

ATACCC 2009

Maxillofacial Trauma

- 1300-1340 Characterization of Craniofacial Battle Injuries
COL Robert G Hale
- 1340-1420 Synthetic Antimicrobial Decapeptide Ameliorates
Stress-Impaired Healing in Mice
LTC Richard Williams
- 1420-1500 The Next Generation of Cell-Based, Tissue
Engineered Products for Wound Care
Dr Lynn Allen-Hoffman

Characterization of Craniofacial Battle Injuries
Limitations of Conventional Treatment
Direction of Future Research



Robert G. Hale, D.D.S.

Colonel, US Army Dental Corps

Director of Craniomaxillofacial Research

US Army Institute of Surgical Research

- Historical Perspective
- Maxillofacial Blast Injury
 - Battle Injury Statistics
 - Case Examples
 - Conventional Treatment Limitations
- Future Direction
 - Tissue Engineering
 - Composite Tissue Allotransplantation
 - Regenerative Medicine

WWI

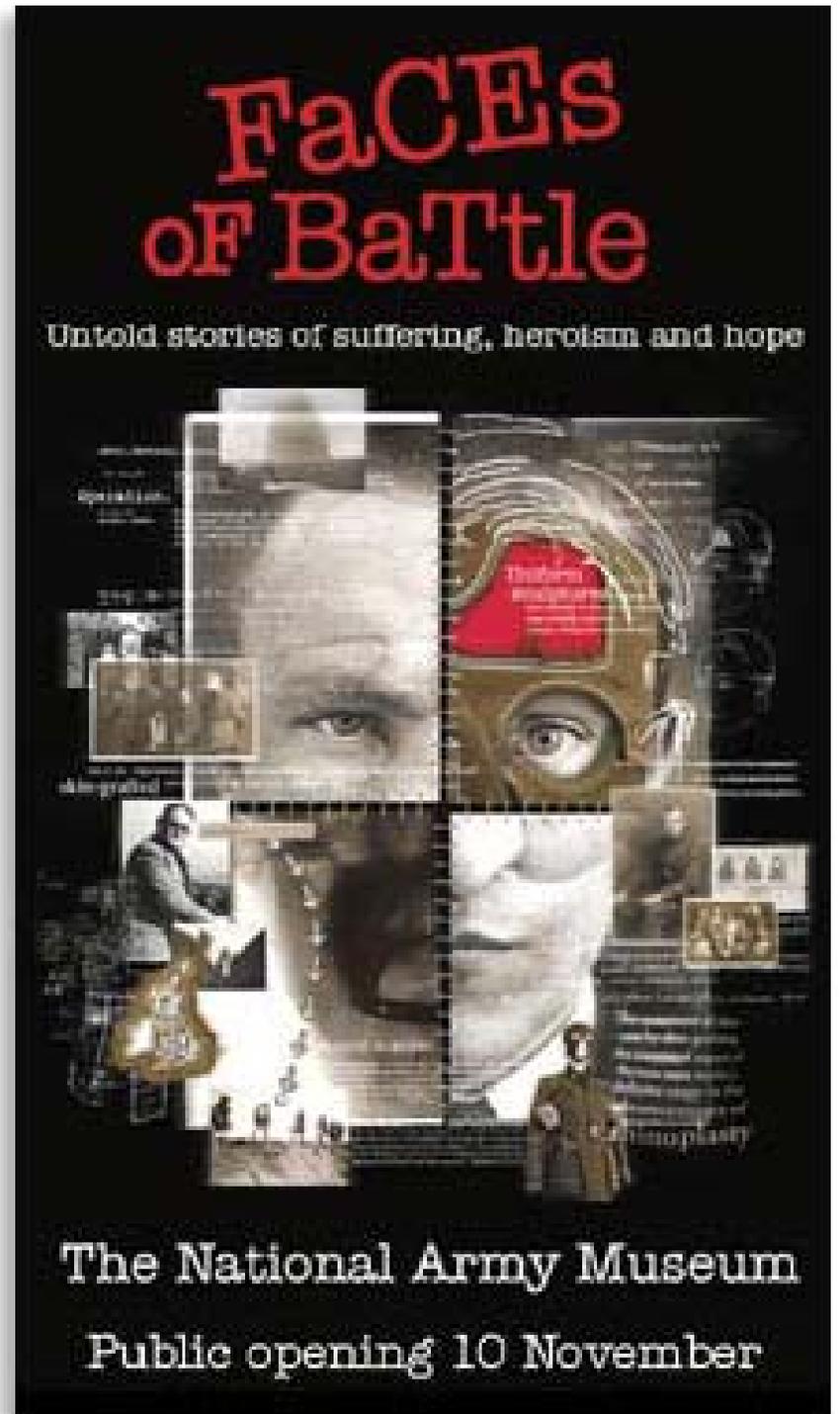
Wounded:

US 0.2 M

UK 1.6 M

FR 4.3 M

RU 4.9 M



WWI: 40,000 Maxillofacial Wounds



Sir Harold Gilles' Records, 1919-1922



No. on Register 3805.

495562 Private S , A.J. 6th. London.

Age 23. Wounded 4.4.18. Admitted from Tooting Military Hospital, 3.6.19.

G.S.W. Face. Whole of chin and floor of mouth shot away. Tongue still present. Fractured mandible with large loss of bone in symphysis region.

Splints fixed at Tooting Hospital, where patient had diphtheria, but recovered.

21.8.19. Operation (Mr. Chubb):

 Tubing flap from chest to forearm for future use in plastic on chin.

11.10.19. Operation (Mr. Chubb).

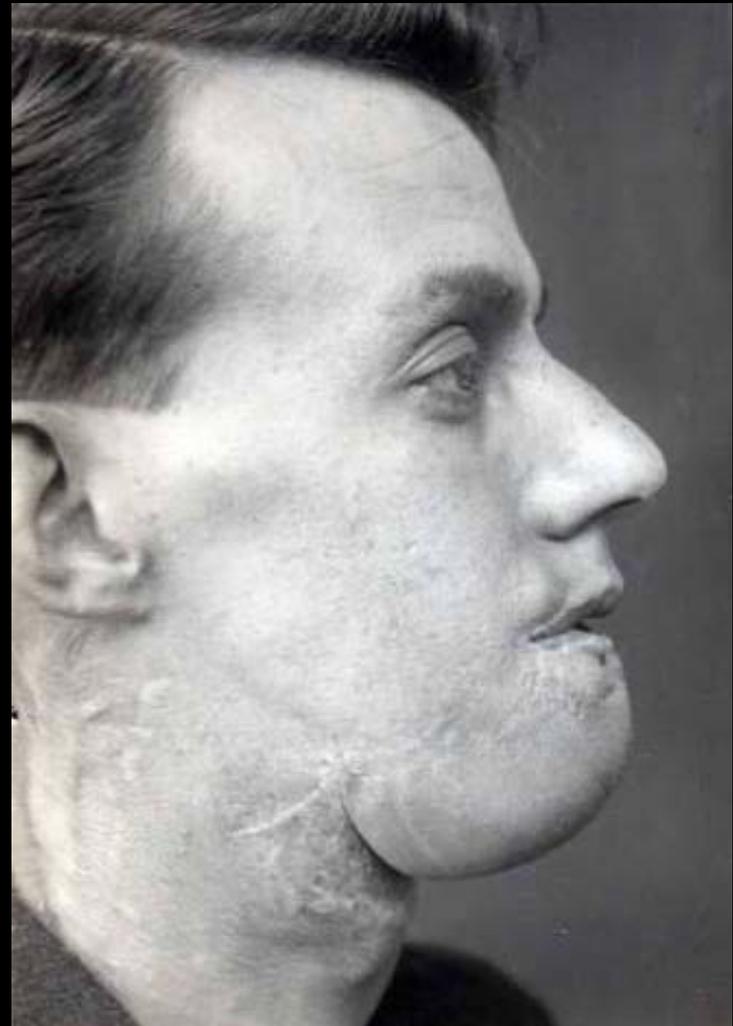
 Pedicled flap from chest to forearm freed at chest attachment and flap of required size brought up and sutured in position on chin to replace missing portion of chin. Arm held in position across chest by strapping.

Inspired by Dr Hippolyte Morestin, French Surgeon

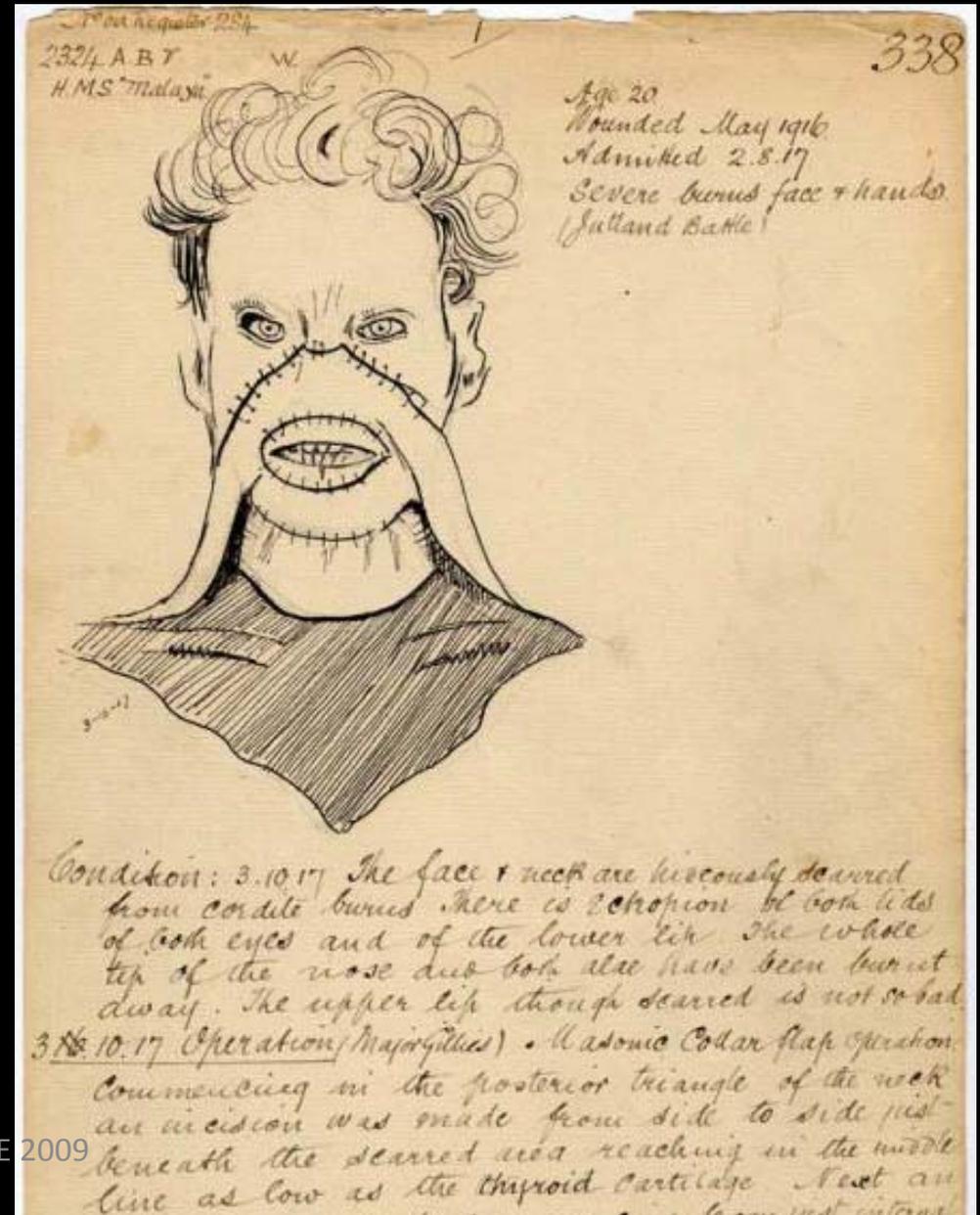
















Battle Injury Data



Comparison of Wounds by Body Region

	% Body Area	WWII	Korea	Vietnam	Iraq/AFG	
H&N	12%	21%	21%	16%	29%	↑
Chest	16%	14%	10%	13%	6%	↓
Abdomen	11%	8%	8%	9%	11%	
Extremities	61%	58%	60%	61%	54%	

Mechanism of Injury From Previous US Wars

	<u>GSW</u>	<u>Explosion</u>
Civil War	91%	9%
WWI	65%	35%
WWII	27%	73%
Korea	31%	69%
Vietnam	35%	65%
Iraq/Afghan	19%	81%

Owens, J Trauma FEB 2008

Mechanism of Injury Previous US Wars



Mechanism of Injury Within Regions Iraq/Afghanistan

96% Penetrating

Region	GSW	Explosion	Vehicle
Head & Neck	8%	88%	4%
Chest	19%	78%	3%
Abdomen	17%	81%	2%
Extremity	17%	81%	2%

Owens, J Trauma FEB 2008

Increased Rates of H&N Injuries

- Body armor
- Improved medic training
- Advanced battlefield surgical capabilities
- Increased use of explosive weapons
- Urban warfare

Joint Theater Trauma Registry

Oct 19, 2001 to Dec 12, 2007

(50% Battle Injured recorded; excludes eyes, ears, face burns)

# Soldiers w/ Battle Injuries (no 72 hr RTD)	7,770	
# Soldiers w/ MxF Battle Injuries	2,014	(26%)
Total MxF Battle Injuries	4,783	

2.4 MxF BI per Soldier

Average age 26

Range 18-57

98% Male

Army 72%

Marines 24%

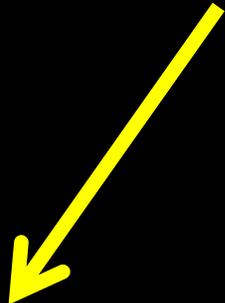
Navy 2%

Air Force 1%

Types of Maxillofacial Battle Injuries

Simple penetrating soft tissue	2,128	44%
Complicated penetrating soft tissue	660	14%
Fractures (76% open)	1,280	27%
Abrasions Contusions	342	7%
Dental	204	4%
Unknown/Other	169	4%
TOTALS	4,783	100%

41%



Hale, 2008

Face Burns

Burns comprise 5% of casualties evacuated
142 BI burns treated at USAISR April 2003 to
April 2005
86% caused by explosive devices
77% face burns

Kauvar, Burns, 32 (2006)

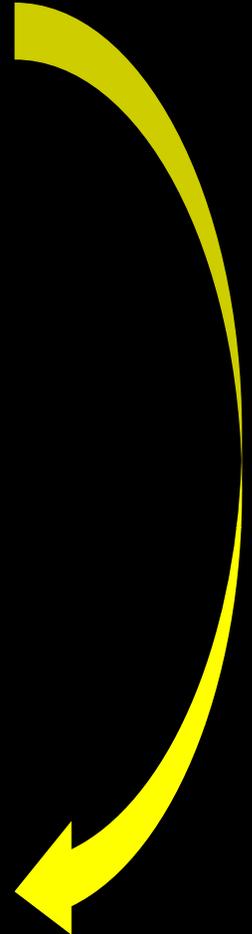
Maxillofacial Blast Injury

- Roadside-130mm Artillery HE Load
- Vehicle Borne-1,000# HE
- Exploding Vest-30# HE
- Rocket-Propelled Grenade-5# HE

MxF Battle Injury Pattern:

- Perforating Soft Tissue Injuries
- Open, Comminuted Fractures
- Avulsions
- Burns

Severe MxF BI Rate <10%



Severe Maxillofacial Battle Injury Rate

26% of Battle Injuries to Maxillofacial
(excludes eyes, ears and face burns)

41% Severe Maxillofacial Injuries

14% Complicated Soft Tissue

27% Fractures

4% Face Burns (Kauvar, 2006)

