# PREDICTIONS OF GROWTH

Presented by:
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- Most predictions of growth are based on some mathematical model of the growth process, two kinds of which can be distinguished:
- (1) the transformed coordinate method of D'Arcy Thompson, applied to human growth by Medawar and to craniofacial growth by Moorrees and Lebret, and
- (2) equations producing curves descriptive of processes :some intended to be of general application.
- Others were intended only for specific kinds of growth, such as Huxley'sle allometric equation and Tanner's equation

- shortcoming :
- They do not adequately describe any single growth series.
- **Methods of prediction**
- Several predictive methods are used in industry and science. grouped under the following four headings:
- (1) theoretical
- (2) regression
- (3)experiential
- (4) time series

## THEORETICAL METHODS OF PREDICTION:

- Astronomers recently discovered an earth sized planet several thousand light years away from us by collecting a series of inexplicable, apparently random data on the behavior of theoretical model could be constructed mathematically which might explain all the unusual activity observed, and a test for a hypothesis was devised. The model assumed the existence of an unknown planet of a certain size in a certain orbit, which was subsequently found precisely in the theoretically predicted location.
- NO one had suggested the existence of such a planet until the model was formulated ; the model began theoretically and was proved practically.
- Theoretical models of craniofacial growth have not yet been defined mathematically in terms precise enough to permit the application of the method to prediction.

## REGRESSION METHODS:

These methods serve to calculate a value for one variable, called dependent, on the basis of its initial state and the degree of its correlations with one or more independent variables.

Johnstonl' has recently evaluated and reviewed the regression methods of approach to craniofacial prediction.

He concluded that

(1) the ultimate accuracy of cephalometric prediction may be limited to some extent by intrinsic errors within the cephalometric method itself and

(2) contemporary methods seem inadequate to provide an efficient estimate of individual changes attributable only to growth.

there are both theoretical and practical implications in the use of these methods in predicting the growth of a single person. Chiefly, these are the following:

- 1. The assumption within the method that the coefficients remain constant over the whole time period. Growth does not proceed in this manner in the real world.
- 2. An individual whose growth is to be predicted in clinical practice may not even be a member of the population upon which the regression equation was based.

## EXPERIENTIAL METHOD

Experiential methods are based on the clinical experience of a single investigator who attempts to quantify his observations of practice in such a way that they can be codified for use by others.

The best-known example of the experiential method in craniofacial growth prediction is that of Ricketts whose estimates of growth prediction for the individual utilize means derived from a large sample of treated orthodontic patients.

The method is popular and widely used, but its theoretical base is shaky on two counts

- First, the assumption must be made that the individual being predicted will behave as the mean of a population of which he is not a member.
- Second, the morphology of the mandible and other parts is a clue to the future growth of the face, a point disputed by Horowitz and Hixon, Balbach, and Woodside.

## TIME-SERIES METHODS

- The methods are of essentially two types:
- (1) time-series analysis which extracts in a mathematical form the fundamental nature of the process as it relates to time, and
- (2) smoothing methods, either moving averages or exponential, which operate to give representative or average values to the parameters of a previously derived time-series equation.

## TIME SERIES ANALYSIS

- For purposes of analysis, a time series is considered to be composed of four parts.

1) trend or long-term movement,
2) oscillations about a trend,
3) Cyclic or periodic events, and
4) random (unsystematic) components.

The analysis consists of the assessment of each of these parts by means of specific statistical tests, In craniofacial growth predicition, it is necessary as the first part of the analysis to determine which components of the time series are present in the specific measure to be predicted ; that is, whether its growth behavior is best described as a trend, a cyclic event, or some combination, etc. Thus, the time-series analysis can reveal the nature of the changes of state of the process with time and describe each change mathematically by means of appropriate models

## EXPONENTIAL SMOOTHING

way of estimating the current value of a parametcr by means of some sort of average of past values of that parameter.

Prediction is then based on coefficients derived from the smoothed parameters. Since the coefficients will change in accord with changes in the parameter, the predicted value will reflect the past behavior of the specific variable for which the prediction is to be made.

It is possible with this method to make the initial value of the smoothed statistic equal to the mean value of the variable at that time as derived from some other source.

Subsequent statistics are, obtained from the cephalograms in the one subject's series. In craniofacial growth prediction, this means that one could predict from a single cephalogram if mean values for an appropriate population are available as well.

However, more precise predictions can be obtained if there are at least two successive cephalograms of the individual to be predicted.

## WHAT ARE WE INTERESTED IN PREDICTING IN THE CRANIOFACIAL COMPLEX?

- **1.future size of a part**-the prediction of future size **as burstone,** is primarily a problem of predicting future increments
- Most of the size dimensions of interest to the orthodontist display a combination growth curve through time.
- An example would be prediction of the length of the mandible.

- **Relationship of parts**. Perhaps the most important prediction for the clinician is the future relationship of parts, that is, the future facial pattern.
- Pattern, however represented, is a summation of growth and size in several component

**Timing of growth events**. Because growth does not proceed evenly, certain facial dimensions demonstrate marked changes in their velocity curve. These "spurts" make prediction much more difficult.
If one were to predict a "spurt" he might want to predict the time of its onset, the duration of the increased rate of growth, and the rate of growth during the spurt

**Vectors of growth**. Most predictive methods thus far presume a continuation of the pattern first seen. Therefore, the presumption is made that the vectors of growth present at the time of prediction will remain,
There is much documentation that this presumption is not true. Mandibles which grow vertically for a period of time inexplicably start to grow horizontally.

- **Velocity of growth**. It would be of use to know the future expected rate of growth. Prediction of velocity is most important during the pubescent spurt.
- The effects of orthodontic therapy on any of the above predicted parameters: Although Burstone has pointed out that our knowledge of prediction might best proceed by learning to predict untreated growing faces, the clinician must always wonder what effects his therapy is having on the predicted and actual growth of one specific face.

**How well can we predict each of these parameters?**

**Future size**. A number of studies of the size-size, size-gain, and gain-gain type have been reported for a variety of craniofacial dimensions, but the findings are of little clinical use as yet, despite an occasional statistically significant value.
Craniofacial growth is so complex that it is unlikely that any simple series of size predictions will prove clinically useful.

- **Relationship of parts**. Harvold, has attempted to predict maxillomandibular relations at one age on the basis of maxillomandibular relations and mandibular size at an earlier age. Johnston found measures of relationship and proportion to be of greater predictive significance than the linear size of anatomic parts. Balbach' attempted to predict the future occlusal position of the mandible on the basis of its morphology.

**Timing of growth events**: Bjork and Helm related several maturational events to attempt to predict the maximum pubertal spurt in growth.
Frisancho, an anthropologist working at the Center for Human Growth and Development on problems of malnutrition and growth, has had some success in predicting the individual spurt in stature from noting the timing of calcification of the sesamoid bone.

**Vectors of growth**. Ricketts assumes that the morphology of the mandible is a clue to the future vectors of growth of the craniofacial complex.
Woodside recently reported findings from work done on the Burlington sample which showed only part of Ricketts' assumed vectors to be true.
Balbach found support for the idea of relative stability of mandibular morphology which may explain the modest success some have had in prediction by simply adding mean increments to the existing facial pattern.

