MODE OF ACTION OF FUNCTIONAL APPLIANCES

Introduction:

- Correction of malocclusion, primarily by means of controlled movement of the developing and mature dentition into a desirable occlusal relationship

- Control and modification of growth of skeletal structures of the craniofacial complex, especially via tooth borne appliances

Historical perspective:

- Genetic control theory:

  -inheritance and immutability of normal and abnormal facial form

  - genotype supplies all information required for phenotypic expression

Historical perspective:

- Late 1890s: Wolff's law and Roux hypothesis:

  changes in functional stress produced changes in internal bone architecture and external shape
- Early 1900s: Pierre Robin: *monobloc*

  - passive positioning device
- Modified from bite jumping vulcanite maxillary guide planes designed by Norman Kingsley (1880)
- Vorbissplatte: Hotz

Historical perspective:

- Viggo Andresen : Activator
- Lischer's theory:

If abnormal musculature can exacerbate existing malocclusions, can not the same muscles be used to correct these problems?

- Andresen: modified Hawley type retainer with lower lingual horse shoe flange

  Significant sagittal basal bone and neuromuscular improvement

Historical perspective:

- Initially not accepted in US:

  - facial growth could not be affected

  - tooth position can be altered with appropriate appliances and biomechanics

Theories of growth:

- Genetic theory

- Sutural growth theory: Sicher (1947): growth at the sutures results in growth of cranial vault and downward and forward growth of the midface

- Cartilage- directed growth theory:

Scott (1956): synchondroses, nasal septum and mandibular condyle are centers of growth

Theories of growth:

- Functional matrix hypothesis:

Melvin Moss (1960)

- Craniofacial skeleton develops initially and grows in direct response to its extrinsic, epigenetic environment

- Functional matrix and skeletal unit

- " Bones do not grow, bones are grown." - Moss (1972)

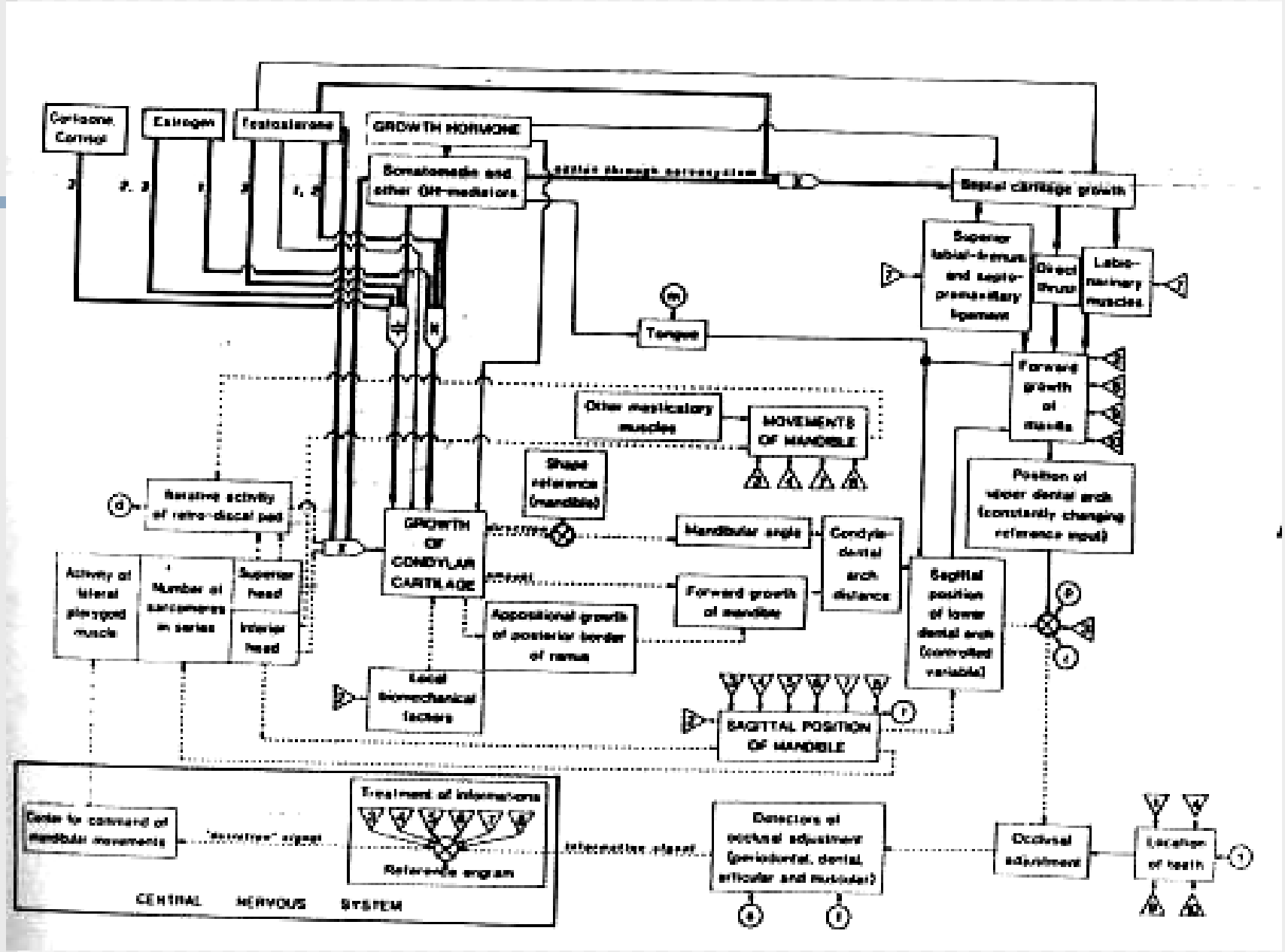
Theories of growth:

- Servosystem theory of craniofacial growth: Alexandre Petrovic (1970s)

- 2 factors:

  - hormonally regulated growth of the midface and anterior cranial base, which provides a constantly changing reference input via the occlusion

  - rate-limiting effect of growth of the midface on the growth of the mandible


Cortisone
Estrogen
Testosterone
GROWTH HORMONE
Somatomedin and other GH-mediators
Septal cartilage growth
Superior labial-, mentum- and supra-premaxillary ligaments
Direct thrust
Labio-mandibular muscles
Tongue
Forward growth of maxilla
Other masticatory muscles
MOVEMENTS OF MANDIBLE
Shape reference (mandible)
Position of upper dental arch (constantly changing reference input)
Resting activity of retro-discal pad
GROWTH OF CONDYLAR CARTILAGE
Mandibular angle
Condylo-dental arch distance
Activity of lateral pterygoid muscle
Number of sarcomeres in series
Superior head
Inferior head
Forward growth of mandible
Sagittal position of lower dental arch (controlled variable)
Apositional growth of posterior border of ramus
Local biomechanical factors
SAGITTAL POSITION OF MANDIBLE
Centre for command of mandibular movements
Treatment of interferences
Reference engram
Detection of occlusal adjustment (periodontal, dental articular and muscular)
Occlusal adjustment
Location of teeth
CENTRAL NERVOUS SYSTEM

Activator:

- Initial appliance: passive
- Loose appliance:Biting into the appliance effected the extrinsic force; worn only at night
- Andresen and Haupl:

altering skeletal relationship depending on the direction and amount of jaw growth incorporated in appliance (*Norwegian system*)

Activator:

- Activator: Andresen and Haupl
- Sagittal positioning of the mandible
- Elimination of abnormal musculature
- Musculoskeletal adaptation by inducing a new pattern of mandibular closure

- Condylar adaptation: growth in upward and backward direction to maintain integrity of TMJ structures

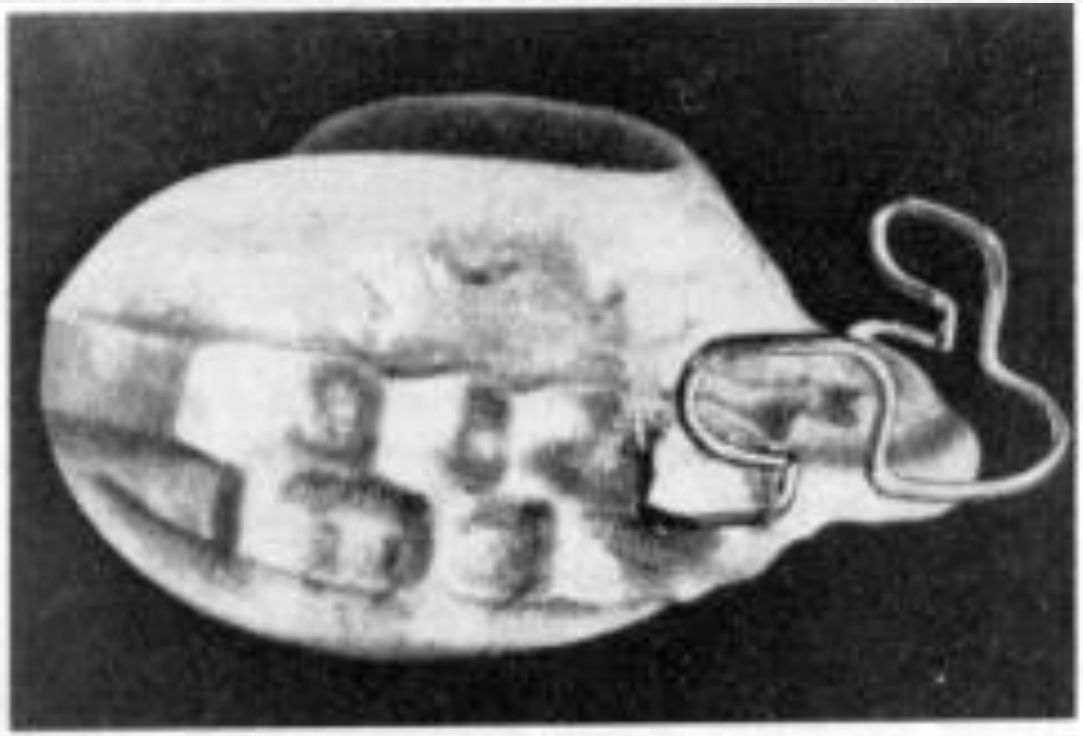


Fig. 6-3. Original activator according to Andresen and Häupl

Activator:

- Stimulation of myotactic reflex activity, causing isometric muscle contractions
- Loose fit of appliance with low vertical dimension
- Muscle force transmitted onto teeth: uses kinetic energy
- Increased activity of elevator and protractor muscles with relaxing and stretching of retractors

Activator:

Other views:

- Muscle contraction: superior head of lateral pterygoid muscle
  - Petrovic (rat studies), McNamara (primate studies)
  - variations in the mode and direction of dislocation of mandible
- Condylar unloading: Lysle Johnston

Activator:

- Viscoelastic activity:

Herren(1953), Woodside(1973), Harvold(1974

- Viscoelastic reaction:

  - emptying of vessels
  - Pressing out of interstitial fluid
  - Stretching of fibres
  - Elastic deformation of bone
  - Bioplastic adaptation

Activator:

- Herren: anterior crossbite relationship
- Woodside: 10- 15 mm. Beyond postural rest vertical dimension

- Opening of 4-6 mm: Eschler(1952) no overcompensation
- Transitional type of activator action
- Uses isometric and isotonic contractions

Activator:

- Head posture during sleep:

Changes of head posture alter the magnitude and direction of force

- Change in mandibular position varies force vectors acting on mandible and different muscle groups
- Plane of sleep(light or deep), intraoral air pressure, dream cycle, state of mind also affects activator response during sleep

Activator:

- Skeletal effects:

  - movement of condle in forward and downward position due to the appliance

  - adaptation to the new position through condylar growth; growth in more backward and upward direction

  - adaptation to new position through fossa remodeling

  - more posterior orientation of trabaculae

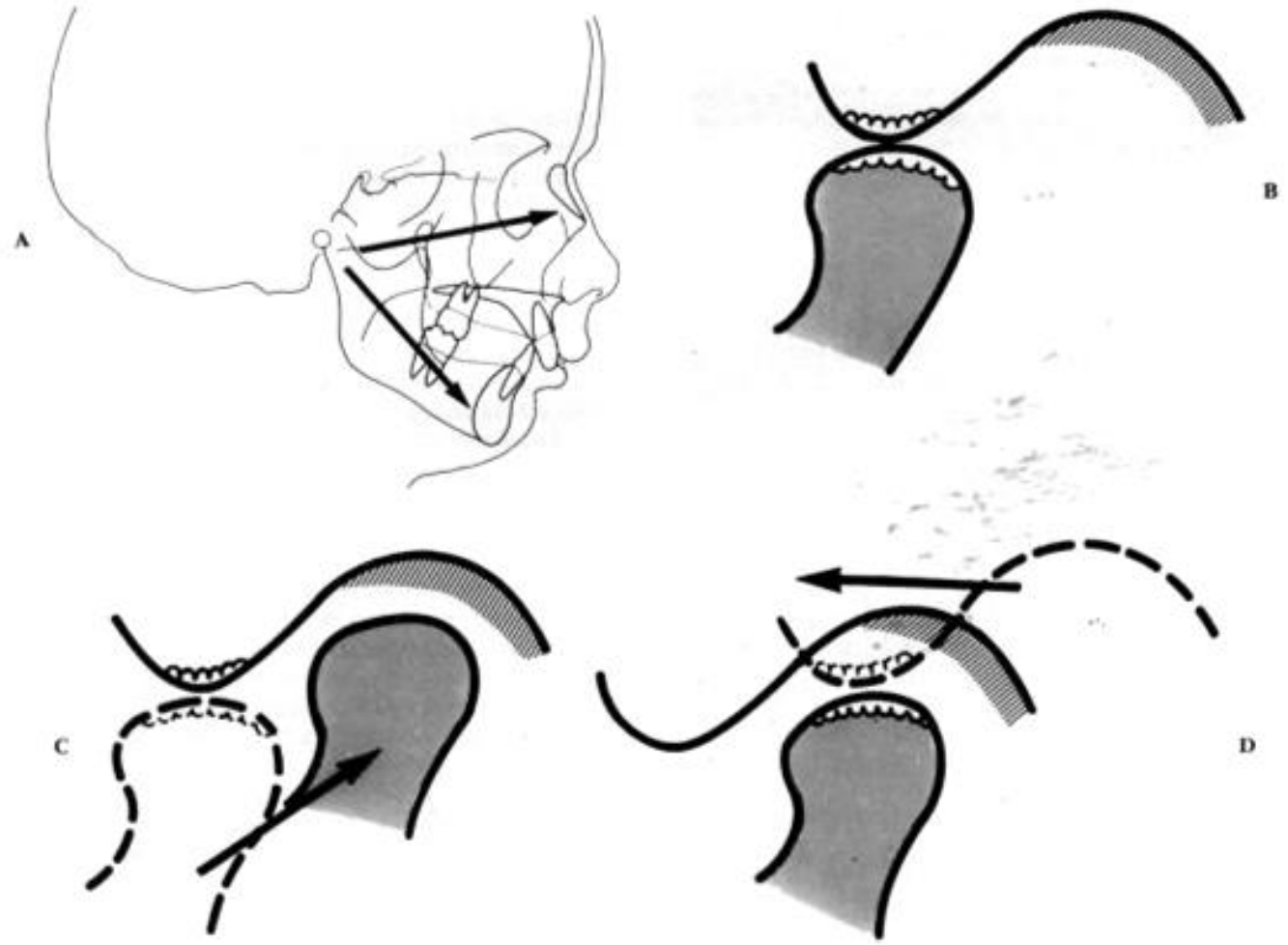


Fig. 6-11. A, Divergent growth vectors that move the jaw bases in a forward direction. **B,** The articular effectiveness of the activator moves the condyles into a forward-downward position. **C,** Adaptation to the new position through condylar growth. **D,** Adaptation to the new position by remodeling in the fossa.

Activator:

- Dental effects:

  - forward displacement of lower anterior segment (Bjork,1969)

  - bodily displacement of incisors (Jacobsson, 1967)

  - labial tipping of lower incisors (Richardson,1982)

  - lingual tipping (Moss, 1962)

Activator:

- Types of force employed in activator therapy:

- sagittal: mandible downward and forward- muscle force to condyle and slight reciprocal force to maxilla

- vertical: teeth and alveolar processes are either loaded or relieved of normal forces ; high construction bite inhibits growth, direction and inclination of maxillary base

- transverse: incorporation of screws and springs; midline correction

Bionator:

- Balters (1943)
- Equilibrium between tongue and circumoral muscles infleunces shape of dental arches and intercuspation
- Tongue is the center of reflex activity in the oral cavity

Fig. 9-2. The Balters Bionator basic appliance.

Fig. 9-3. Palatal bar of 12 mm hard stainless steel for the basic appliance.

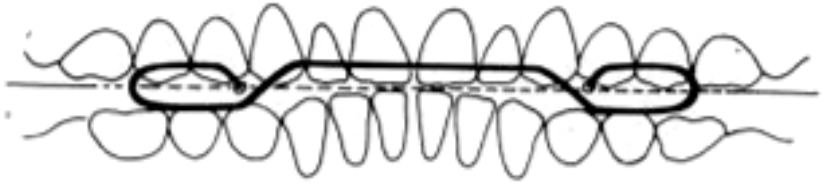


Fig. 9-4. Labial bow of 0.9 mm hard stainless steel for the basic appliance.

Bionator:

- Position of the tongue:

posterior displacement: class II

low anterior displacement: class III

narrow arches and crowding: low outward pressure

open bite: hyperactivity and forward posture

Bionator:

- Forward posturing of mandible:
  - enlargement of oral space
  - dorsum of tongue contacting soft palate
  - accomplish lip closure

Bionator:

Effects:

- Modulation of muscle activity of tongue
- elimination of abnormal influences of perioral musculature
- Stimulation of myotactic muscle activity and isotonic muscle contractions

Bionator:

Effects:

- No vertical component except for guiding eruption of teeth
- No viscoelastic response
- Prevention of deleterious parafunctional activity at night : relaxation of lateral pterygoid (used for TMJ problems)

Frankel function regulator:

Frankel philosophy:

- Potential restraining influence of the active muscle and tissue mass of the buccinator mechanism and the orbicularis oris complex
- Artificial matrix allowing the muscles to exercise and adapt