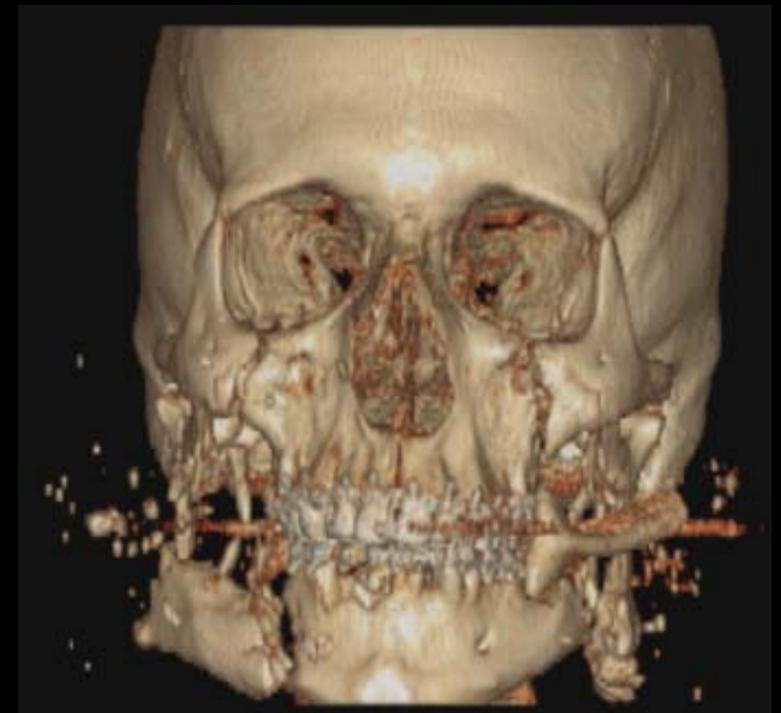
$26\% \times (41\% + 4\%) = 11.7\%$

Open Comminuted Fractures & Avulsions



Composite facial injuries

- Soft Tissue:
 - Peri-oral soft tissue avulsion
- Hard Tissue:
 - Maxillary Fractures
 - Comminuted Mandibular ramus/body fractures
 - Bilateral condyle fractures (Right side non-repairable)

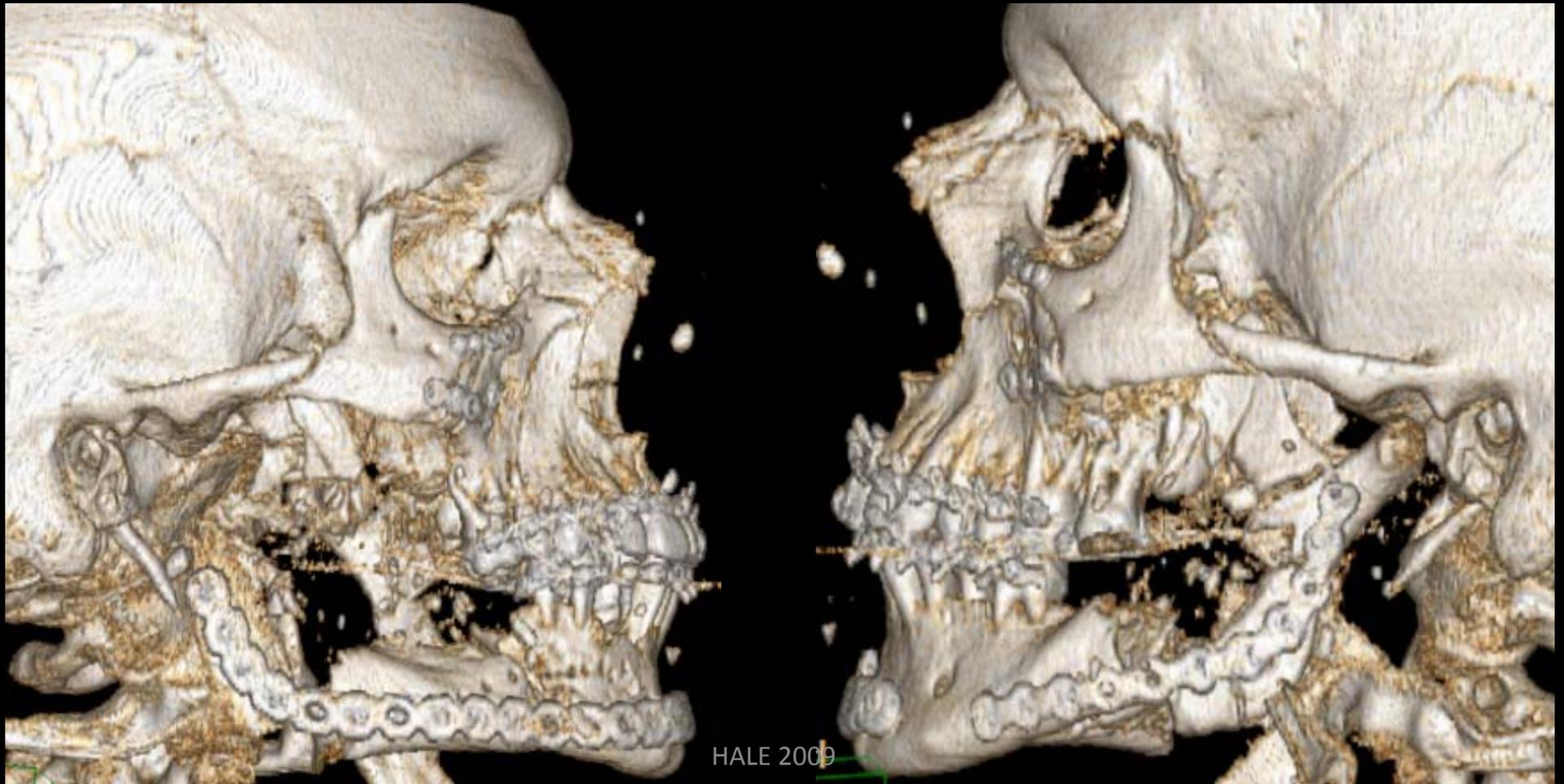


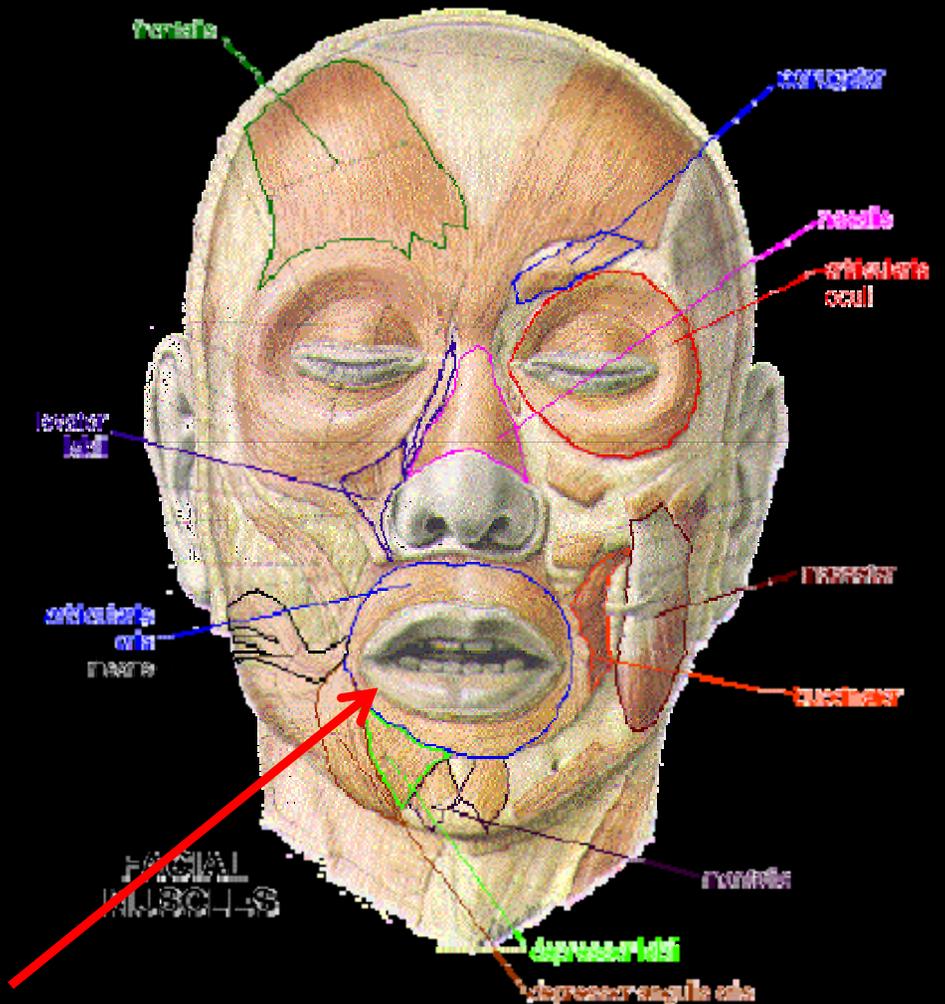


- Stereolith model
- Reconstruction of mandible on model
- Pre-bend reconstruction plates



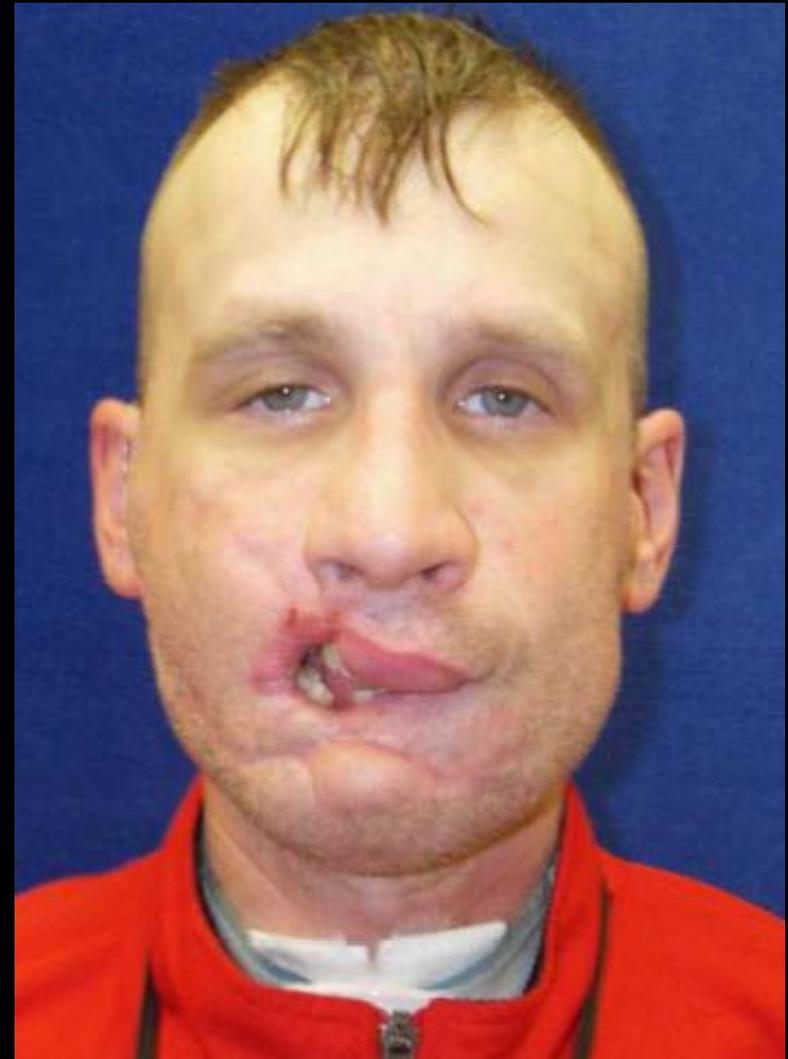
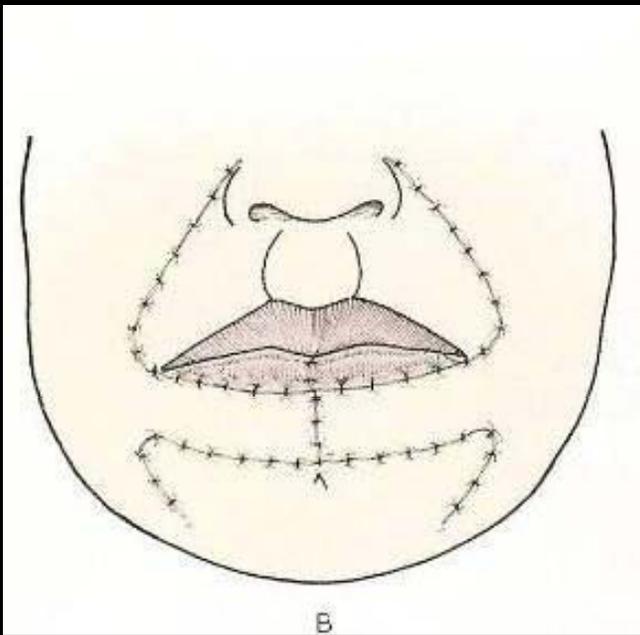
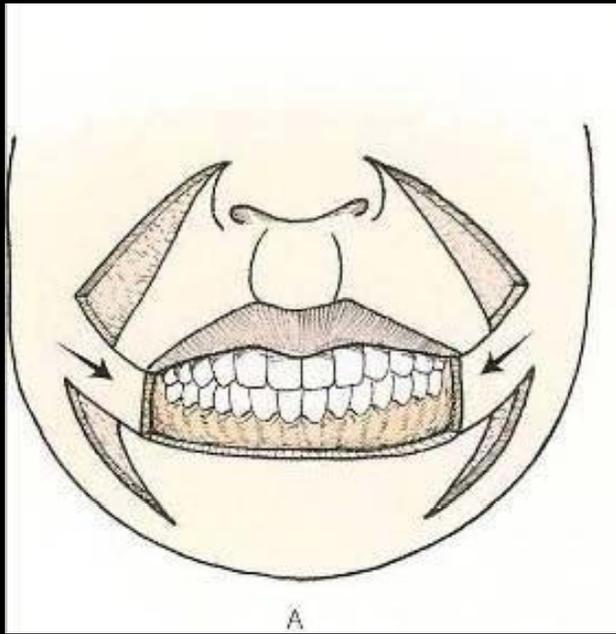
- Surgery 7Sep07
 - Via Neck Dissection
 - Reconstruction Plates Bilateral Ramus/Body
 - R Condyle Reconstruction with Rib Graft





Obicularis Oris
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Webster Modification of Bernard-von Burrow Flap