- **Velocity**. If one is truly to predict facial growth, one must account for variations in velocity
- Hunter and Miller found that changes in rate of growth occurred at different times in horizontal maxillary measures than in vertical ones.

- **The effects of orthodontic therapy on growth**. As our skill in treatment has increased, SO has our ability to alter the growth of the facial structures remarkably

  Balbaeh suggests that the most important single factor in prediction for the orthodontist is to be able to predict what effect his therapy will have on the growing face that he is treating.
- Jenkins, in a personal communication, has suggested a method of predicting the rate of response of measure to orthodontic therapy.
- Perhaps the success of the Ricketts method and others like it is due in large part to the clever clinician's ability to make his treatment harmonize with his predicted goals. He sets his predictions and then works to make them come true.

**Use of time series in craniofacial prediction**. The time-series method, as briefly explained earlier in this article, was applied to a selected list of six craniofacial measures, chosen as representative of the types of measure which orthodontists have been trying to predict.

In terms of time-series components, upper face height (A point-SN), maxillary length (PTM-A point) and anterior cranial base length (S-N) behave primarily as linear trends, while ramus height (Art-Go) and mandibular length (Art-Gn) are compound growth curves, composed of linear trends, and the maxillomandibular relationship (AB-FOP angle) is a constant.

- longitudinal method- has a general limitation in that the pattern of growth is not constant and the pattern recorded at a juvenile age may well have changed by adolescence .
- For clinical purposes, the analysis of the vertical development of the face may be improved by using what can be called natural reference structures in the mandible, as illustrated by Fig. 1. By superimposing two radiographs taken at different ages and orienting them with reference to these structures, one may estimate the growth pattern of the mandible with a fairly high degree of accuracy. The growth rotation of the mandible in relation to the cranial base can then be real from the angle between the nasion-sella lines for the two ages

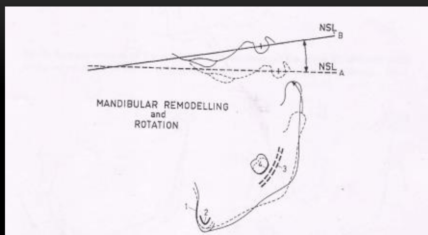
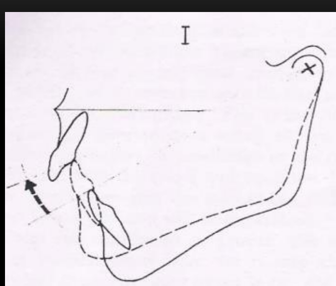


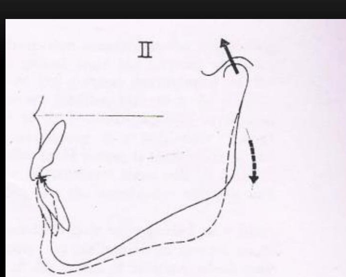

**Fig. 1.** Longitudinal method of analysis of mandibular growth rotation from the angle between the nasion-sella lines, at two stages (A and B) after superimposition of the mandibles on natural reference structures: tip of the chin (1), inner cortical structure at the inferior border of the symphysis (2), trabecular structures related to the mandibular canal (3), and the lower contour of a molar germ (4) from the time mineralization of the crown is visible until the roots begin to form.

## FORWARD ROTATION

- may occur in the following three ways :
- *Type I.* In this type (the one that is usually considered) there is a forward rotation about centers in the joints which gives rise to a deep-bite, in which the lower dental arch is pressed into the upper, resulting in underdevelopment of the anterior face height. The cause may be occlusal imbalance due to loss of teeth or powerful muscular pressure. This lowering of the bite may occur at any age.




- **Type II**. Forward growth rotation of the mandible about a center located at the incisal edges of the lower anterior teeth is due to the combination of marked development of the posterior face height and normal increase in the anterior height. The posterior part of the mandible then rotates away from the maxilla.




- **Type III.** In anomalous occlusion of the anterior teeth the forward rotation of the mandible with growth changes its character. In the case of large maxillary overjet or mandibular overjet, the center of rotation no longer lies at the incisors but is displaced backward in the dental arch, to the level of the premolars. In this type of rotation the anterior face height becomes underdeveloped when the posterior face height increases. The dental arches are pressed into each other and basal deep-bite develops.

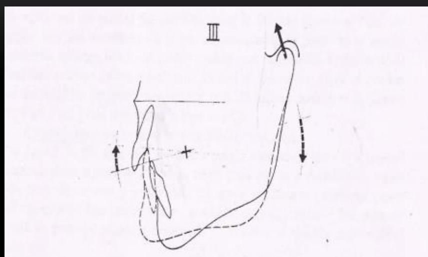



Fig. 2. Forward rotation of the mandible with the center at the joints (I), with the center at the incisal edges of the lower incisors (II), and with the center at the premolars (III).

## BACKWARD ROTATION

- of the mandible is less frequent than forward rotation
  and has been examined by the implant method in considerably fewer subjects.
  Two types have been recognized
  **Type 1**. here the center of the backward rotation lies in the temporomandibular joints. This is the case when the bite is raised by orthodontic means, by a change in the intercuspation or by a bite-raising appliance, and results in an increase in the anterior face height :

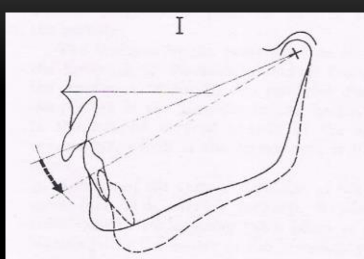
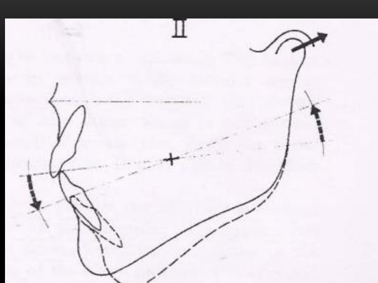



Fig. 3. Backward rotation of the mandible wi
center at the last occluding molars (II).

- **Type II.** Backward rotation here occurs about a center situated at the most distal occluding molars. This occurs in connection with growth in the sagittal direction at the mandibular condyles. In the subjects analyzed so far, the dircction of this sagittal growth has curved increasingly backward. As the mandible grows in the direction of its length it is carried forward more than it is lowered in the face, and because of its attachment to muscles and ligaments it is rotated backward.




ith the center at the joints (I) and with the

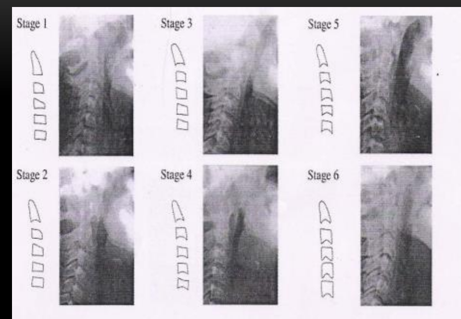
## *STRUCTURAL SIGNS OF GROWTH ROTATION*

- Seven structural signs of extreme growth rotation will be considered in relation to the condylar growth direction.

