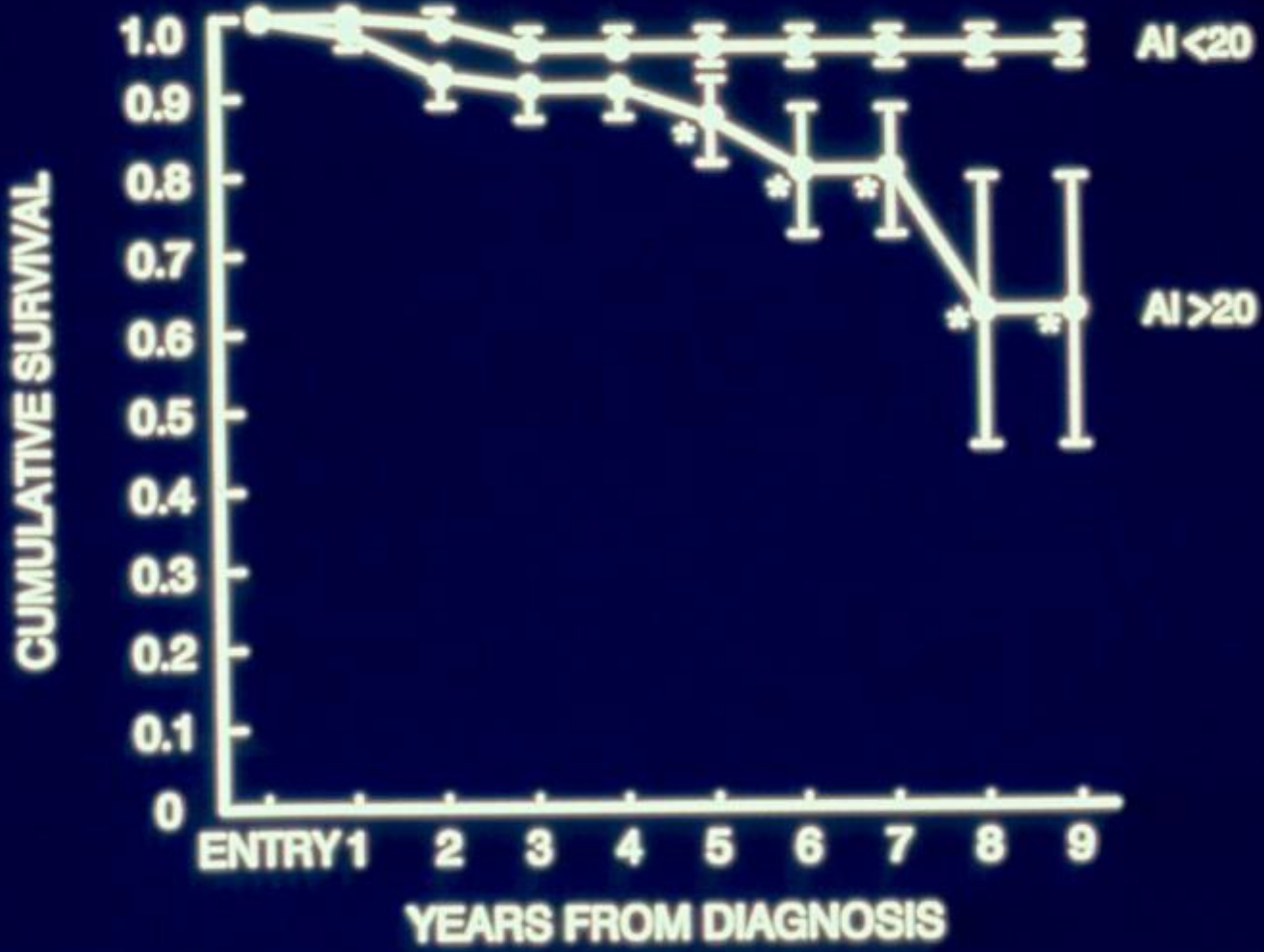
MI AND OSA

- 23 times risk of MI in high OSA

  ref Lancet

EFFECT OF AI ON MORTALITY

UNTREATED, ALL AGES



Source: He J, Kryger M, Zorick F, et.al. Mortality and Apnea Index in Obstructive Sleep Apnea. Chest 1988; 94: 9-14.

OBSTRUCTIVE SLEEP APNEA MORTALITY

- Mild OSA (<20 apneas/hour)
  - 4 % mortality at 8 years
- Moderate and Severe OSA
  - 37 % mortality
- Treated vs. Non-treated
  - 0 % vs. 11 % mortality at 5 years

HE J CHEST 1988

OBSTRUCTIVE SLEEP APNEA MORBIDITY / MORTALITY

- 75 % of patients that suffer from OSA have motor vehicle accidents attributable to EDS

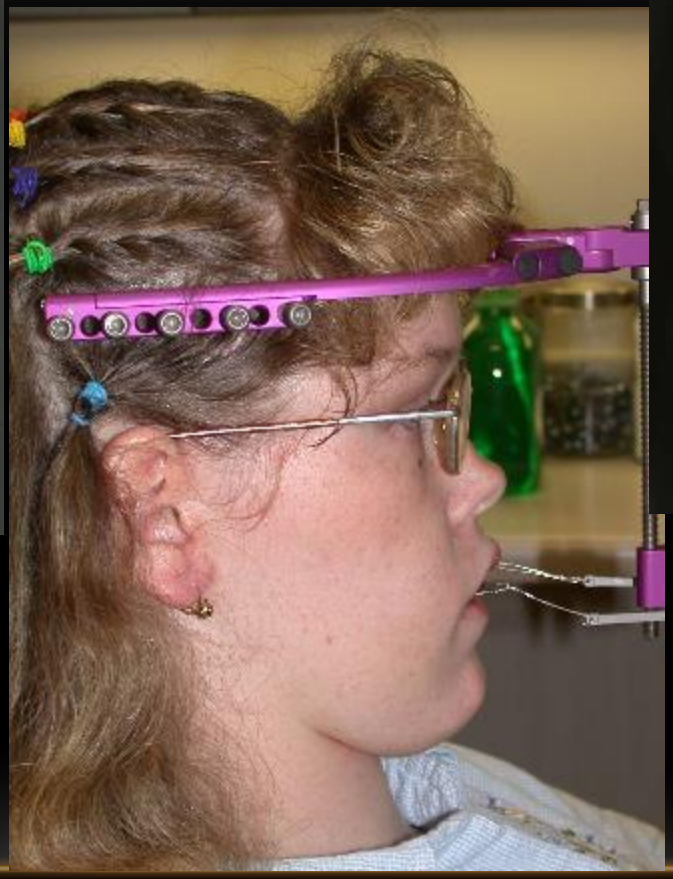
SLEEP INDUCED DISASTERS

- In 1998, 200,000 MVAs were caused by sleepiness in the US, National comm on sleep 92
- "fall asleep MVA" are now one of leading causes of fatal crash, 25% Horne 94, Lamberg JAMA 96, Lyznicki JAMA 98
- 30 –90% of work place accidents- Chernobyl,

  3 mile island, Exxon valdes, Bhopal, and Challenger disaster National comm on sleep 92, Dinges 95

OBSTRUCTIVE SLEEP APNEA
CPAP: SIDE EFFECTS

- Mask rash
- Conjunctivitis
- Rhinorhea
- Sinusitis
- Congestion
- Epistaxis
- Smothering sensation
- Bed partner acceptance



OBSTRUCTIVE SLEEP APNEA
CPAP REQUIREMENTS

- Patient intellect and motivation
- Patent nasal airway
- Good pulmonary function
- Pressure setting by PSG
- Close follow-up exams and PSG
- Expensive over life time

OBSTRUCTIVE SLEEP APNEA
CPAP: COMPLIANCE

- 65 - 90 %
  - Sanders et al. 1986
- 46 % when monitored
  - Defined compliance as >4 hrs/night; 70 % of nights
  - Only 25 % on nightly basis
  - Kribbs et al. 1993

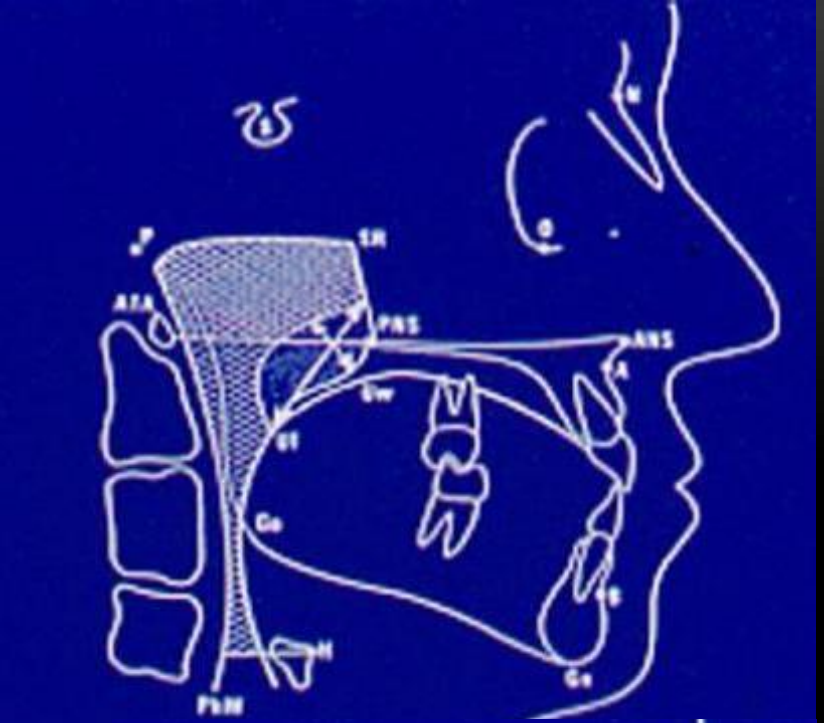
OBSTRUCTIVE SLEEP APNEA
BIPAP

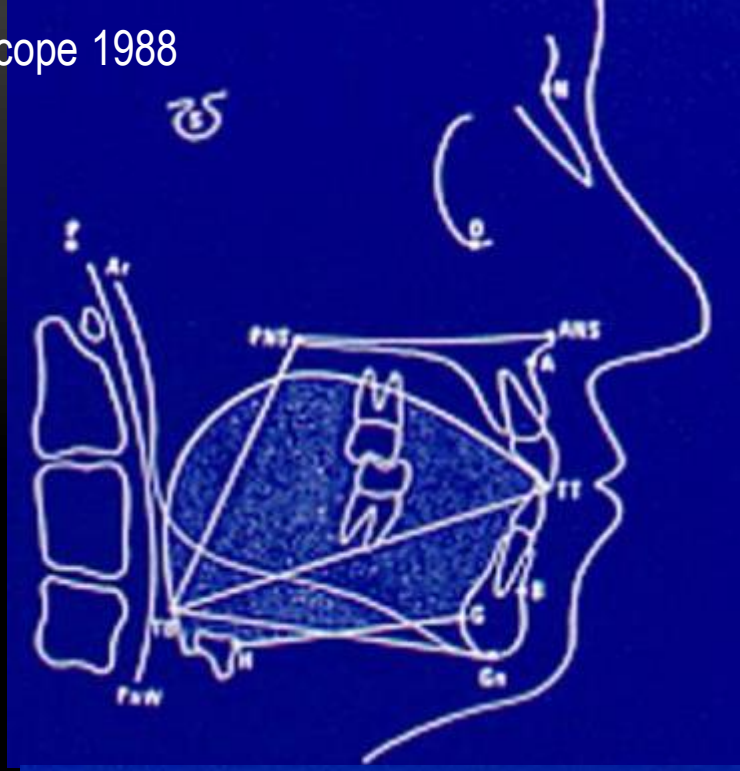
- Allows independent adjustment of inspiratory and expiratory pressure.
- Improved compliance?
  - Compliance rate 50 % (>4 hours; 70 % of nights)
  - Reeves-Hoche et al. 1983

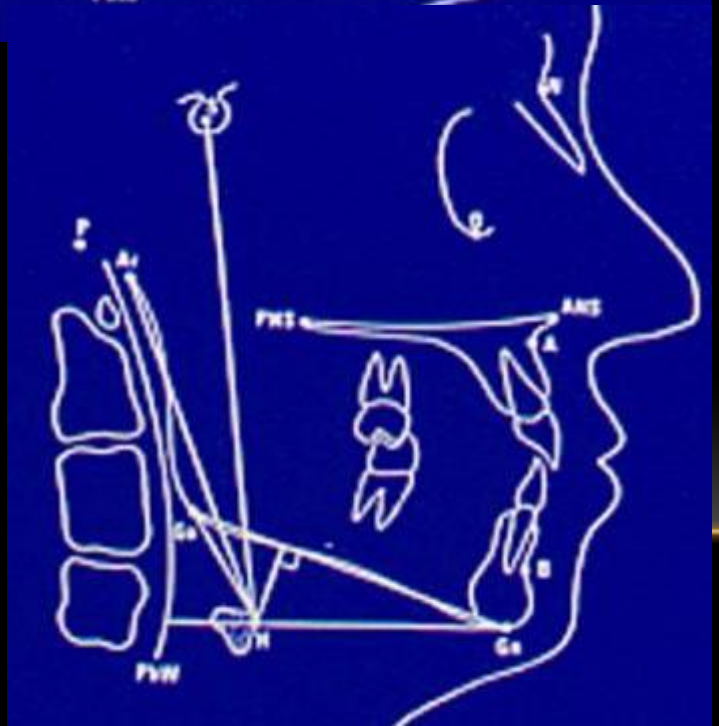
OBSTRUCTIVE SLEEP APNEA CEPHALOMETRIC ANALYSIS

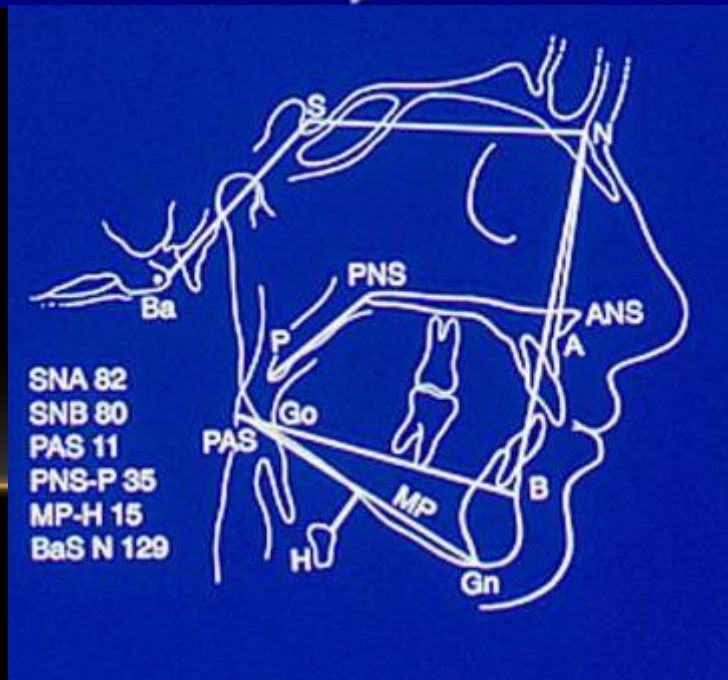
- Key measurements and norms
  - SNA
  - SNB
  - Posterior airway space (PAS) = 10 +/- 3mm
  - Soft palate length = 42 +/- 5
  - MP- H = 17 +/- 6 mm
  - N-S-Ba (cranial base angle) = 129 +/- 5
  - Frankfort to MPA= 24+/- 5

Strelzow Laryngoscope 1988



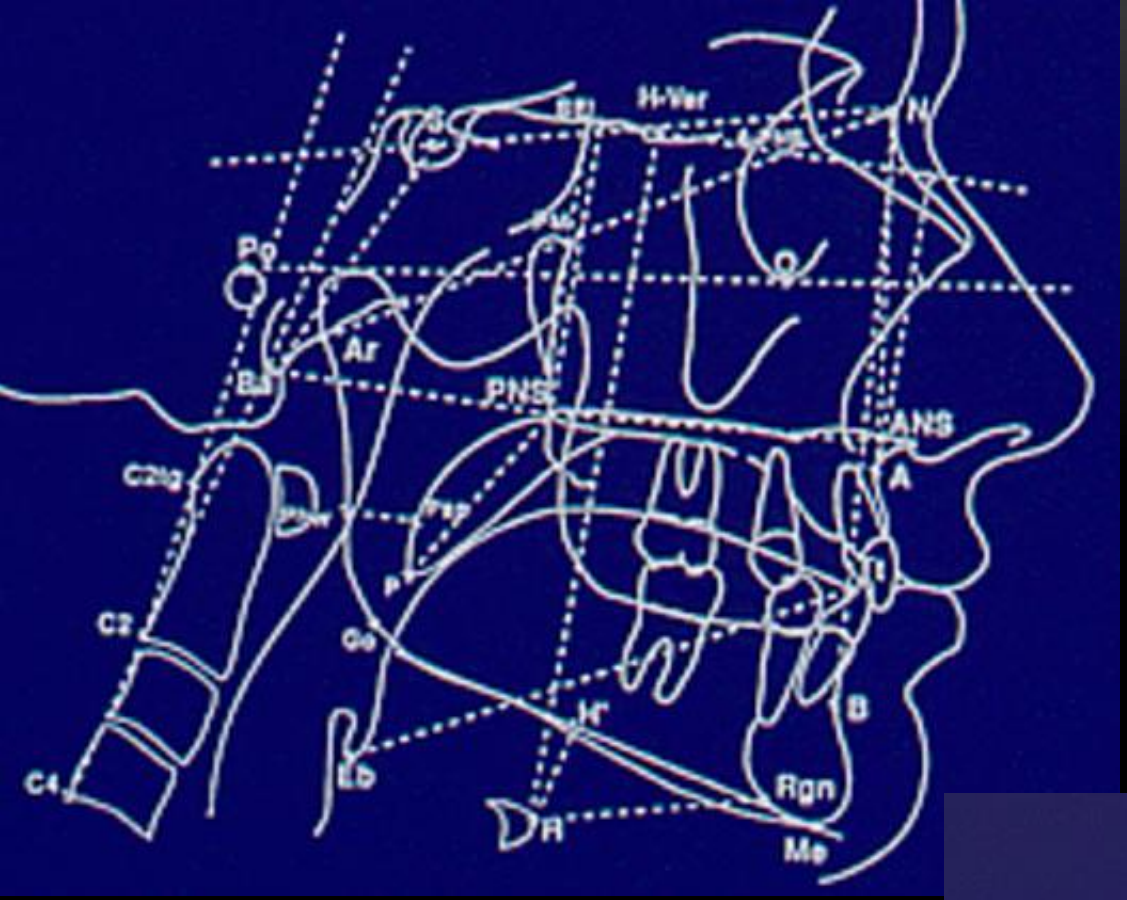




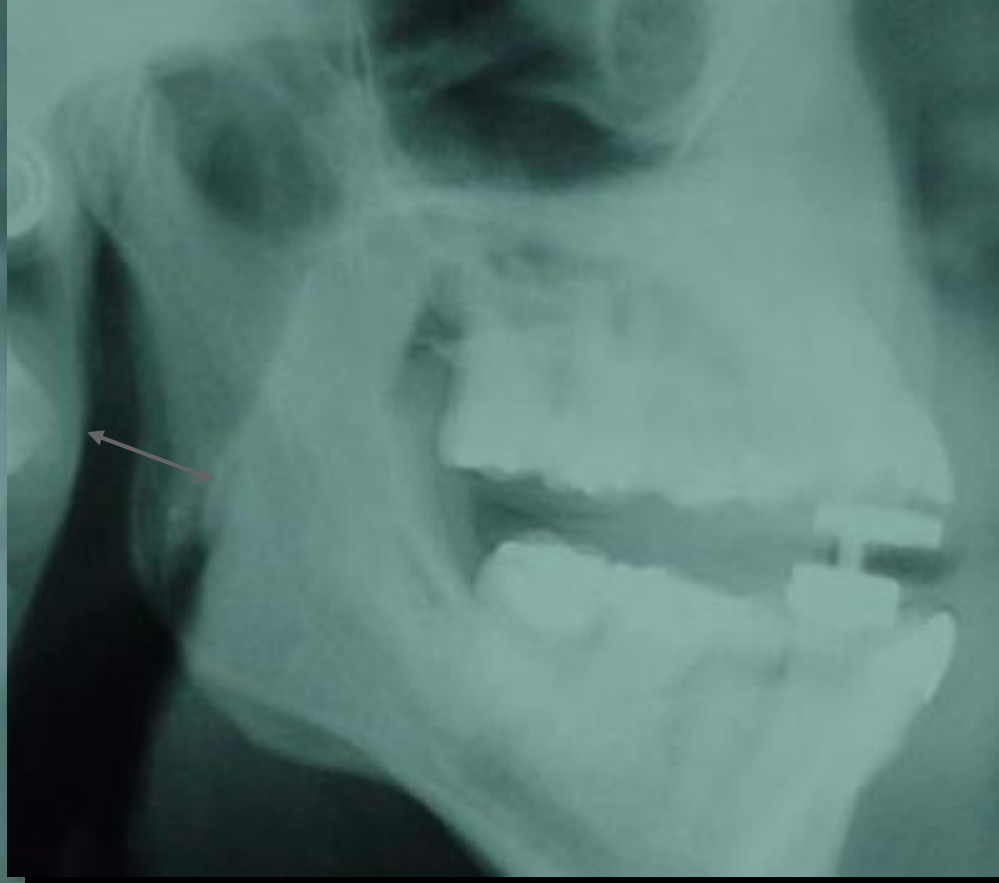


OBSTRUCTIVE SLEEP APNEA CEPHALOMETRIC ANALYSIS

- Case Western Reserve University Craniofacial Index
  - 82 - 87 % accurate in predicting OSA when used in conjunction with BMI
- Study of cephalometric data from OSA populations demonstrates obstructions at multiple sites most common