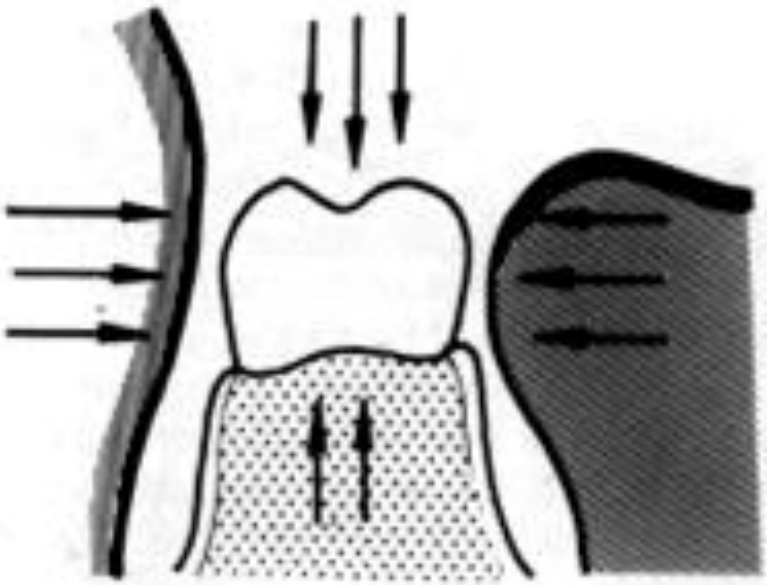
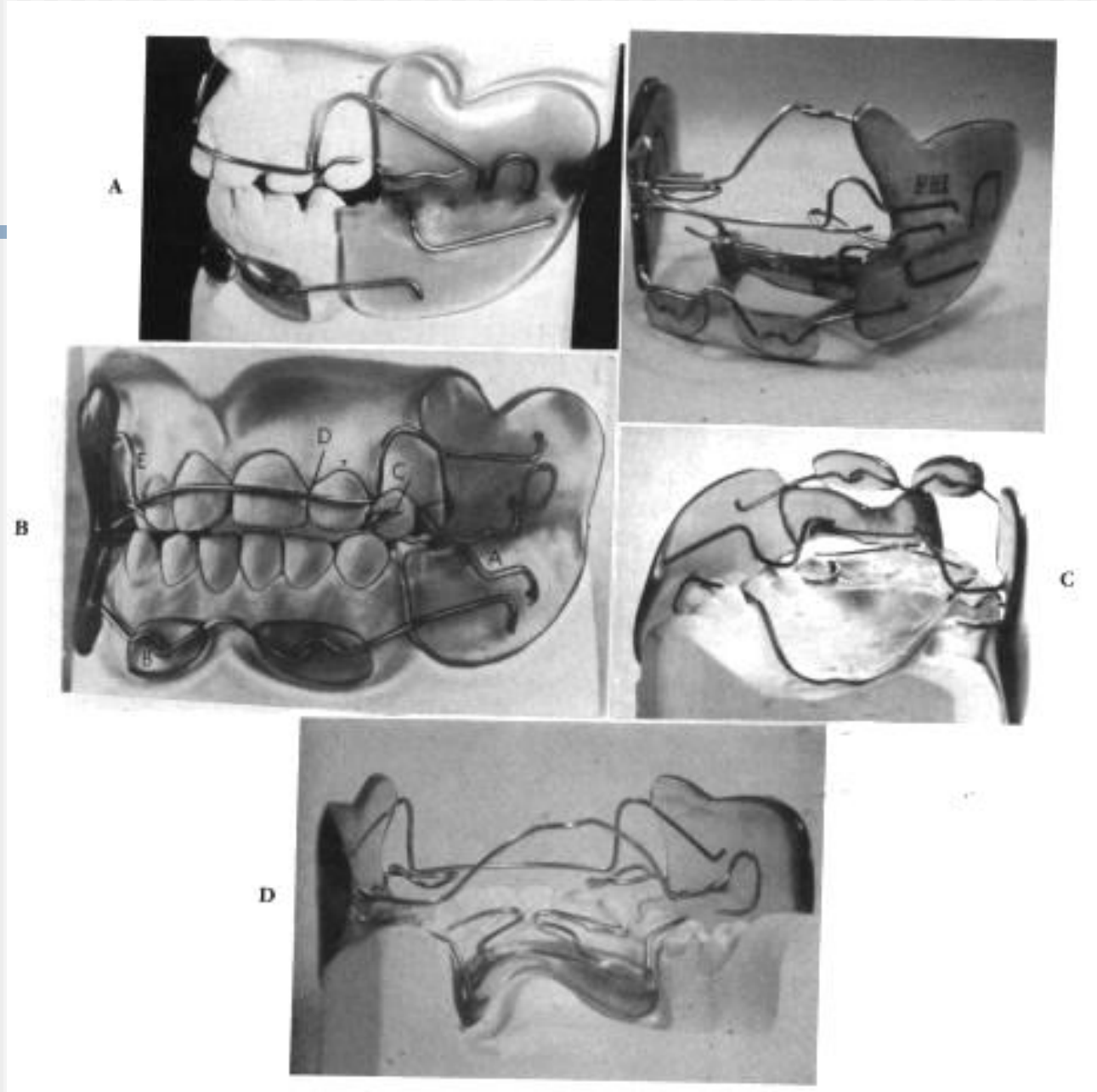


Fig. 9-1. In the transverse plane, muscle forces influence the position of the teeth; in the vertical plane, occlusal forces do this.


A
B
C
D
E
D
C
A
B

Frankel function regulator:

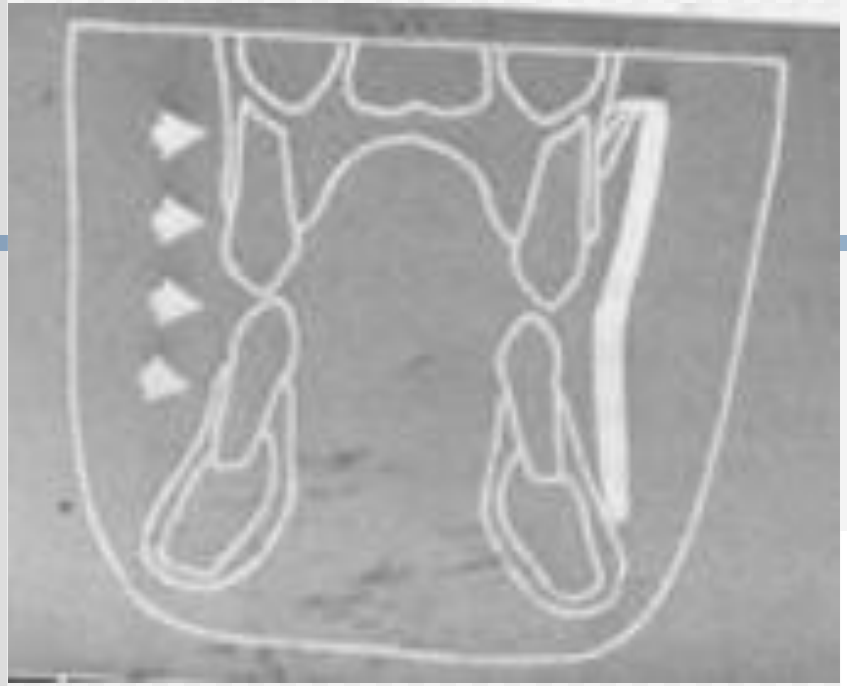
- Exercise device: stimulates normal function, eliminating the lip trap, hyperactive mentalis, aberrant orbicularis oris and buccinator
- Negative pressure of the muscles during deglutition is prevented

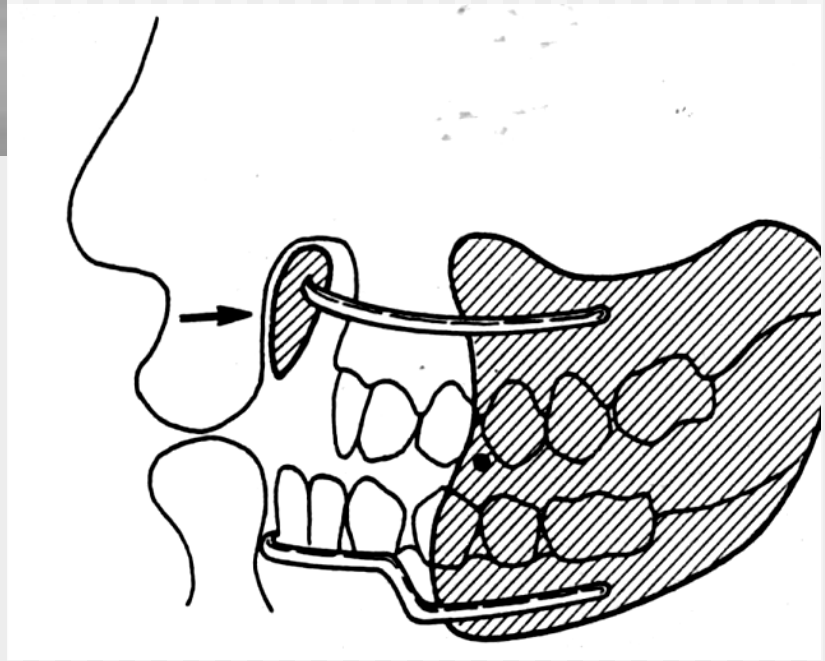
- Bodily buccal movement of posterior teeth
- Oral gymnastics: lip seal exercises

Frankel function regulator:

- Periosteal pull of buccal shields and lip pads increases bone activity
- Stimulation of mid palatal suture growth lesser extent increasing bone apposition on the external subperiosteal layer of maxilla

(Stutzmann et al 1983, Graber et al 1991)