(1) inclination of the condylar head,
(2) curvature of the mandibular canal,
(3) shape of the lower border of the mandible,
(4) inclination of the symphysis,
(5) interincisal angle,
(6) interpremolar or intermolar angles, and
(7) anterior lower face height.

## SKELETAL MATURATION EVALUATION USING CERVICAL VERTEBRAE

- Hassel and farman developed a system of skeletal maturation determination using the cervical vertebrae.
- Shape of the cervical vertebrae were seen to differ at each level of skeletal development
- This provided a mean to determine the skeletal maturity of a person and their by determine whether the possibility of potential growth existed
- **STAGE -1**
- This stage called initiation **.**




- Corresponds to beginning of adolescent growth with 80% to 100%of adolescent growth expected.
- Inferior borders of C2,C3 and C4 were flat at this stage.
- The vertebrae were wedge shaped.
- Superior vertebrae border were tapered from posterior to anterior

## STAGE -2

- This stage is called acceleration.
- Growth begins at this stage with 65% to 85% of adolescent growth expected.
- Concavities were developed in the inferior border of C2,C3.
- The inferior border of C4 was flat.
- The bodies of C3 and C4 were nearly rectangular in shape.

## STAGE-3

- This stage is called transition.
- Acceleration of growth towards peak height velocity with 25%to65%of adolescent growth expected
- Concavities seen in inferior border of C2 and C3.
- Concavities was beginning to develop in the inferior border of C4.
- The bodies of C3 and C4, were rectangular in shape

## STAGE-4

- This stage called deceleration.
- Corresponds to deceleration of adolescent growth spurts with 10% to 25 % of adolescent growth expected.
- Concavities seen in the inferior border of C2,C3 and C4 .
- The vertebral bodies of C3 and C4 were becoming more in square in shape.

## STAGE-5

- This stage called maturation.
- Maturation  of the vertebrae took place during this stage,with 5% to 10% of adolescent growth expected.
- More accentuated concavities were seen in the inferior border of C2,C3 and C4 .
- The bodies of C3 and C4 were nearly square to square in shape.

## STAGE-6

- This stage is called completion.
- Corresponds to completion of growth .
- Little or no adolescent growth could  be expected.
- Deep concavities were seen in the inferior border  of  C2,C3. and C4.
- The bodies of C3 and C4 were square.
- Bodies greater in vertical dimension than horizontal dimension.

## *HAND WRIST RADIOGRAPHS-*

- The handwrist radiographs were evaluated according to the method described by Hagg and Taranger (1980). The epiphyseal development of the middle phalanx of the third finger and of the distal part of the radius were used as indicators of skeletal maturity .

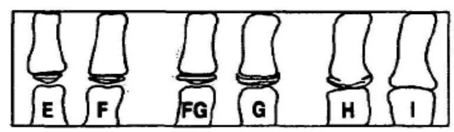



**Figure 2** Skeletal maturity stages of the middle phalanx of the third finger (MP3) in progressive order (Hägg and Taranger, 1980):
Stage E: the epiphysis is not yet as wide as the metaphysis.
Stage F: the epiphysis is as wide as the metaphysis.
Stage FG: the epiphysis is as wide as the metaphysis and there is a distinct medial and/or lateral border of the epiphysis forming a line of demarcation at right angles to the distal border.
Stage G: the sides of the epiphysis have thickened and also cap its metaphysis, forming a sharp edge distally at one or both sides.
Stage H: fusion of epiphysis and metaphysis has begun.
Stage I: fusion of epiphysis and metaphysis is completed.

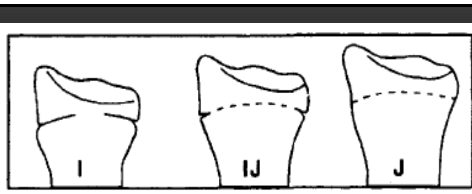



**Figure 3** Skeletal maturity stages of the distal epiphysis of the radius (R) in progressive order (Hägg and Taranger, 1980):
Stage I: fusion of epiphysis and metaphysis has begun.
Stage IJ: fusion is almost completed but there is a small gap at one or both margins.
Stage J: fusion of epiphysis and metaphysis is completed.

## VISUAL TREATMENT OBJECTIVE (VTO)

- Visual treatment objective is an effort to predict rate and direction of growth in dentofacial region.
- Dentofacial growth, if judged to be favorable, would aid orthodontic treatment.
- In class II malocclusion a forward rotating mandible would be regarded as a desirable growth  pattern whereas a backward rotation of the mandible would represent unfavorable growth.

- The maxillomandibular relationship seen at 2years after the start of treatment in a growing child may not be the same at maturity.
- Therefore treatment of a case (whether Angle's class I,II,or III) to proper facial balance at age of 12years may prove unsuccessful at the age of 25years.
- This consideration is especially true in cases in which an abnormally large amount of growth is predicted for the teen years.

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# Properties of Orthodontic Wires

Part I

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## Introduction

Moving teeth and craniofacial harmony
Forces and moments

**Wires**

Light continuous forces

## History

1. Material Scarcity, Abundance of Ideas (1750-1930)

- noble metals
- Gold, platinum, iridium and silver alloys
- good corrosion resistance
- acceptable esthetics
- lacked the flexibility and tensile strength

## History

- Angle (1887) → German silver (a type of brass)
- Opposition ×Farrar
- Neusilber brass (Cu 65%, Ni 14%, Zn 21%)
- various degrees of cold work
  - jack screws,
  - expansion arches,
  - Bands

## History

- Wood, rubber, vulcanite, piano wire and silk thread
- Steel - as ligature wire.

## History

- Stainless steel (entered dentistry -1919)
- Opposition × Emil Herbst

↓

gold wire was stronger than stainless steel. (1934)

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# History

2. Abundance of materials, Refinement of Procedures (1930 – 1975)

- Improvement in metallurgy and organic chemistry
- Cobalt chrome (1950s)
- Nitinol (1970s)

# History

3. The beginning of Selectivity (1975 to the present)

- Beta titanium (1980)
- CAD/CAM
- Composites and Ceramics
- Iatrogenic damage

↓

Nickel and bis-GMA

# Basic Properties of Materials

- Elements – no simpler form
  - ➥ Atoms
- Electrons – orbits around nucleus

Electron shells

Electrons form the basis of bonds

- In metals, the energy levels are very closely spaced and the electrons tend to belong to the entire assembly rather than a single atom.

# Basic Properties of Materials

- Molecules – 2 or more atoms
- Amorphous – similar properties in all directions – isotropy → Glass
- atoms organize themselves into specific lattices → geometry

CRYSTAL

↓

anisotropy

# Basic Properties of Materials

- anion – cation –anion – cation
- extremely strong
- Wiskers →reinforce
- If like ions are forced together, breakage results. Unlike metals, crystals cannot deform.