Buccal Advancement Flap

Lip Incompetence

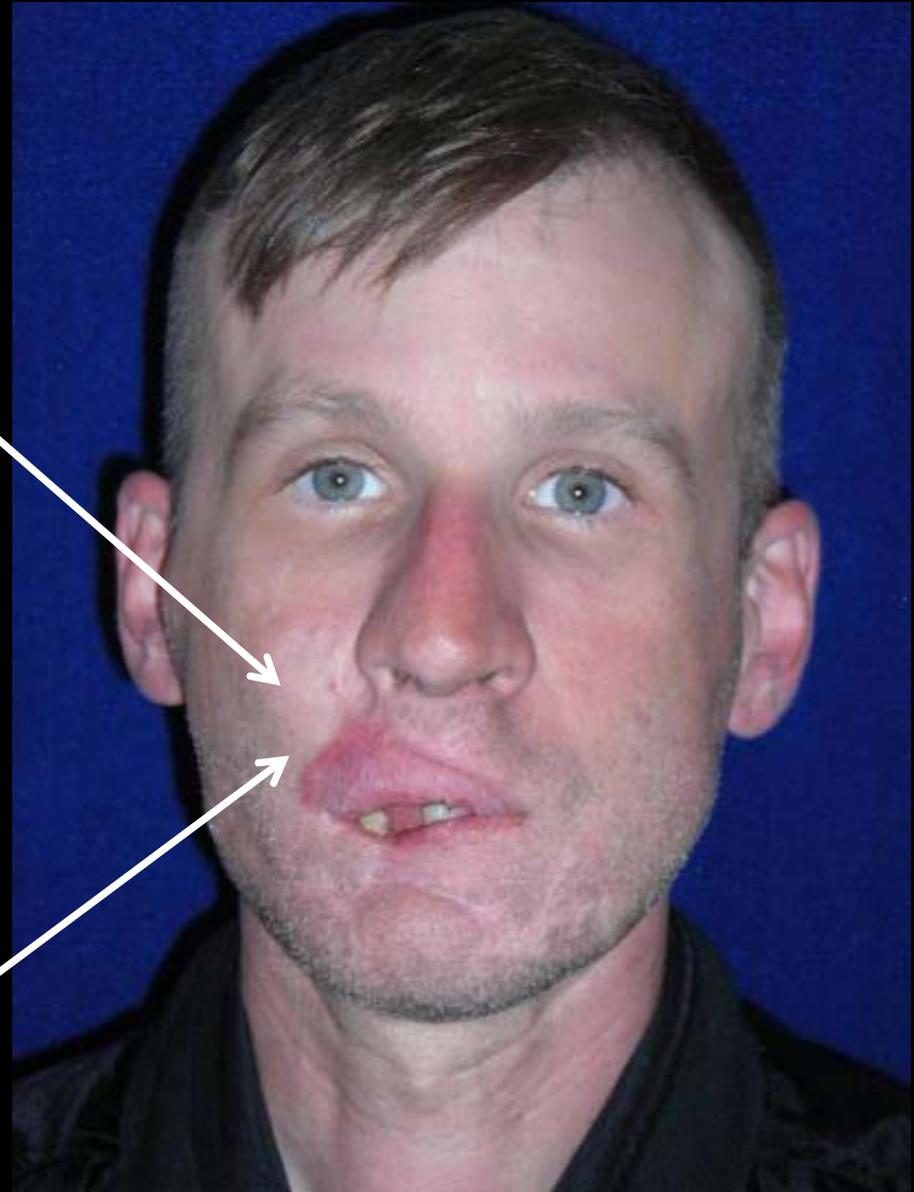
Microstomia

Deformed Fixed Mx Lip

Inadequate Md Lip Height

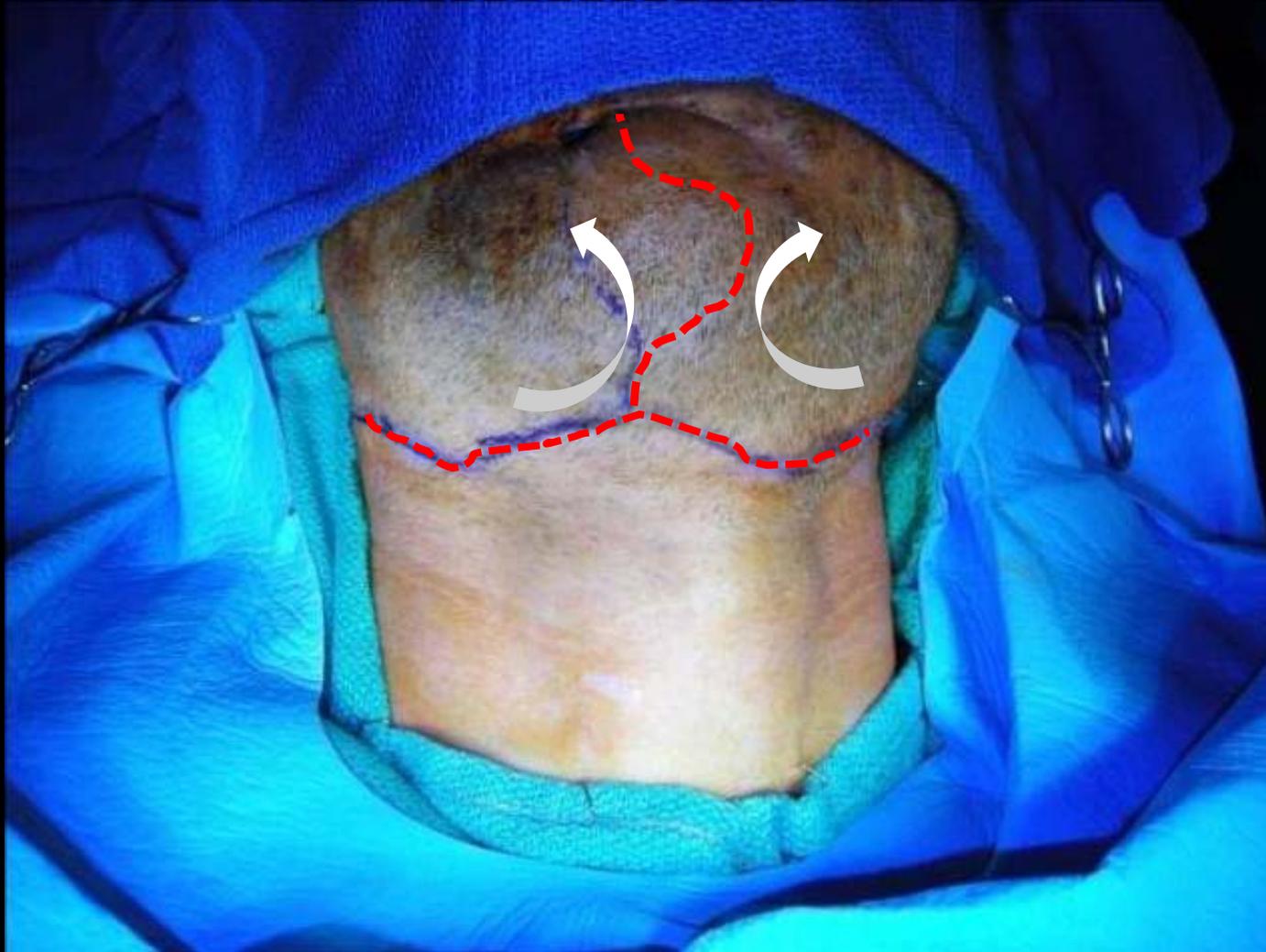
Missing Md Lip Vermillion

Extra-Articular Ankylosis

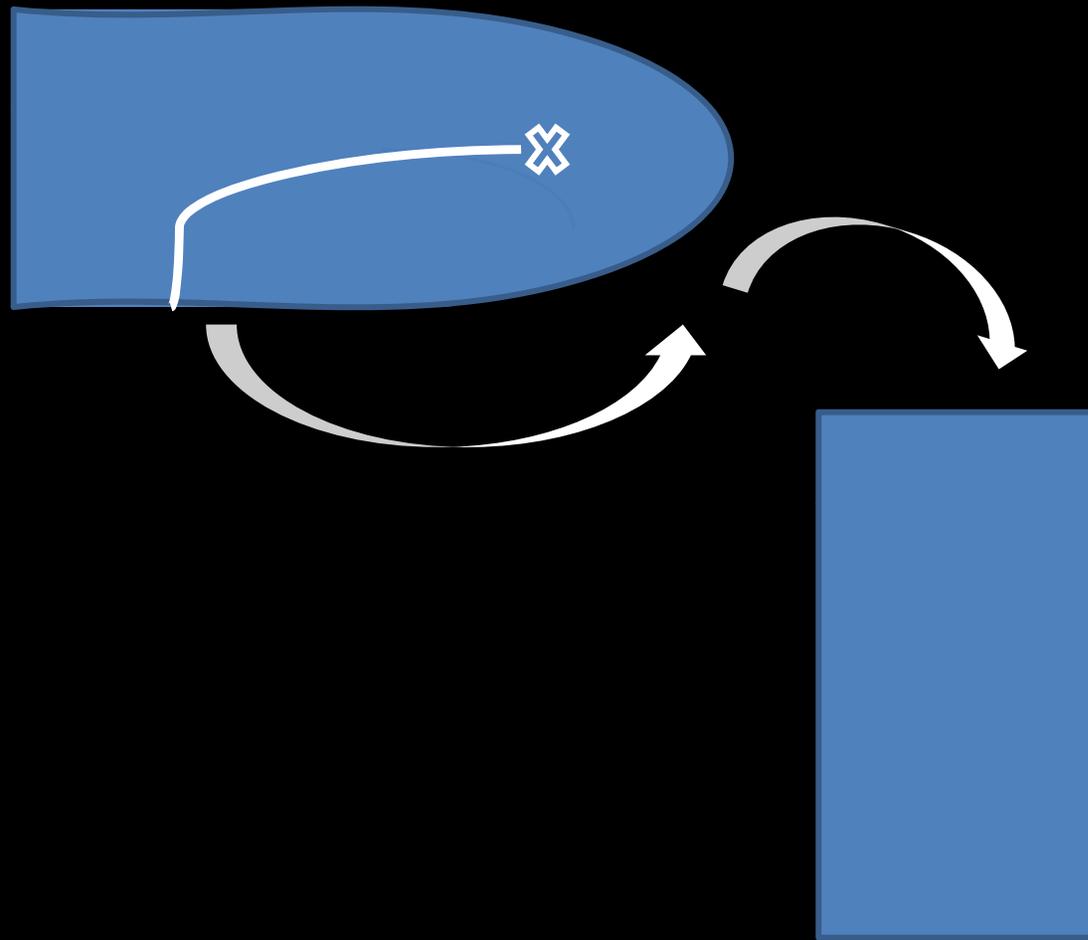


Scar Release &
Full Thickness Graft

Bilat. advancement/rotational cervicofacial flaps

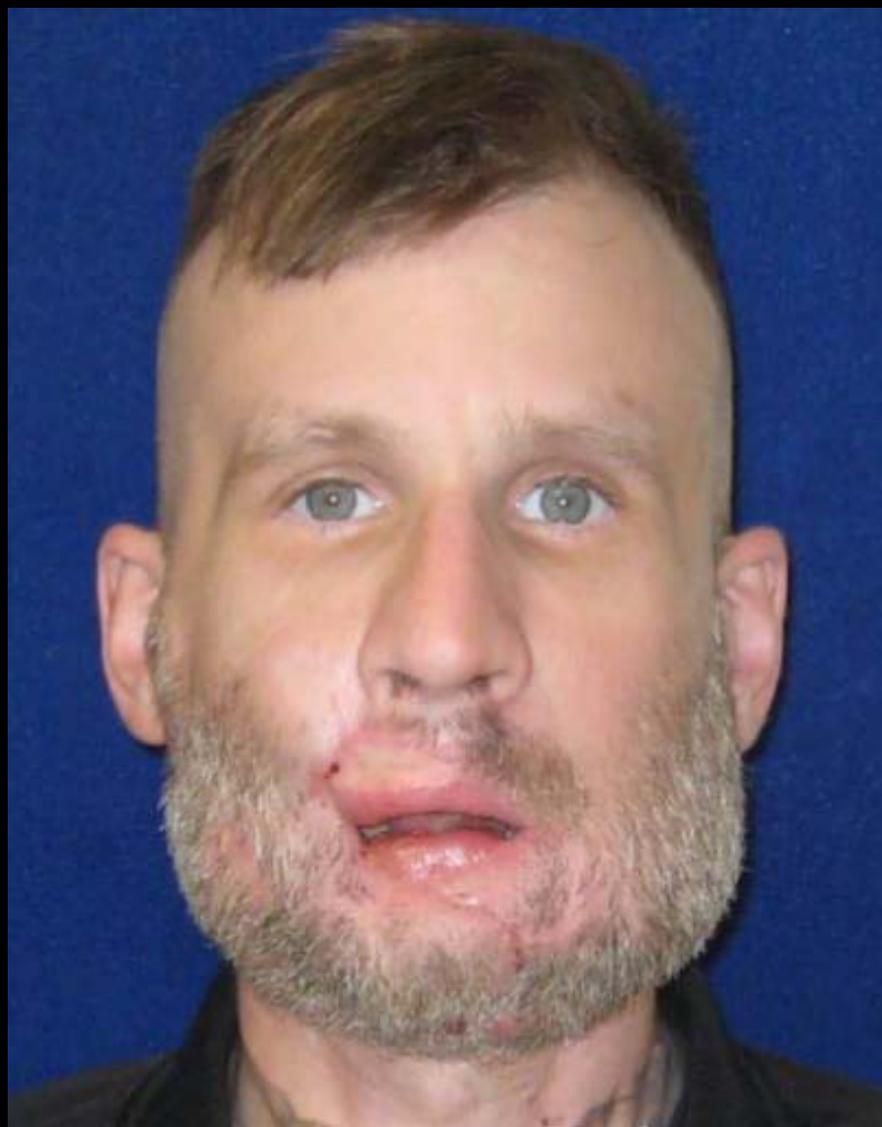


Anterior based ventral tongue flap



Advancement/rotational cervicofacial flap Anteriorly based ventral tongue flap







Microstomia

Extra-Articular Ankylosis

Lip Incompetence

Deformed Lips/Lack of Projection



3-61 CAV

Squadron
Ball 2009

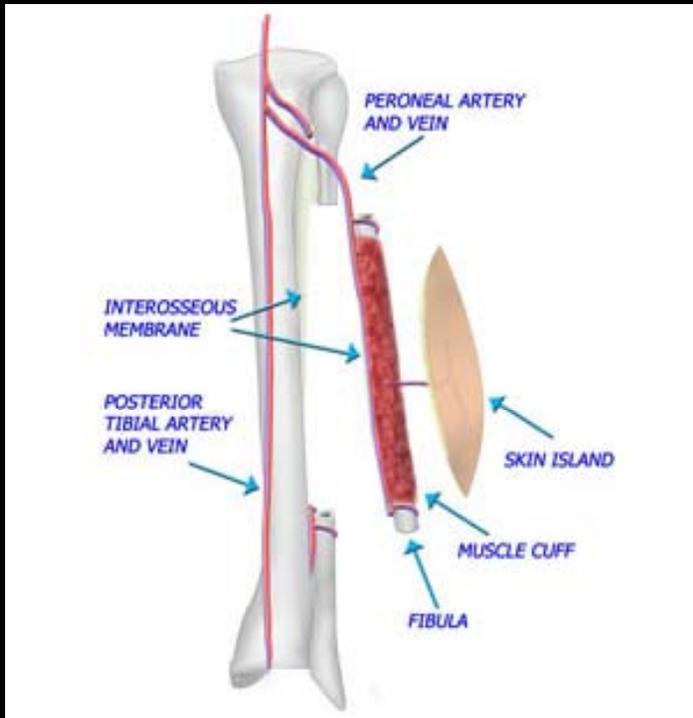
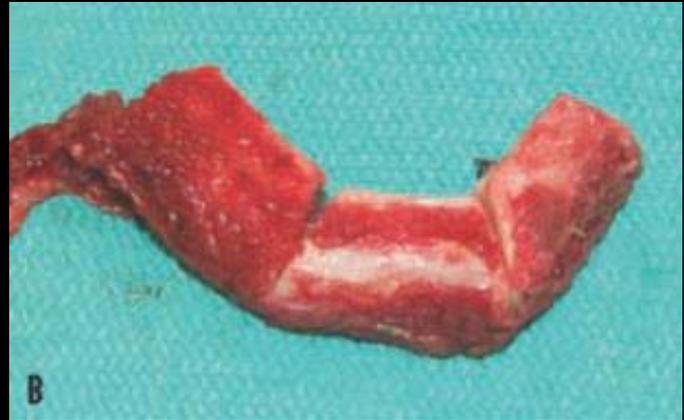




Microvascular Flap Transfer

- Fibula Osteomyocutaneous Flap
 - Mandibular continuity and projection
 - Soft tissue oral vestibule
 - Skin paddle for lower lip and chin
- 8-12 hour surgery, 2 surgical teams
- 240 minutes to re-establish blood flow to transferred tissue