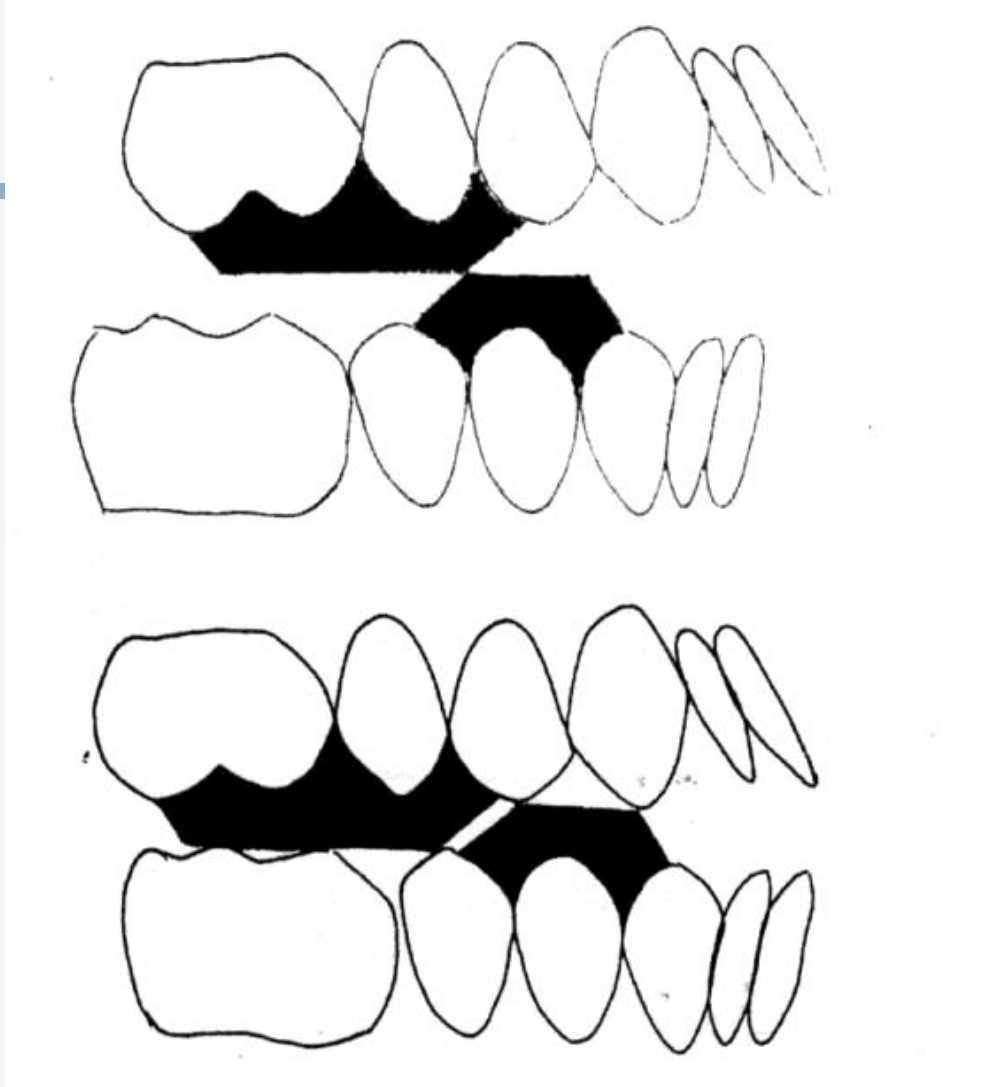
Frankel function regulator:

Dental effects:

- Appliance anchored to maxillary arch; allows more downward and outward movement of upper teeth
- Lower posterior teeth are allowed to erupt upward and forward; sagittal and vertical correction

Twin block:

- Clark ,1977
- Modification of occlusal inclined planes by means of acrylic inclined planes on bite blocks
- Guide mandible downward and forward
- Favorable proprioceptive contacts of inclined planes
- Adaptation of the muscles of mastication
- Vertical and transverse control



Twin block:

Mode of action:

- McNamara(1980)
- Rapid neuromuscular response
- Gradual dentoalveolar response
- Pterygoid response: pain while retracting the mandible

Twin block:

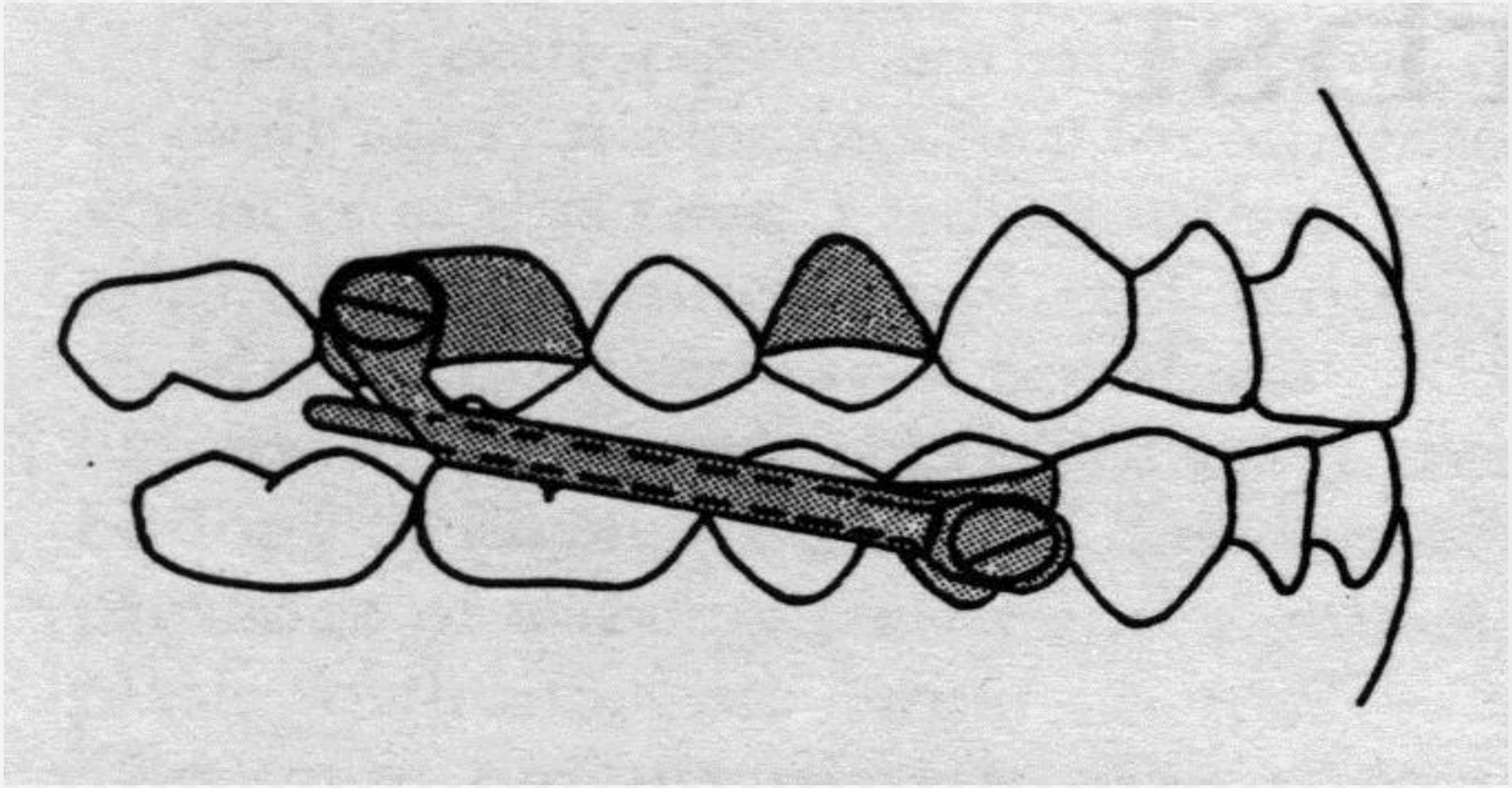
- Proliferation of connective tissue and blood vessels in the retrodiscal area
- Johnston(1976) unloading of the condyle
- Discomfort on removal of appliance due to compression in the tension zone behind the condyle

Functional appliances and extraoral force:

- Class II div 1 with excessive vertical growth
- Unloading of the condyle by forward posture of mandible
- Retardation of horizontal and vertical maxillary growth by headgear
- Margolis ACCO(1976); Jacobsson splint (1967); Stockli and Teuscher activator-headgear combination

Fixed functional appliances:

- Herbst, 1909- *Scharnier*
- Mandible was kept forward continuously, eliminating the need for patient compliance
- Herbst and Schwartz, 1934
- Pancherz, 1979



Fixed functional appliances:

Sagittal changes:

- Restraint of maxillary growth: headgear like effect
- Stimulation of mandibular growth:

  - remodeling on lower border of mandible(Pancherz and Ruf,1997)

  - modification of TMJ fossa(Paulsen,1997; Buschang,1998)

  - ultimate condylar position in fossa is unaffected

Fixed functional appliances:

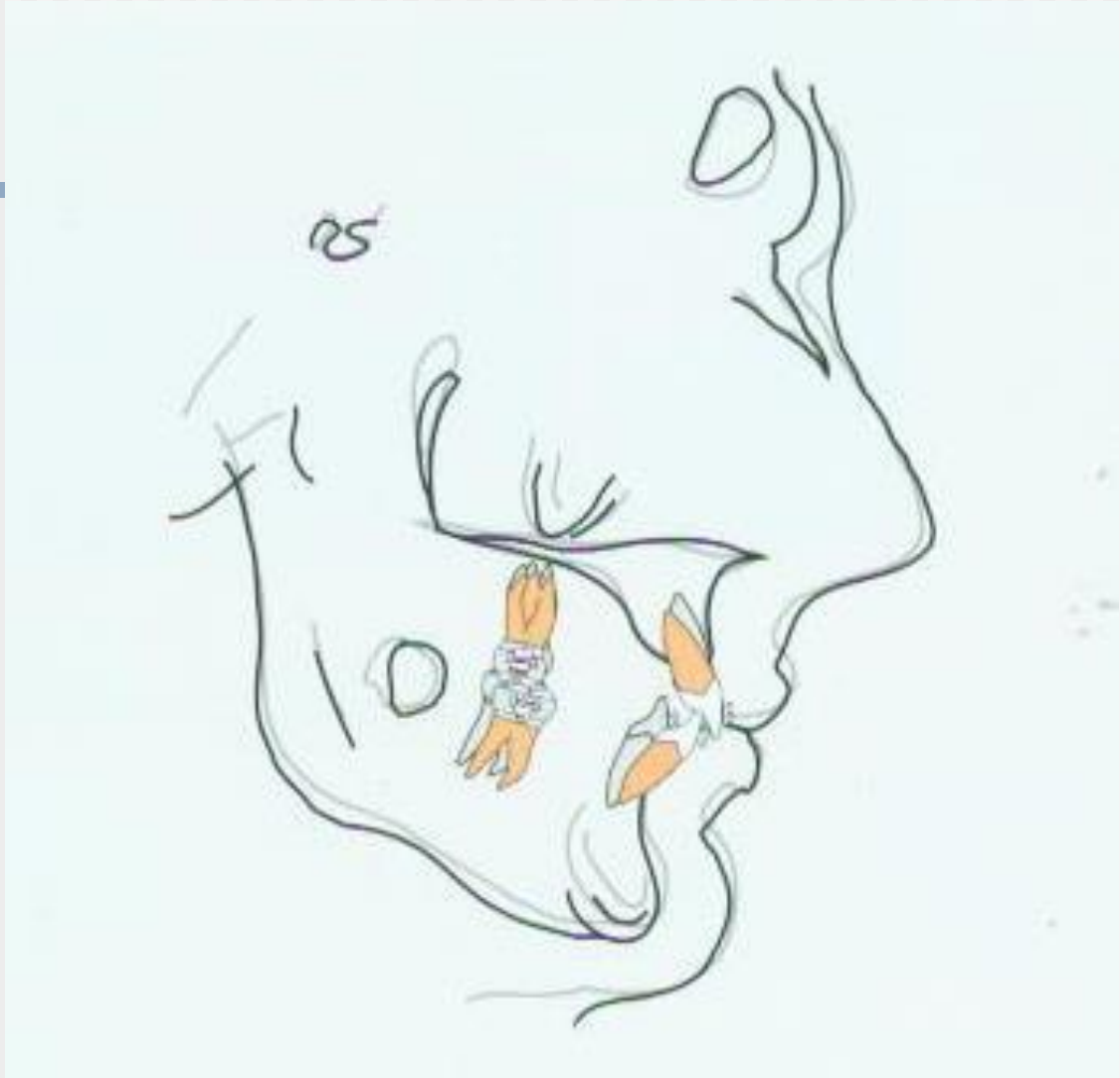
Sagittal changes:

- Proclination of lower incisors
- Posterior movement of upper molars: headgear like effect

Fixed functional appliances:

Vertical changes:

- Eruption of lower molars; intrusion of lower incisors: reduction of overbite
- Proclination of lower incisors contributing to overbite reduction



Fixed functional appliances:

Long term changes:

- Class I relationship is maintained with stable cuspal interdigitation
- Causes of relapse:

  - too early treatment
  - mixed dentition treatment
  - persistent abnormal musculature
  - unstable post treatment occlusion
  - insufficient length of appliance wear and retention

Fixed functional appliances:

Soft tissue changes:

- Reduction of soft tissue convexity, excluding the nose
- Increase in soft tissue convexity, including the nose, because of normal nasal growth
- Retrusion of upper and lower lips in relation to esthetic line due to normal chin and nose growth

Fixed functional appliances:

Jasper jumper:

- James Jasper, 1987
- Effects:

- functional effect similar to Herbst appliance
- dentoalveolar changes

Fixed functional appliances:

- Repositioning effect:
- Farrar effect: reciprocal clicking
- Recapturing of the disc
- Repositioning of condyle
- Maintaining the repositioning effect
- Orthodontic occlusal correction in the desired position

Diskusrepositionierung

Dysfunktion - Ferrer

Diskusrepositionierung

Jaspar Jumper Therapie

Mode of action:

Condylar growth:

- Forward positioning of mandible
- Increased activity of LPM
- Intensification of repetitive activity of retrodiscal pad

Mode of action:

- Condylar growth:

- increase in growth stimulating factors:

1. enhancement of local mediators
2. Reduction of local regulators

- change in condylar trabacular orientation
- additional growth of condylar cartilage
- additional subperiosteal ossification of posterior border of mandible
- lengthening of mandible

Mode of action:

- Increased activity of LPM
- Retrodiscal pad- mediator of response

1. Blood circulating effect:

   - increase in blood and lymph flow,
   - increase in nutritive and growth stimulating factor supply

   (STH-somatomedin, testosterone and estrogen in low doses, insulin, prostaglandin F2, mitogenic peptides)

Mode of action:

- decrease in locally produced catabolites and other negative feedback factors

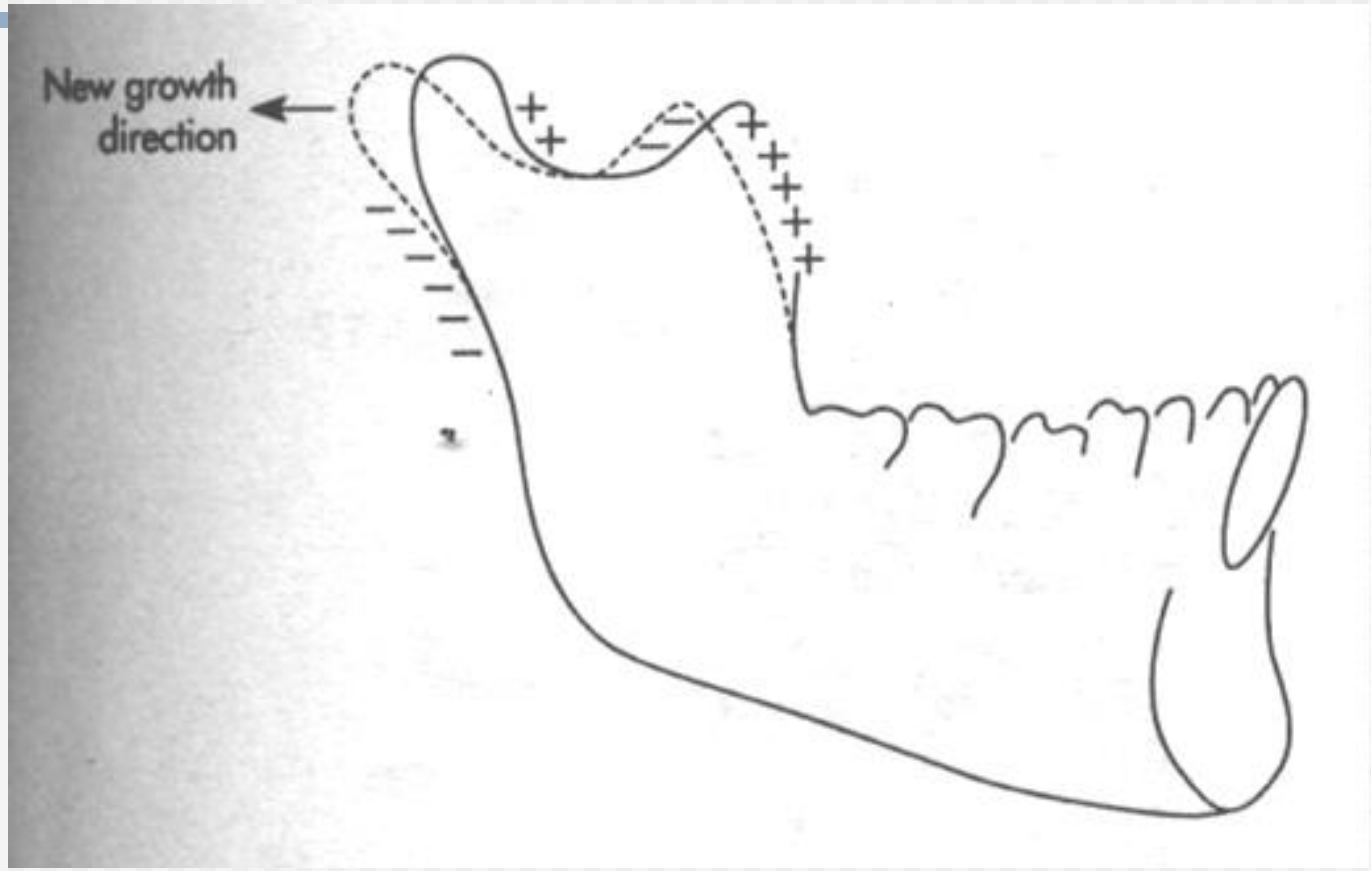
(prechondroblast’s multiplication restraining signal, cAMP, prostaglandin E2, somatostatin-like substance)

- iterative action

Mode of action:

2. Biomechanic effect:

- Accentuated concavity at the posterior border of mandibular ramus due to increase in condylar growth and more posterior directed growth
- piezoelectric effect: increase in negative charges along posterior border, causing increased periosteal bone formation and vice versa
- supplementary lengthening of mandible


New growth
direction

Herren and LSU activator:

- Bite opened well beyond postural rest position
- Forward positioning of mandible leads to reduced increase in length of LPM
- Sensory engram formed for new position of mandible
- Functioning of mandible in more forward position when appliance is not worn
- Increased activity of retrodiscal pad with acceleration of condylar growth

- Growth restriction of glenoid fossa:

normal growth of glenoid fossa is in posterior and inferior direction

Anterior slope of articular eminence undergoes bone deposition on posterior slope and resorption on anterior slope