# Basic Properties of Materials

- alloy crystals grow
- anion – cation –anion – cation

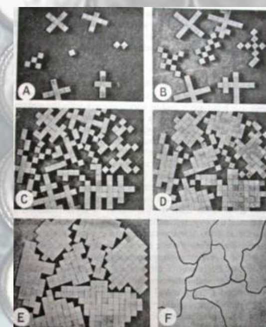
Order is the dream of man,

and chaos the rule of nature

## Basic Properties of Materials

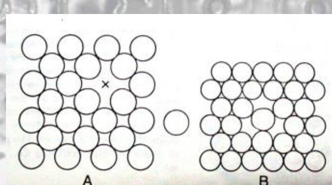
- Crystals penetrate each other such that the crystal shapes get deformed
- *Grains* → microns to centimeters
- *Grain boundaries*
- Atoms are irregularly arranged, and this leads to a weaker amorphous type structure.
- Alloy → combination of crystalline (grains) and amorphous (grain boundaries)

## Basic Properties of Materials

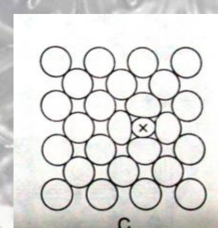



## Basic Properties of Materials

- ***Vacancies*** **– These are empty atom sites**

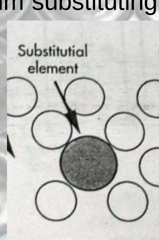



- ***Interstitials*** – **Smaller atoms that penetrate the lattice Eg – Carbon, Hydrogen, Oxygen, Boron.**




## Basic Properties of Materials

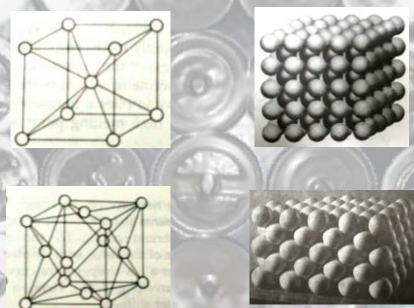
- **Substitutial Element** – another metal atom can substitute one of the same or similar size. E.g. - Nickel or Chromium substituting iron in stainless steel.




## Basic Properties of Materials

- The three dimensional arrangement of lines that can be visualized as connecting the atoms in undisrupted crystals, is called a lattice.
- *Unit cell*
- Crystal → combination of unit cells, in which each shell shares faces, edges or corners with the neighboring cells
- 14 crystal lattices

## Basic Properties of Materials

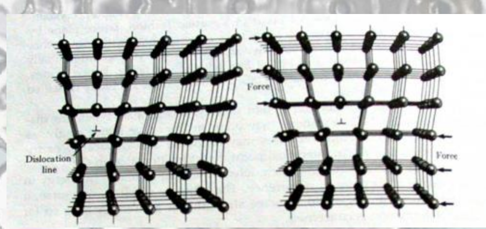


## Basic Properties of Materials

- **The atoms, which are represented as points, are not static. Instead, they oscillate about that point and are in dynamic equilibrium.**

## Basic Properties of Materials

- **various defects → *slip planes***




## Basic Properties of Materials

- **shear stress → atoms of the crystals can glide**
- **more the slip planes →easier is it to deform**
- **Slip planes intercepted at grain boundaries**

## Basic Properties of Materials

**If the shearing force is:-**

- *Small* **- atoms slip, and return back to their original position (elastic deformation)**
- *Beyond the elastic limit -* **crystal suffers a slight deformation permanent (plastic deformation)**
- *Greater stress* **- fracture**

## Basic Properties of Materials

- **During deformation - atomic bonds within the crystal get stressed ➥↑ resistance to more deformation**

**Number of atoms that get stressed also increases ➩↑ resistance to more deformation**

*Strain or work hardening or cold work*

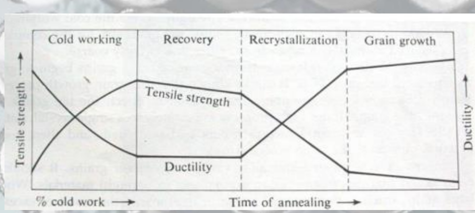
## Basic Properties of Materials

- Strain hardening
  - ➥ Hard and strong
  - ➥Brittle.
- Annealing – heat below melting point.
  - More the cold work, more rapid the annealing
  - Higher melting point – higher annealing temp.
  - ½ the melting temperature (ºK)

## Basic Properties of Materials

- Recovery
- Recrystallization
- Grain Growth

## Basic Properties of Materials




**Before Annealing**

**Recovery – Relief of stresses**

**Recrystallization – New grains from severely cold worked areas**

**Grain Growth – large crystal "eat up" small ones**

## Basic Properties of Materials

- Recovery Heat Treatment
  - Relief of internal stresses
  - Heating to low temperatures (370 – 480ºC) for 11 mins
  - Increase in *measured* elastic properties
  - Residual stresses + External stresses

## Basic Properties of Materials

- Various methods of obtaining smaller grain size

1. Enhancing crystal nucleation by adding fine particles with a higher melting point, around which the atoms gather.
2. Preventing enlargement of existing grains. Abrupt cooling (quenching) of the metal.

- Dissolve specific elements at elevated temperatures. Metal is cooled

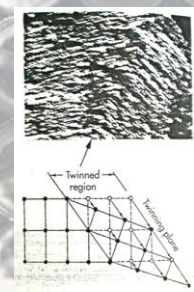
  Solute element precipitates ➩barriers to the slip planes.

## Basic Properties of Materials

Twinning

- Closed packed hexagonal type of crystals
- Two symmetric halves
- Fixed angle
- NiTi
- Subjected to a higher temperature, de - twinning occurs

## Basic Properties of Materials




## Basic Properties of Materials

Polymorphism

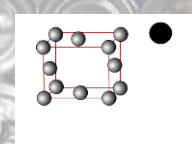
- Metals and alloys exist as more than one type of structure
- Transition from one to the other
- *Allotropy*
- At higher temperature, iron ⇨ FCC structure (austenite)
- lower temperatures, ⇨ BCC structure (ferrite)

## Basic Properties of Materials

Iron → FCC form (austenite),

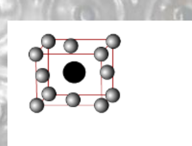
Lattice spaces greater,

Carbon atom can easily be incorporated into the unit cell



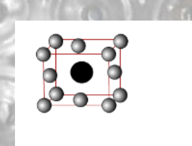
## Basic Properties of Materials

- On Cooling
- FCC → BCC
- Carbon diffuses out as FeC
- FeC adds strength to ferrite and austenite
- TIME



## Basic Properties of Materials

- Rapidly cooled (quenched)
  - Carbon cannot escape
- Distorted body centered tetragonal lattice called *martensite*



## Basic Properties of Materials

- Grain boundaries are more in number
- Alloy is stronger and more brittle
- Interstitials are intentionally incorporated into the alloy to make it hard when it is quenched.