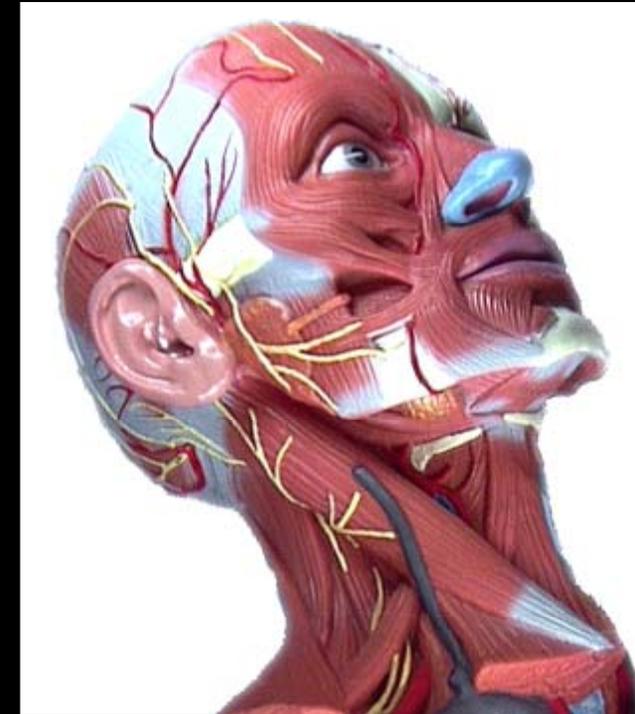




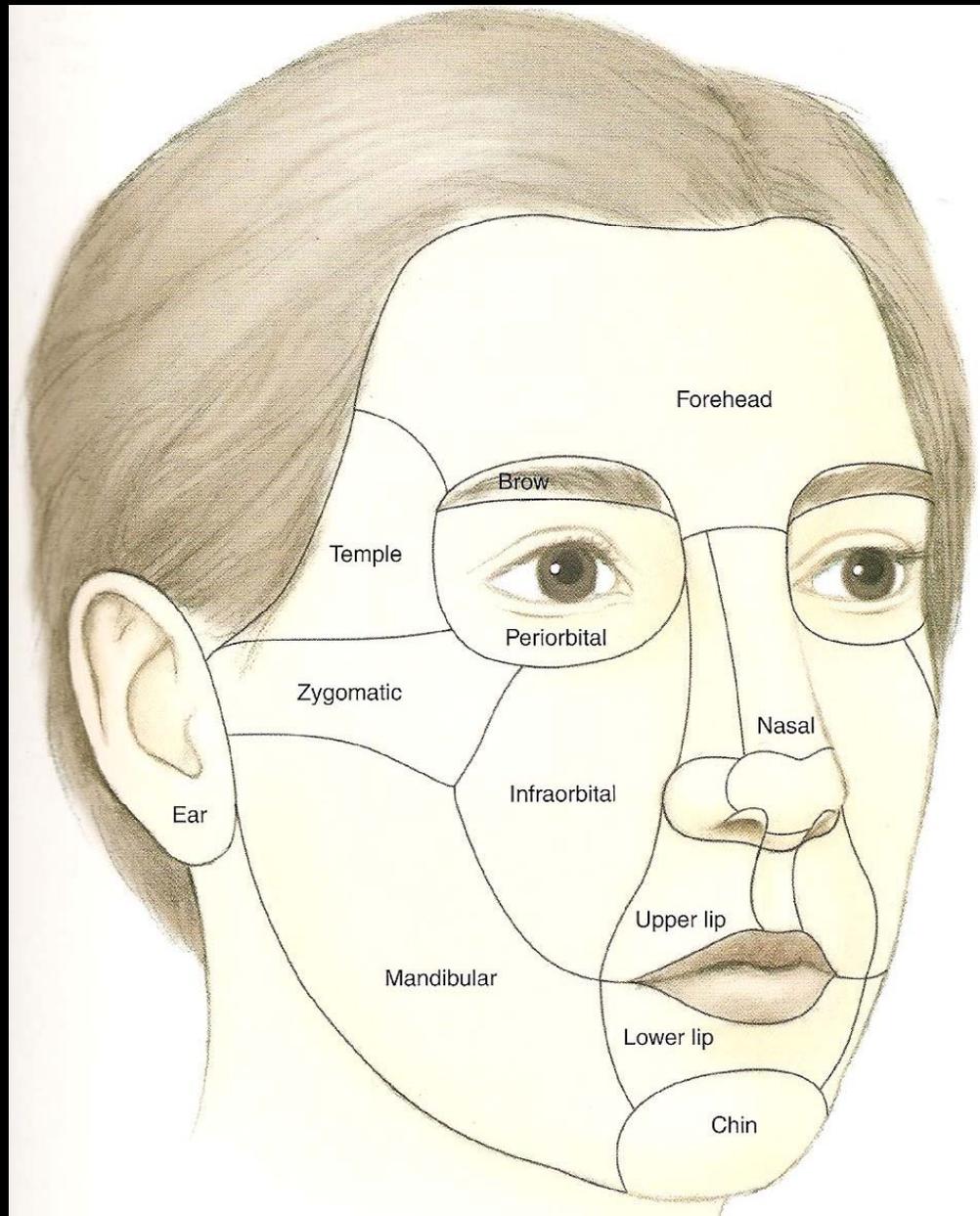


Maxillofacial Defect Repair

- Skin and mucosa
- Lip competence
- Motor control
- Bony support
- Jaw mobility
- Sensation
- Speech
- Dentition
- Esthetics

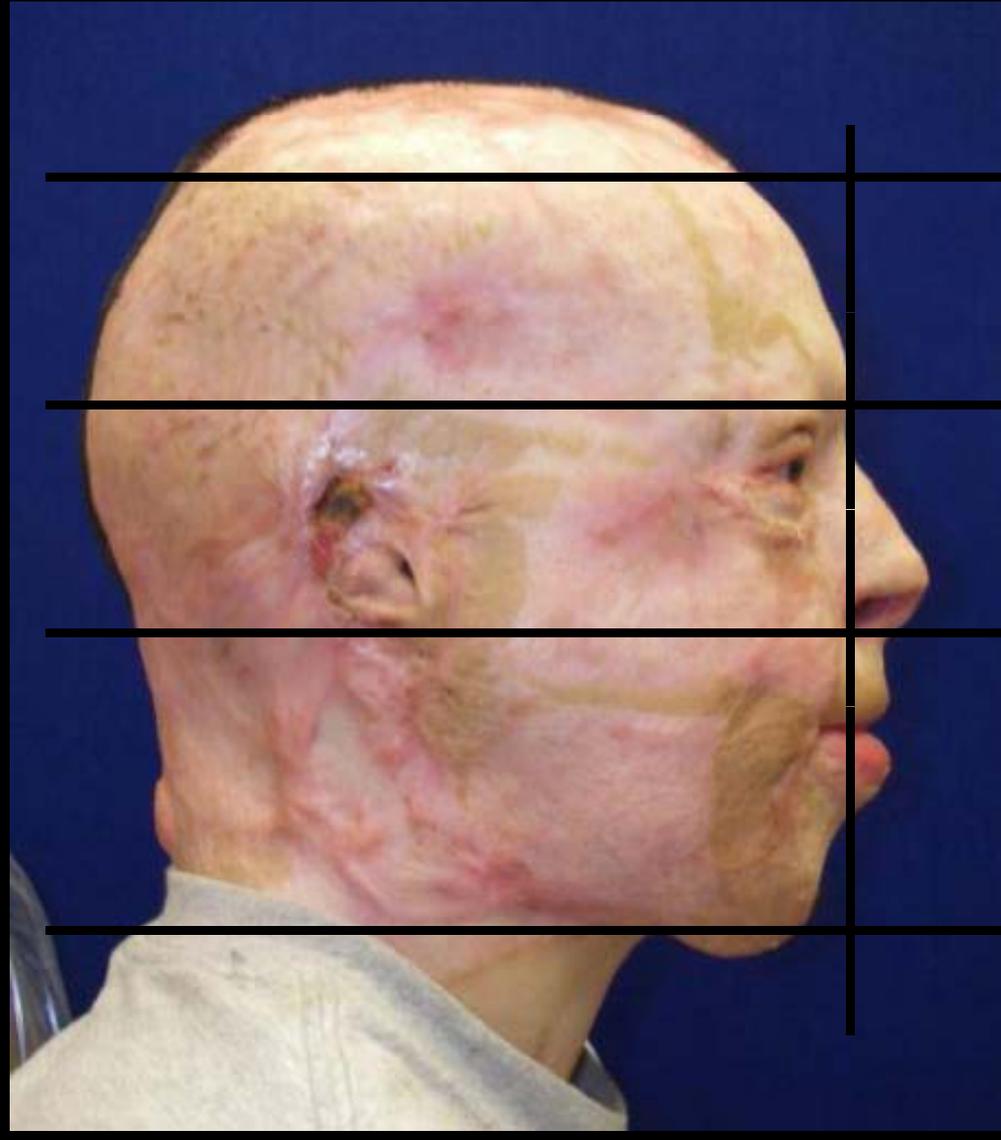
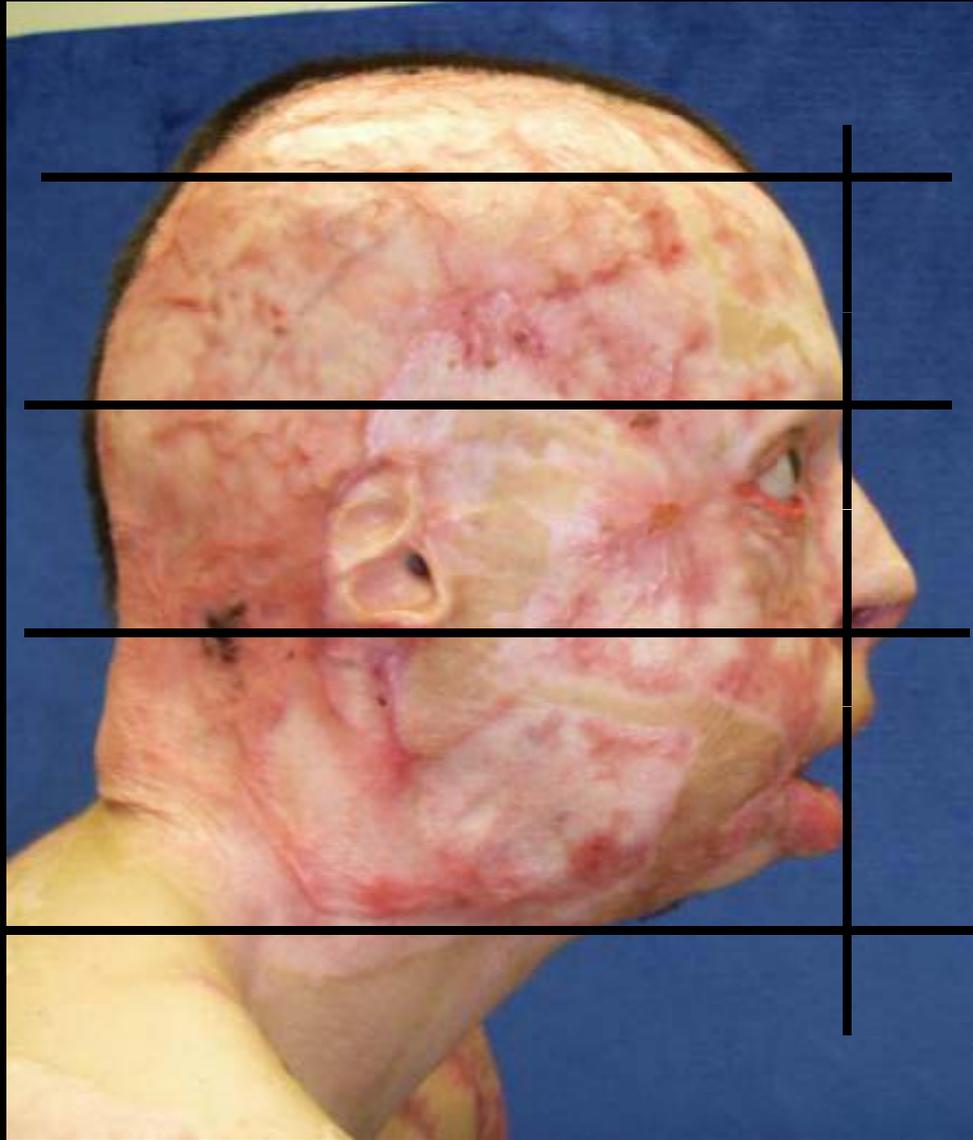


Ideal Treatment: Replace Missing Tissue with “Like” Tissue as a Functional Subunit



Face Burns







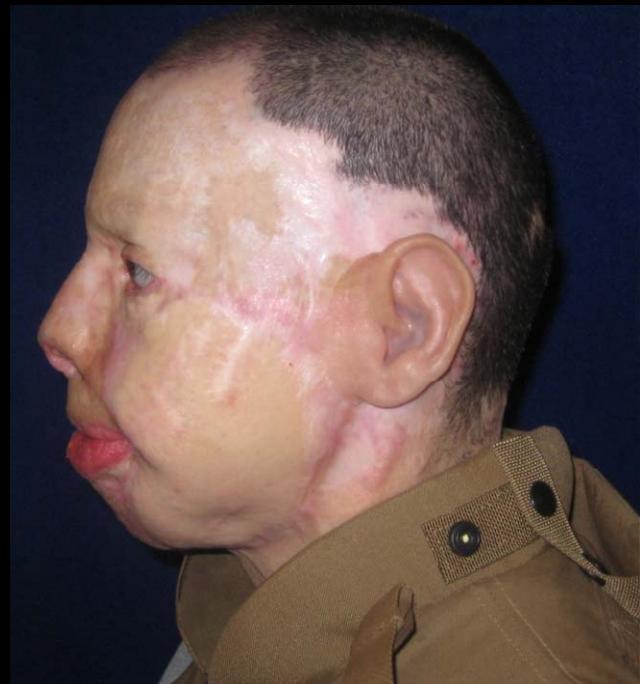
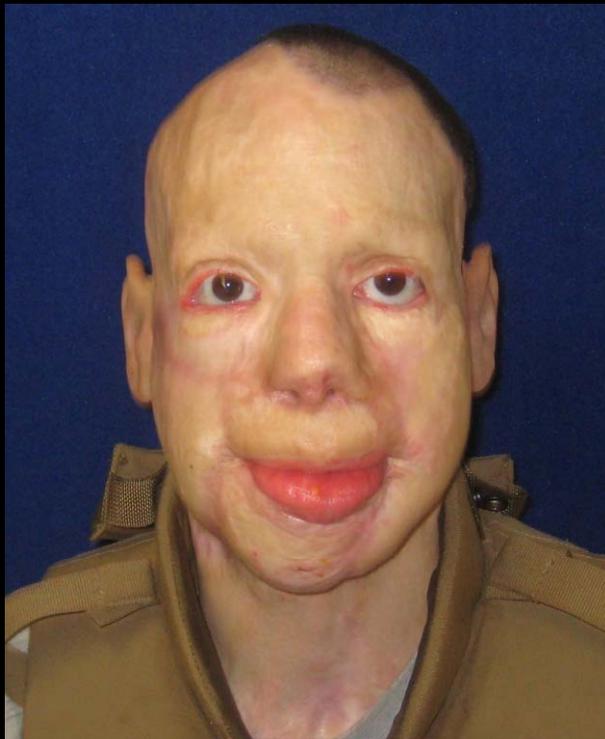
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Expanded Transpositional Supraclavicular Flaps