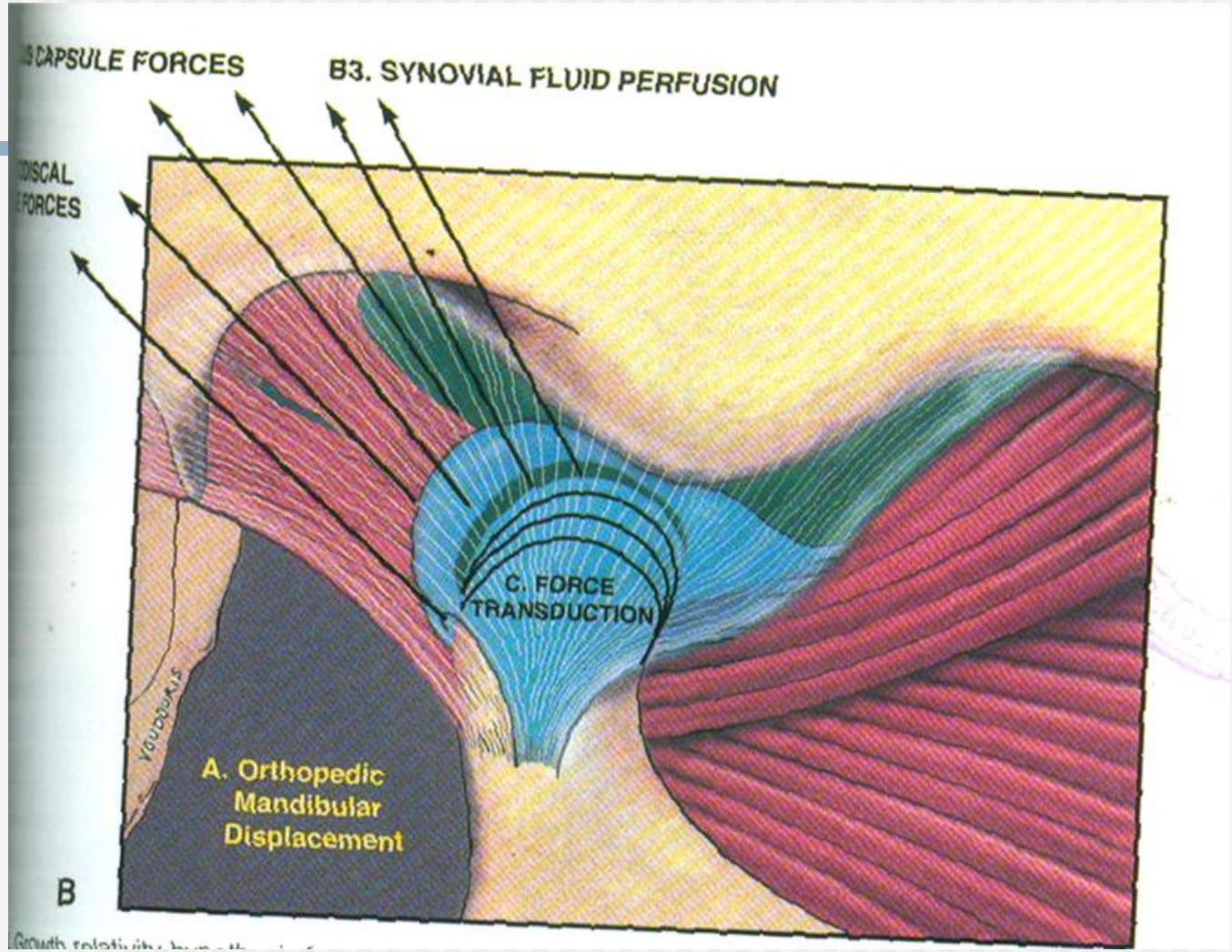
Anterior relocation of glenoid fossa in orthopedic treatment

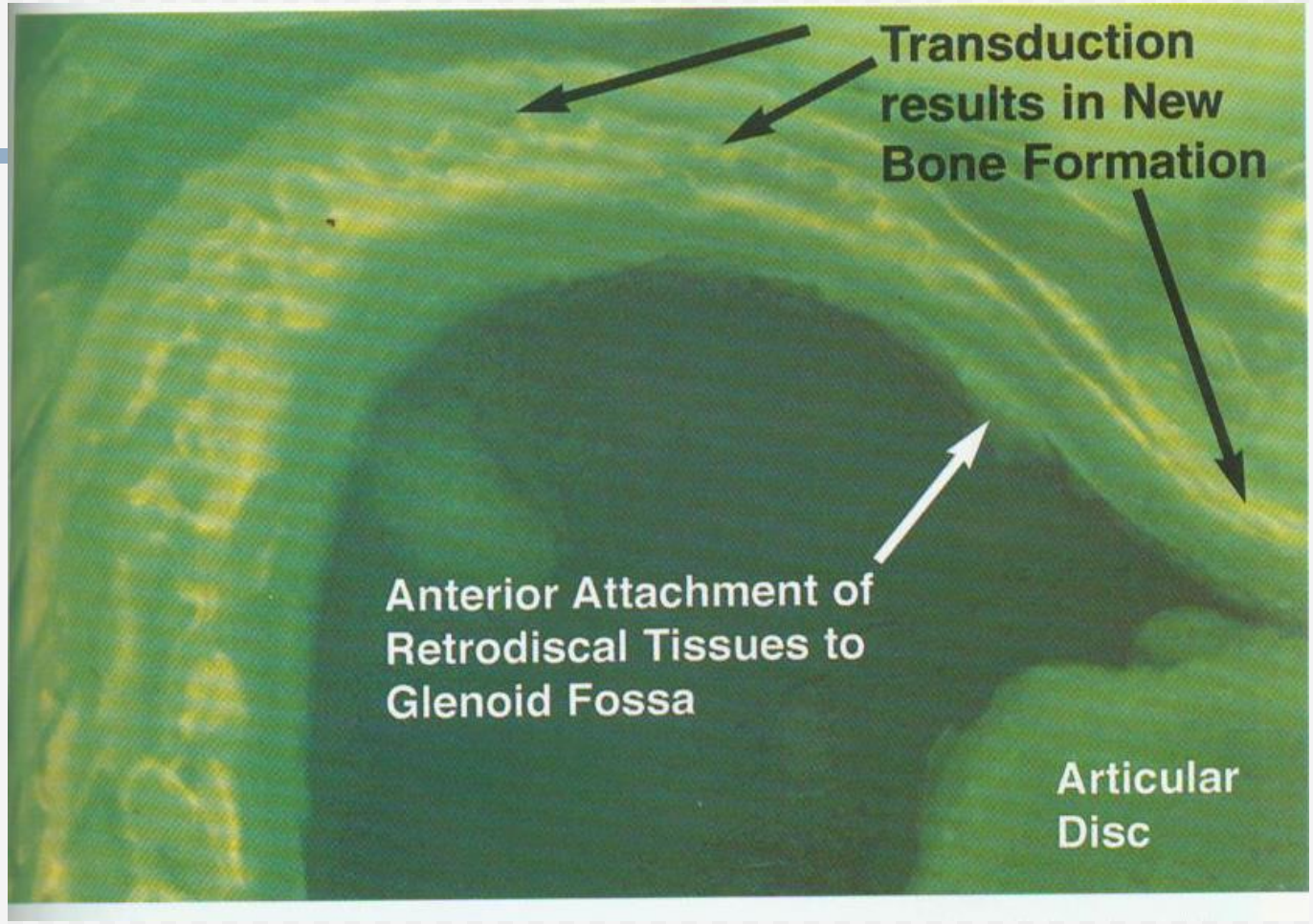
Reciprocal forces from viscoelastic tissue between condyle and fossa

Growth relativity hypothesis:

Voudoris, Kuftinec AJODO March 2000

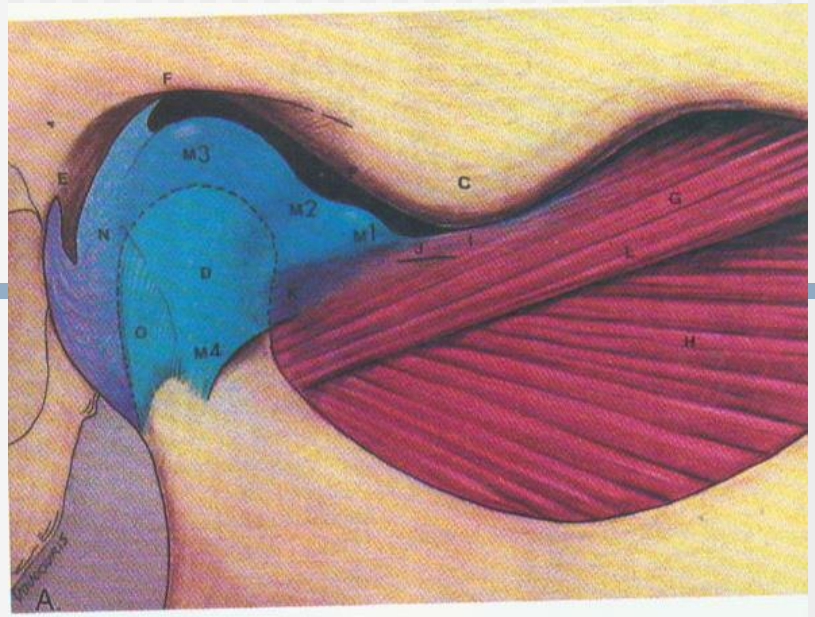
- Mandibular advancement
- Fibrocartilagenous lining in glenoid fossa induces bone formation locally
- Stretch of nonmuscular viscoelastic tissues
- New bone formation some distance from the actual retrodiscal attachments in the fossa