## Basic Properties of Materials

- Cooled slowly
- Other crystal structures are formed at intermediate temperatures ➔Softer
- Some are stable at room temperature
- Ultimately, the final structure is softer and more workable

## Basic Properties of Materials

Tempering –

- Reheat the alloy to intermediate temperature
- Partial formation of the softer alloys
- More workable

## Basic Properties of Materials

- Some alloys
- FCC to BCC by rearrangement of atoms
- *Diagonal plane of the BCC unit becomes the face of the FCC unit*
- Shape memory alloys – Easy switching from one type of structure to another.
- *Bain distortion*
- Over a range of temperature {hysteresis}

## Elastic Properties

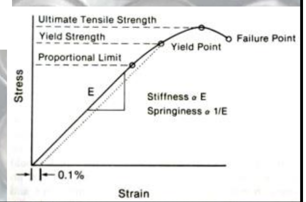
- Force applied to wire ⇨Deflection
- External force ⇨Internal force (equal and opposite)
- $\frac{\text{Internal force}}{\text{Area of action}}$ = Stress
- Deflection ⇨ $\frac{\text{change in length}}{\text{Original length}}$ = Strain

## Elastic Properties

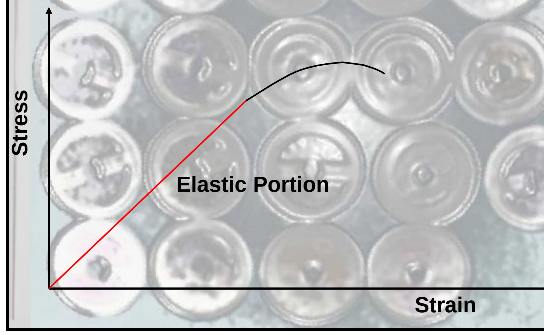
Types of stress/strain

- *Tensile*
- *Compressive*
- *Shear*
- *Complex force systems*

## Elastic Properties



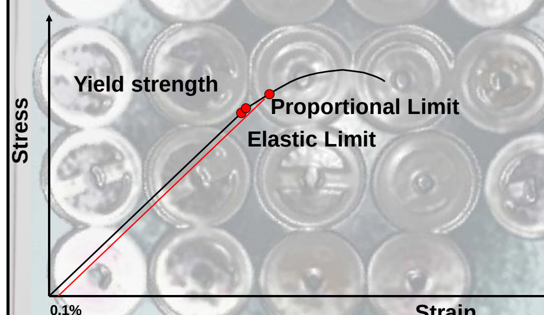

## Elastic Properties



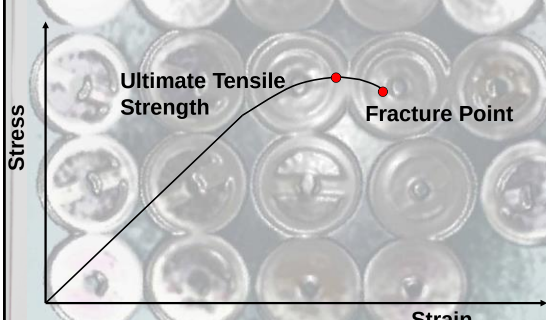

## Elastic Properties

- When the stress is removed, the wire returns back to its original dimension.
- Hooke's law

## Elastic Properties



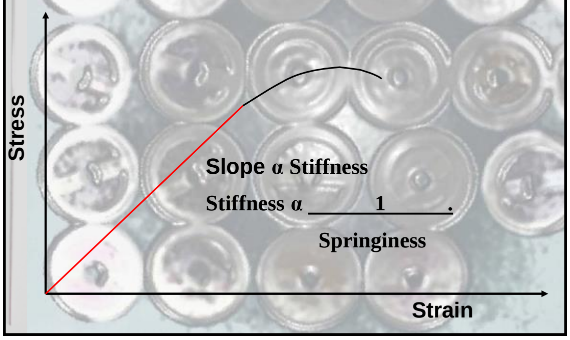

## Elastic Properties



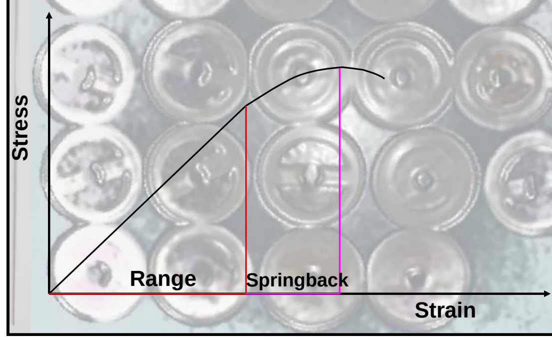

## Elastic Properties

- *ultimate tensile strength* is higher than the yield strength
- important clinically ⇨ maximum force that the wire can deliver
- Ultimate tensile strength higher than the stress at the point of fracture
  - reduction in the diameter of the wire

## Elastic Properties




## Elastic Properties




## Elastic Properties

Strength = Stiffness x Range

## Elastic Properties

*Resiliency -*

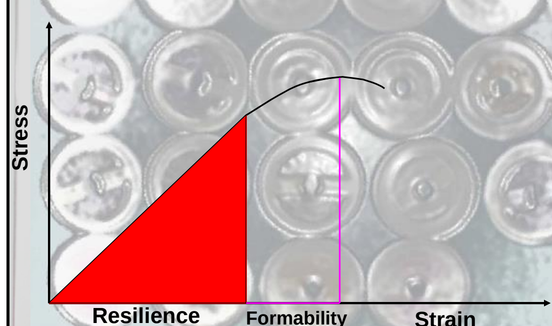
- When a wire is stretched, the space between the atoms increases. Within the elastic limit, there is an attractive force between the atoms.

Energy stored within the wire.

## Elastic Properties

- *Formability* - amount of permanent deformation that the wire can withstand without breaking
- Indication of the ability of the wire to take the shape
- Also an indication of the amount of cold work that they can withstand

## Elastic Properties



## Elastic Properties

- *Flexibility*
- large deformation (or large strain) with minimal force, within its elastic limit.
- Maximal flexibility is the strain that occurs when a wire is stressed to its elastic limit.

  Max. flexibility = Proportional limit / Modulus of elasticity.

## Elastic Properties

- *Toughness* –force required to fracture a material. Total area under the stress – strain graph.
- *Brittleness* –opposite of toughness. A brittle material, is elastic, but cannot undergo plastic deformation.
- *Fatigue* – Repeated cyclic stress of a magnitude below the fracture point of a wire can result in fracture. This is called fatigue.

## Requirements of an ideal archwire (Kusy

1. Esthetics
2. Stiffness
3. Strength
4. Range
5. Springback
6. Formability
7. Resiliency
8. Coefficient of friction
9. Biohostability
10. Biocompatibility
11. Weldability

## 1. Esthetics

- Desirable
- No compromise on mechanical properties
- White coloured wires discolour
- Destroyed by oral enzymes
- Deformed by masticatory loads
- Except the composite wires

## 2. Stiffness / Load deflection Rate

- Thurow - force:distance ratio, measure of resistance to deformation.
- Burstone – Stiffness is related to – wire property & appliance design

  Wire property is related to – Material & cross section.
- Wilcock – Stiffness α Load / Deflection

## Stiffness / Load deflection Rate

- Magnitude of the force delivered by the appliance for a particular amount of deflection.