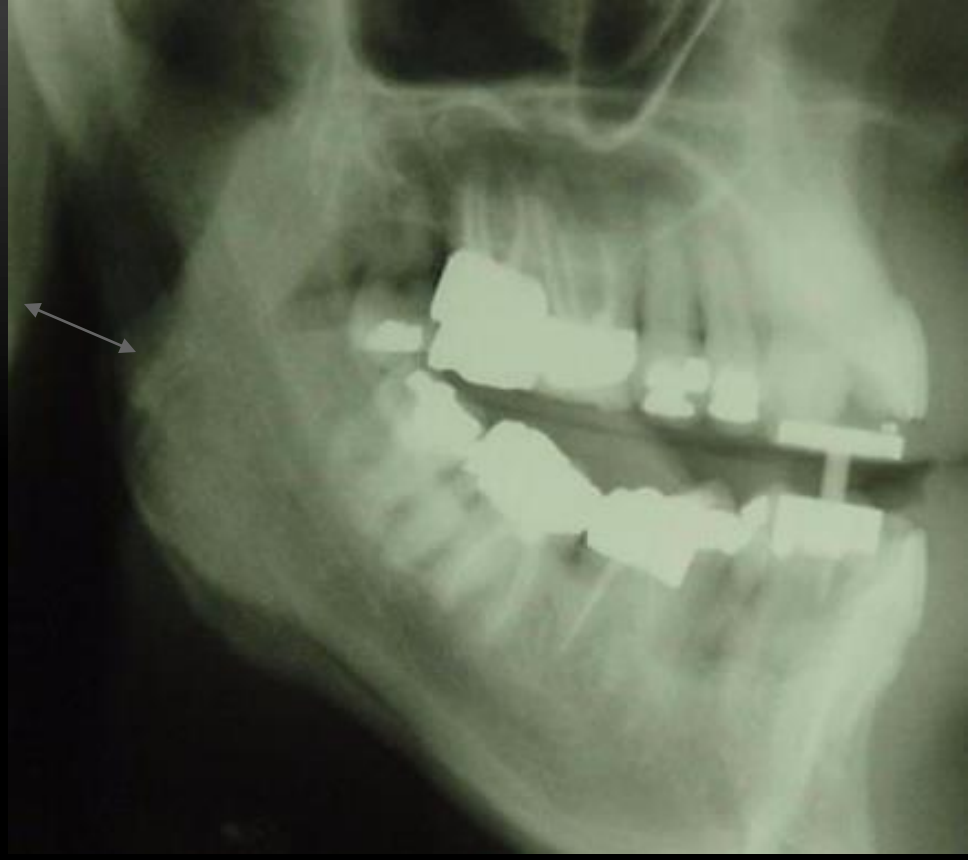


Craniofacial Index Score = −7.465 − 0.0163 (<BaSN) + 0.0486 (<C2C4-SN) + 0.1055 (A-PNS) − 0.0127 (Age) + 0.0618 (BMI) + 0.1105 (H-MP) + 2.5907 (CI/FI) − 0.0547 (InMxLth) + 0.1074 (P-PNS) − 0.0282 (Phw-Psp) − 0.0572 (PNS-Ba) + 0.0127 (RAM/MCF) − 3.5778 (T/InMx) − 0.0002 (T-area) − 0.0236 (TI) − 0.0971 (Head Post.)



Retropalatal space increase by dental appliance. Advancement of mandible moves soft palate and base of tongue.
CT scans of paralyzed patients: Kato, Chest 2000





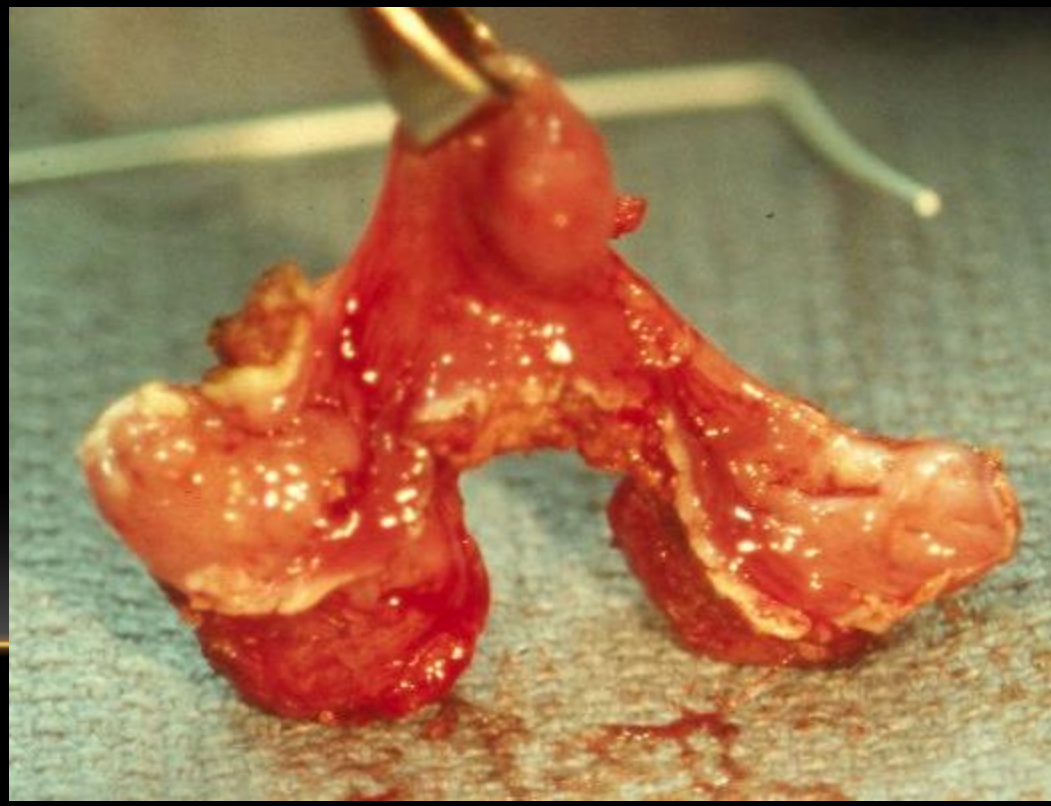
Class III does not respond as well as class II

OBSTRUCTIVE SLEEP APNEA UVULOPALATOPHARYNGOPLASTY (UP3)

- Remove tonsils if present
  - if prior tonsillectomy chance of success decreases markedly
- Good indication in children with OSA
- Technique quite variable

OBSTRUCTIVE SLEEP APNEA
HISTORY OF PALATOPLASTY

- For snoring
  - Ikematsu, 1952
- For OSA
  - Fujita, 1981



OBSTRUCTIVE SLEEP APNEA
UP3: SUCCESS

- Patients commonly report subjective improvement
- Cure defined as 50 % reduction in RDI
  - 24 % if site of obstruction retrolingual
  - 67 % if site of obstruction is retropalatal
- Cure defined as RDI < 20
  - 5 % if site of obstruction is retrolingual
  - 46 % if site of obstruction is retropalatal

OBSTRUCTIVE SLEEP APNEA
UP3: LONG-TERM SUCCESS

- Henk Boot et al. 2000
  - median 34 months (11-74)
  - Snoring
    - 63 % had improvement
    - 23 % no change
    - 14 % had deterioration
  - Oxygen desaturation index
    - Patients that demonstrated short-term improvement relapsed after 6 months
  - EDS
    - relapsed to preoperative levels after 6 months

OBSTRUCTIVE SLEEP APNEA
UP3: DISADVANTAGES

- Painful
- Painful
- Operative morbidity
  - hemorrhage
  - loss of airway post operatively
- mortality
- Potential for VPI
- Does not work except in mildest cases of OSA

OBSTRUCTIVE SLEEP APNEA
LAUP

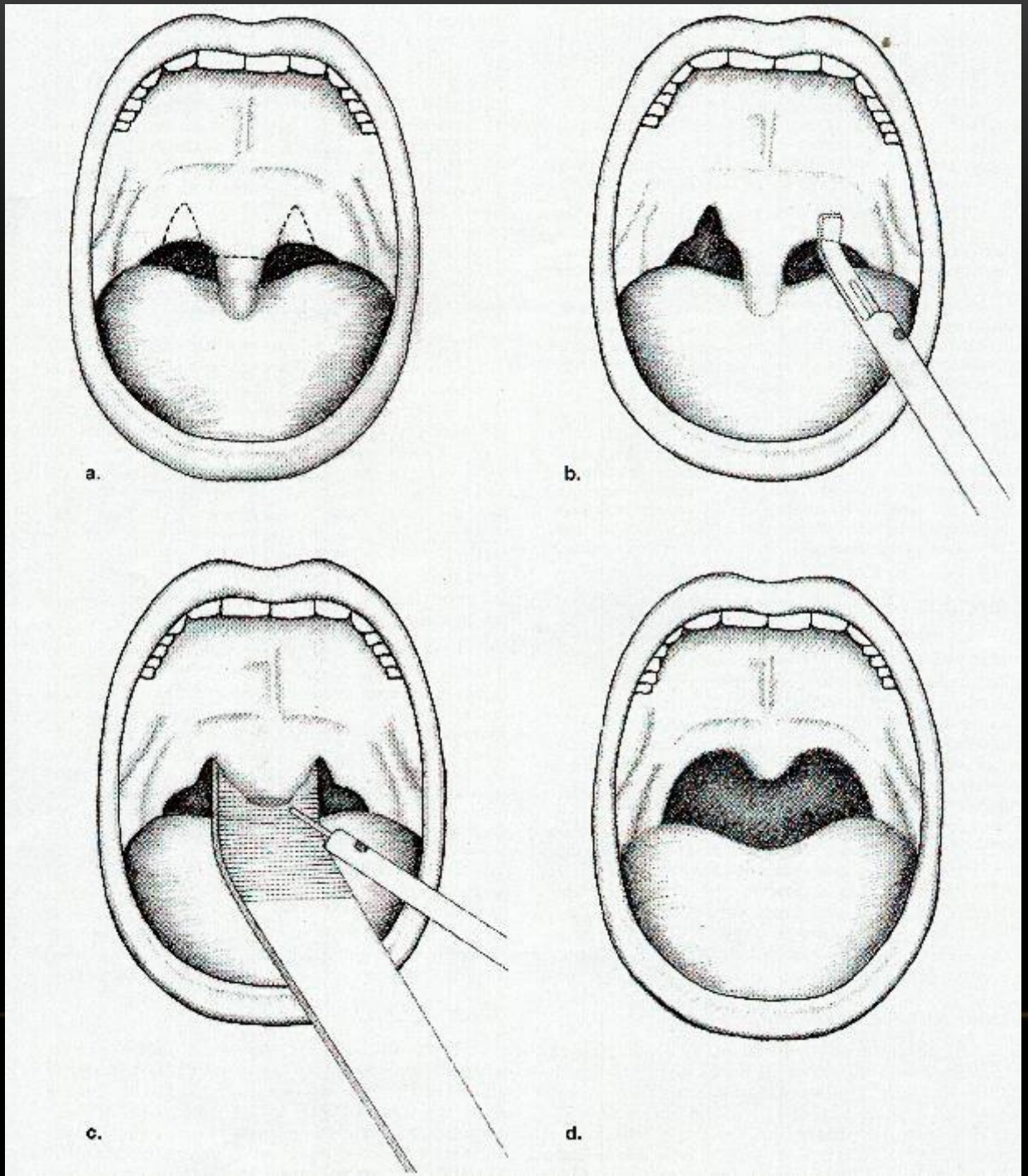
- Snoring
- Limited role in OSA
- Advantages
  - Office procedure (with caution)

LASER ASSISTED UVULA PALATOPLASTY

- Kamami, Laser CO_2 for surgery, Acta Oto Rhino Larng. 1990
- LVPP laser vaporization Palato Plasty
- Local Anesthesia
- Simple reliable bloodless painless
- 5 – 7 staged sessions, 77%success

LASER ASSISTED UVULOPLASTY (LAUP)

- Utley, A cost effective and rational surgical approach to patient with snoring, upper airway resistance syndrome , obstructive sleep apnea, Laryngoscope 1997
- Sher , The efficacy of surgical modifications of the upper airway in adults with OSAS, Sleep 1996 Metanalysis
  - 40.7% success rate in apnea
  - 73% success for snoring
  - 82% success for upper airway resistance


a.
b.
c.
d.

EFFICACY OF LAUP FOR OSA

SOURCE	N	Pre RDI	Post RDI	Respon
Kamami, 94	63	41.3	20.3	87.3%
Walker ,97	38	30.3	22.2	47.4%
Mickelson, 96	13	31.2	15.7	53.8%
Handa, 96	51	14	8.5	62.7%
Lauretano, 97	17	27.9	29.1	na
Utley, 97	12	8.9	10.3	41.7%

RESULTS:

MAXILLO-MANDIBULAR ADVANCEMENT FOR THE TREATMENT OF OSA: A SYSTEMEATIC REVIEW AND META-ANALYSIS, HOLTY GUILLEMINAULT, SLEEP MEDICINE REVIEWS, 14, 2010, 287

- 53 reports, 627 adults
- Success rate 86% mean follow up at 44mo
- Predictors: younger, lower BMI, lower pre AHI and larger maxillary advancement (not mand)
- Complication rate: 1%

OBSTRUCTIVE SLEEP APNEA MMA: UAB EXPERIENCE WAITE ET AL. JOMS 1989

- 23 patients
- Technique
  - 7 had UP3 also
  - 15 had HOM (high genioplasty)
  - 8 had partial glossectomy
  - No hyoid suspension
  - Septoplasty
  - Most did not have orthodontics

OBSTRUCTIVE SLEEP APNEA
MMA: UAB EXPERIENCE
RESULTS

- Strictest definition of cure: RDI <10 and no desaturations
- 65 % cured
- 100 % success in patients that had UP3 and MMA

OBSTRUCTIVE SLEEP APNEA
MMA: UAB RESULTS
N=71

Results	RDI	# SaO2 <90	# of Pts	Percent
Excellent	<10	0	20	28.2
Good	<10	<20	26	36.6
Satisfactory	<20	>20	15	21.1
Poor	>20	>20	10	14.1

LONG TERM RESULTS. ORAL AND MAXILLOFACIAL SURGERY CLINICS OF NORTH AMERICA, MAY 1995

- 15 patients, age 30-76, 9male, 6 female
- 39mo follow-up
- Maxillary advance 8.3mm
- Mandibular advance 10.3mm
- Airway increase 7.8mm
- BMI 31.9 – 32.5
- AHI 44.3 - 9.5
- Arousal index 31 .5 – 5.5
- Longest event 50 – 26 sec.

LONG TERM RESULTS 6YRS





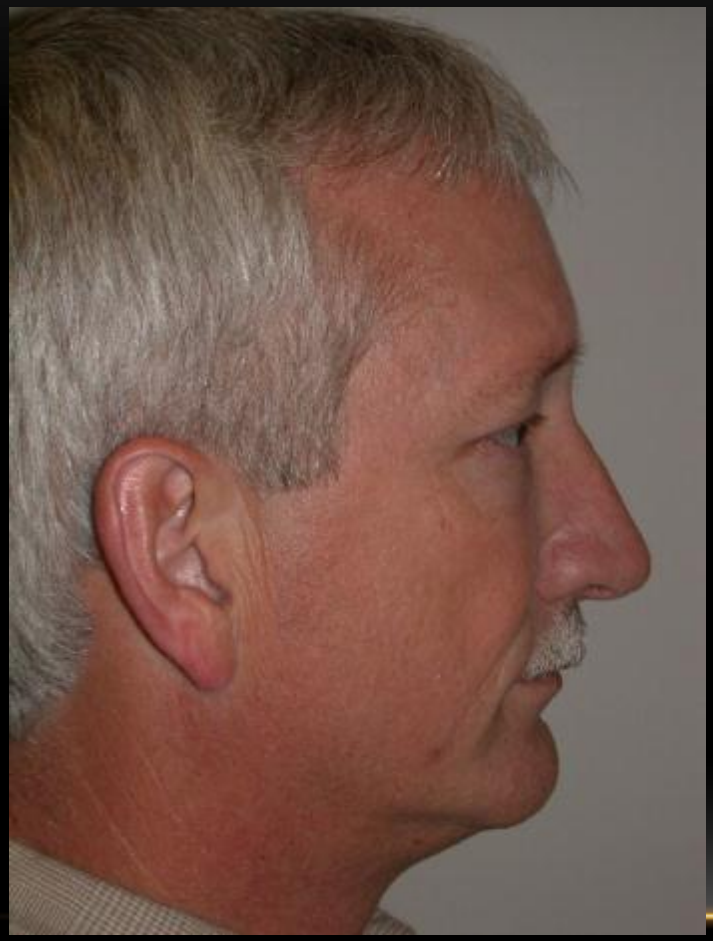

LONG TERM RESULTS 7YRS.

REPORTED SUCCESS RATE OF MAXILLOMANDIBULAR ADVANCEMENT SURGERY

Author	Institution	No. pts	Success	Criteria for Success
*Waite et al[25]	U.A.B.	23	65%	RDI<10, improvement of symptoms (97% of pts benefited from the procedure)
*Riley et al[18]	Stanford University	40 (phase II)	97%	RDI<20, 50% decrease of respiratory events, normal or near normal SaO_2
*Riley et al[2]	Stanford University	24 (phase II)	100%	RDI<20,50% decrease or RDI, LSAT equivalent to nasal CPAP
Hochban et al[28]	Marburg University	21	95%	RDI<10 (**no pt with BMI>30 kg/m^2**)
Tiner[5]	University of Texas	22	95%	RDI<20, improvement of symptoms
*Prinsell[29]	Private practice, GA	50	100%	RDI<15, AI<5, LSAT>80%, >60% decrease in RDI and AI**
*Li et al[22]	Stanford University	21 (phase II)	81%	RDI<20 (**all pts with BMI>40 kg/m^2**)

TECHNIQUE: HOW I DO IT.