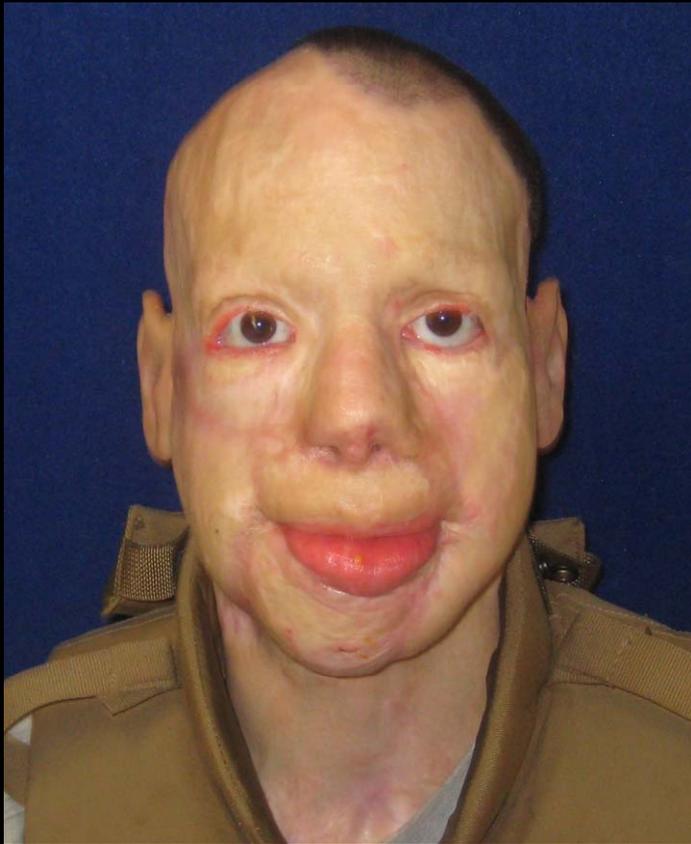




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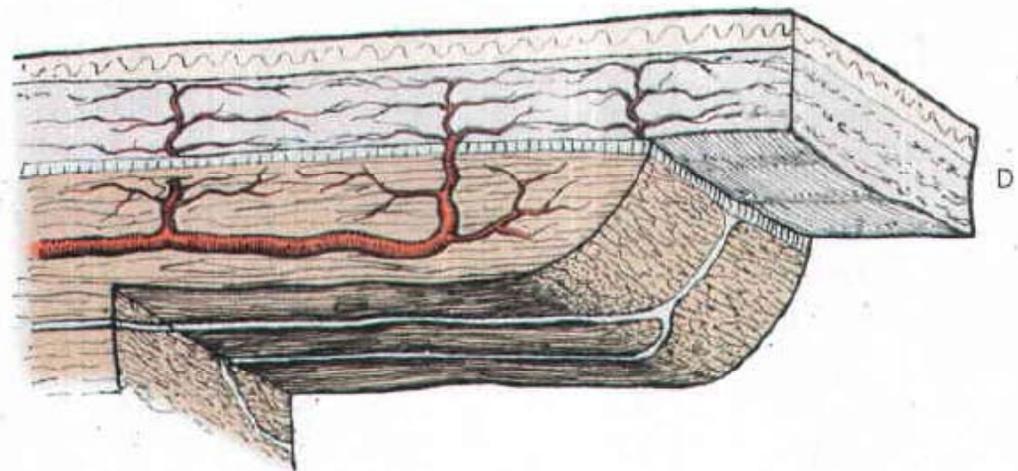
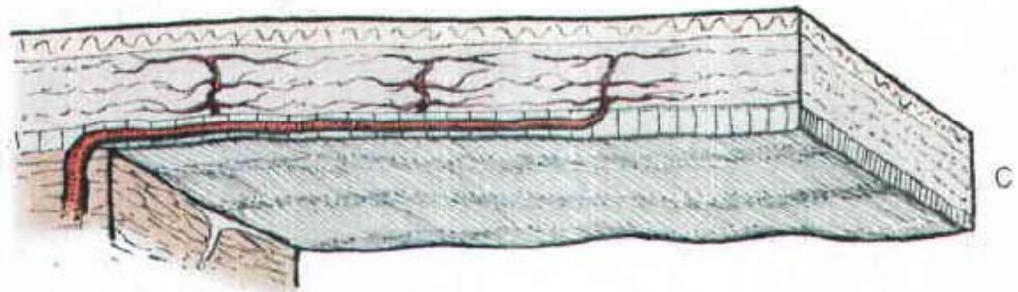
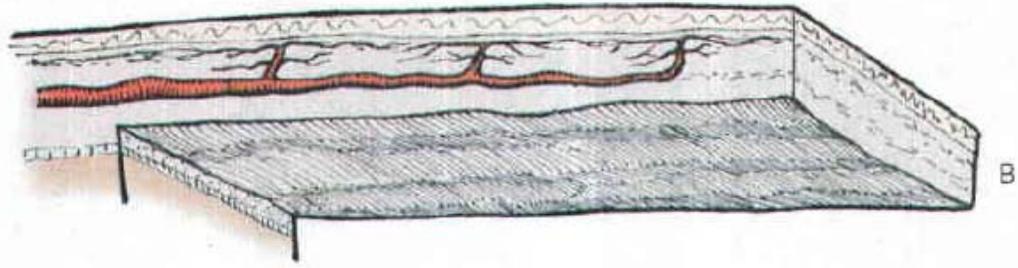
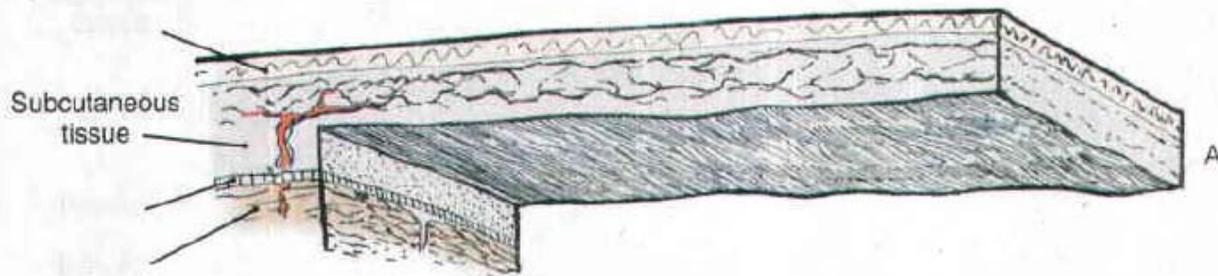


Goals of Face Burn Reconstruction

- Functional
 - Pliable skin
 - Protect eyes - ectropian
 - Prevent microstomia
 - Prevent lip eversion
 - Prevent cervicofacial contracture
- Esthetics



Ideal Treatment: Vascularized skin flap to resurface face and replace major features: eyelids, nose, lips and ears.



Defect Repair

1. Tissue Transfer

Local Flaps, Pedicled Flaps, and Vascularized Free Flaps

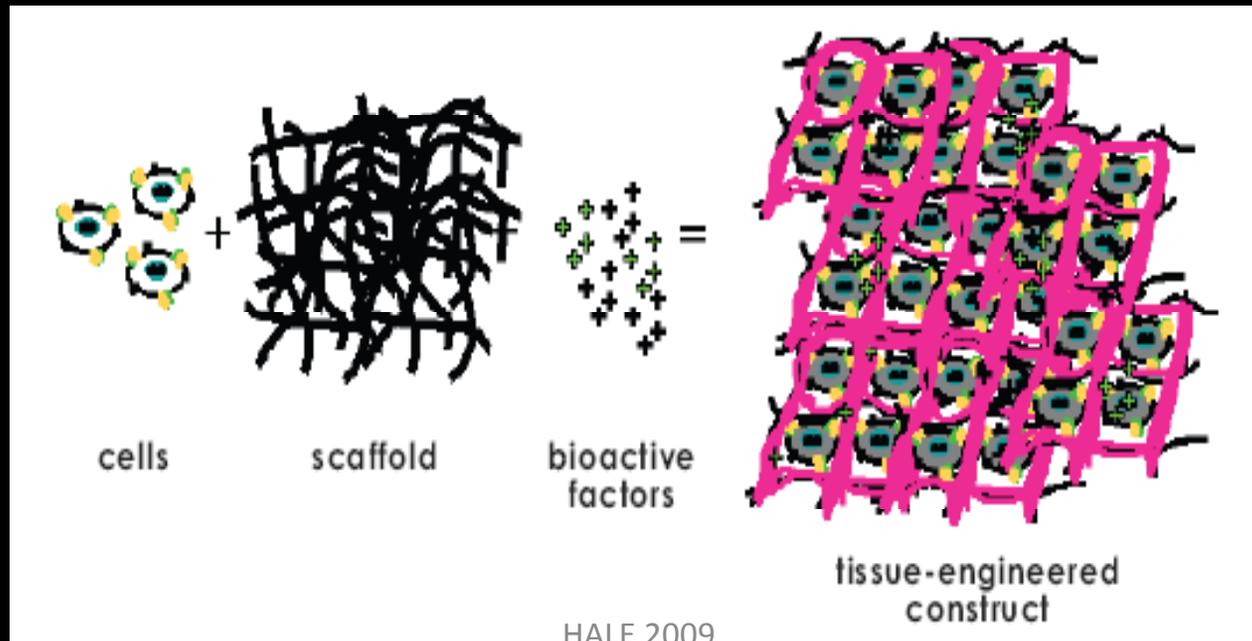
2. Tissue Engineering

Bone, cartilage, skin

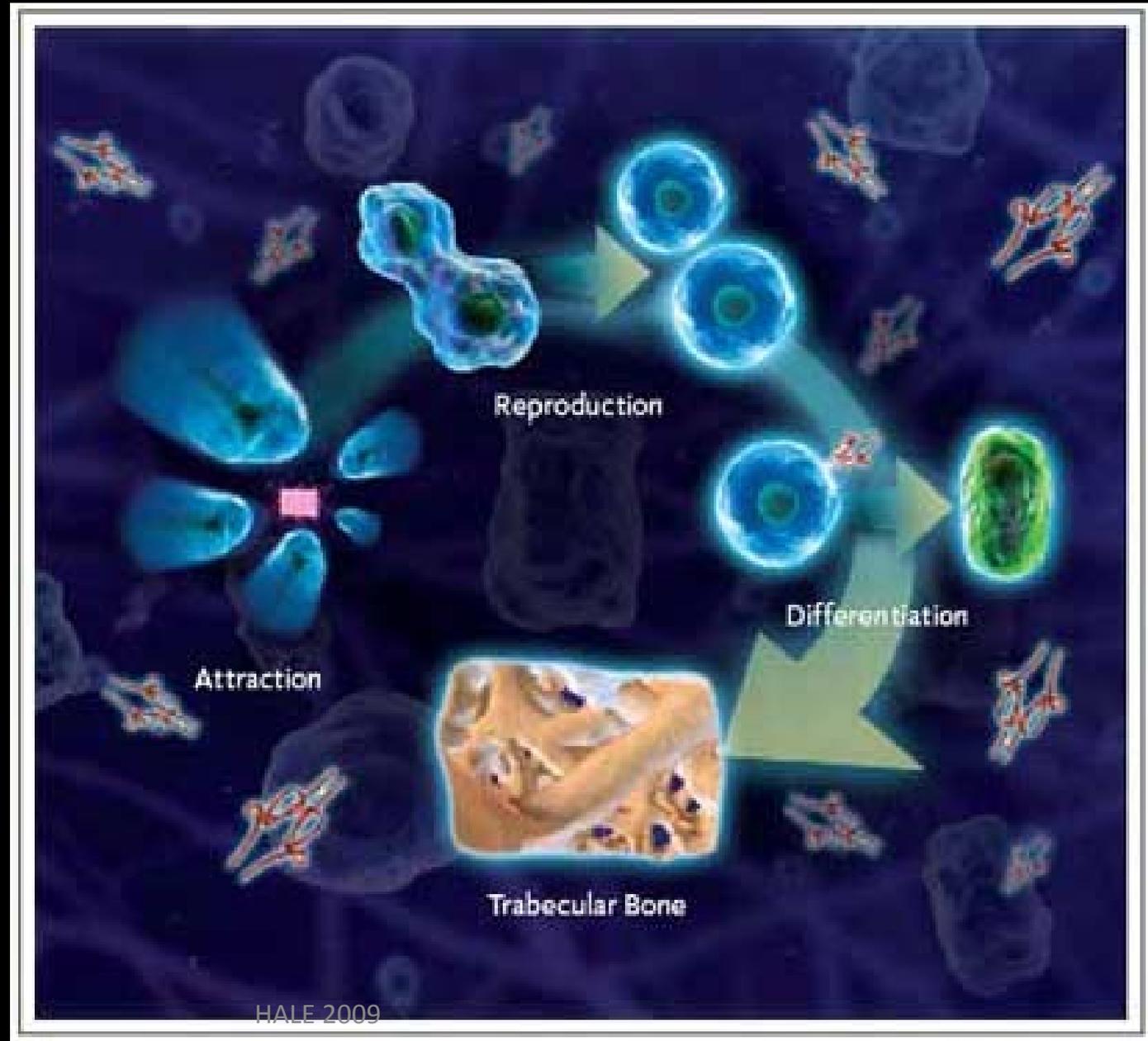
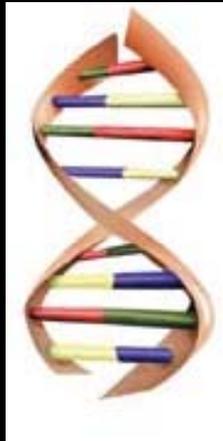
3. Composite Tissue Allotransplantation

4. Regenerative Medicine

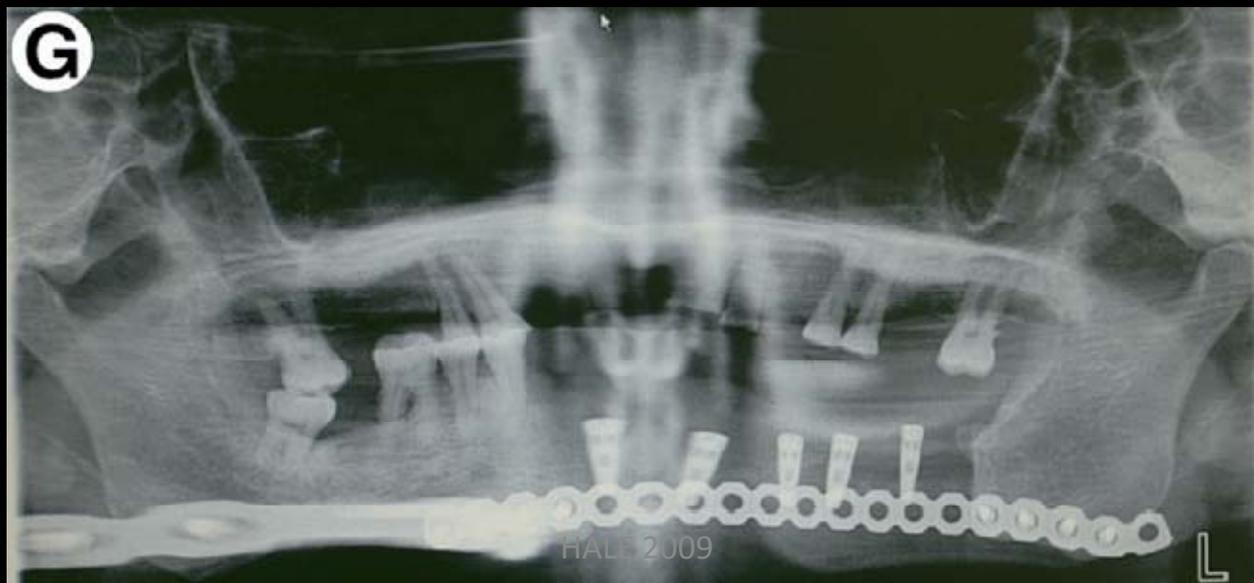
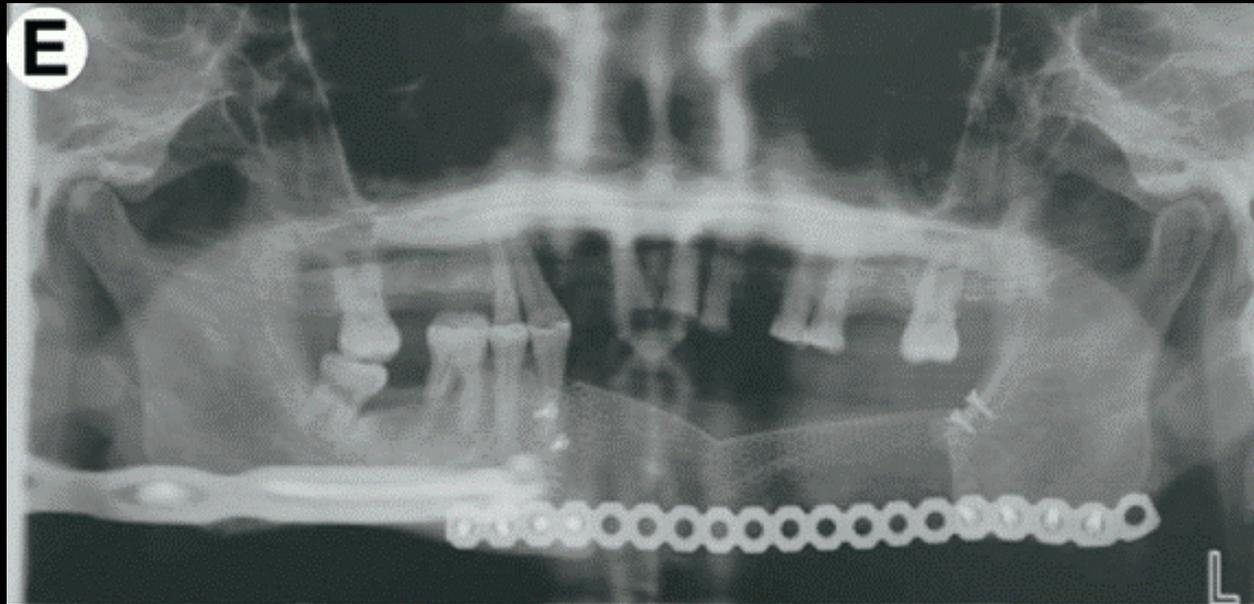
Tissue Engineering