Low stiffness or load deflection rate implies that:-

1) Low forces will be applied
2) The force will be more constant as the appliance deactivates
3) Greater ease and accuracy in applying a given force.

## Stiffness / Load deflection Rate

- The shape and cross section of a wire have an effect on the strength of the wire. The effects of these will be considered subsequently.

## 3. Strength

- Yield strength, proportional limit and ultimate tensile/compressive strength
- Kusy - force required to activate an archwire to a specific distance.
- Proffit - Strength = stiffness x range.
- Range limits the amount the wire can be bent, Stiffness is the indication of the force required to reach that limit.

## 4. Range

- Distance that the wire bends elastically, before permanent deformation occurs (Proffit).
- Kusy – Distance to which an archwire can be activated
- Thurow – A linear measure of how far a wire or material can be deformed without exceeding the limits of the material.

## 5. Springback

- Large springback
- Activated to a large extent.
- Hence it will mean fewer archwire changes.
- Ratio – $\frac{\text{yield strength}}{\text{Modulus of elasticity}}$

## 5. Springback

- Kusy - The extent to which a wire recovers its shape after deactivation
- Ingram et al – a measure of how far a wire can be deflected without causing permanent deformation. (Contrast to Proffit).

## 6. Formability

- Kusy – the ease in which a material may be permanently deformed.

## 7. Resiliency

- Amount of energy stored in a body.

## 8. Coefficient of friction

- Brackets (and teeth) must be able to slide along the wire
- High amounts of friction ⇨ anchor loss.

- 9. Biohostability:- site for accumulation of bacteria, spores or viruses. An ideal archwire must have poor biohostability.
- 10. Biocompatibility:- Resistance of corrosion, and tissue tolerance to the wire.
- 11. Weldability:- the ease by which the wire can be joined to other metals, by actually melting the 2 metals in the area of the bond. (A filler metal may or may not be used.)

## Properties of Wires

- Before the titanium alloys were introduced into orthodontics, the practitioners used only steel wires. So the way to control the stiffness of the wire was:-

1. Change the cross section of the wire
2. Increase the length of the wire (↑ inter bracket distance, incorporate loops.)

## Effects of Wire Cross Section

- Wires of various dimensions and cross sections.
- Does the wire need to be move teeth over large distances, or does it need to correct the torque of the tooth?
- Is it primarily going to be used to correct first order irregularities, or second order?

## Effects of Wire Cross Section

- primary factor ↴
  *load deflection rate* or stiffness
- play of the wire not very significant
- ligature ties minimizes the play in the first order

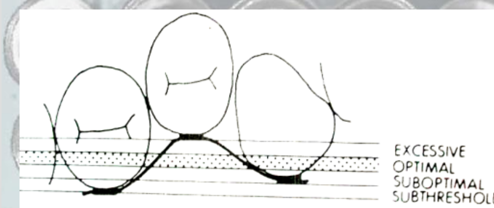
## Effects of Wire Cross Section

- Play in the second order –

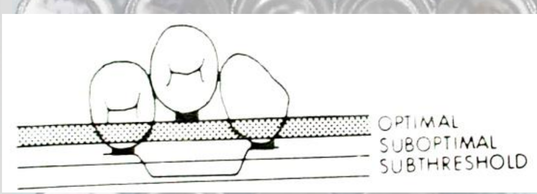
  0.016” wire in 0.022” slot is only 1.15 times the play of a 0.018” wire.

  The play in the second order becomes significant if the wire dimensions are drastically different (0.010” and 0.020”)

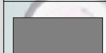
## Effects of Wire Cross Section




## Effects of Wire Cross Section

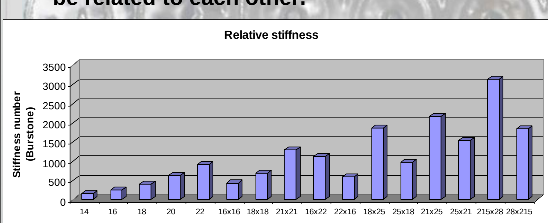



## Effects of Wire Cross Section

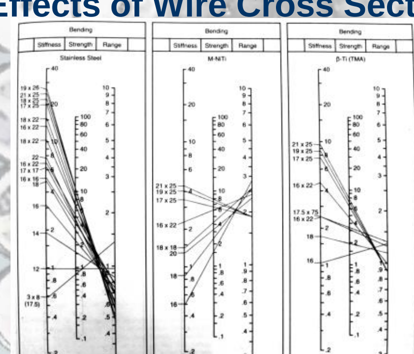
| Shape | Moment of Inertia | Ratio to stiffness of round wire |
|---|---|---|
|  | $\frac{\Pi d^4}{64}$ | 1 |
|  | $\frac{s^4}{12}$ | 1.7 |
|  | $\frac{b^3h}{12}$ | 1.7 $b^3h:d^4$ |

## Effects of Wire Cross Section

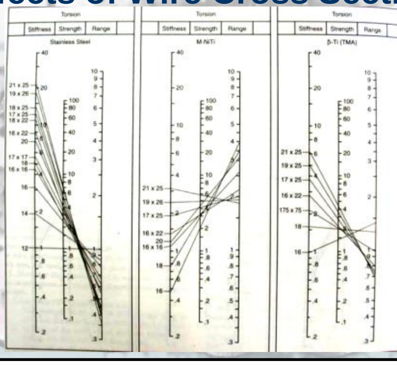
- Stiffness of different dimensions of wires can be related to each other.




## Effects of Wire Cross Section



## Effects of Wire Cross Section

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A rough idea can be obtained clinically as well

- Forming an arch wire with the thumb gives an indication of the **stiffness** of the wire.
- Flexing the wires between the fingers, without deforming it, is a measure of **flexibility**
- Deflecting the ends of an archwire between the thumb and finger gives a measure of **resiliency**.

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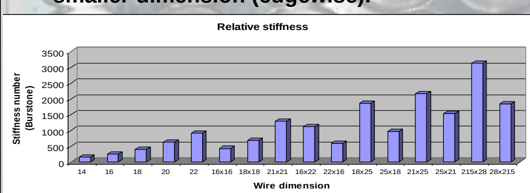
## Effects of Wire Cross Section

- Rectangular wires → bending perpendicular to the larger dimension (ribbon mode)
  easier than bending perpendicular to the smaller dimension (edgewise).

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## Effects of Wire Cross Section

- The larger dimension ⇨ correction is needed.
- The smaller dimension ⇨ the plane in which more stiffness is needed.
- > first order, < second order – RIBBON
- > Second order, < first order - EDGEWISE

---

## Effects of Wire Cross Section

- > 1st order correction in anterior segment
- > 2nd order in the posterior segment, wire can be twisted 90º

  ribbon mode in anterior region and edgewise in posterior region.

---

## Effects of Wire Cross Section

- If both, 1st & 2nd order corrections are required to the same extent, then **square** or **round wires**.
- The square wires - advantage -
  simultaneously control torque
  better orientation into a rectangular slot.
  (do not turn and no unwanted forces are created).