TECHNIQUE: PEARLS AND PITFALLS

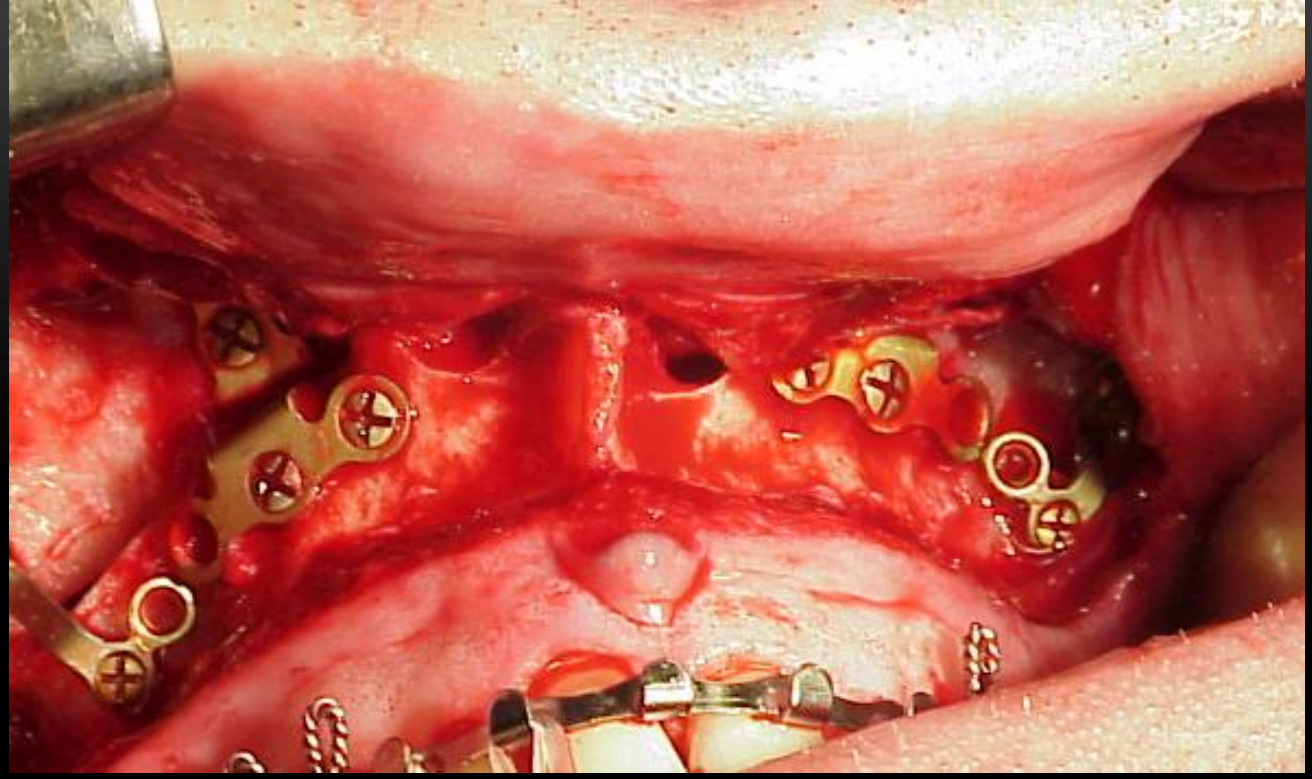


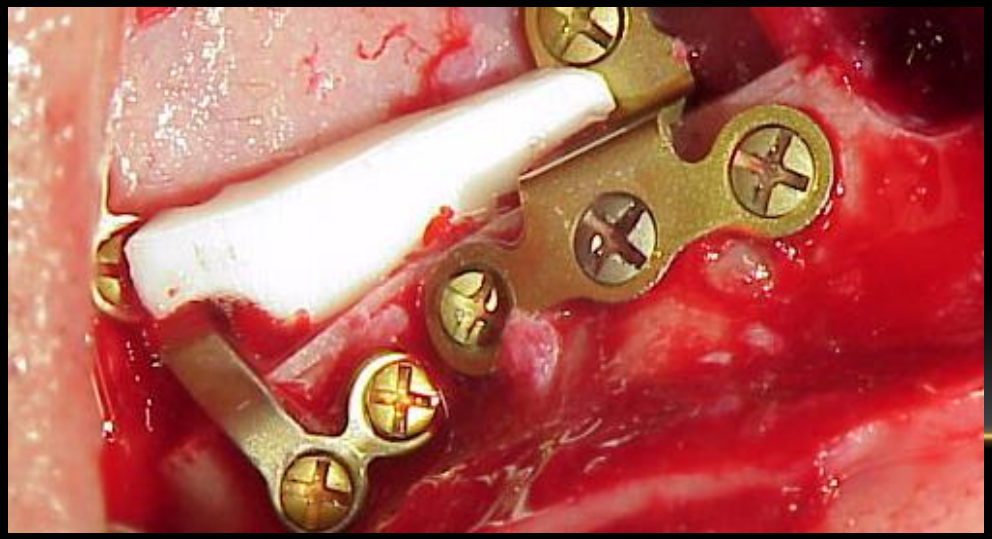
Pre advance

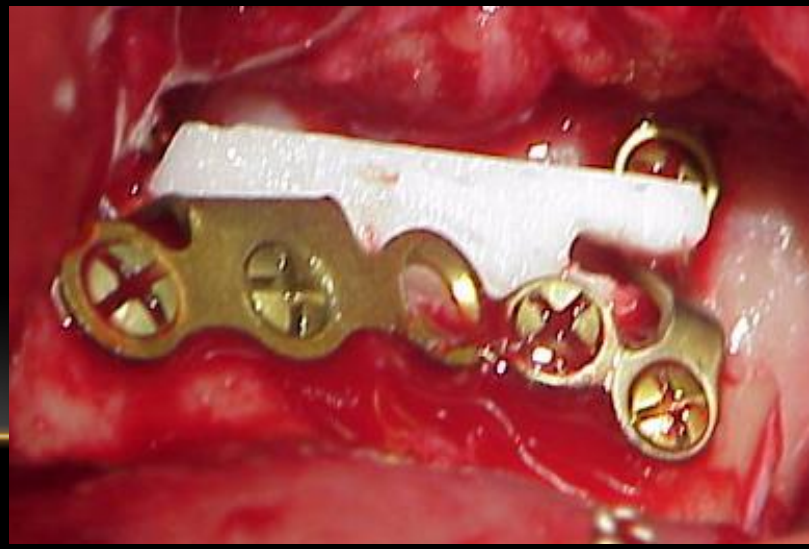
Post advance

Prediction advance

Actual advance







PEARL: BONE GRAFT LARGE MAXILLARY ADVANCEMENTS

PEARL: PREBENT PLATES INSURE ADEQUATE ADVANCEMENT

- Lye KW, Waite PD, Wang D, Sittitavornwong S Predictability of prebent advancement plates for use in maxillomandibular advancement surgery. J Oral Maxillofac Surg. 2008 Aug;66(8):1625-9.
- Lye KW, Deatherage JR, Waite PD. The use of demineralized bone matrix for grafting during Le Fort I and chin osteotomies: techniques and complications. J Oral Maxillofac Surg. 2008 Aug;66(8):1580-5

Table 1: Bone Graft Group

Maxillary Advancement and relapse as measured at UPI, ANS, APT and PNS

	UPI		ANS		APT		PNS	
Patient	Adv.	Rel.	Adv.	Rel.	Adv.	Rel.	Adv.	Rel.
$\bar{X}$	9.7	0.6	10.6	0.7	9.9	0.8	9.1	0.7

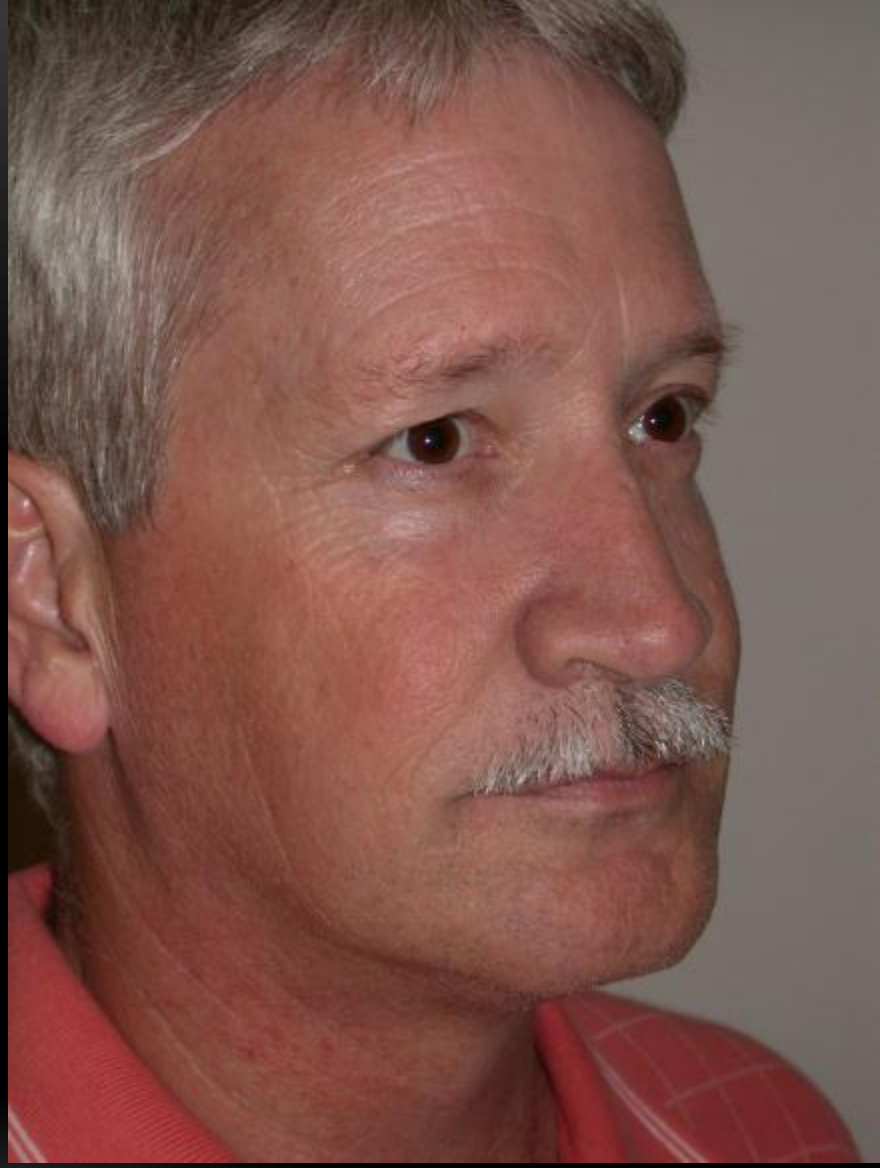
Table 2: Non-Bone Graft Group

Maxillary Advancement and relapse as measured at UPI, ANS, APT and PNS

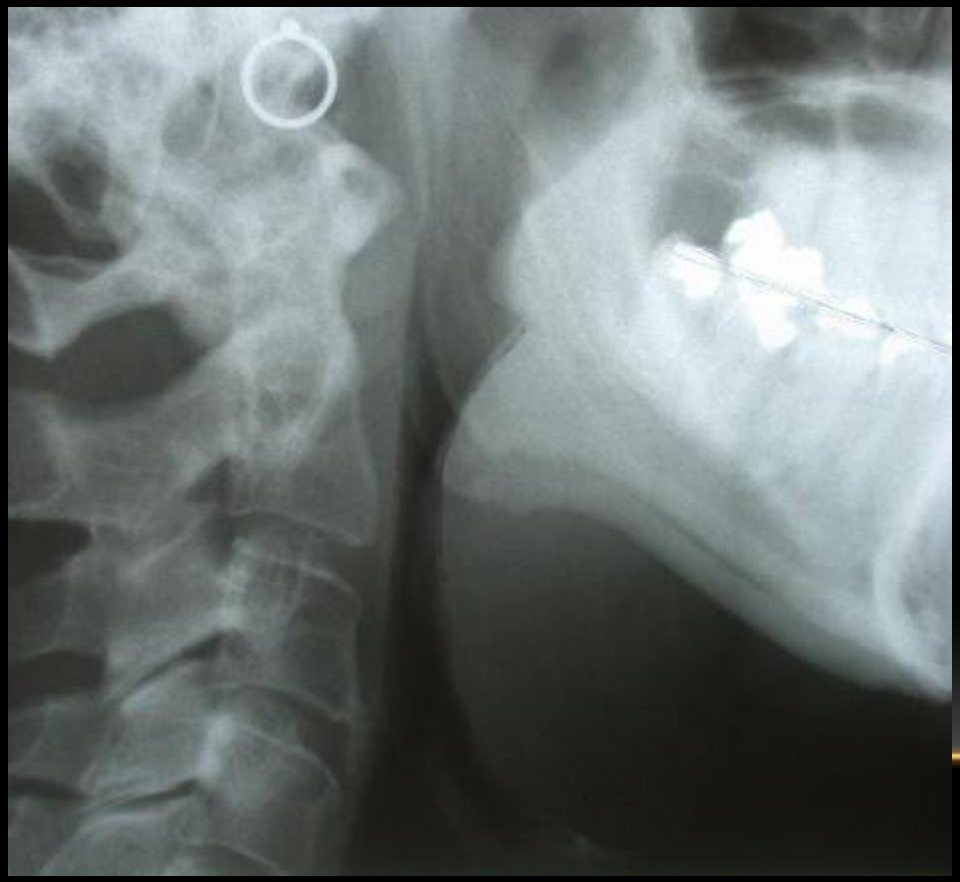
	UPI		ANS		APT		PNS	
Patient	Adv.	Rel.	Adv.	Rel.	Adv.	Rel.	Adv.	Rel.
$\bar{X}$	10.0	1.8	11	1.9	9.5	1.7	9.6	1.9

STABILITY

- Waite PD, Tejera TJ, Anucul B. The stability of maxillary advancement using Le Fort I osteotomy with and without genial bone grafting. Int J Oral Maxillofac Surg. 1996 Aug;25(4):264-267
- Nimkarn Y, Miles PG, Waite PD. Maxillomandibular advancement surgery in obstructive sleep apnea syndrome patients: long-term surgical stability. J Oral Maxillofac Surg. 1995 Dec;53(12):1414-8; discussion 1418-9
- Louis PJ, Waite PD, Austin RB. Long-term skeletal stability after rigid fixation of Le Fort I osteotomies with advancements. Int J Oral Maxillofac Surg. 1993 Apr;22(2):82-6.

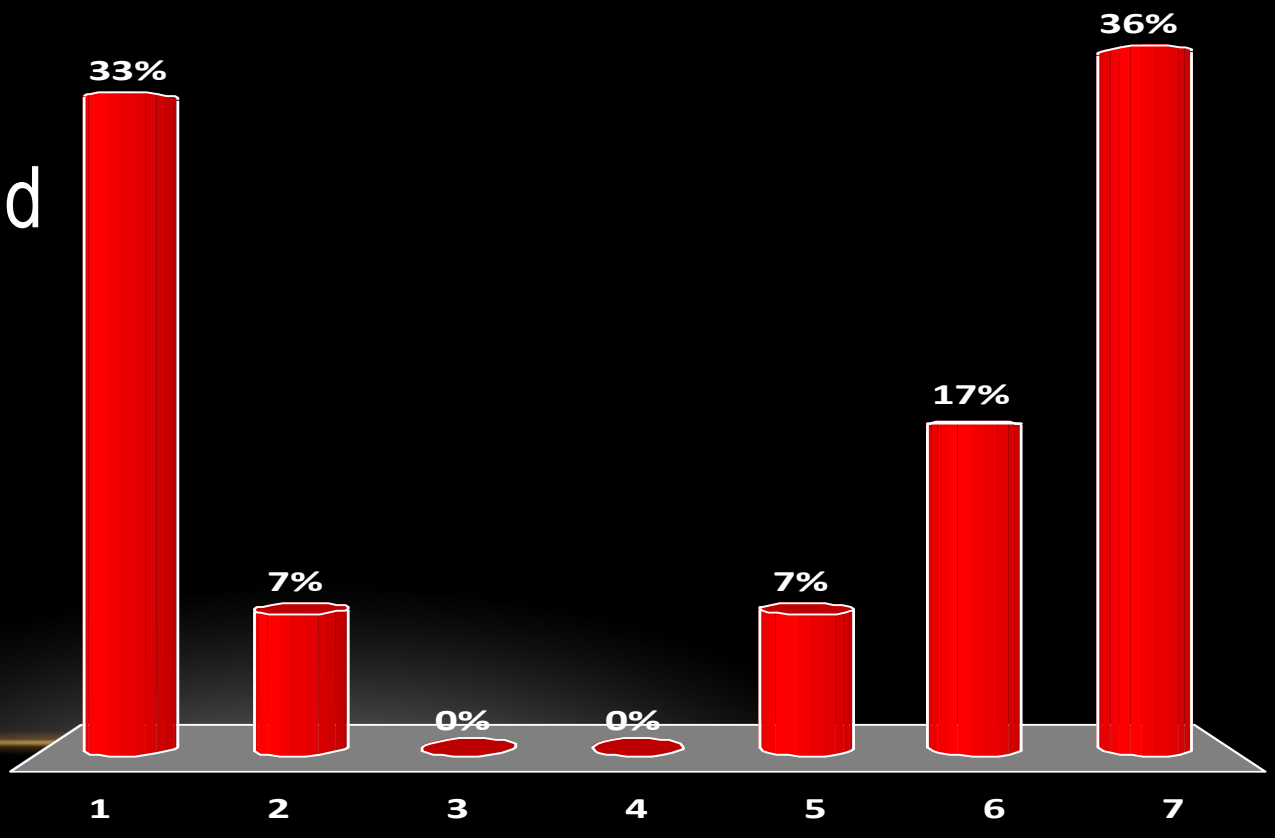


PITFALL:
CEPHALOMETRIC CHANGES IN PAS DO NOT EQUAL SUCCESS



QUESTION: ARE THE SURGICAL GOALS OF MMA THE SAME AS ORTHOGNATHIC SURGERY

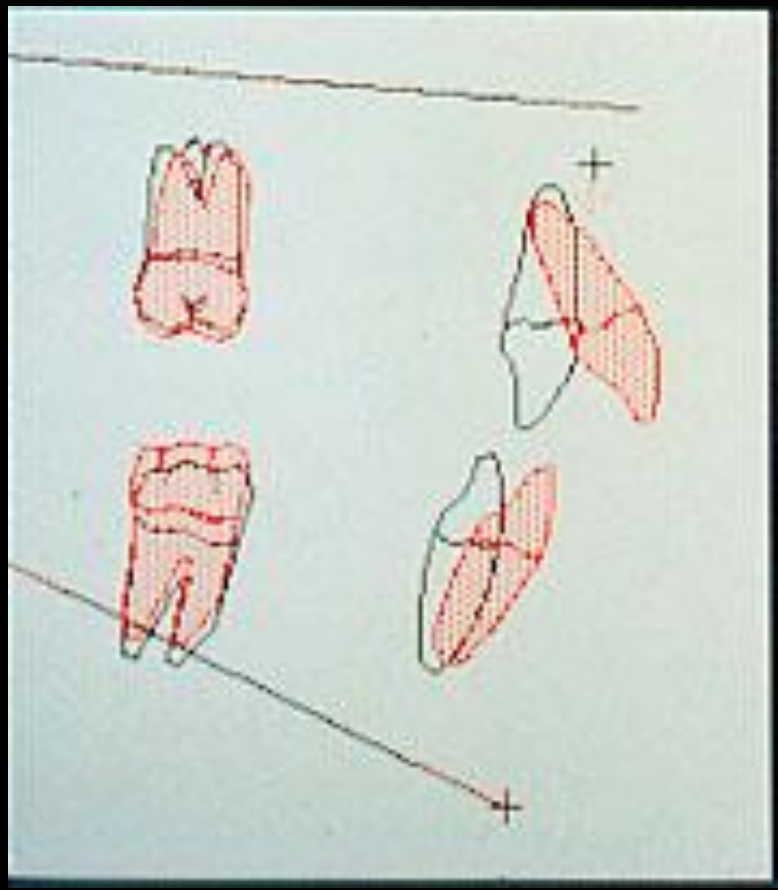
Please rate 1-7, with 1 being strongly agree and 7 being strongly disagree