CAPSULE FORCES
B3. SYNOVIAL FLUID PERFUSION
DISCAL
FORCES
C. FORCE
TRANSDUCTION
A. Orthopedic
Mandibular
Displacement
B


Transduction
results in New
Bone Formation
Anterior Attachment of
Retrodiscal Tissues to
Glenoid Fossa
Articular
Disc

Growth relativity hypothesis:

- Fibrocartilage caps the condyle in 3 dimensions: posterior, anterior and 2 collateral along with fibrous capsule and synovial fluid
- Advancement: engorgement of blood vessels, influx of nutrients and biodynamic factors
- Reseating of condyle in fossa: expulsion of these factors
- Resulting metabolic pump-like action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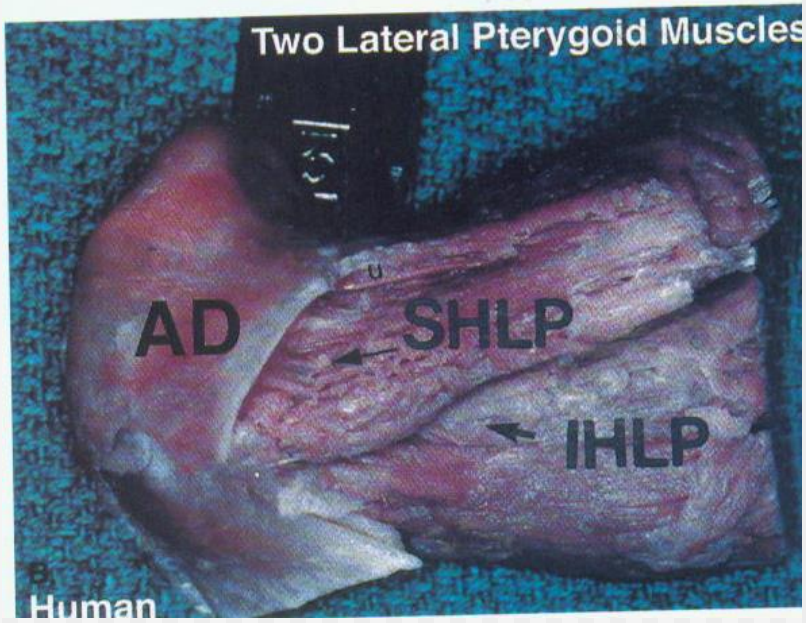

Two Lateral Pterygoid Muscles
U
AD
SHLP
IHLP
B
Human

Growth relativity hypothesis:

- Disoccluding appliances cause low intra-articular subatmospheric pressures within TMJ in open position (Nitzan, 1994)
- Shift of synovial fluid perfusion on a posteriorly displaced direction
- Negative pressures are below capillary perfusion pressure
- Greater flow of blood to the region

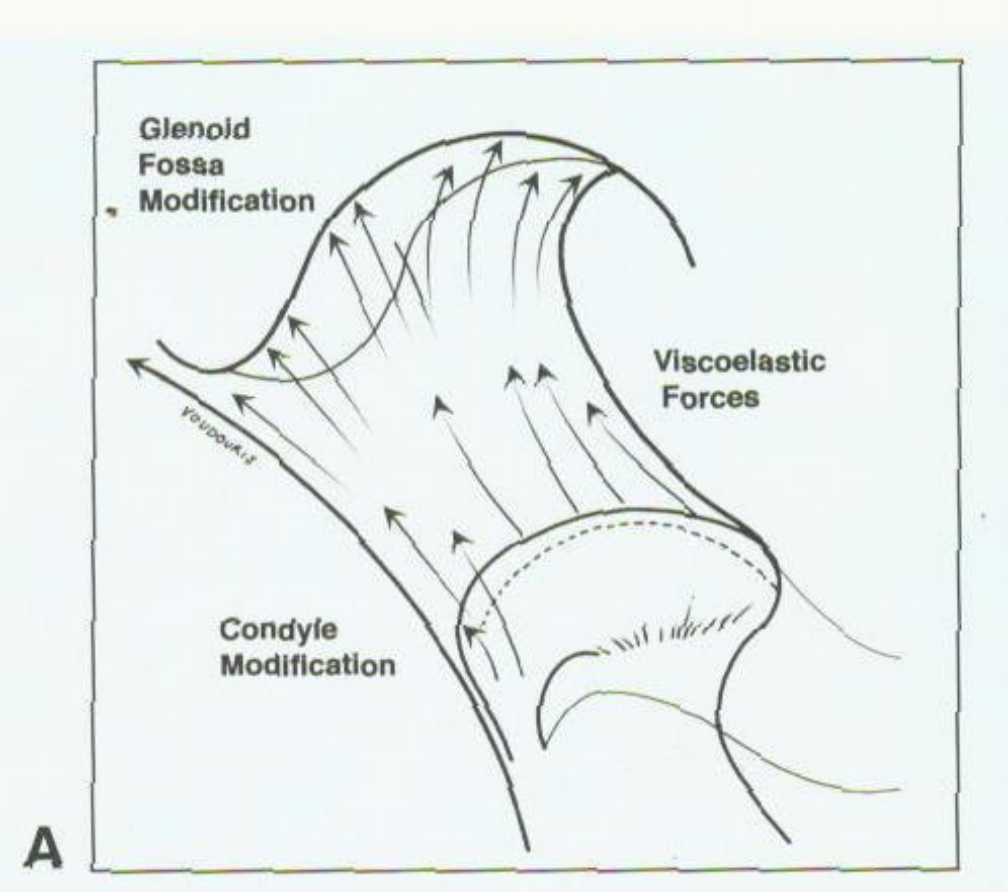
Growth relativity hypothesis:

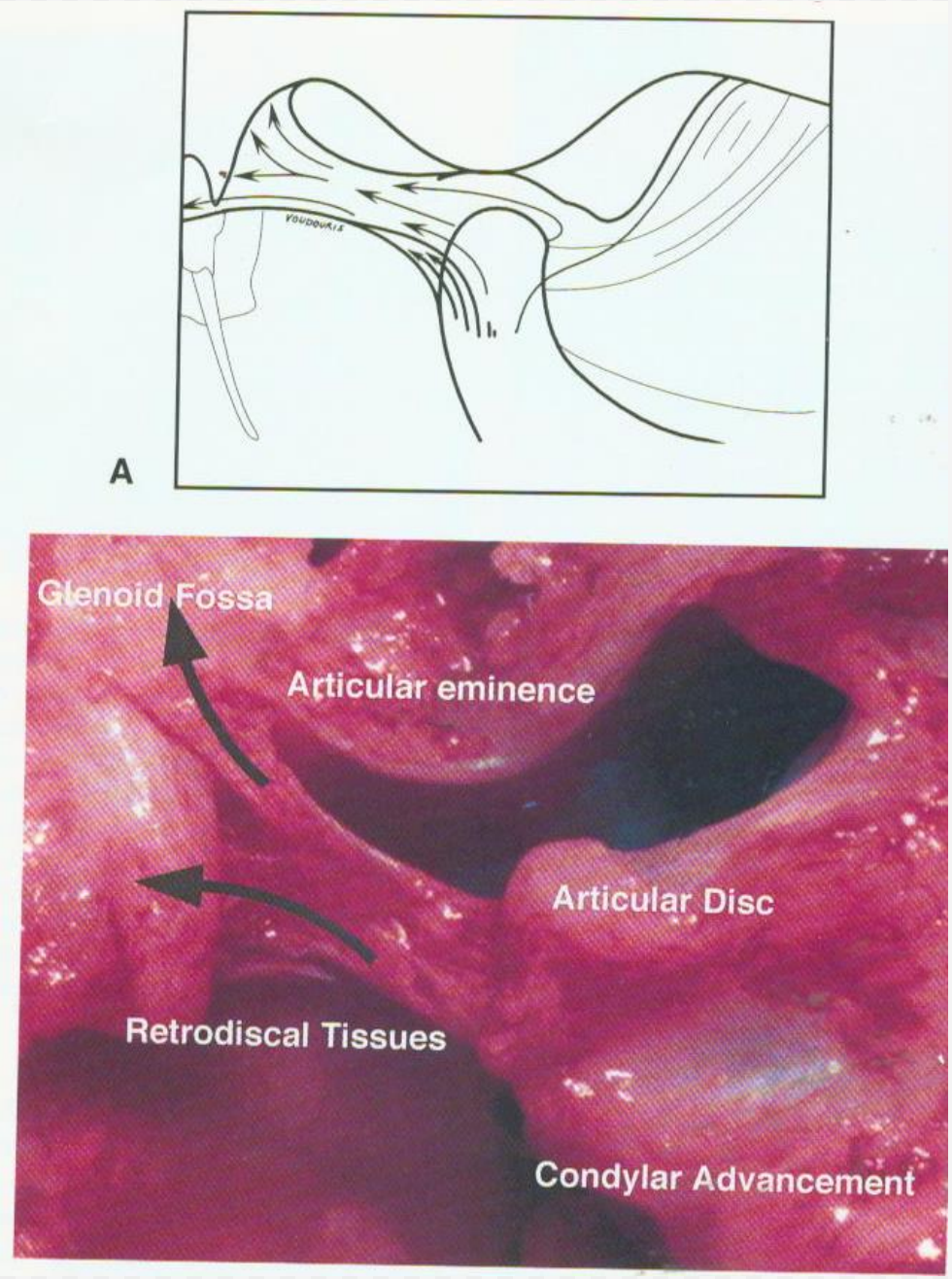
Bone architecture is influenced by the neuromusculature and the contiguous nonmuscular, viscoelastic tissues anchored to the glenoid fossa and the altered dynamics of the fluids enveloping bone