## Effects of Wire Cross Section

- In torsion - absolute values of strength, stiffness and range are different,
- but the overall effect of changing the diameter of the wire is the same.

1. Strength – Increases with increase in diameter
2. Stiffness – increases
3. Range – decreases.

## Effects of Length

- Loops,
- ↑ the inter-bracket distance

- For bending
1. Strength – decreases proportionately
2. Stiffness – decreases as a cubic function
3. Range – increases as a square.

## Effects of Length

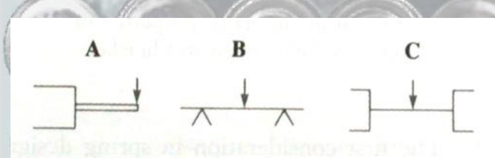
- In the case of torsion, the picture is slightly different. Increase in length –

1. Stiffness decreases proportionately
2. Range increases proportionately
3. Strength remains unchanged.

## Effects of Length

- Way the beam is attached also affects the values
- cantilever, the stiffness of a wire is obviously less
- wire is supported from both sides (as an archwire in brackets), again, the stiffness is affected

## Effects of Length




## Effects of Length

- Stiffness is also affected by the method of ligation of the wire into the brackets.

- Loosely ligated, so that it can slide through the brackets, it has ¼th the stiffness of a wire that is tightly ligated.

## Clinical Implications

- LIGHT CONTINUOUS FORCES
- Stiff wires should be taboo to the orthodontist?
- Springier wire, can be easily distorted in the harsh oral environment.
- Aim at ***balance***.

## Clinical Implications

- Removable appliance → cantilever spring
- The material of choice is usually steel. (Stiff material)
- Sufficiently thick steel wire
- Good strength to resist masticatory and other oral forces.
- Increase the length of the wire →
  - Proportionate decrease in strength, but the stiffness will decrease as a cubic function
  - Length is increase by either bending the wire over itself, or by winding helicals or loops into the spring

## Clinical Implications

- In archwires of stiffer materials the same principle can be used.
- The length of wire between brackets can be increased
  - loops, or smaller brackets, or special bracket designs.
- Also, the use of flexible wires

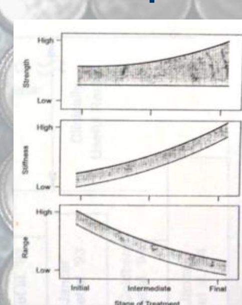
## Clinical Implications

- <u>Multi-stranded wires</u>
- Twisting of the two wires causes the strength to increase, so that the wire can withstand masticatory forces.
- The properties of multistranded wires depend on the individual wires that are coiled, and on how tightly they are coiled together.

## Clinical Implications

- Variable cross-section orthodontics.
- Variable modulus orthodontics.

## Clinical Implications



## Clinical Implications

- variable modulus orthodontics – Advantage-
  - relatively constant dimension
  - important for the third order control
- variable stiffness approach,
  - compromise control for getting a wire with adequate stiffness,
  - had to spend clinical time bending loops into stiffer archwires, which would offer less play.

## Clinical Implications

- Take into account the amount of force that wire can deliver.
- For example, a NiTi wire ⇨ efficient in tipping teeth to get them into alignment, but may not be able to achieve third order corrections.
- After using rectangular NiTi wires for alignment, rectangular steel wire must always be used to achieve the correct torque of the tooth.

## Corrosion

Nickel -

1. Carcinogenic,
2. mutagenic,
3. cytotoxic and
4. allergenic.

- Stainless steels, Co-Cr-Ni alloys and NiTi are all rich in Ni

## Corrosion

Placement in the oral cavity

↓

Greater peril than implanting

↓

Implanted material gets surrounded by a connective tissue capsule

↓

In the oral cavity, the alloy is free to react with the environment.

## Corrosion

- Passivating film ⇨ traces of Fe Ni and Mo.
- Aqueous environment
  - inner oxide layer
  - outer hydroxide layer.
- CrO is not as efficient as TiO in resisting corrosion ⇨some Ni release
- Improper handling ⇨ sensitization

## Corrosion

1. Uniform attack –
- the entire wire reacts with the environment,
- hydroxides or organometallic compounds
- detectable after a large amount of metal is dissolved.

2. Pitting Corrosion –
- manufacturing defects
- sites of easy attack

## Corrosion

Steel

NiTi

## Corrosion

3. Crevice corrosion or gasket corrosion -

- Parts of the wire exposed to corrosive environment
- Sites of tying to the brackets
- Plaque build up ⇨ disturbs the regeneration of the passivating layer
- Reach upto 2-5 mm
- High amount of metals can be dissolved in the mouth.

## Corrosion

4. Galvanic corrosion

- two metals are joined
- or even the same metal after different type of treatment (soldering etc)
- difference in the reactivity ⇨

Galvanic cell.

↙ ↘

Less Reactive (Cathodic) | More Reactive (Anodic)

## Corrosion

| Anodic | Cathodic |
|---|---|
| ⬇ | ⬇ |
| Looses Electrons | Accepts electrons |
| ⬇ | ⬇ |
| Soluble ions | Even less reactive |
| ⬇ | |
| Leach out | |

## Corrosion

5. Intergranular corrosion

- Sensitization

6. Fretting corrosion

- Wire and brackets contact
- Friction ⇨ surface destruction
- Pressure ⇨ rupture of the oxide layer
- Debris get deposited at grain boundaries, grain structure is disturbed.

## Corrosion

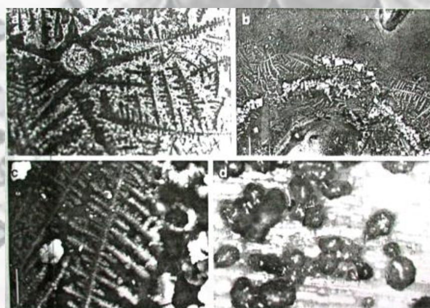
7. Microbiologically influenced corrosion

- Adhersive
- Craters at the base of brackets
- Or wires directly bonded on to teeth

shown by matasa.

- Certain bacteria dissolve metals directly form the wires.
- Others affect surface structure.

## Corrosion




## Corrosion

8. Stress corrosion

- Similar to galvanic corrosion
- Bending of wires ⇨ different degress of tension and compression.
- Alter the electrochemical behavior

↙ ↘

anode cathode

## Corrosion

9. Fatigue corrosion –

- Cyclic stressing of a wire
- Accelerated in a corrosive medium such as saliva

## Corrosion

- Analysis of used wires also indicated that a biofilm was formed on the wire.

*Eliades et al*

- Calcification
  - – Shielding the wire
  - – Protecting the patient form the alloy

## Corrosion

- Ni and Cr
  - – impair phagocytosis of neutrophils and
  - – impair chemotaxis of WBCs.
- Ni at conc. Released from dental alloys
  - – activating monocytes and endothelial cells,
  - – promote intracellular adhesion.
  - – This promotes inflammatory response in soft tissues.
- Arsenides and sulfides of Ni - carcinogens and mutagens.
- Ni at non toxic levels - DNA damage.