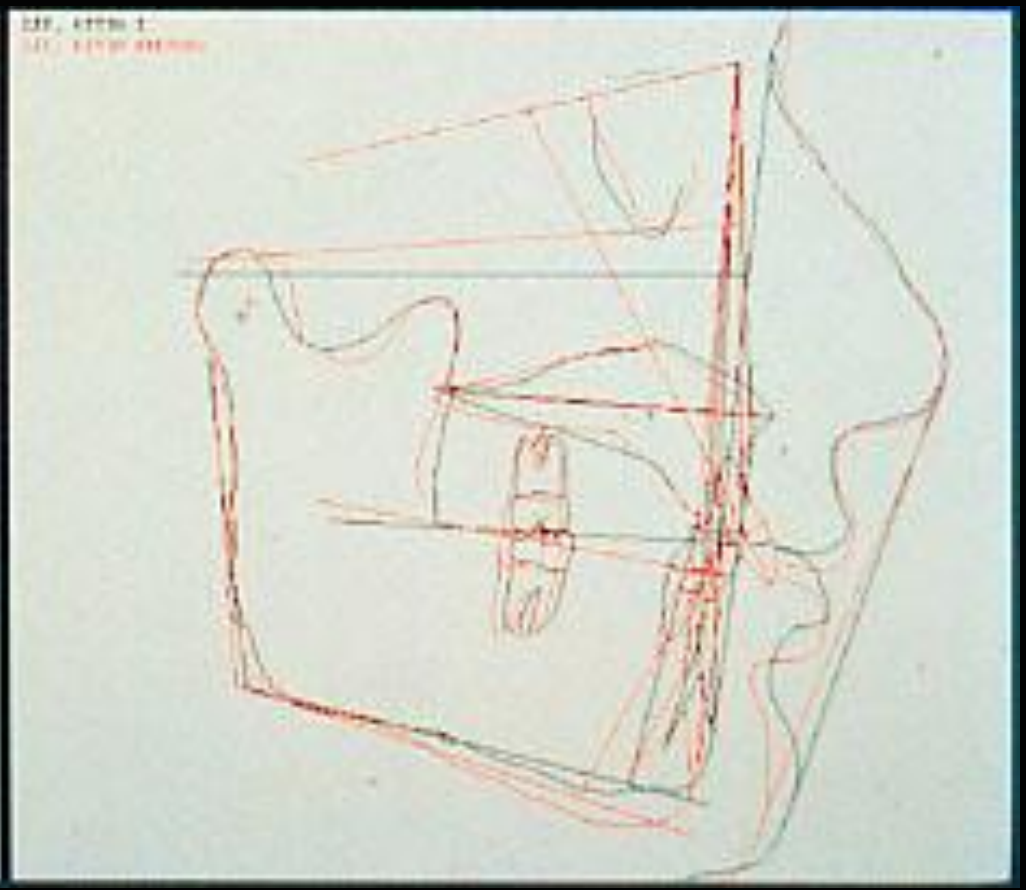


PRESURGICAL ORTHODONTIC PLAN

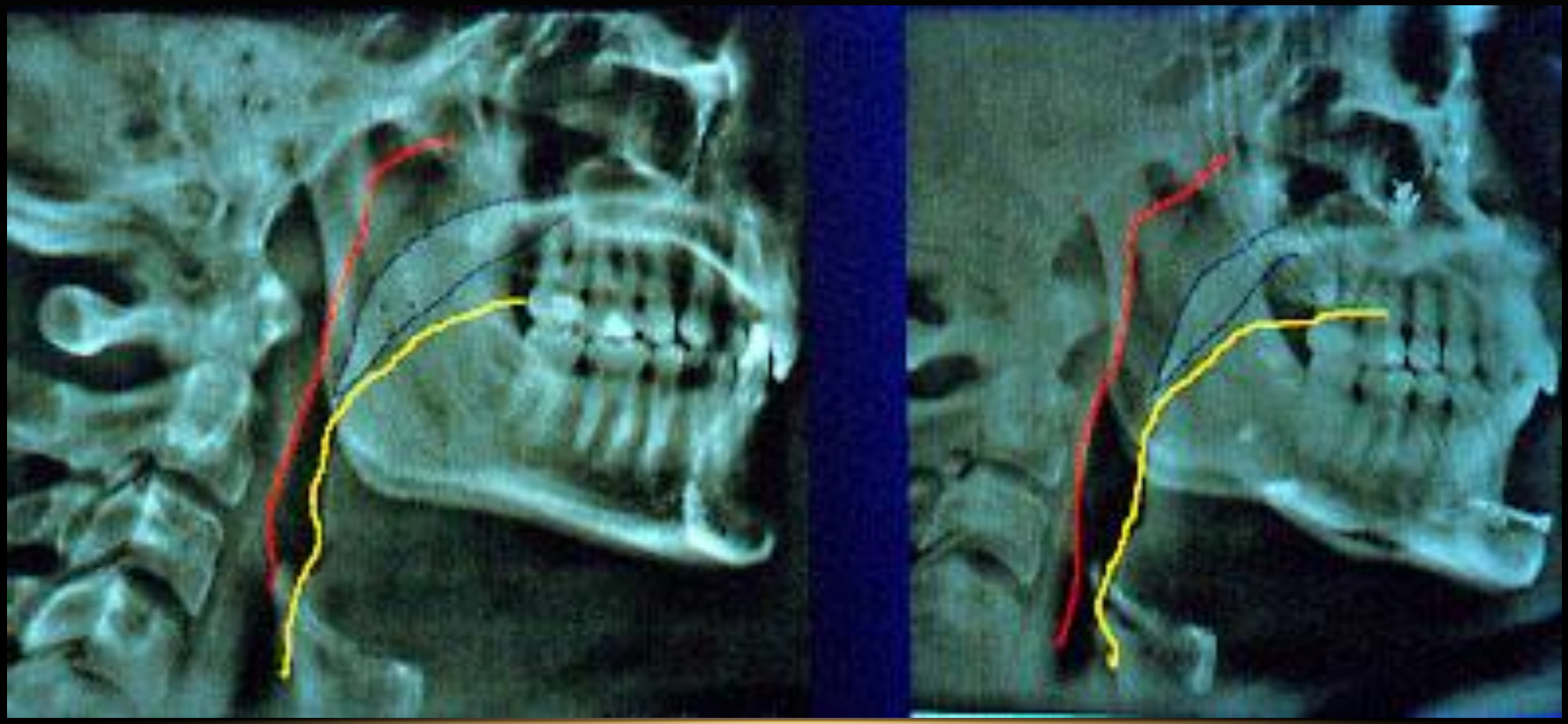
- Place fixed appliances to align and decrowd
- Torque and advance upper incisors
- Progress to full dimension arch wires and surgery
- **Sarver DM, The role of orthodontics in the surgical treatment of osa. OMS clinic of NA May 1995**

CEPHALOMETRIC SUPERIMPOSITION

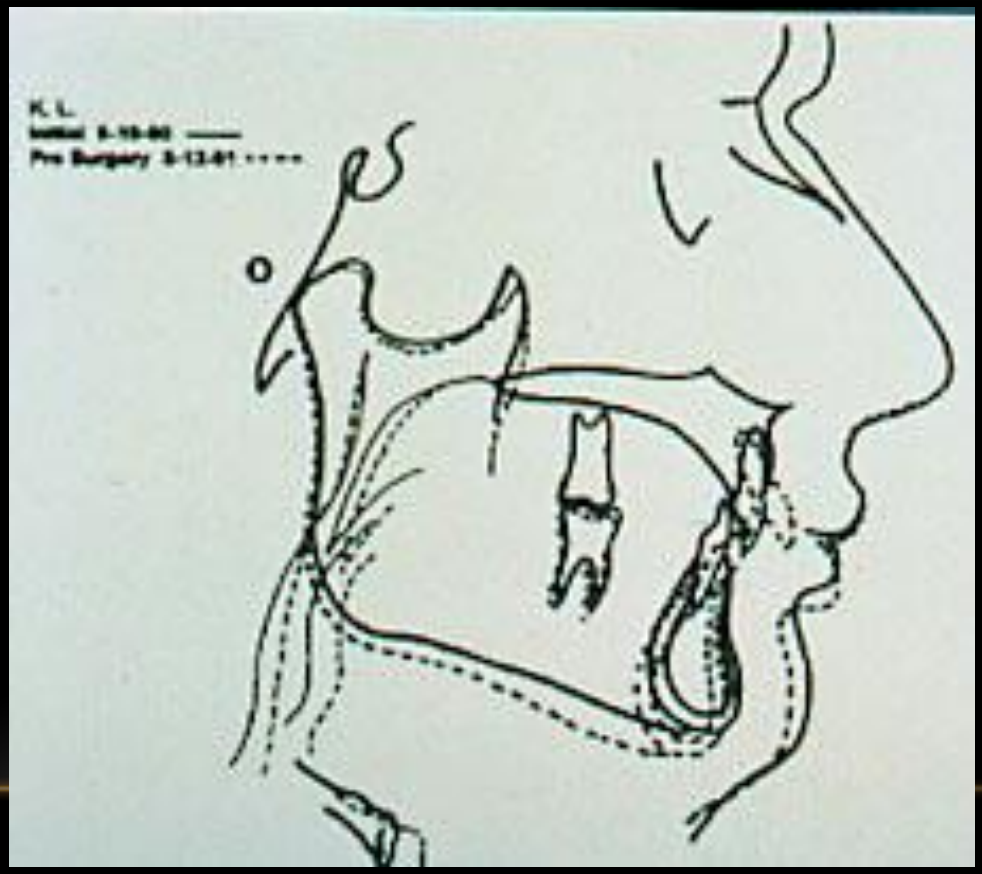




POSTERIOR AIRWAYS



CEPHALOMETRIC SUPERIMPOSITION



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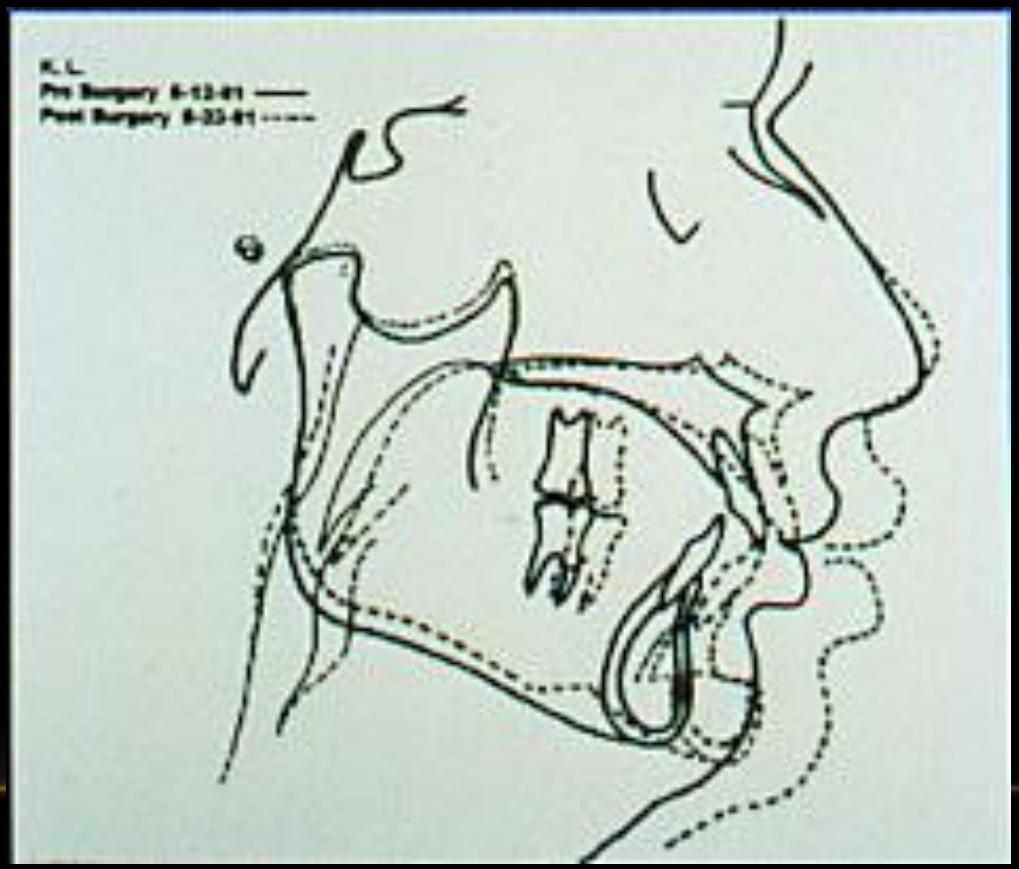
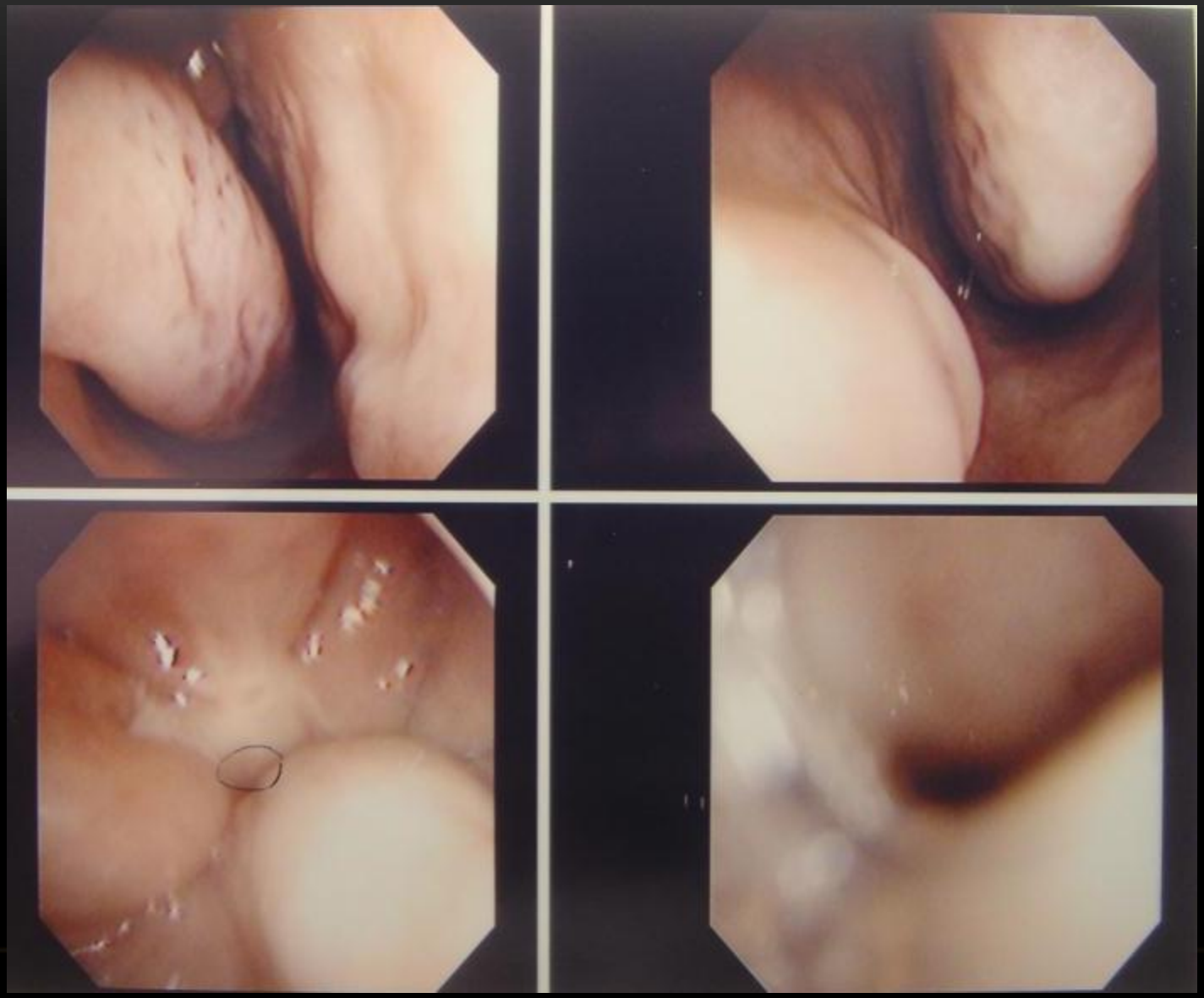
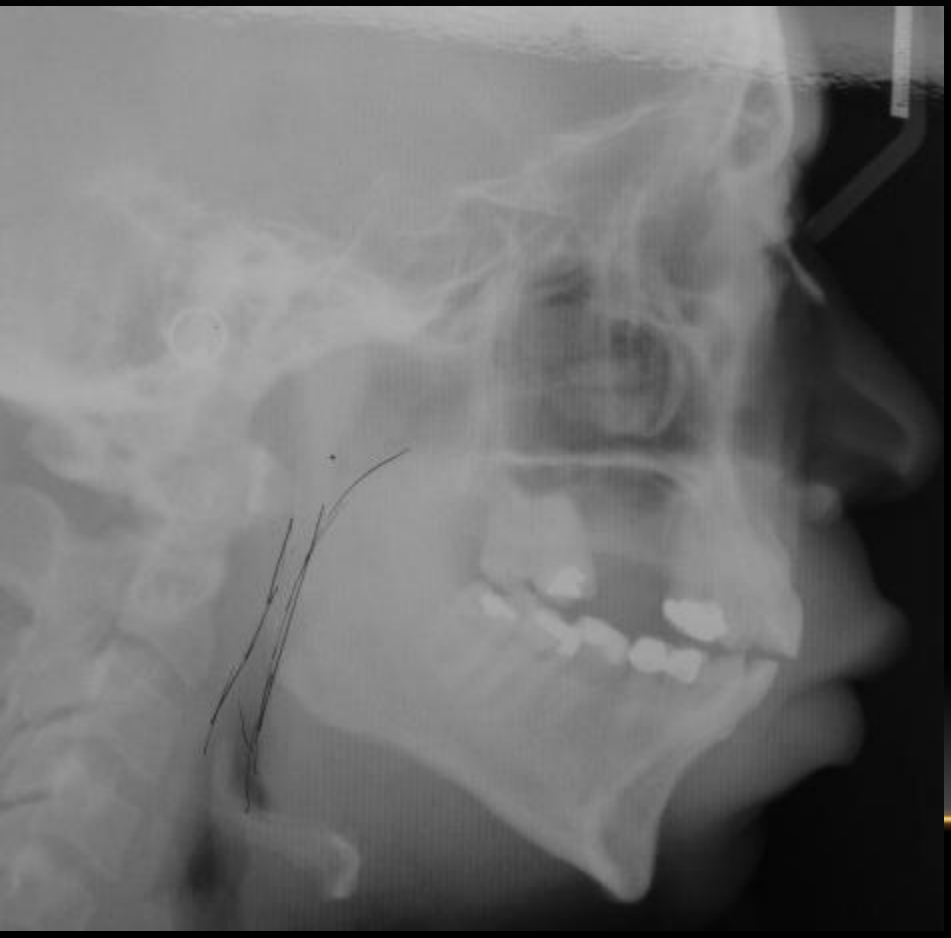


1995

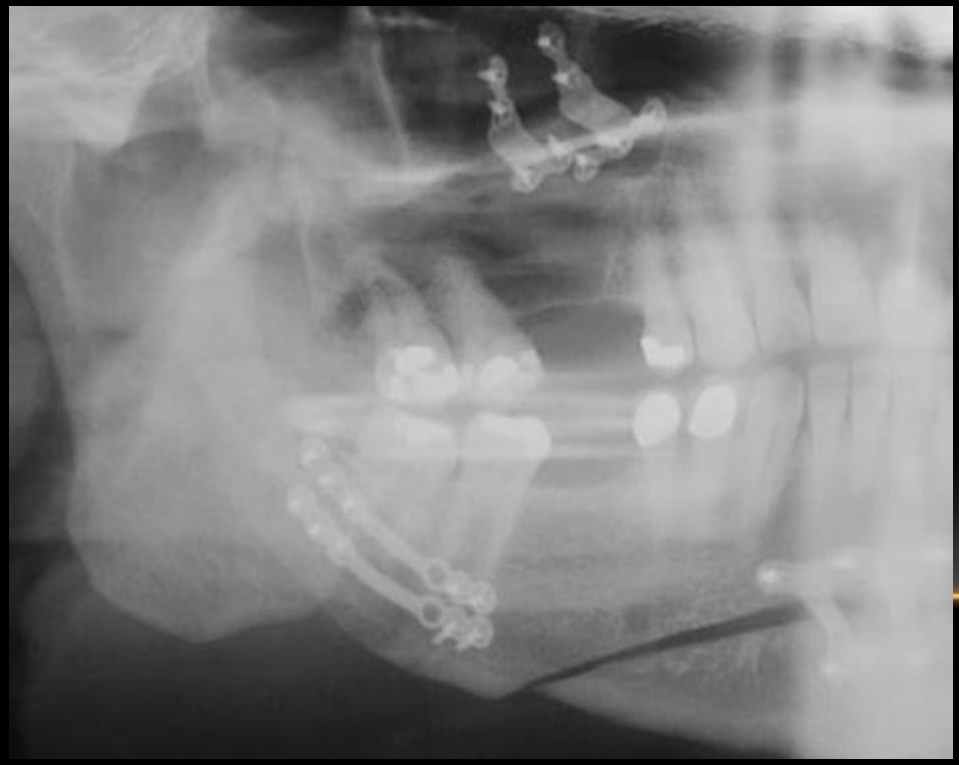
CS: SEVERE OSA POST GASTROPLASTY



PEARL: LARGE ADVANCEMENT = LARGE AIRWAY

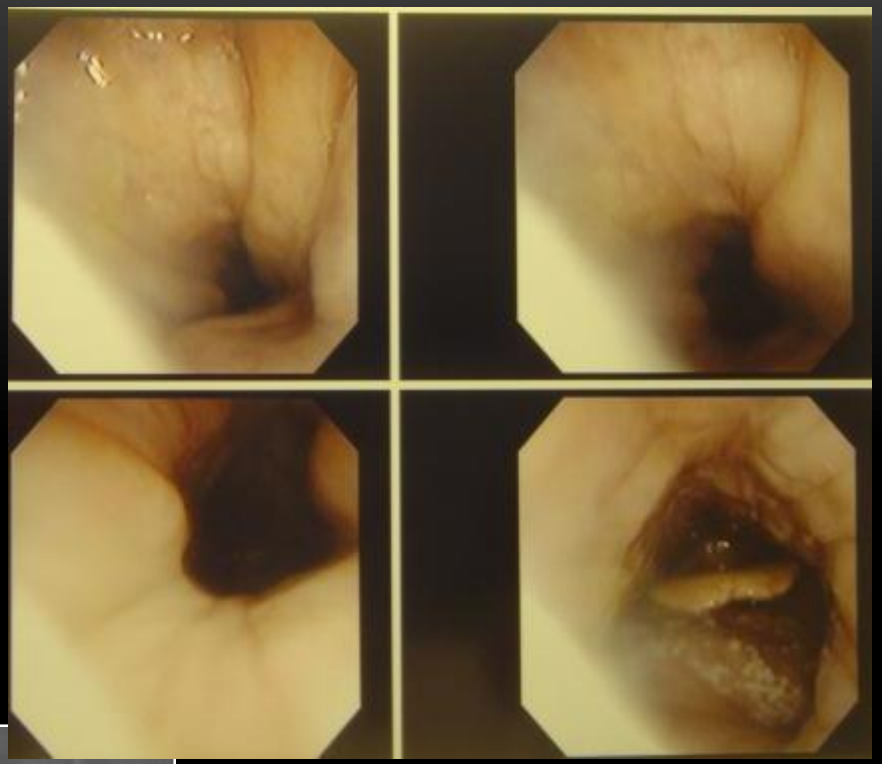


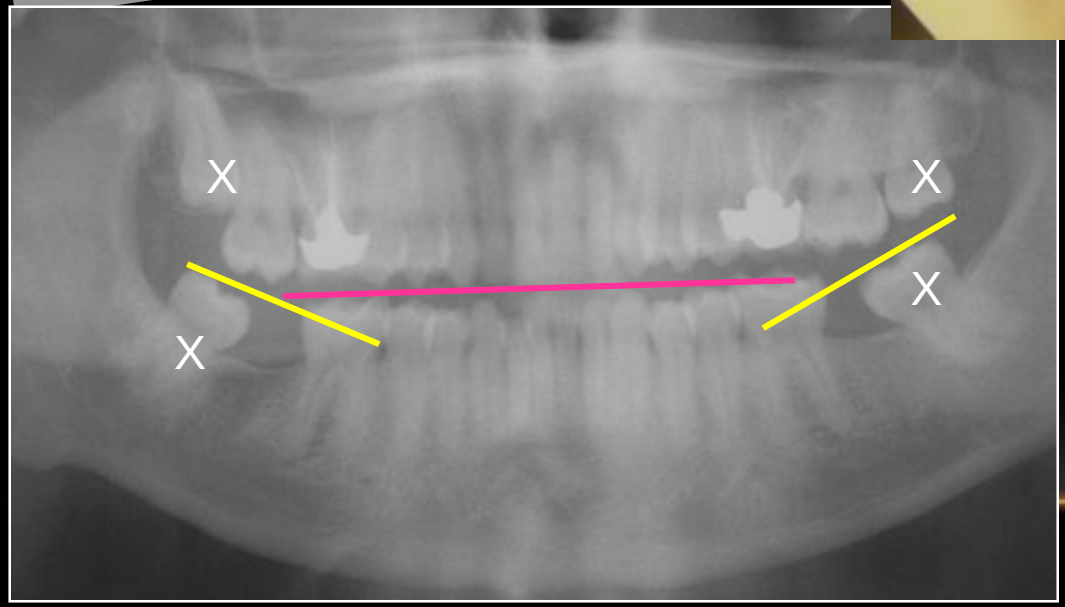
PEARL: DOUBLE PLATE



TG

- 40 yobm cc OSA
- 144/78, 77, 276wt, neck 18”, RDI 78
- Mallampati class 4, mueller maneuver 4
- 9-24-08; MMA, UP3, osa plates, bicortical screws and monocortical plate
- 3-2-09: post RDI 4.7