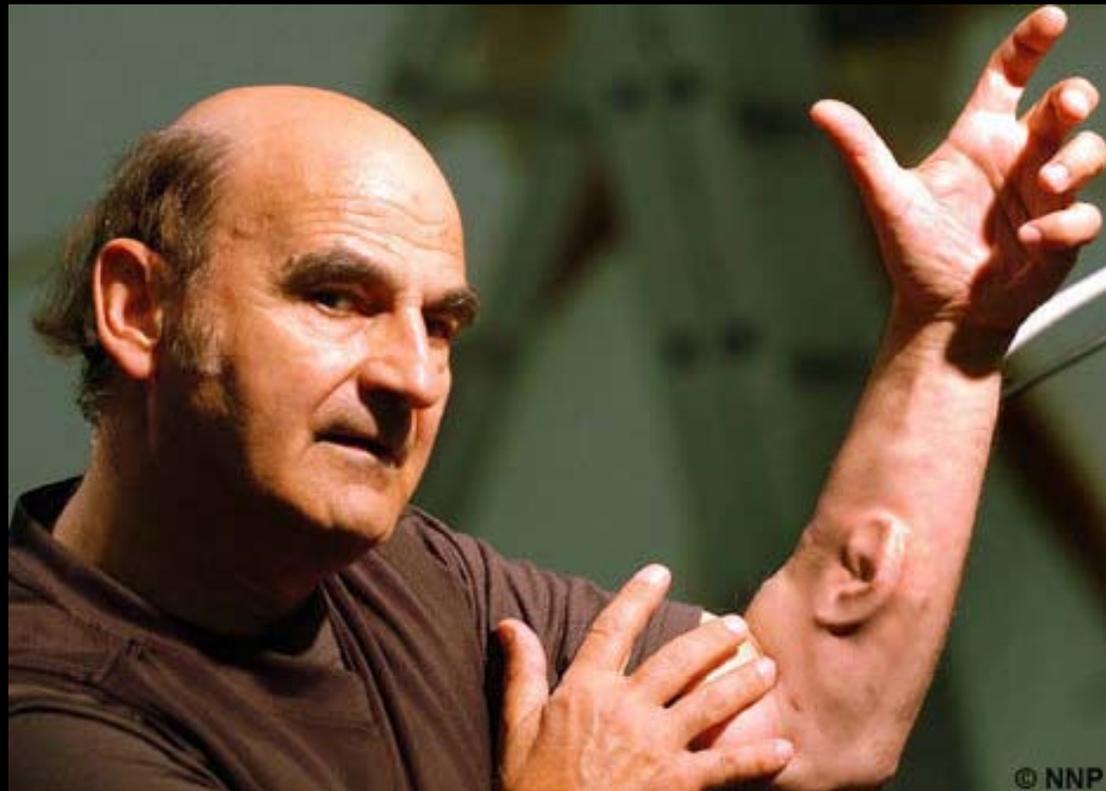
rhBMP 2 (INFUSE-Medtronic)



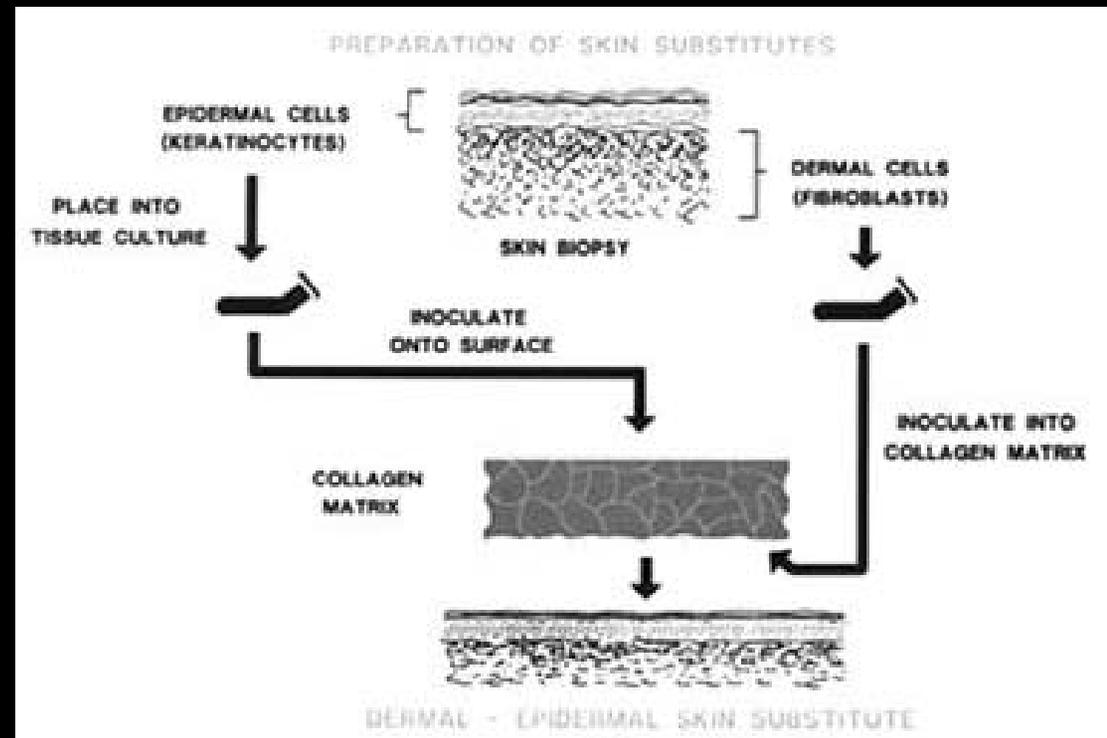
Reconstruction of Mandibular Continuity Defects With Bone Morphogenetic Protein-2 (rhBMP-2)



Engineered Ear Cartilage



Engineered Skin Substitute,

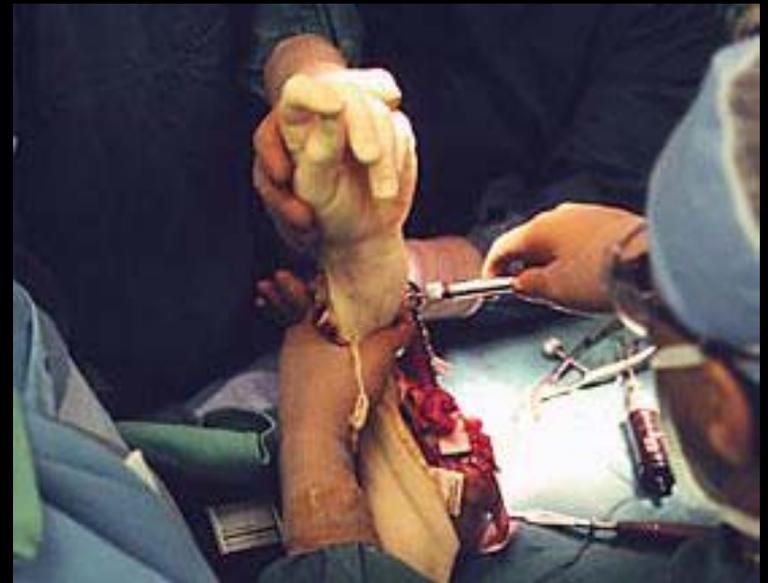
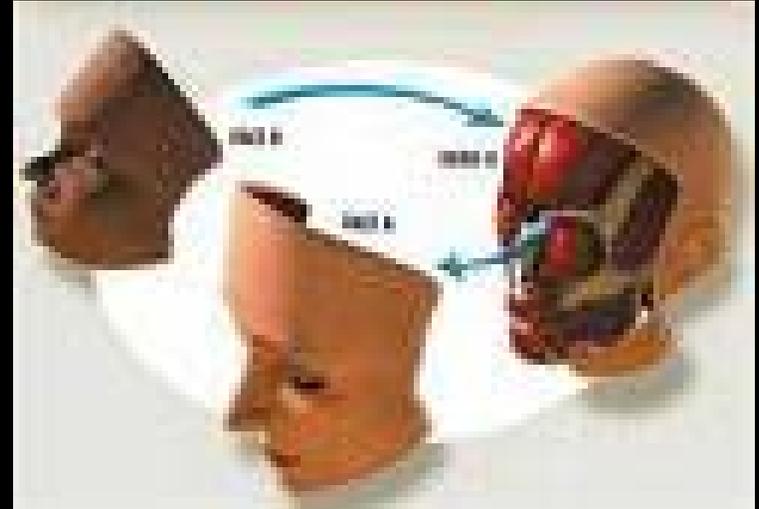


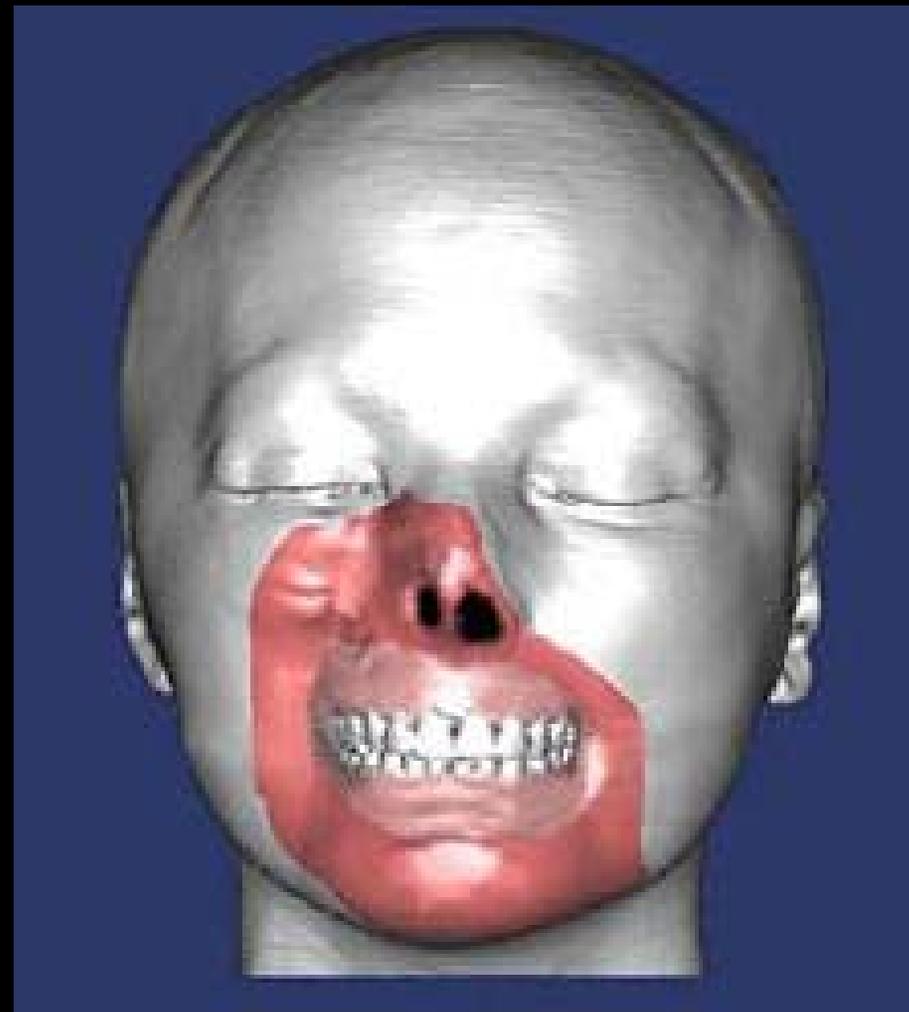
Face Composite Tissue Allotransplant

Composite Tissue Allotransplants

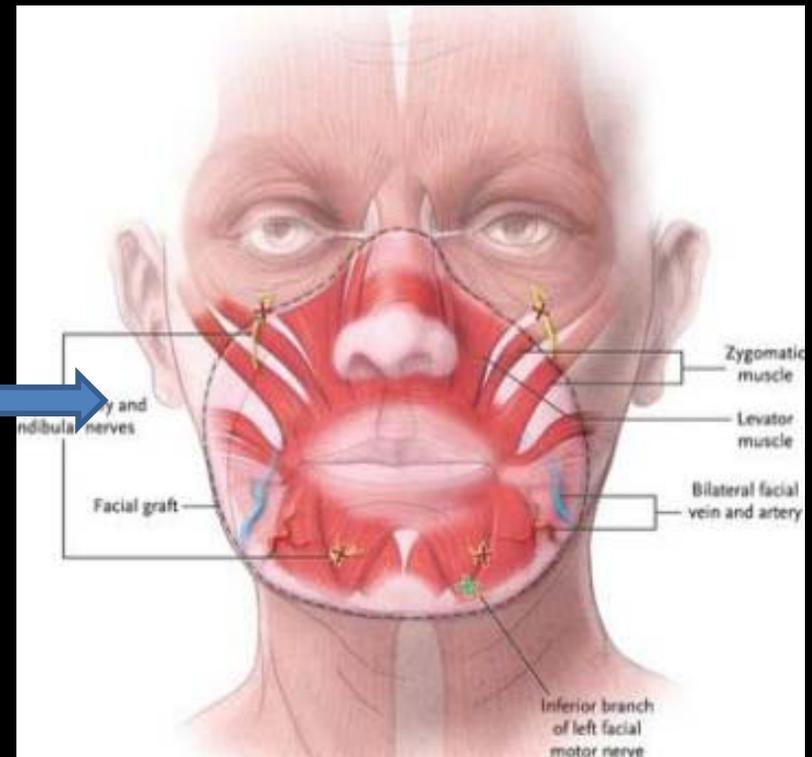
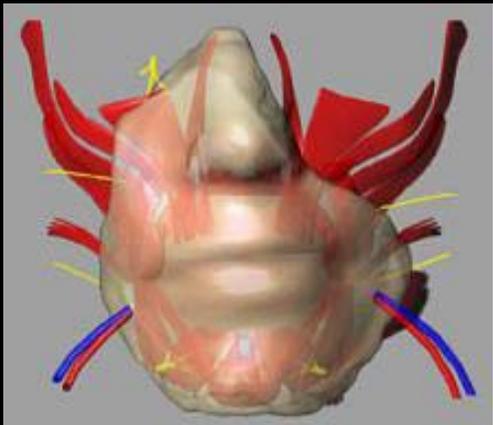
10 year history
Triple Immunosuppressed
Trend to steroid-sparing