Displacement+ viscosity+ referred force

- Three growth stimuli:

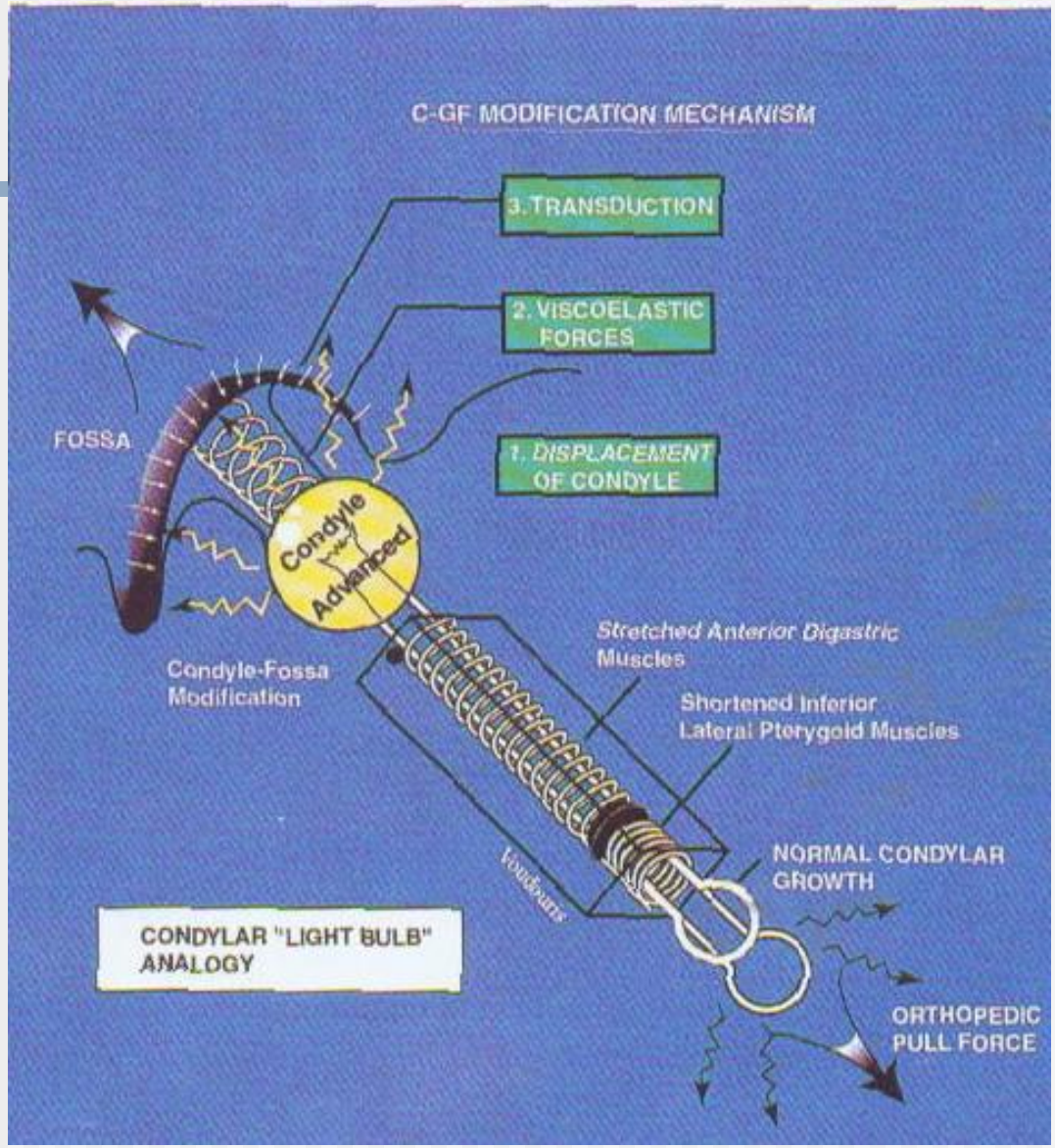
1. Anterior orthopedic displacement
2. Posterior viscoelastic tissues between condyle and fossa
3. Transduction of forces over the fibrocartilage cap of the condylar head, increases radiating endochondral bone formation beneath condylar fibrocartilage and periosteal bone formation in the fossa

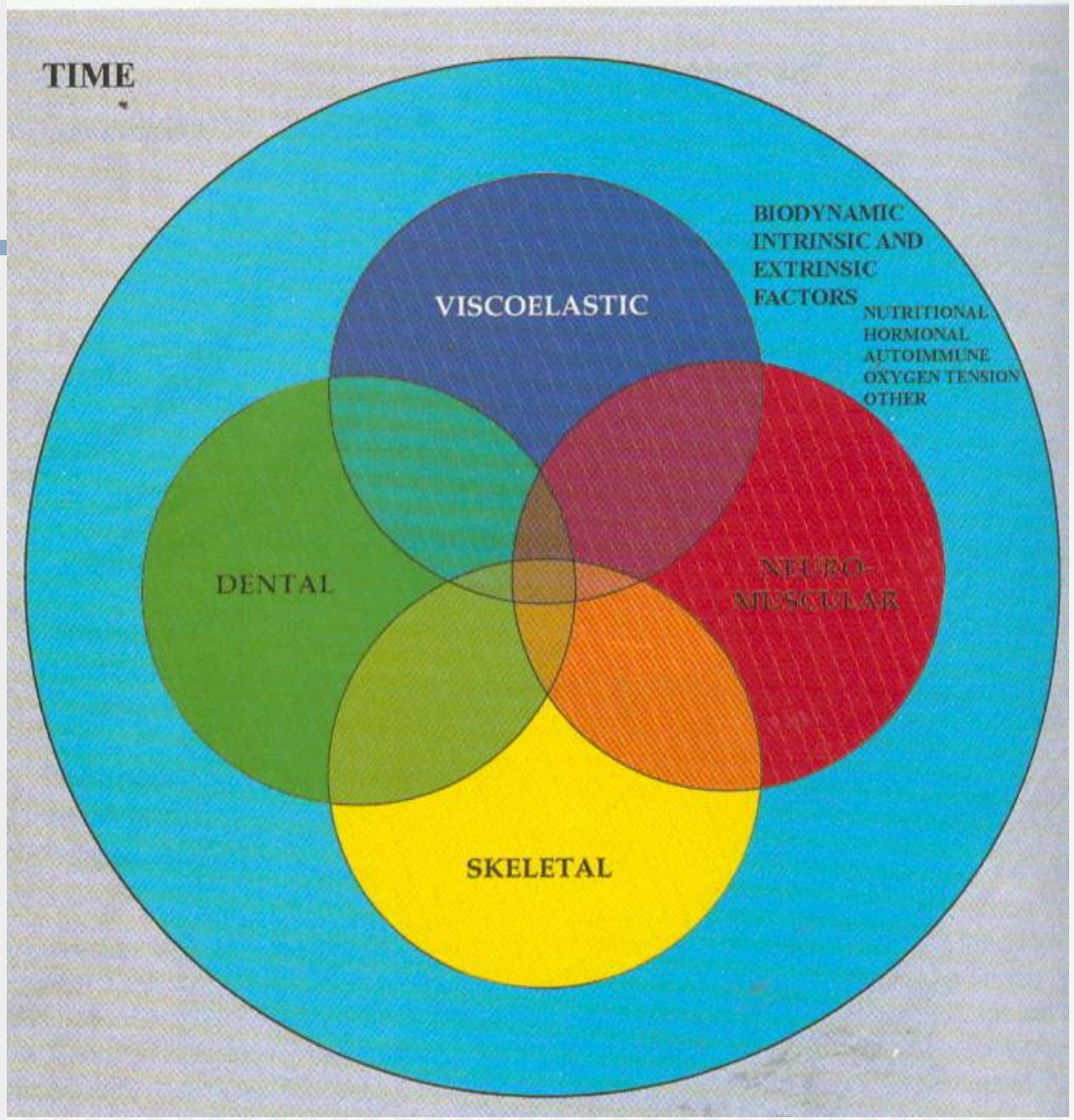

Glenoid
Fossa
Modification
Viscoelastic
Forces
Condyle
Modification
A


A
Glenoid Fossa
Articular eminence
Articular Disc
Retrodiscal Tissues
Condylar Advancement

Condylar light bulb analogy:

- Condyle acts like a light bulb on a dimmer switch
- Lights up during advancement, dimming back to near normal levels during retention
- Growth potential diminishes with age while remodeling potential last long into adulthood


C-GF MODIFICATION MECHANISM
3. TRANSDUCTION
2. VISCOELASTIC FORCES
1. DISPLACEMENT OF CONDYLE
FOSSA
Condyle Advanced
Condyle-Fossa Modification
Stretched Anterior Digastric Muscles
Shortened Inferior Lateral Pterygoid Muscles
NORMAL CONDYLAR GROWTH
ORTHOPEDIC PULL FORCE
CONDYLAR "LIGHT BULB" ANALOGY


TIME
VISCOELASTIC
BIODYNAMIC
INTRINSIC AND
EXTRINSIC
FACTORS
NUTRITIONAL
HORMONAL
AUTOIMMUNE
OXYGEN TENSION
OTHER
DENTAL
NEURO-
MUSCULAR
SKELETAL

Clinical implications:

- Prevention of condylar compression by using Herbst with thin posterior bite blocks
- Rapid maxillary expander to reduce occlusal interferences and functional shifts due to the anterior positioned mandible