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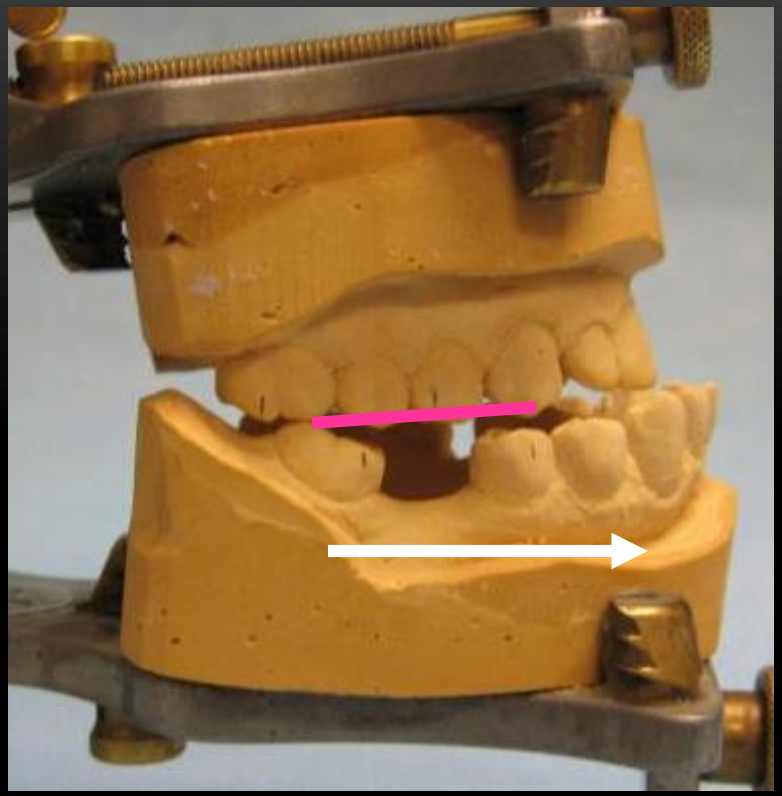
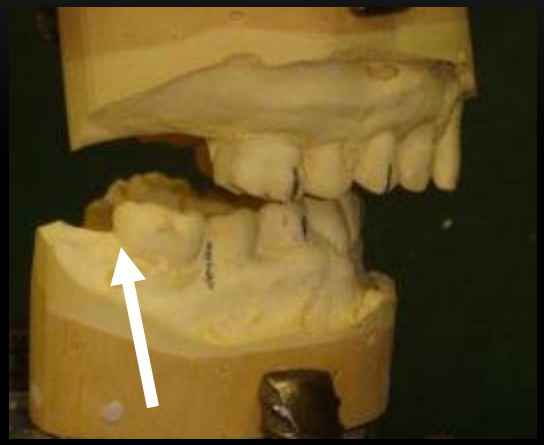
X
X

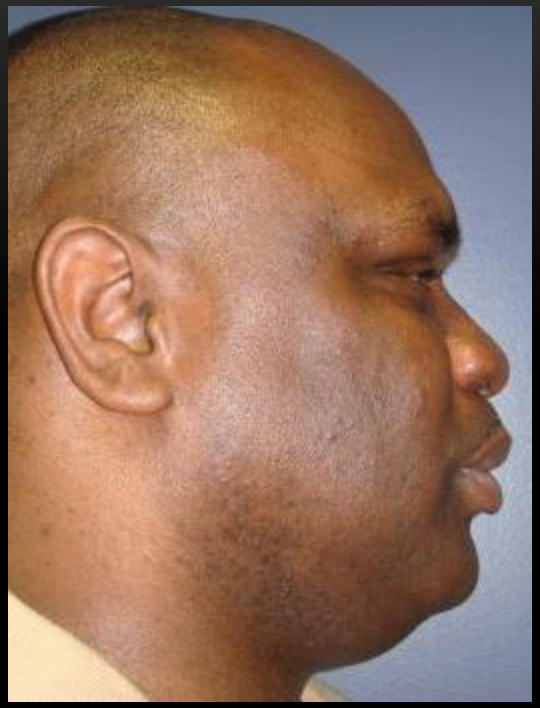


PEARL: ADVANCE THE MANDIBLE FIRST WITH ADVANCEMENT SPLINT.



Unstable splint, may change plane of occlusion.

Mandible: first more stable

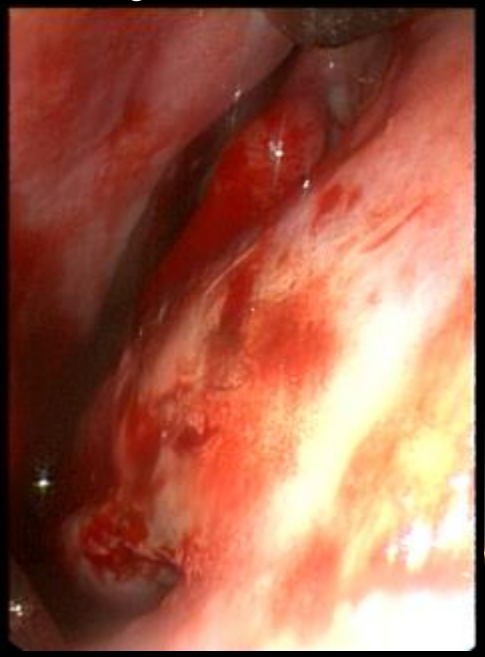


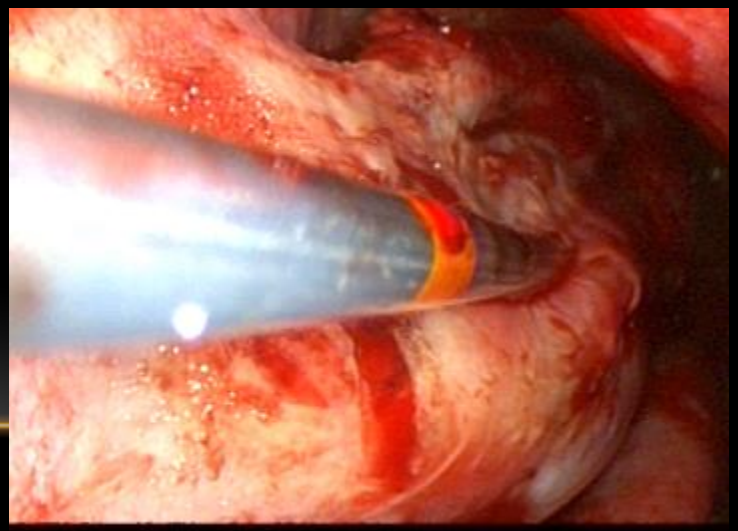
FOLLOW UP

- 3 months post op pt. notes significant improvement of OSA symptoms
- However, he does c/o nasal and sinus congestion
- Exophytic lymphatic tissue noted on tongue base
- Plan for revision septoplasty, B/L turbinoplasty, irrigation of R maxillary sinus, and coblation glossectomy

COBLATION

- Controlled Ablation
- Dissolves tissue using plasma-based radiofrequency
- Radiofrequency excitation frequencies range from 100 - 500 kHz.
- Plasma-forming radiofrequency controller settings are used for removing tissue in a defined area (ablation)
- Non-plasma-forming settings are used for tissue shrinkage or tissue





ORAL, HEAD AND NECK APPLICATIONS

- Tonsillectomy/Tonsillotomy
- Adenoidectomy
- Turbinate reduction
- Partial glossectomy
- UP3
- Polypectomy

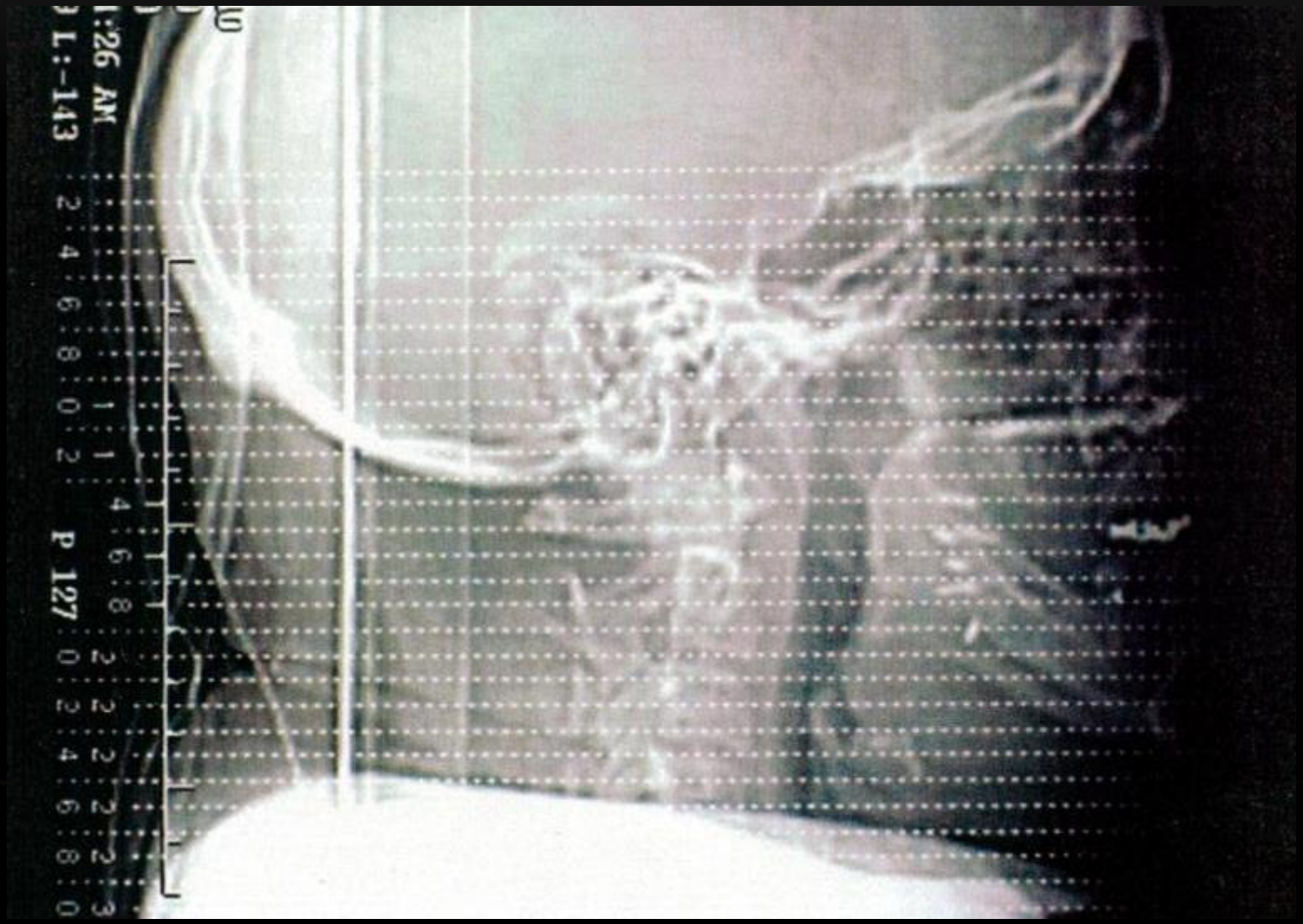
THE PLASMA FIELD

- The plasma field is an ionized gas consisting of free electrons, ions and excited radicals
- The electrons contained in the plasma field are energetic, but the ions and neutral particles in the plasma remain relatively cool
- The plasma particles are active enough to disintegrate organic tissue into molecules
- The tissue is dissolved in a gentle fashion at low temperature with minimal or no damage to surrounding tissue.

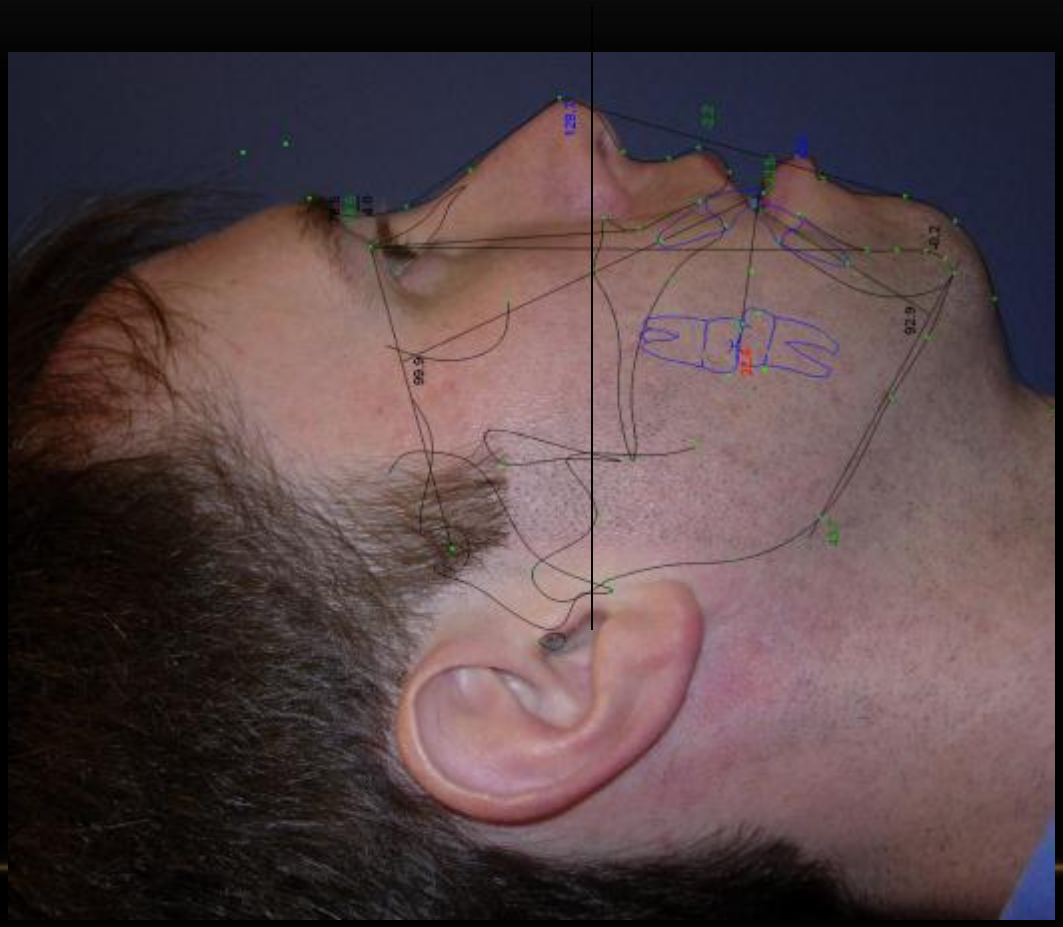
COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF THE POSTERIOR AIRWAY SPACE AFTER MMA FOR OSAS

Funded under NIH R21 Grant

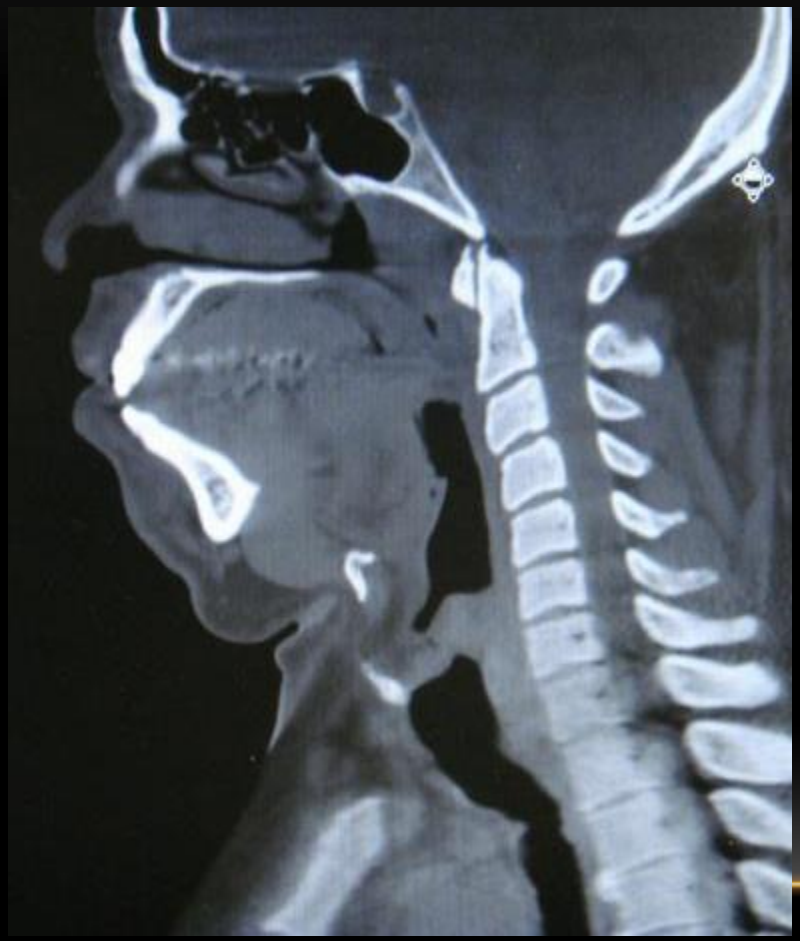
IMAGING THE AIRWAY



FRANKFORT PLANE: FOR THE REFERENCE OF HEAD POSITION DURING PERFORMING FACIAL CT SCANS. POINT A, B AND PG WERE MEASURED IN PRE- AND POST-OP CT.