M&M Statistics:
47 hand transplants
 1 noncompliance
 1 chronic rejection
7 face transplants
 1 non-compliance/died
 1 sepsis/died



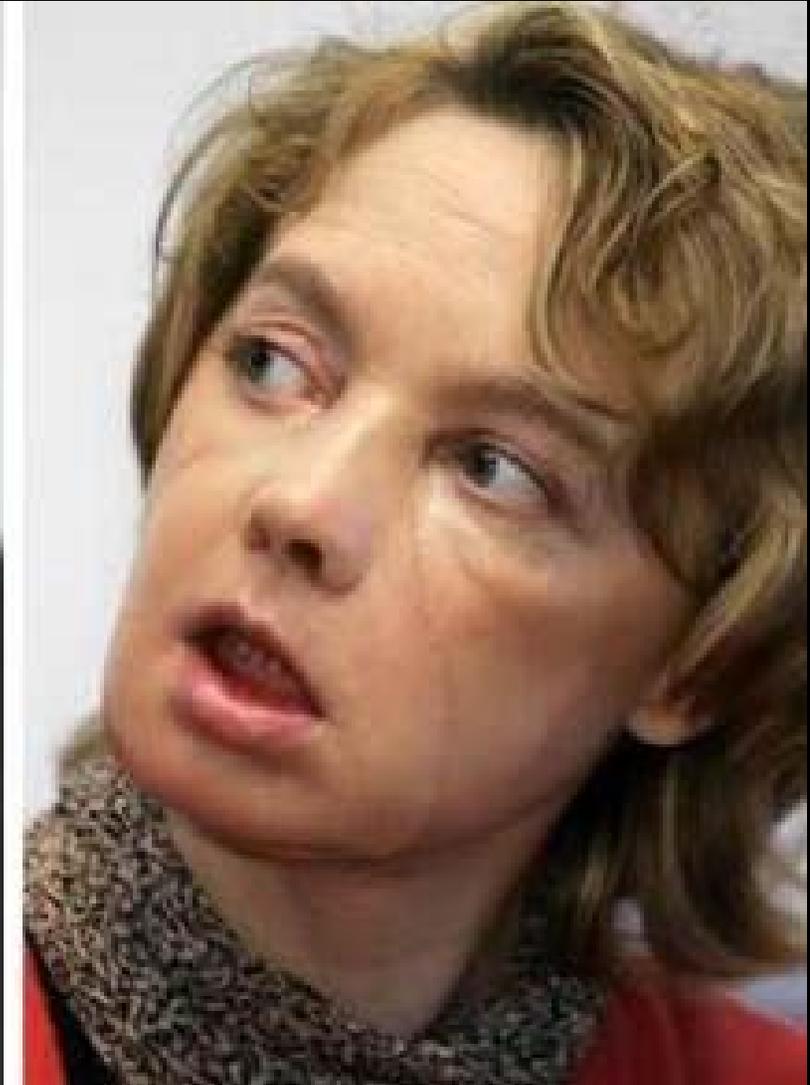


Triple Drug Immunosuppression



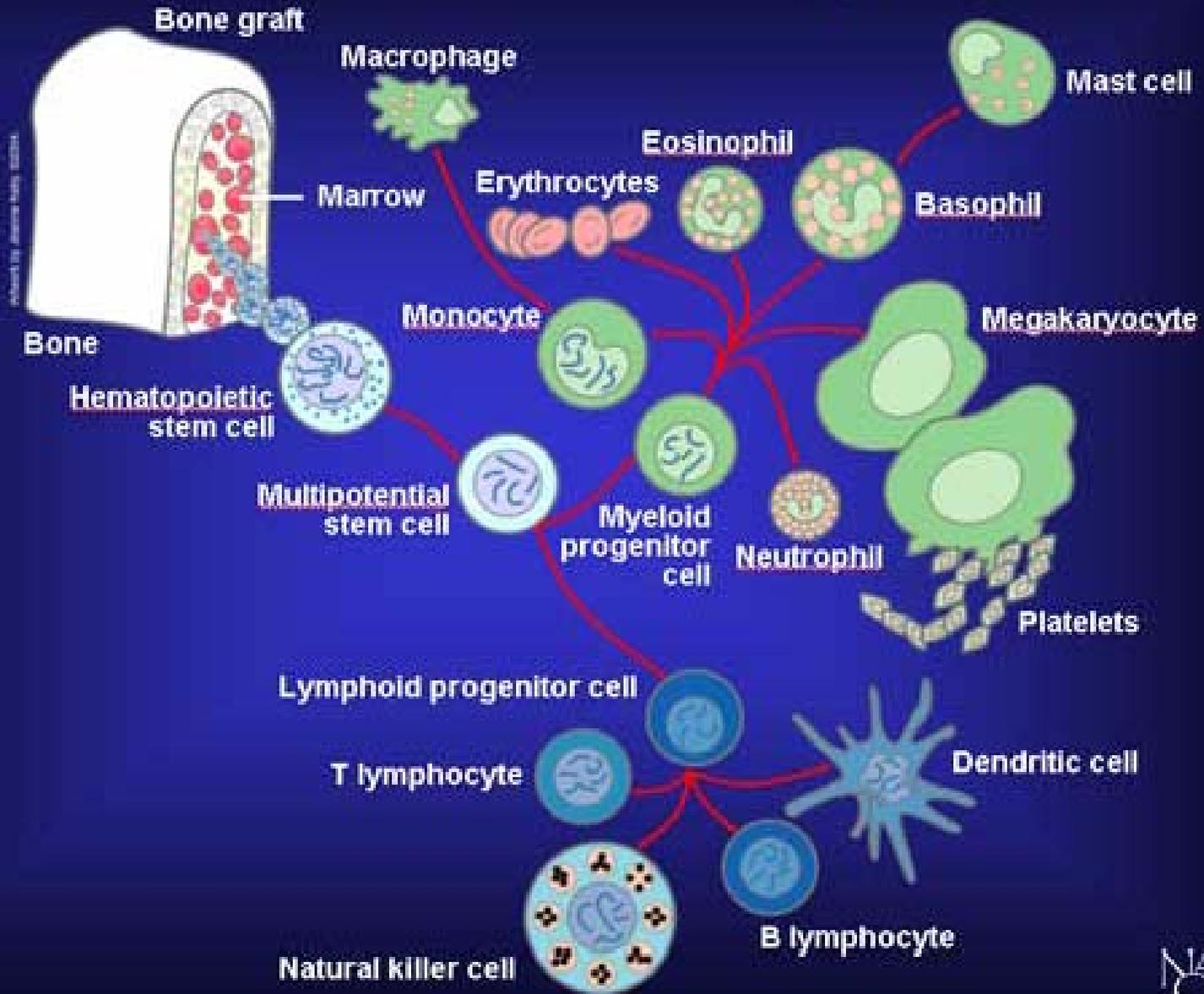


One Year Post-op 2 Major Rejection Episodes

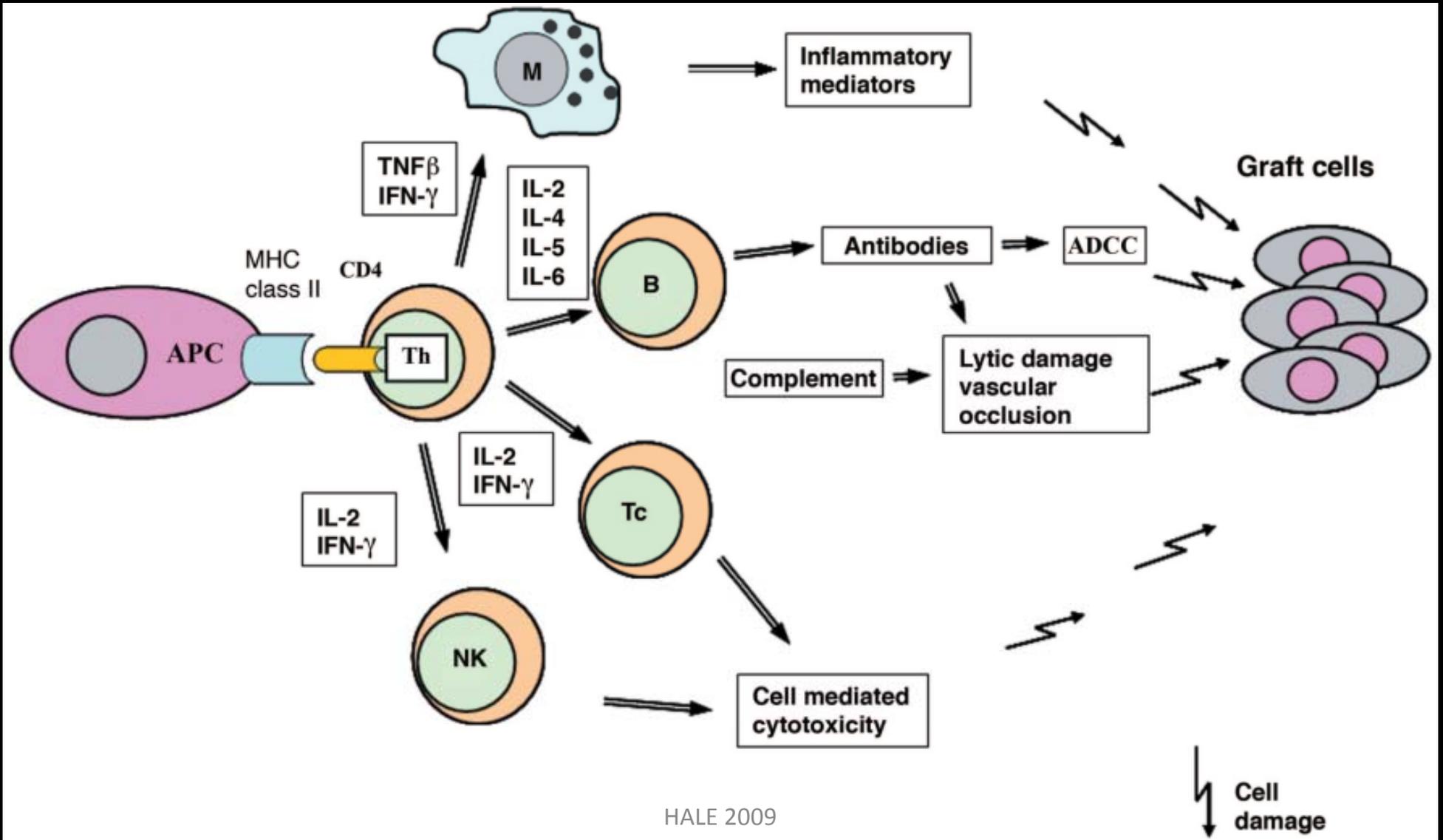




Cells of the Immune System

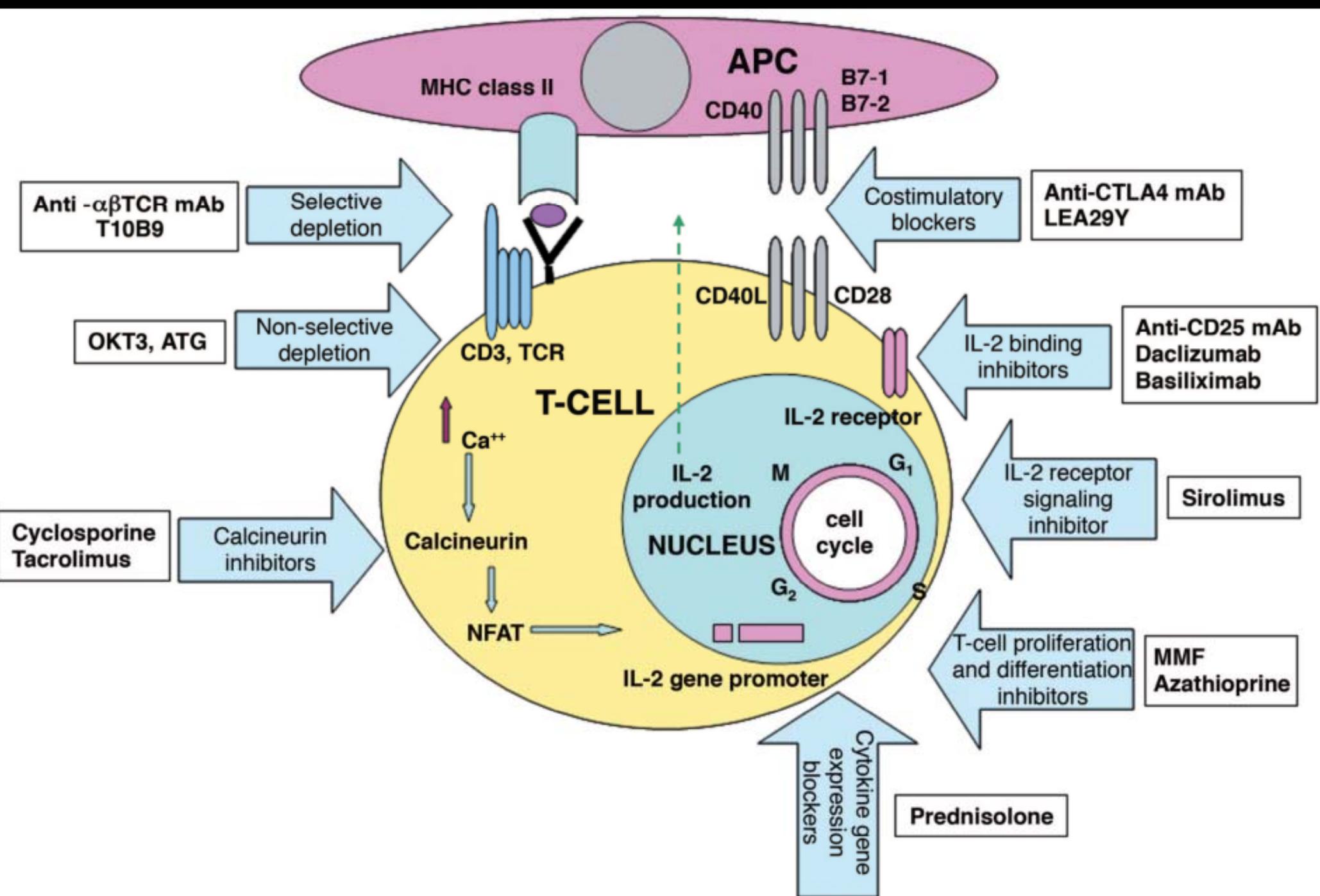


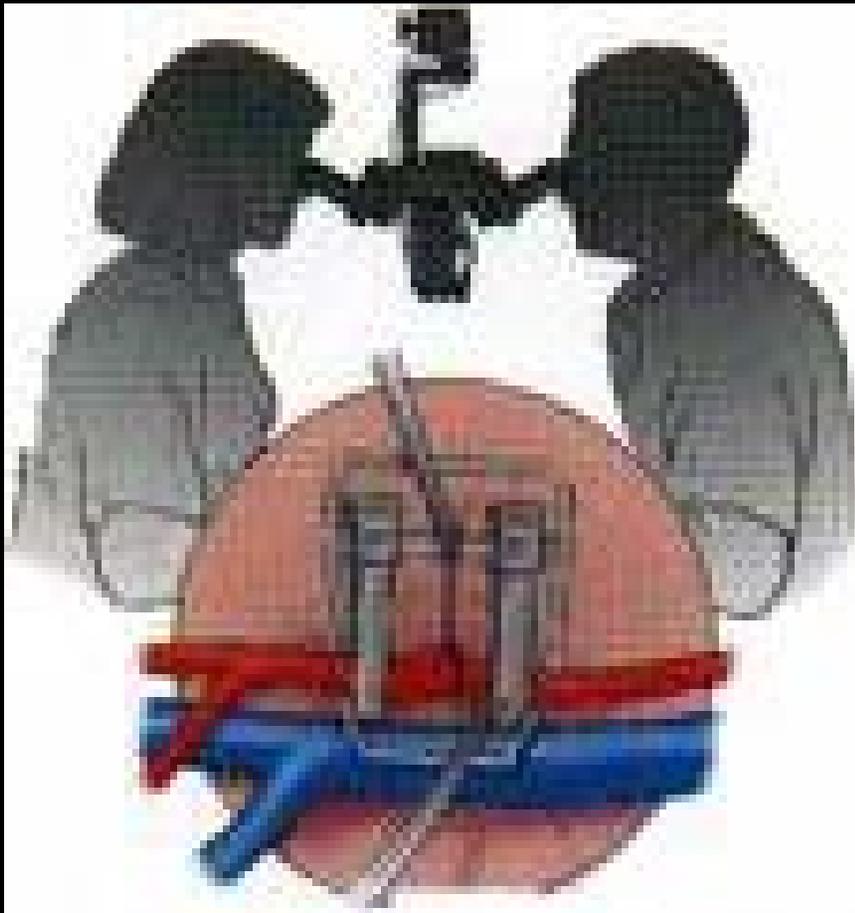
Immune System >>> Graft Rejection



Immunosuppressants

- Corticosteroids
- Antimetabolites
 - Azathioprine
 - MMF
- Calcineurin Inhibitors
 - Cyclosporin
 - Tacrolimus
- T cell Depleting Antibodies