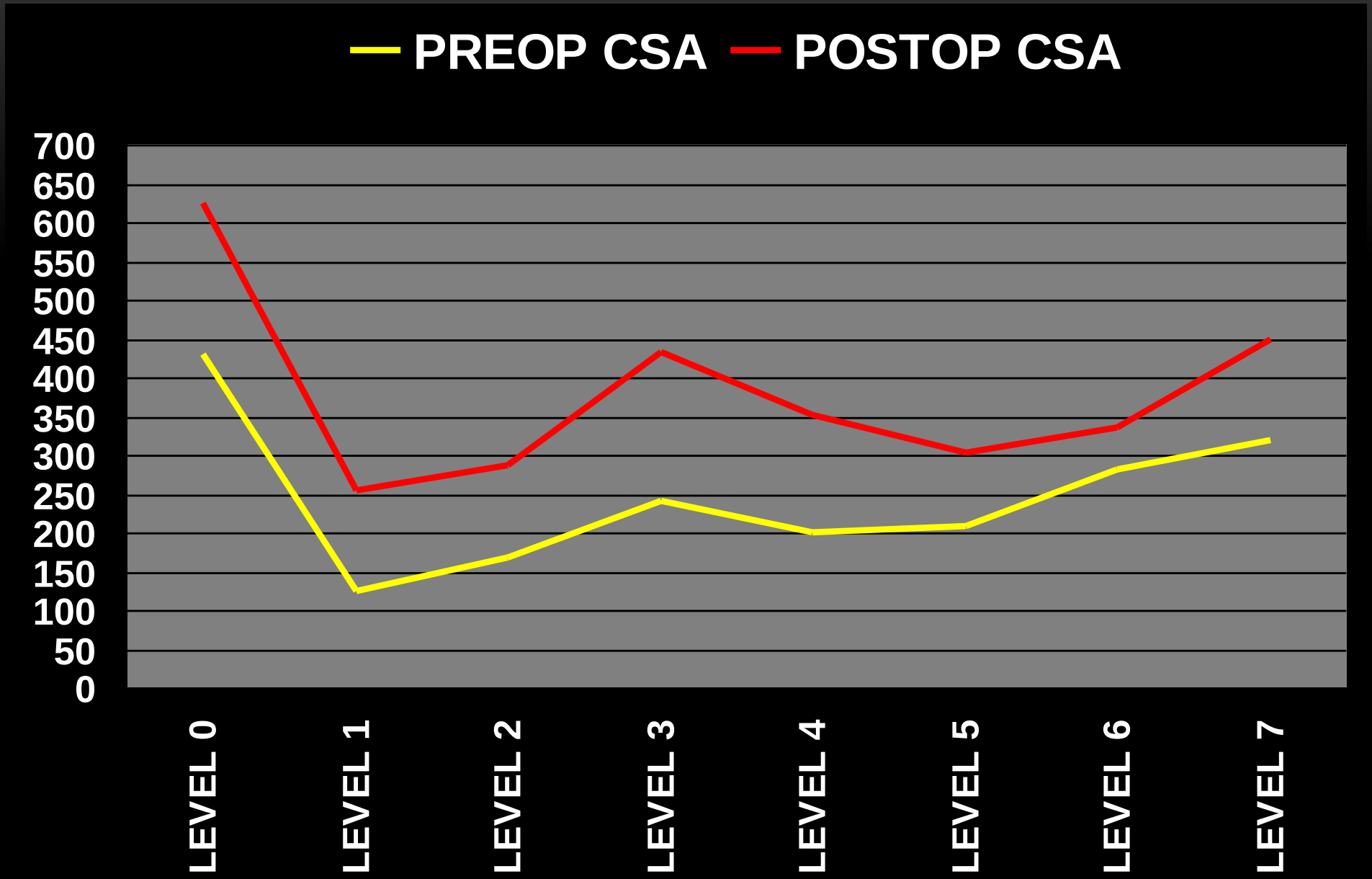
HEAD POSITION IN CT

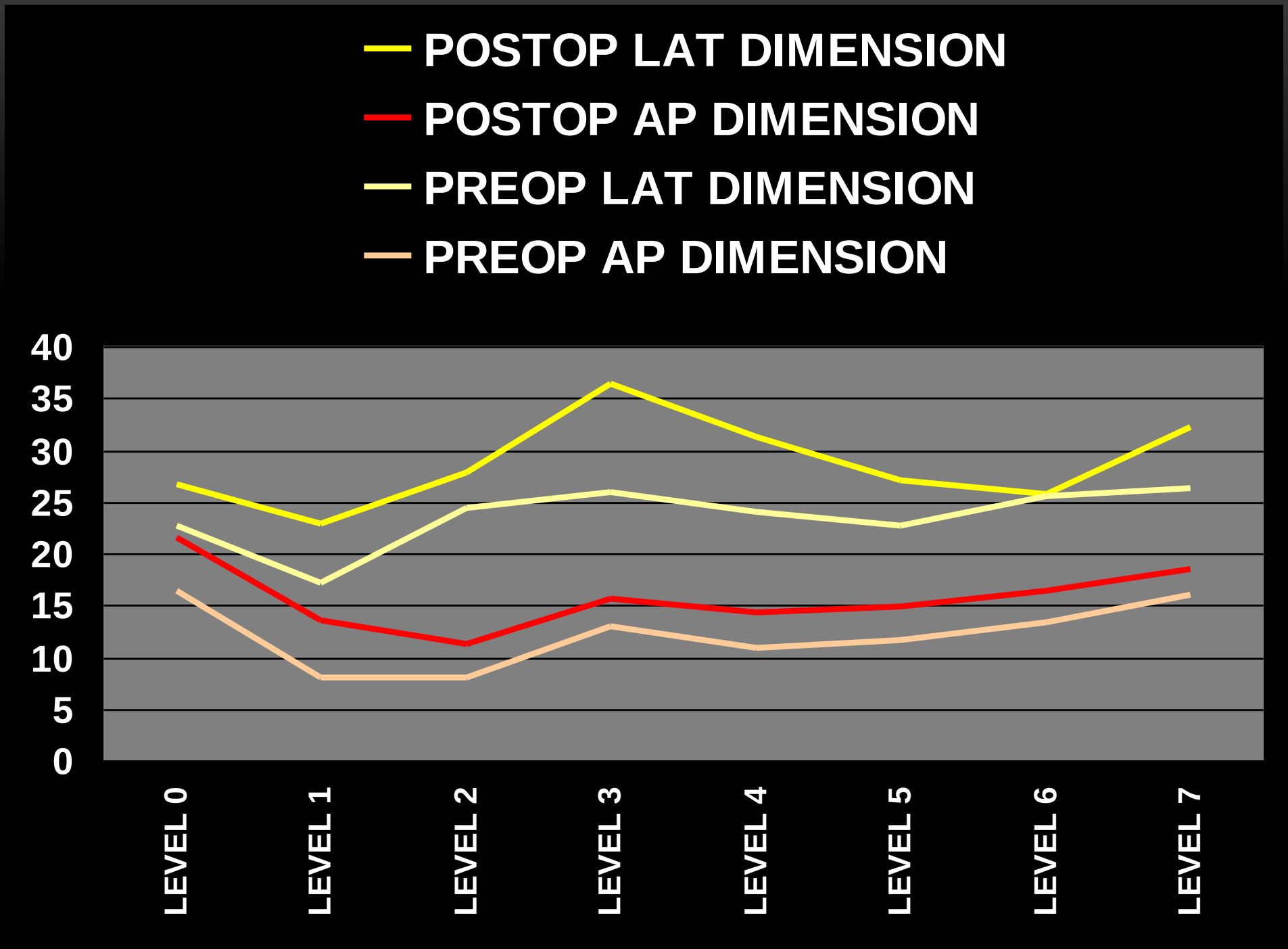


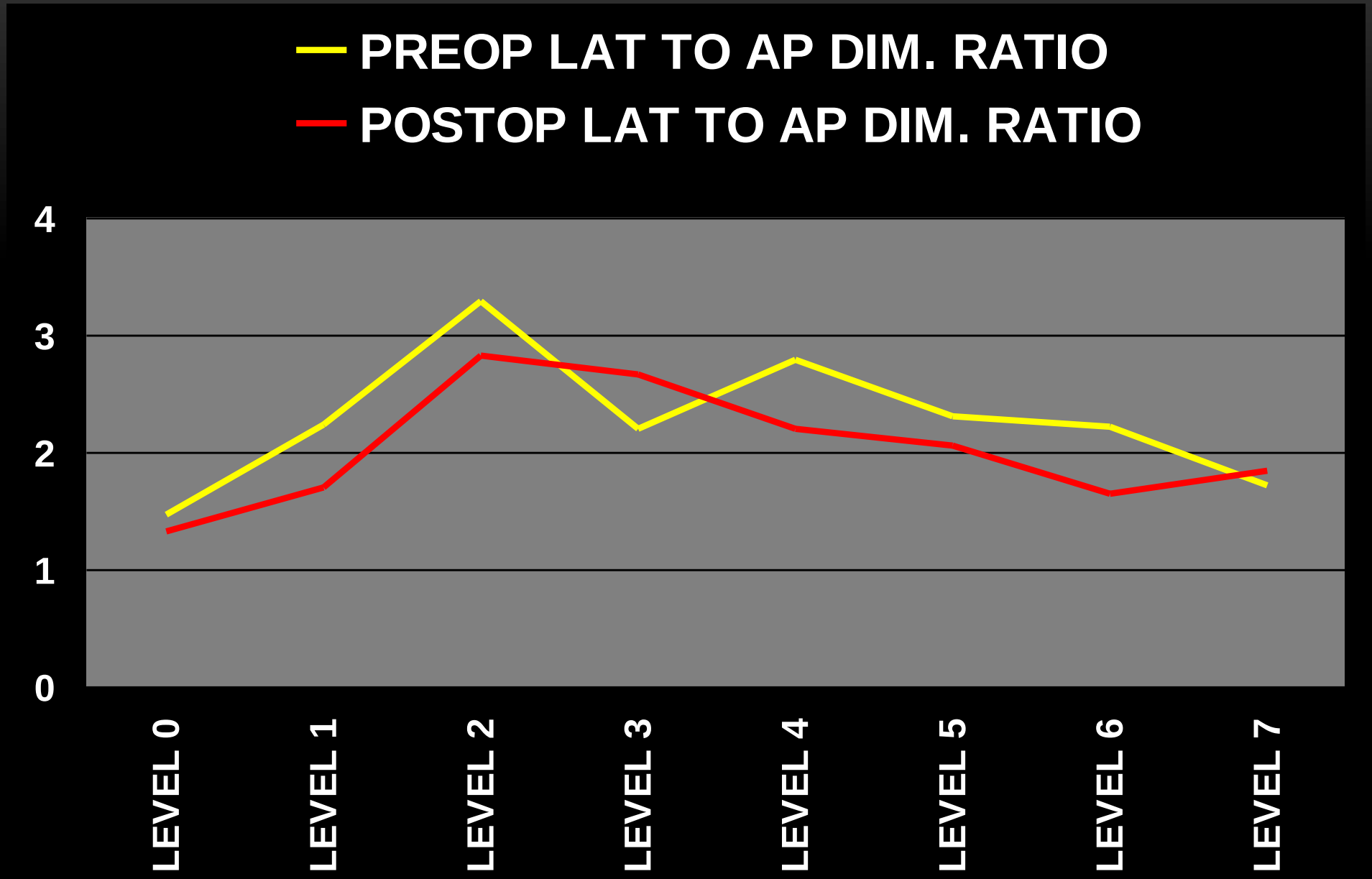
3 MEASUREMENTS AT EACH LEVEL

- AP dimension on the mid sagittal plane
- Maximum LAT in an orientation perpendicular to the mid sagittal plane
- Cross sectional area of the airway CSA

CROSS SECTION AREA: CSA

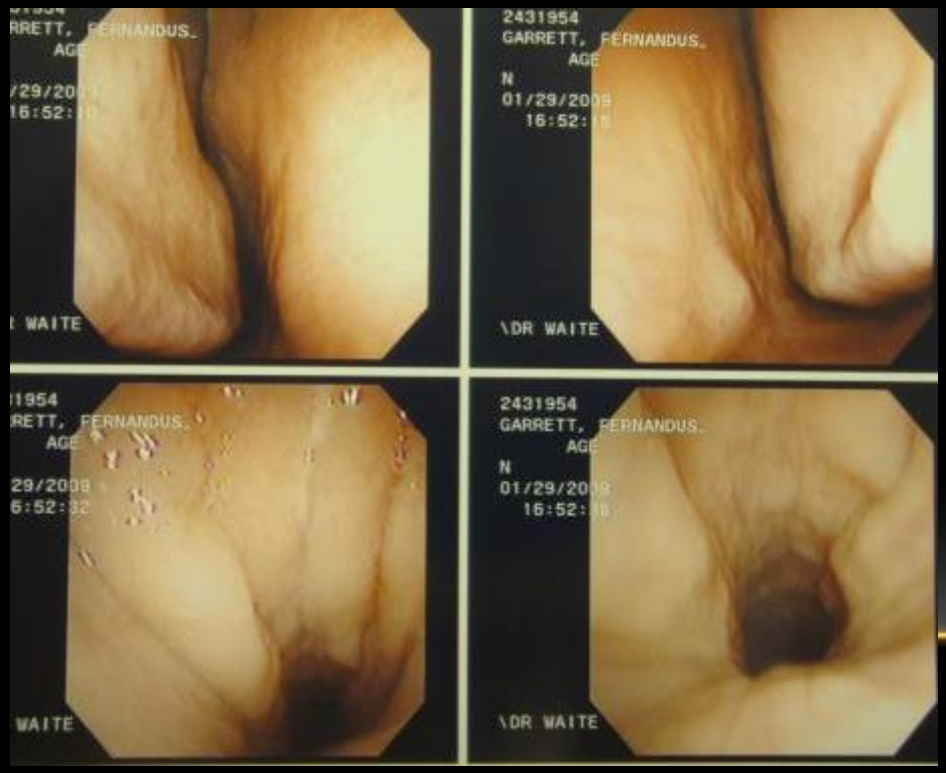

PREOP CSA
POSTOP CSA
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
LEVEL 0
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4
LEVEL 5
LEVEL 6
LEVEL 7

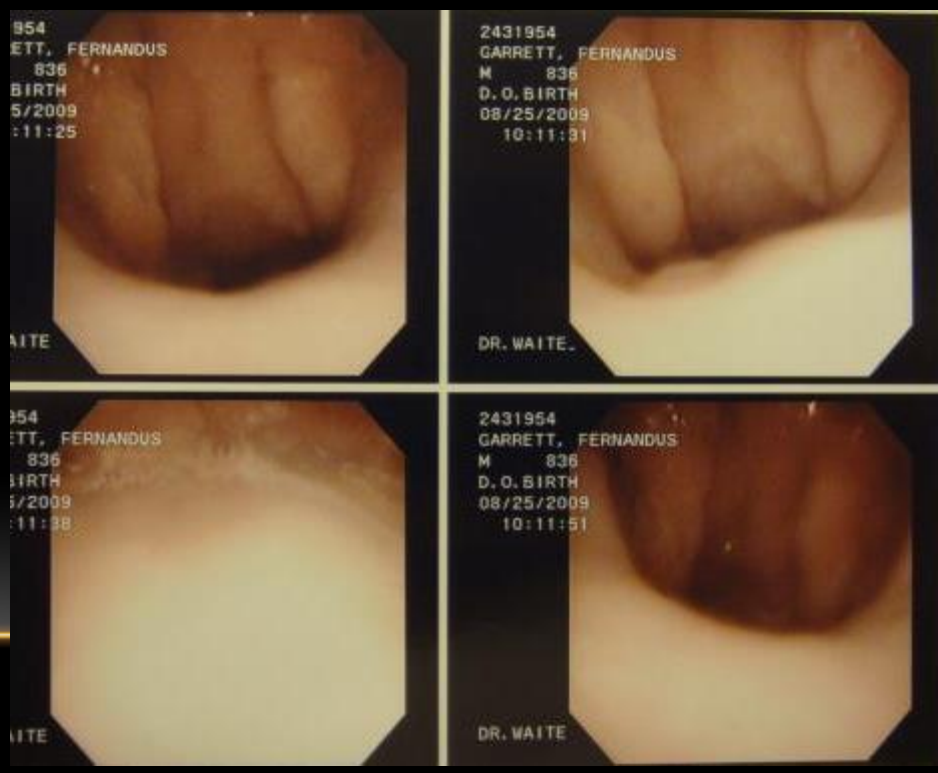

POSTOP LAT DIMENSION
POSTOP AP DIMENSION
PREOP LAT DIMENSION
PREOP AP DIMENSION
40
35
30
25
20
15
10
5
0
LEVEL 0
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4
LEVEL 5
LEVEL 6
LEVEL 7


PREOP LAT TO AP DIM. RATIO
POSTOP LAT TO AP DIM. RATIO
4
3
2
1
0
LEVEL 0
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4
LEVEL 5
LEVEL 6
LEVEL 7

EVALUATION

- Increase in both AP and LAT
- LAT to AP ratio; generally less postop. Except at level 3 (high retroglossal area). At this area MMA stretched the airway in a more lateral than in AP fashion.


2431954
GARRETT, FERNANDUS
AGE
N
01/29/2009
16:52:
\DR WAITE
2431954
GARRETT, FERNANDUS
AGE
N
01/29/2009
16:52:
\DR WAITE


2431954
GARRETT, FERNANDUS
M 836
D.O.BIRTH
08/25/2009
10:11:31
DR. WAITE
2431954
GARRETT, FERNANDUS
M 836
D.O.BIRTH
08/25/2009
10:11:51
DR. WAITE

- **Waite PD, Vilos GA.** Oral Maxillofac Surg Clin North Am. **2002 Aug;14(3):385-99.**
- **Waite PD.** Surgical management of obstructive sleep apnea: changing the upper airway. Alpha Omegan. **2009 Jun;102(2):74-8.**
- **Fairburn SC, Waite PD, Vilos G, Harding SM, Bernreuter W, Cure J, Cherala S.** Three-dimensional changes in upper airways of patients with obstructive sleep apnea following maxillomandibular advancement.J Oral Maxillofac Surg. **2007 Jan;65(1):6-12.**

RESULTS

- MMA increases both the AP and the LAT dimensions of the upper airway. The CSA was increased in all levels.
- The quantitative effect of MMA on the LAT/AP dimension ratio at each level was analyzed.
- *Patients with the best post RDI, had airways stretched more laterally at higher levels.*

RESULTS; LEVEL OF AIRWAY

- Good responders had more lateral change at higher levels
- Poor responders had less lateral change

- MMA increased CSA at all levels by both AP and LAT.

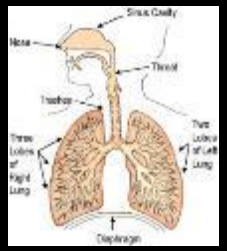
$$VA = \frac{\Delta P\ (Po - Pi)}{R}$$

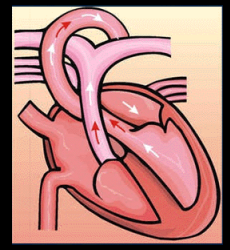
VA = Airway Flow
Po = Atmo. Press
Pi - Inspir. Press
R = Resistence

$$R = \frac{(L)(K)}{r4}$$

APPLICATIONS OF COMPUTER FLUID DYNAMICS

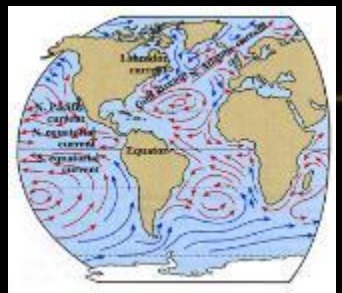
- Transportation
  - Aircrafts, automobiles, ships





- Biological
  - Blood flow, air flow through lungs

- Environmental
  - Weather prediction, spread and control of atmospheric pollution, lava flows ocean currents

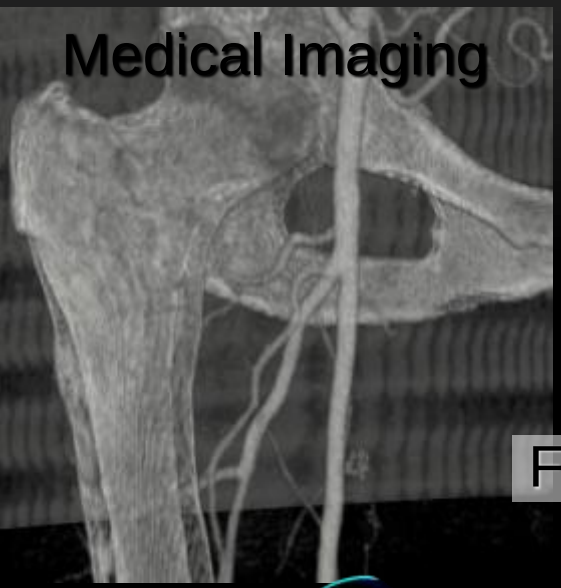


PATIENTS AND METHODS

- 8 cases
- Using pre- and post-operative helical computational tomogram data for MMA
- Created models from 3-D CT: pre- and post-op
- Simulations using computational fluid dynamics (CFD)

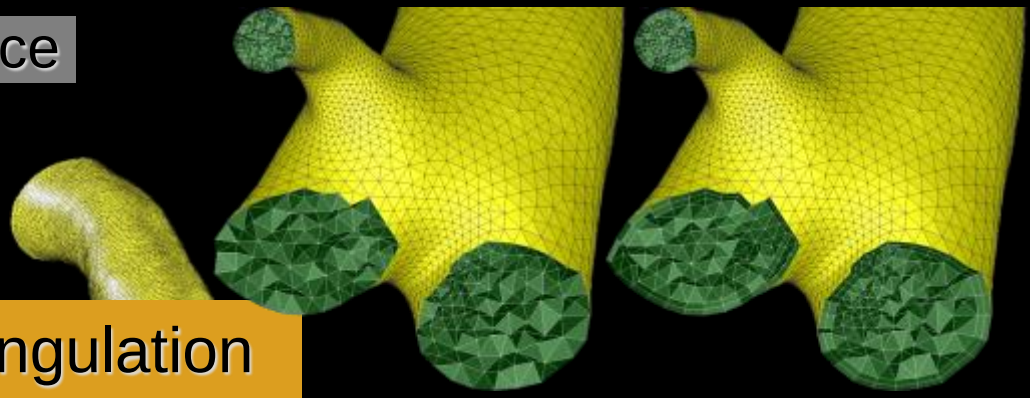
Case	Op	RDI	Distance for jaw movement [mm]					
			Average A - Base	Difference between pre- and post-op	Average B - Base	Difference between pre- and post-op	Average Pg - Base	Difference between pre- and post-op
1	Pre	22.6	114.57	3.95	113.39	6.44	119.23	7.23
	post	9.7	118.52		119.83		126.46	
5	Pre	38	123.59	9.41	122.58	9.9	135.88	10.34
	post	8.2	133		132.48		146.22	
6	Pre	17.1	120.93	6.36	125.54	6.82	131.93	5.61
	post	5.4	127.29		132.36		137.54	
12	Pre	14	121.61	6.17	121.45	4.92	126.37	4.52
	post	0.7	127.78		126.37		130.89	
13	Pre	50	124.25	4.95	123.38	12.5	131.15	10.59
	post	13	129.2		135.88		141.74	
18	Pre	40.3	140.91	7.62	139.18	11.24	149.32	14.53
	post	6	148.53		150.42		163.85	
19	Pre	48	121.96	7.51	120.55	8.48	127.64	12.97
	post	7	129.47		129.03		140.61	
23	Pre	30.9	132.93	10.32	141.52	8.86	149.02	9.15
	post	0.5	143.25		150.38		158.17	

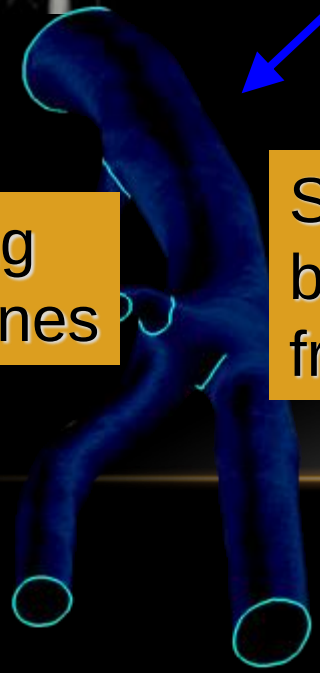
MESH GENERATION BASED ON CT/MRI DATA



Noise reduction
Segmentation
Surface extraction
- ITK, VTK and in-house codes`

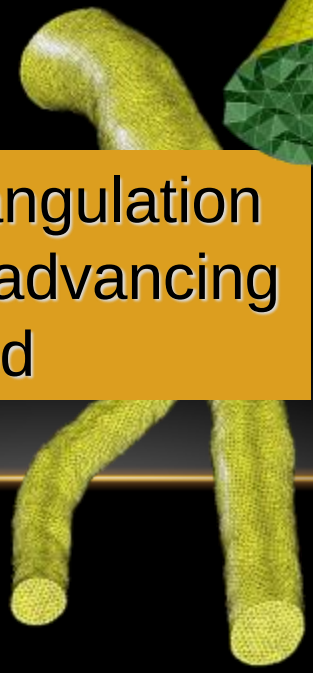
Faceted surface





Extracting feature lines

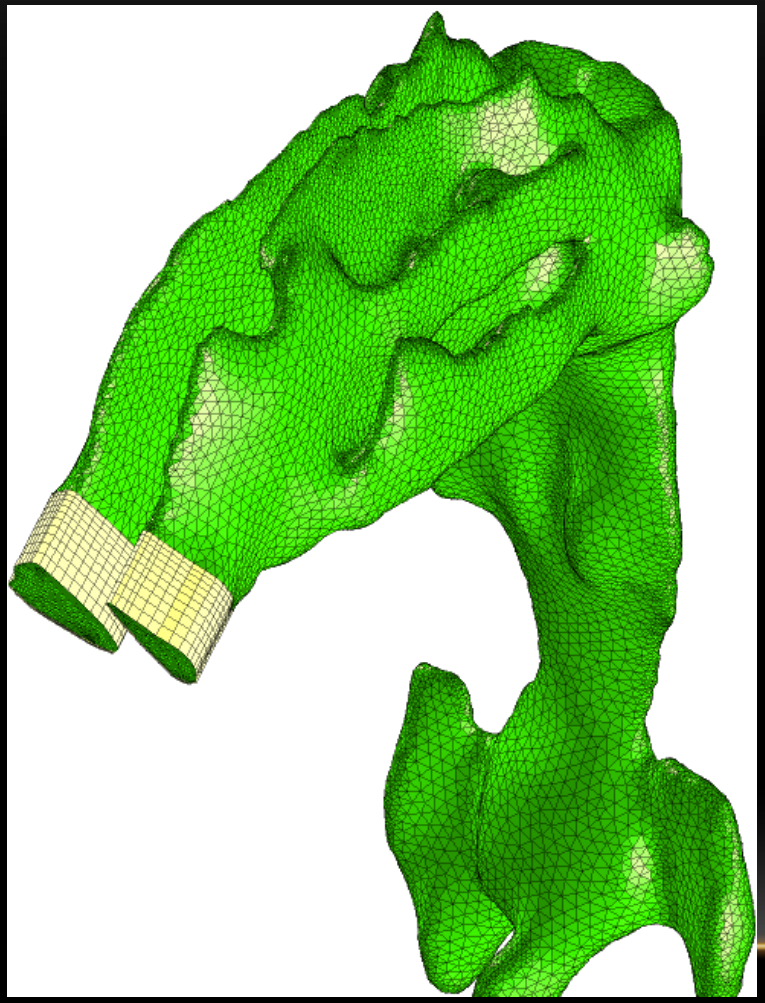
Surface triangulation by a direct advancing front method