IMMUNOTOLERANCE

Cellular Therapy-Tolerance

- Induce Immunosuppression
- Perform CTA
- Series of Donor Bone Marrow Infusions
- Depletes sensitized T cells
- “Tricks” thymus T cells to recognize donor cells as “self”
- Develop tolerance of donor tissue/cells
- Withdraw immunosuppression

CTA Challenges

- Technical
- Medical
- Tissue Procurement

CTA Complications/Side Effects

- Vascular Flap Failure
- Acute Rejection Episodes
- Transient Hyperglycemia/Diabetes
- Nephrotoxicity
- Cushing's Syndrome
- Avascular Necrosis Hip
- Osteomyelitis
- CMV Infections/Papilloma/Herpes Simplex
- Cutaneous Mycosis
- Possible Posttransplant Lymphoproliferative Disease

Tissue Procurement

- 8,000 donors a year in US
- 100,000 waiting for organs
- Organs matched for immunology
 - ABO
 - 6 HLA
- Organs for life

Tissue Procurement

- Face CTA for quality of life
- Face CTA: immunology, gender, age, Fitzpatrick skin types – I-VI, size - L M S
- Organs on ice – transcontinental
- CTA donor on ventilator in adjacent OR
 - Regional
 - Donor family issues
- CTA delays organ harvest

7 Face Allotransplantations:

1. Nov 2005-Mauled by dog
lower face, nose and lips

Drs. Dubernard & Devauchelle, Amiens, France
Functional neuromuscular oral aperture



Face Allotransplantations

2. APR 2006-Mauled by bear
mid face, cheek, nose, zygoma, lip
Dr Shuzhong Guo, Xijing, China
Died after self-cessation of immunosuppressives



Face Allotransplantations

3. Jan 2007-Neurofibromatosis
mid/lower face, cheeks, nose, lips, chin,
parotids, facial nerves

Dr. Lantieri, Paris, France

Dental implants in mandible



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Face Allotransplantations

4. Dec, 2008-Shotgun Blast

mid face, lower eyelids, cheeks, nose,
upper lip, zygomas, maxilla, teeth

Dr Siemionow, Cleveland Clinic, USA

d/c home Feb, 2009 in good condition









Face Allografts

5. Mar, 2009-Shotgun blast
mid face, lips, cheeks, bones
Dr Lantieri, Paris, France

Face Allografts

6. Apr, 2009-Burns to face and hands

Vascularized Flap: face, scalp, eyelids, nose, ears and hands

Dr Lantieri, Paris, France

Immunosuppression Reactivated an Infection

Multi-Drug Resistant Infection-Sepsis

Died

Face Allografts

7. Apr, 2009- Electrocution

Nose, hard palate, upper lip, facial skin,
muscles and nerves

Dr Pomahac, Boston, USA





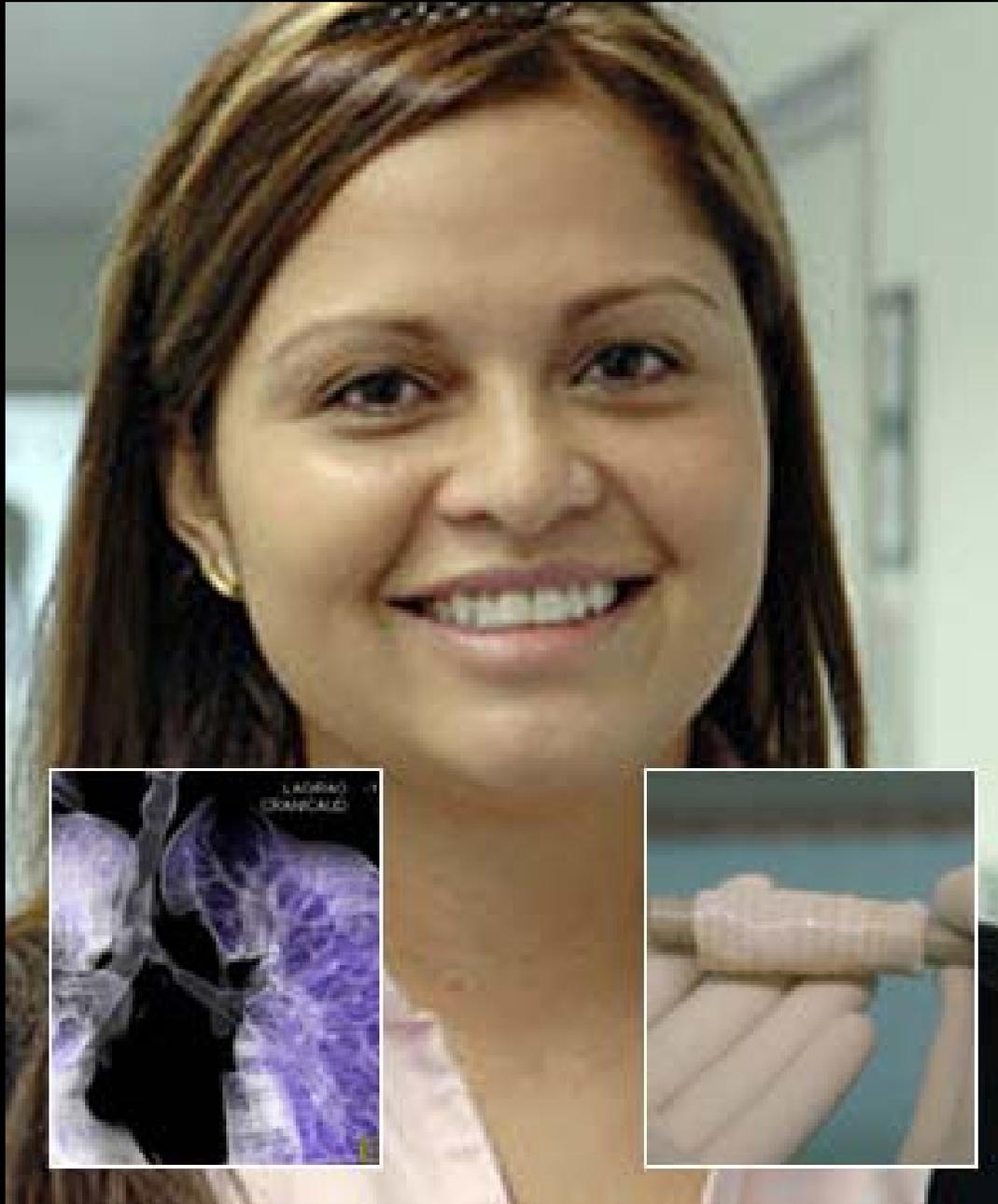
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The Next Step: Face Regeneration

Hybrid Tracheal Transplant

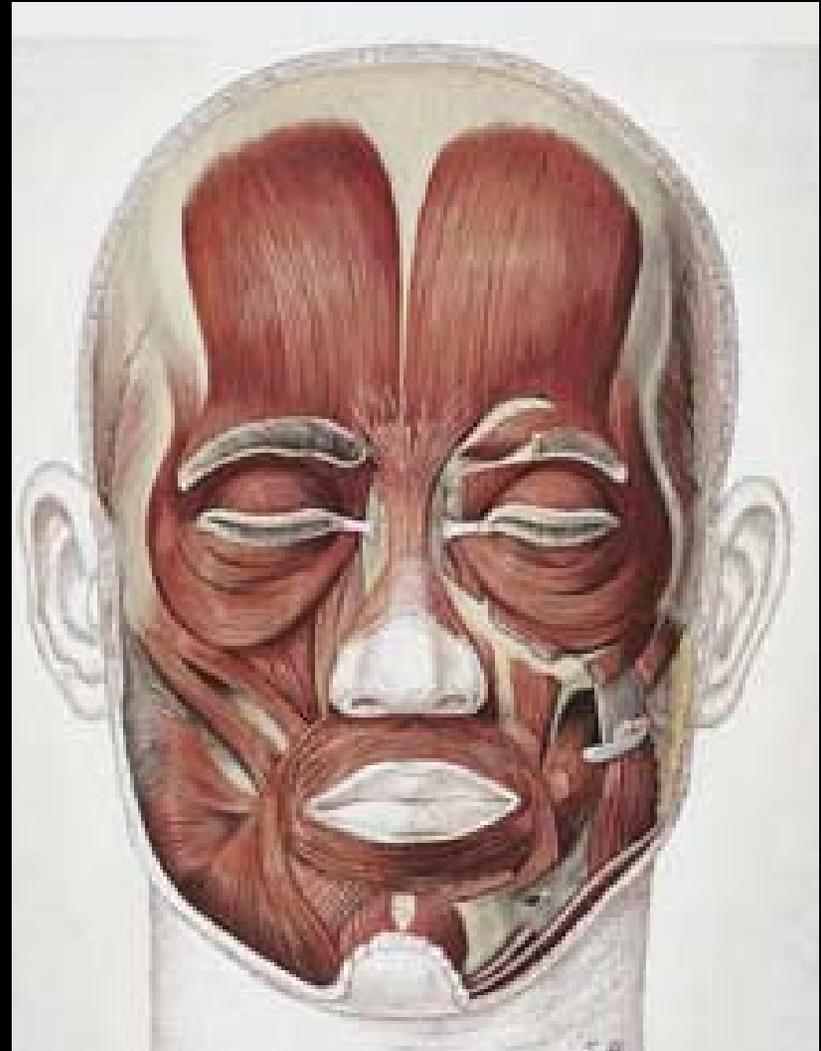
- June, 2008, Spain
- 30 yo F with tracheobronchial stenosis from TB
- Donor trachea treated to deplete cells → Scaffold
- Trachea scaffold seeded with recipient's stem cells in 2-stage lab bioreactor to regenerate cartilage and mucosa
- Tracheal “construct” successfully transplanted
- No need for immunosuppression



The Regenerated Face

- Within the Realm of Possibilities
- Requires Composite Tissue Regeneration
 - Extracellular Matrices + Stem Cells/GF + Bioreactors
 - Vascularized flap
 - Skin with contours and definitions
 - Cartilage and Bone
 - Neuromuscular units, another challenge
- H&N: Non-load bearing, well-vascularized
- H&N is launching pad for Regenerative Medicine

The Regenerated Face



Steps to Face Regeneration

Full Face Regeneration:
Fully Functional Esthetic Replacement
Autogenous Cells

Regenerated Hybrid-Face (Burn Patients)
Regenerated Vascularized Skin and Cartilage Flap
Resurface and Replace Major Facial Features
No Immunosuppression

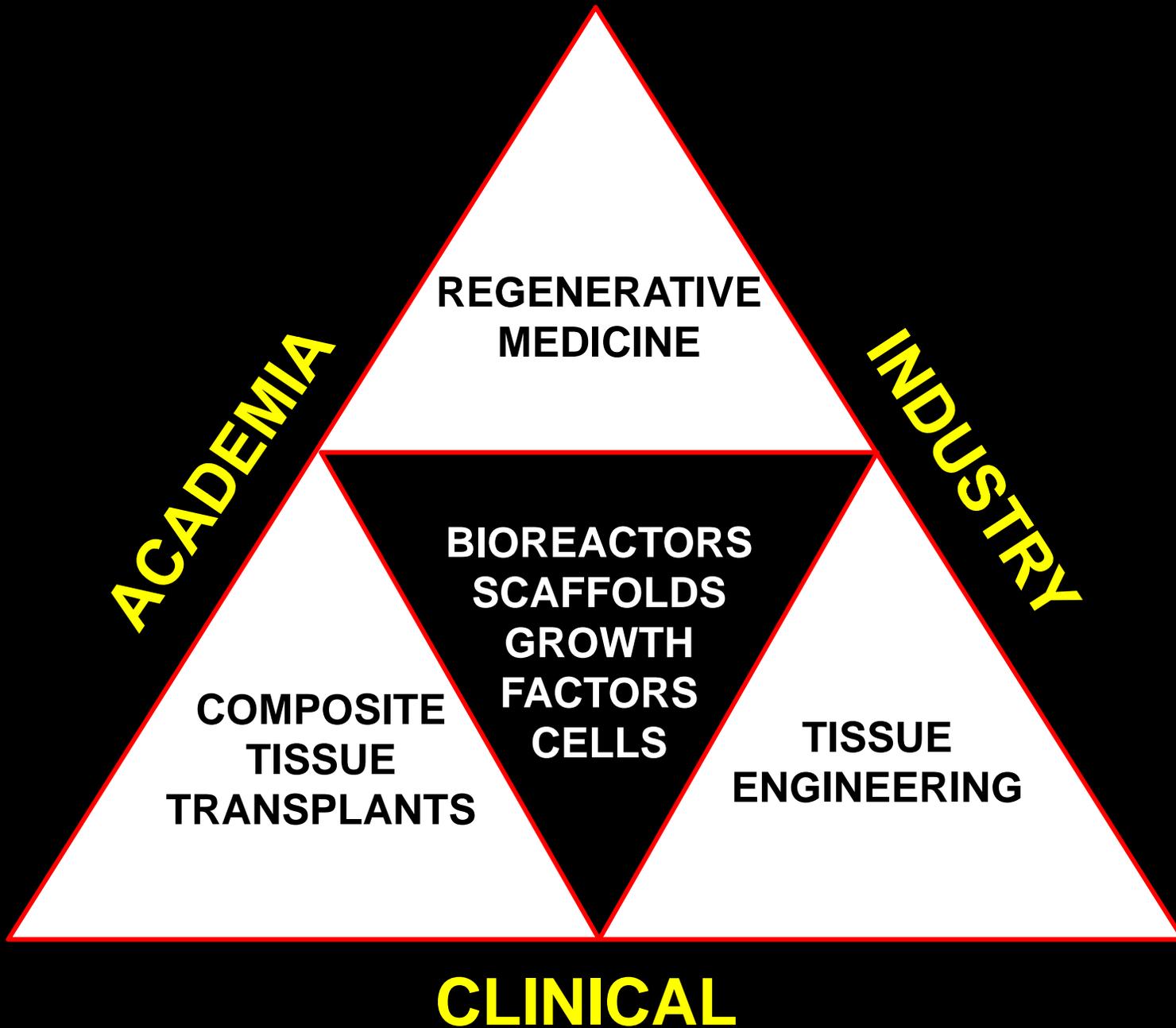
Composite Tissue Allograft Face:
Donated Composite Tissue
Fully Functional Vascularized Flap
Immunosuppression

Today

10 – 15 years

25+years

HATE 2009



SUMMARY

- Statistics: 29% of battle injuries are to the Head & Neck region
- Maxillofacial battle injuries tend to be open wounds complicated by avulsions and burns
- Flaps and tissue transfers have limited results
- Future: Tissue Engineering, Composite Tissue Allotransplantation and Regenerative Medicine