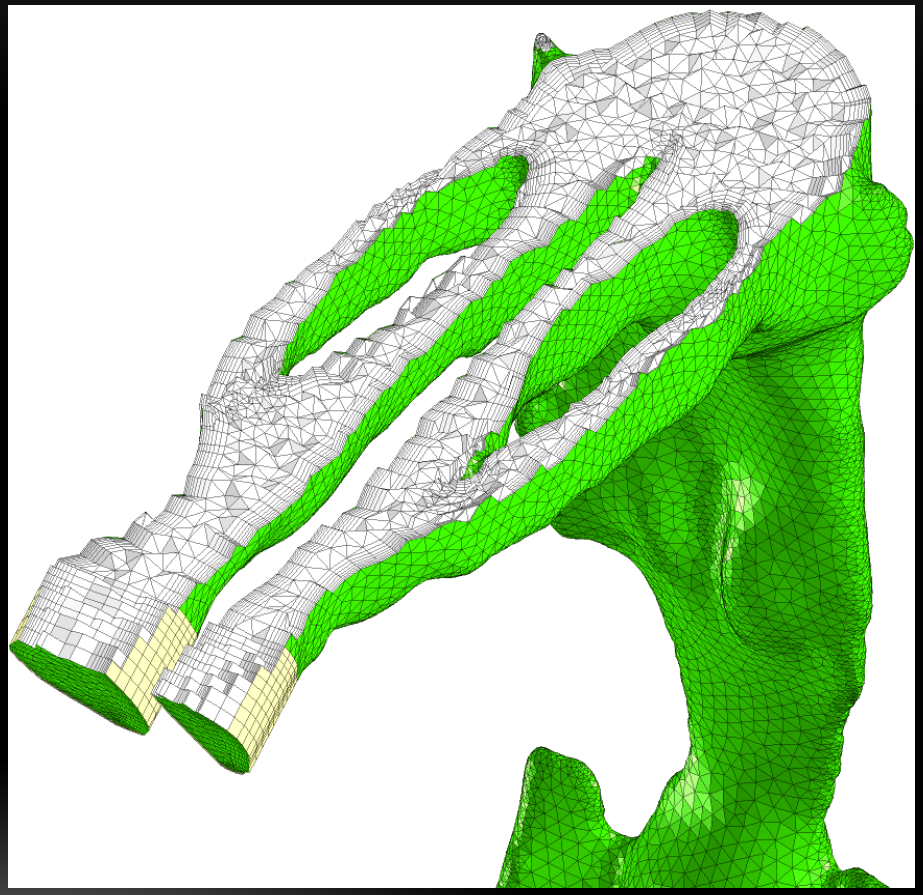


Volume meshing
- Tetrahedral
- Hybrid

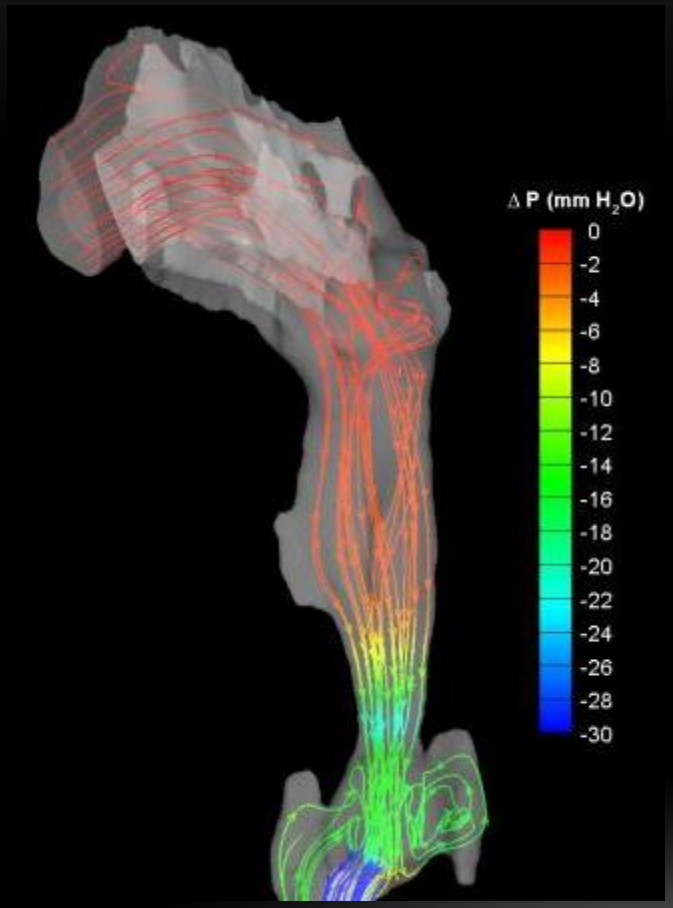
MESH GENERATION BASED ON CT/MRI DATA: COMPUTER FLUID DYNAMICS

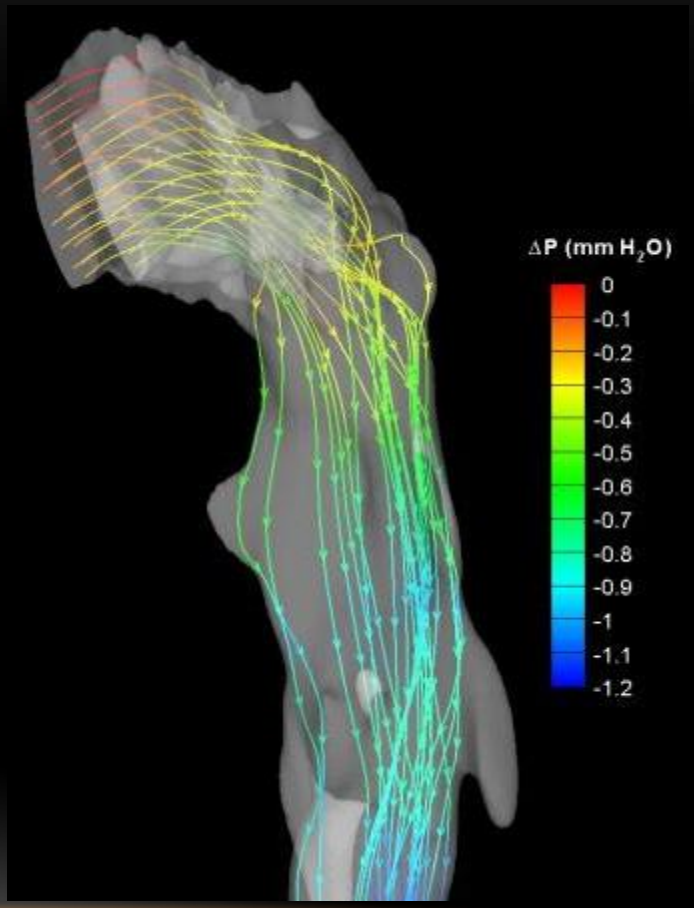
DOMAIN DISCRETIZATION



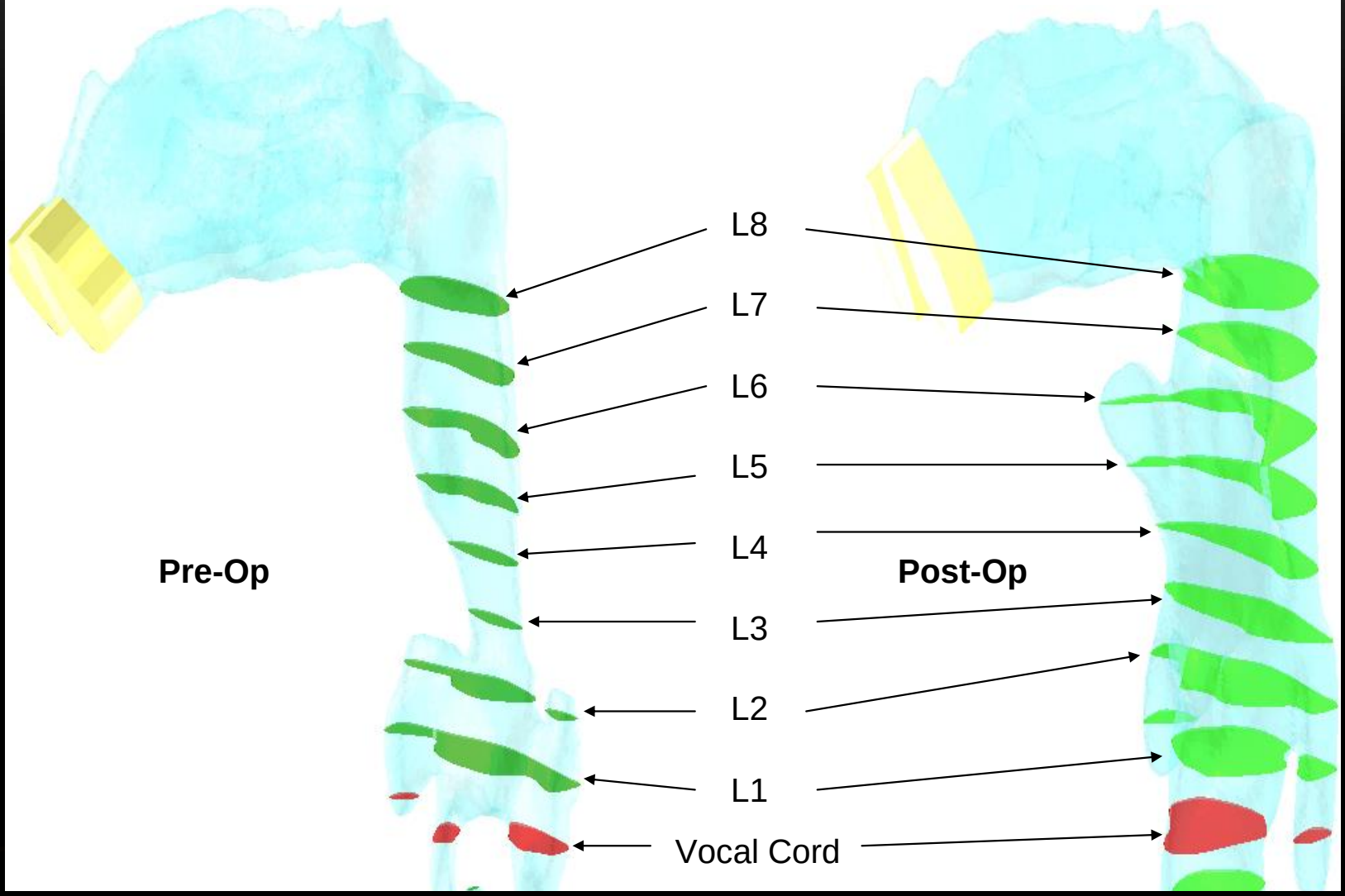


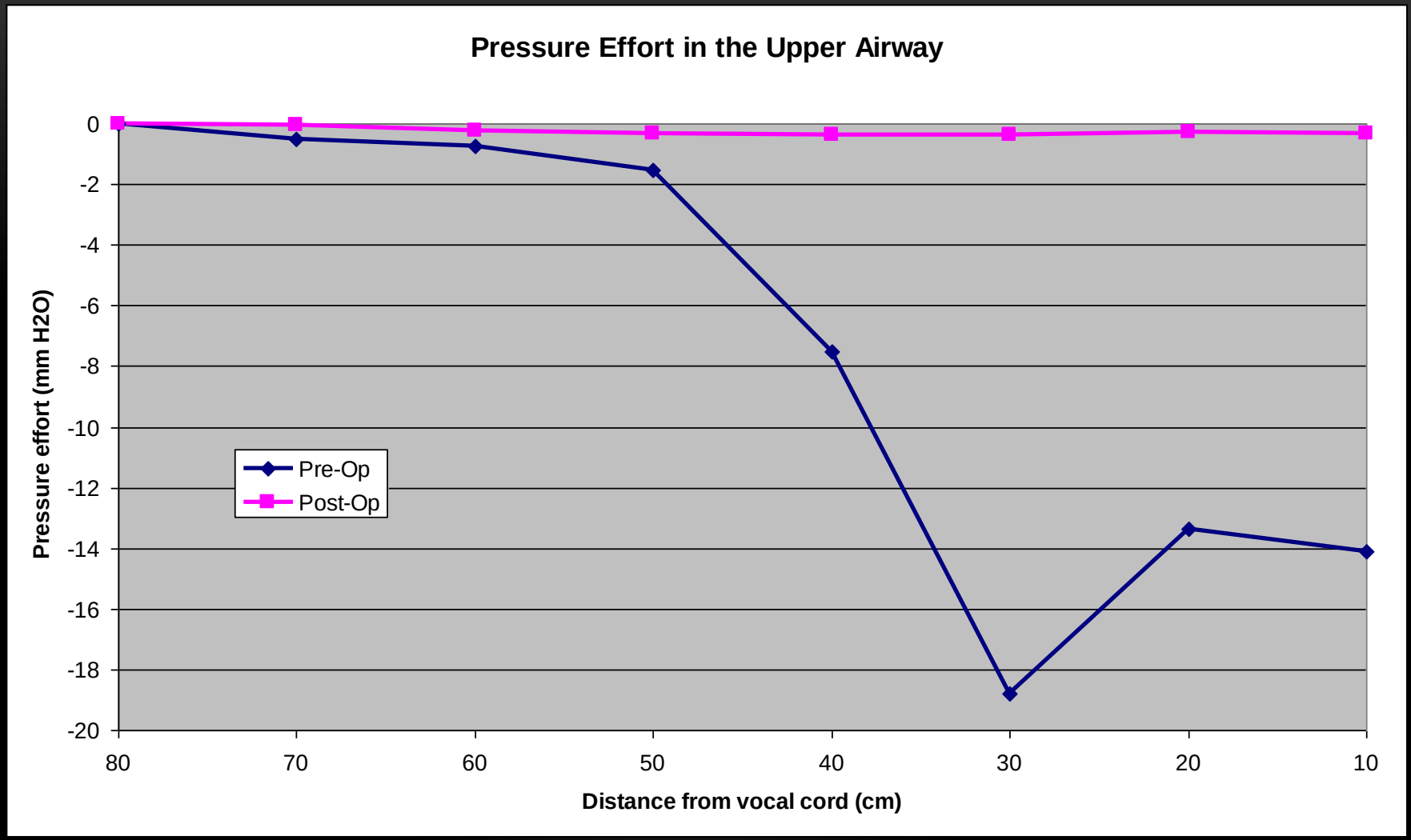
VISUALIZATION: CFD



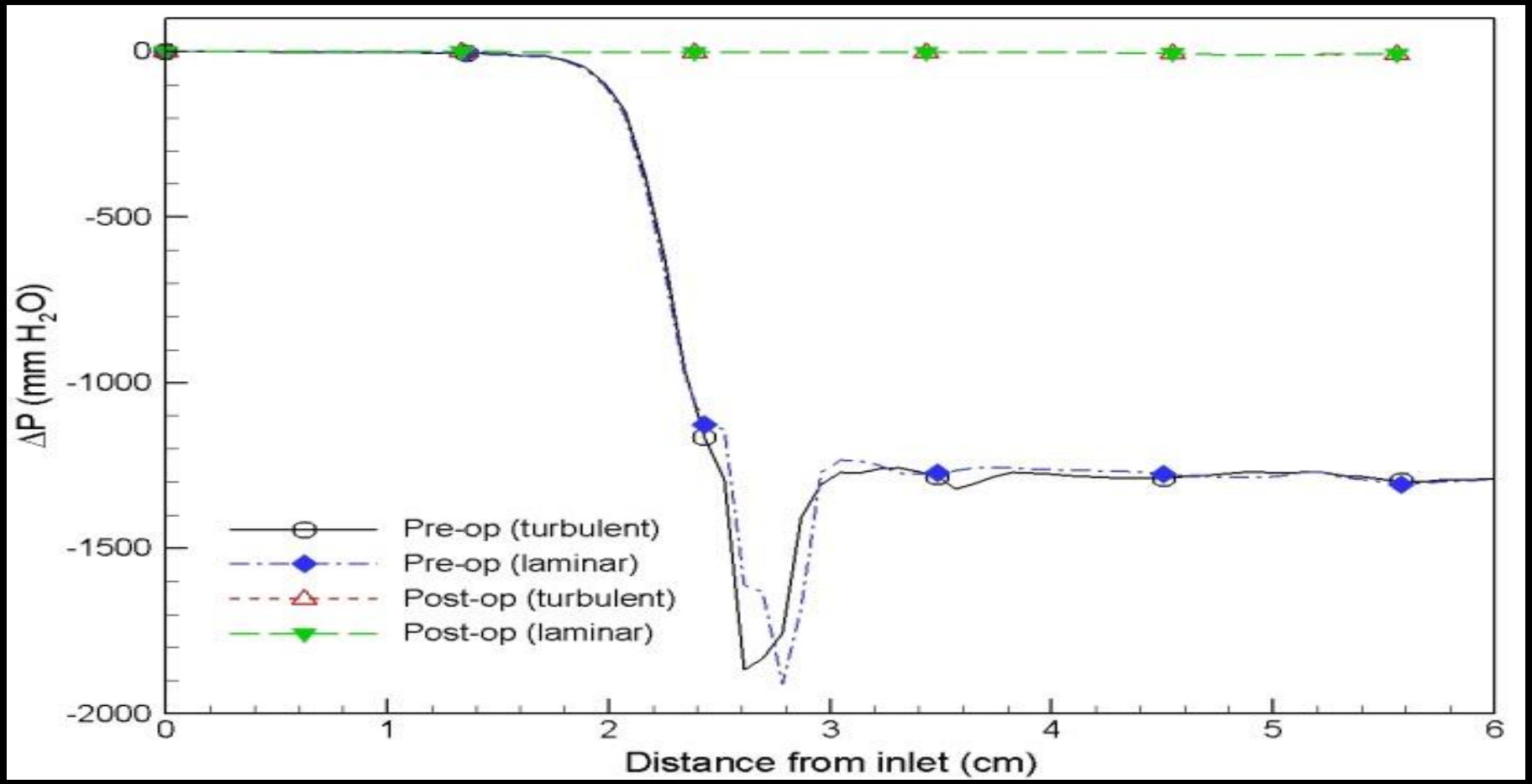


Cross-Section of the Airway from the Vocal Cord

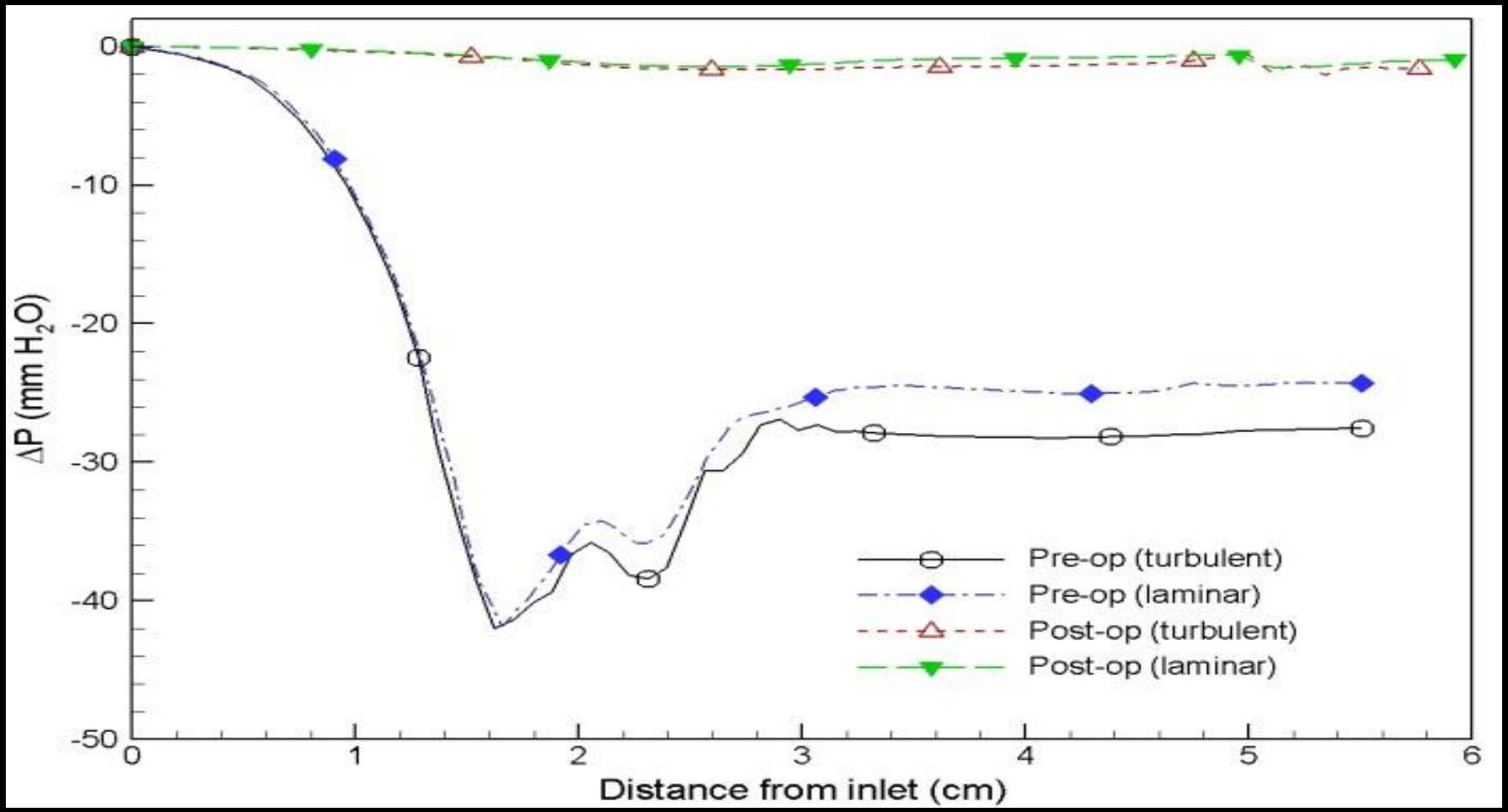



Pressure Effort in the Upper Airway
Pressure effort (mm H2O)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
Pre-Op
Post-Op
80
70
60
50
40
30
20
10
Distance from vocal cord (cm)

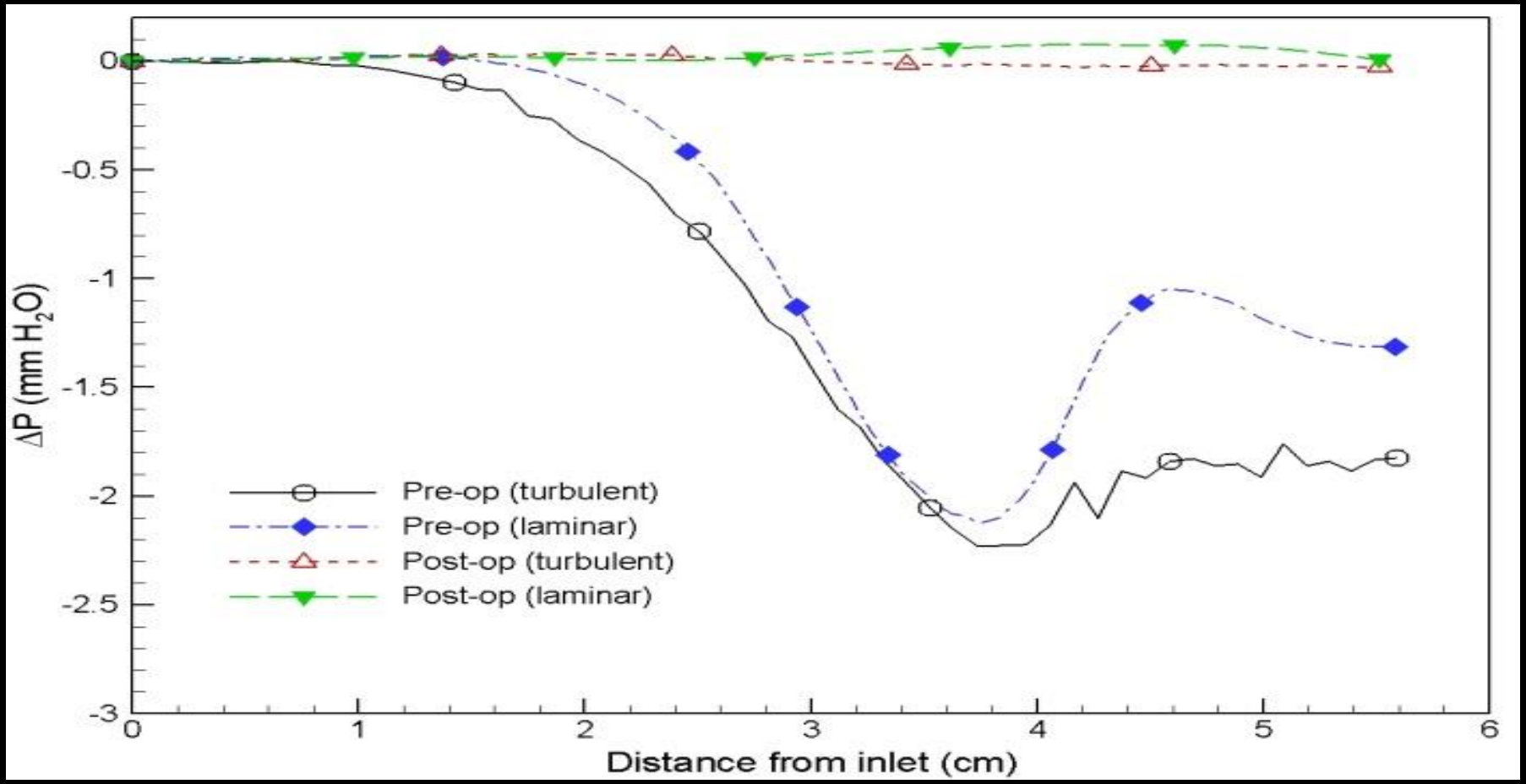
CASE # 6


0
-500
-1000
-1500
-2000
ΔP (mm H2O)
0
1
2
3
4
5
6
Distance from inlet (cm)
Pre-op (turbulent)
Pre-op (laminar)
Post-op (turbulent)
Post-op (laminar)

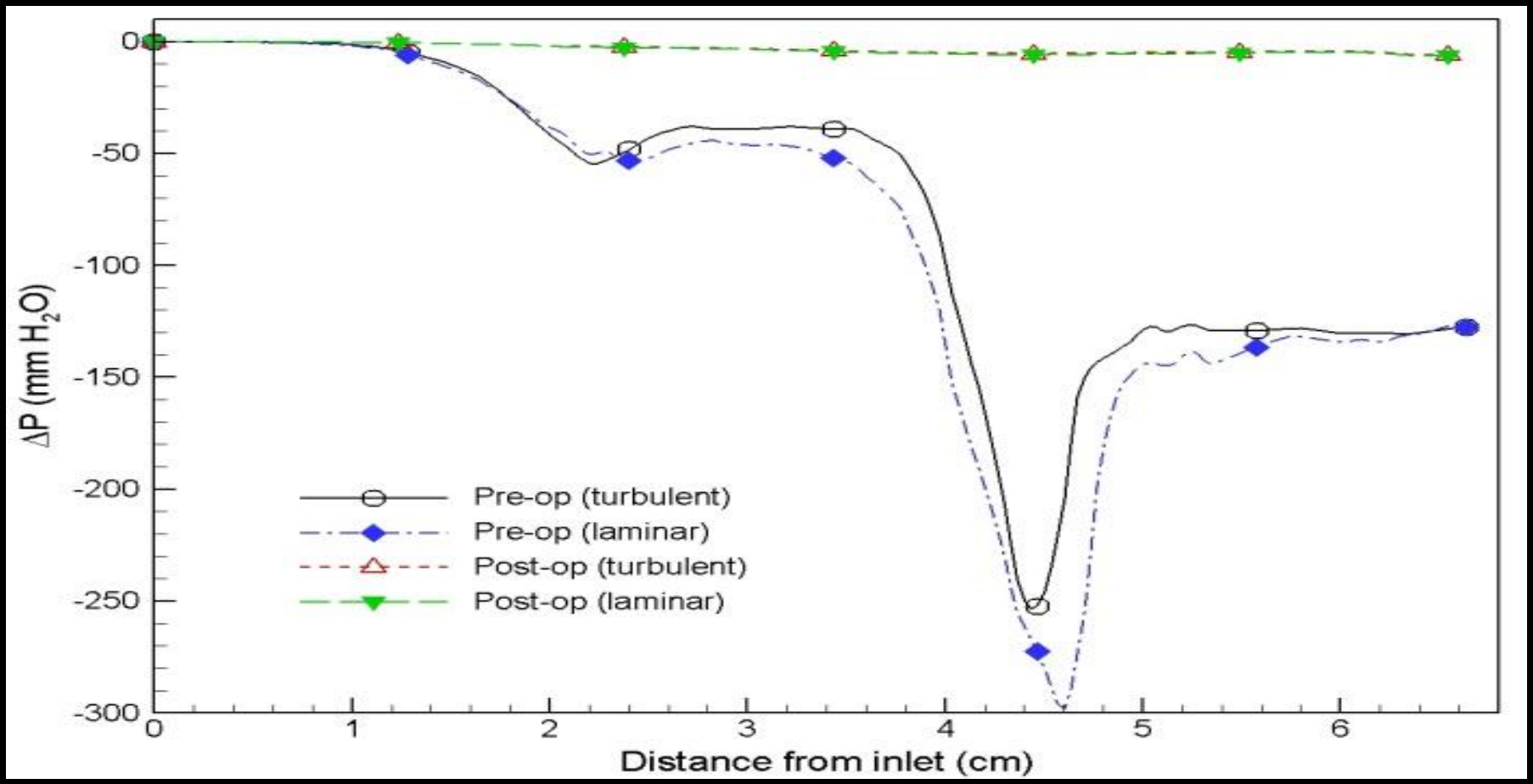
CASE # 13


0
-10
-20
-30
-40
-50
ΔP (mm H2O)
0
1
2
3
4
5
6
Distance from inlet (cm)
Pre-op (turbulent)
Pre-op (laminar)
Post-op (turbulent)
Post-op (laminar)

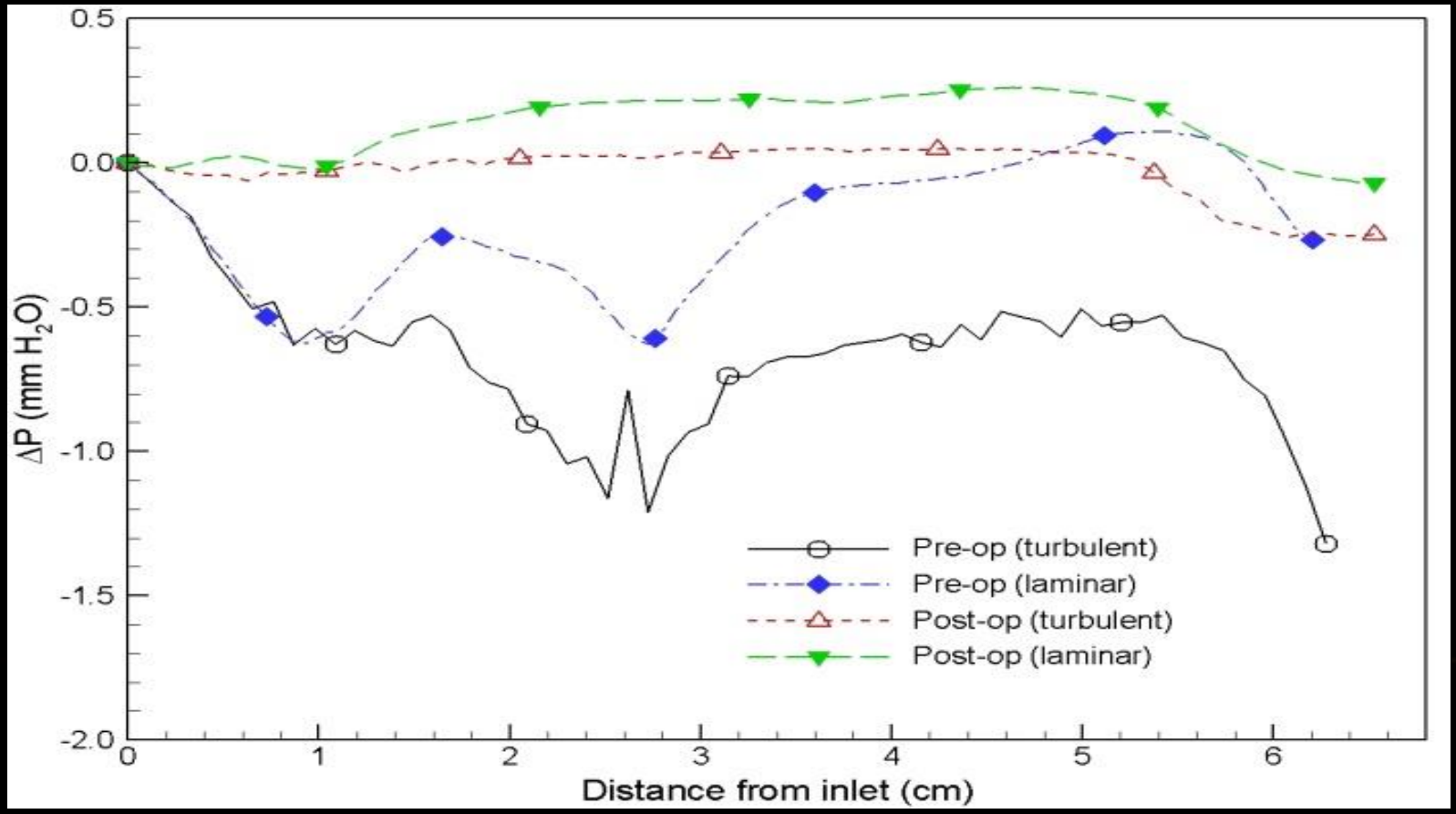
CASE # 18


0
-0.5
-1
-1.5
-2
-2.5
-3
ΔP (mm H2O)
0
1
2
3
4
5
6
Distance from inlet (cm)
Pre-op (turbulent)
Pre-op (laminar)
Post-op (turbulent)
Post-op (laminar)

CASE # 19


0
-50
-100
-150
-200
-250
-300
ΔP (mm H2O)
0
1
2
3
4
5
6
Distance from inlet (cm)
Pre-op (turbulent)
Pre-op (laminar)
Post-op (turbulent)
Post-op (laminar)

CASE # 23


0.5
0.0
-0.5
-1.0
-1.5
-2.0
ΔP (mm H2O)
0
1
2
3
4
5
6
Distance from inlet (cm)
Pre-op (turbulent)
Pre-op (laminar)
Post-op (turbulent)
Post-op (laminar)

MULTIPLE SITES OF OBSTRUCTION

- It is now well recognized that most patients with retropalatal narrowing, have other areas of pharyngeal collapse during sleep.

CONCLUSION

- MMA increases airway in all dimensions
- Maxillary and Mandibular synergy, multiple muscles of support on the airway
- Lateral change is most important for airway.
- I suspect that if CPAP increase the airway so will MMA