## ORTHODONTIC ARCH WIRE MATERIALS

## Precious Metals

- Upto about the 1950s
- Gold alloys
- Only wire which would tolerate the oral environment
- Crozat appliance – according to original design

## Stainless Steel

- 1919 – Germany ⇨ used to make prostheses.
- Extremely chemically stable
- High resistance to corrosion.
- Chromium content.

The chromium gets oxidized,

⬇

Impermeable, corrosion resistant layer.

## Stainless Steel

- Variety of stainless steels
- Varying the degree of cold work and annealing during manufacture
- Fully annealed stainless steel ⇨ extremely soft, and highly formable
- *Ligature wire*
- "Dead soft"

## Stainless Steel

- stainless steel arch wires are cold worked to varying extents, ⇨ yield strength increases, at the cost of their formability
- The steel with the highest yield strength, the Supreme grade steels, are also very brittle, and break easily when bent sharply.

## Stainless Steel

<u>Structure and composition</u>

- Chromium (11-26%)–improves the corrosion resistance
- Nickel(0-22%) – austenitic stabilizer
- copper, manganese and nitrogen - similar
  - amount of nickel added to the alloy
  - adversely affect the corrosion resistance.

## Stainless Steel

- Carbon (0.08-1.2%)– provides strength
- Reduces the corrosion resistance
- *Sensitization*.
- Improper cooling after heat treatment
  - During soldering or welding
  - 400-900°c
- Chromium diffuses towards the carbon rich areas (usually the grain boundaries)

## Stainless Steel

- Chromium carbides
- Amount of chromium decreases
- Chromium carbide is soluble, ⇨ intergranular corrosion.
- Stabilization

## Stainless Steel

- Stabilization –
  - Element which precipitates carbide more easily than Chromium.
  - Usu. Titanium.
  - Ti 6x> Carbon
  - No sensitization during soldering.
  - Most steels used in orthodontics are not stabilized.

## Stainless Steel

- Silicon – (low concentrations) improves the resistance to oxidation and carburization at high temperatures.
- Sulfur (0.015%) increases ease of machining
- Phosphorous – allows sintering at lower temperatures.
- But both sulfur and phosphorous reduce the corrosion resistance.

## Stainless Steel

<u>Manufacture</u>

Various steps –

1. Melting
2. Ingot Formation
3. Rolling
4. Drawing

## Stainless Steel

- Melting
  - Various metals of the alloy are melted
  - Proportion influences the properties
- Ingot formation
  - Molten alloy into mold.
  - Non uniform in compositon
  - Porosities and slag.
  - Grains seen in the ingot – control of grain size.

## Stainless Steel

- Porosities due to dissolved gasses (produced / trapped)
- Vacuum voids due to shrinking of late cooling interior.
- Important to control microstructure at this stage.

## Stainless Steel

- Rolling –
  - First mechanical process.
  - Ingot reduced to thinner bars
  - Finally form a wire
  - Different wires, slightly different composition.

## Stainless Steel

- Altering of the shape of grains during rolling
- Grains get elongated, defects get rearranged
- Work hardening.
- Wires starts to crack if rolling continues
- Annealing is done
- Rolling continued

## Stainless Steel

- Drawing
  - More precise
  - Ingot ⇨ final size.
  - Wire pulled through small hole in a die
  - Progressively smaller diameter.
  - Same pressure all around, instead of from 2 opposite sides.

## Stainless Steel

- Annealing at regular intervals.
- Exact number of drafts and annealing cycles depends on the alloy.

## Stainless Steel

<u>Classification</u>

- *American Iron and Steel Institute (AISI)*
- *Unified Number System (UNS)*
- *German Standards (DIN).*

## Stainless Steel

- The AISI numbers used for stainless steel range from 300 to 502
- Numbers beginning with *3* are all austenitic
- Higher the number ⇨
  - More the iron content
  - More expensive the alloy
  - Numbers having a letter L signify a low carbon content

## Stainless Steel

| Nr | Designation AISI | UNS | Example | Hardness (Rockwell) | Yield 0.2% (Ksi) | Strength (Ksi) | Elong. % | Reduct. % | PRE |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 304* | S-30300 | Ormco Diamond | — | 30 | 75 | 40 | 50 | 19 |
| 2 | 304L* | S-30403 | Advanced Orthod. | 81 (HRB) | 30 | 75 | 50 | 70 | 19 |
| 3 | 316L* | S-31603 | "A"-Co. stand. twins | — | 25 | 65 | 40 | 50 | 25.5 |
| 4 | 630/17-4† | S-17400 | Ormco Mini Diam. | 31 (HRC) | 115 | 140 | 12 | 50 | 16 |
| 5 | 631/17-7† | S-17700 | Ormco Edgelock | 38 (HRC) | 140 | 170 | 6 | 25 | 16 |
| 6 | SAF 2205 | S-31803 | CEOSA Low Ni | 30.5(HRC) | 65 | 90 | 25 | — | 32.15 |
| 7 | Mezanium* | — | Scheu Dental | — | — | — | 29.3 | | |
| 8 | Noninium* | — | Dentaurum | | | | | | |
| 9 | Ni Free‡ | (Fe26Cr 5Mo3Co) | Forestadent | 0 | — | — | — | — | 43 |
| 10 | NoNi‡ | (Fe24Cr 4Mo3Co) | Pyramid. Orthod. | — | — | — | — | — | 35.9 |
| 11 | 18-18 Plus* | S-28200 | — | 95(HRB) | 65 | 110 | 60 | 50 | 29.3 |
| 12 | 431‡ | S43100 | — | — | 110 | — | — | — | 16 |
| 13 | AL 29-4C‡ | S-44735 | Potential | — | 75 | 90 | 25 | — | 42.2 |
| 14 | Brass | — | Angle's German silver | 45(HRB) | 25 | 45 | 35 | — | |
| 15 | Titanium (implant type) | R-56400 | Dentaurum | 33-38(HRB) | — | 135 | 10 | — | — |
| 16 | Titanium (grade 2) | R50400 | Potential | — | 50 | 70 | 20 | — | — |

*Austenitic
†precipitation hardened, martensitic
‡ferritic.

## Stainless Steel

**Austenitic steels (the 300 series)**

- Corrosion resistance
- FCC structure, ⇨ non ferromagnetic
- Not stable at room temperature,
- Austenite stabalizers ⇨Ni, Mn and N
- Known as the **18-8 stainless steels.**

## Stainless Steel

**Martensitic steel**

- FCC ⇨ BCC
- BCC structure is highly stressed.
- More grain boundaries,
  - Stronger
  - Less corrosion resistant
- Making instrument edges which need to be sharp and wear resistant.

## Stainless Steel

**Ferritic steels** – (the 400 series)

- Good corrosion resistance
- Low strength.
- Not hardenable by heat treatment.
- Not readily cold worked.

## Stainless Steel

Austenitic steels more preferable :-

- Greater ductility and ability to undergo more cold work without breaking.
- Substantial strengthening during cold work. (Cannot be strengthened by heat treatment). Strengthening effect is due partial conversion to martensite.
- Easy to weld
- Easily overcome sensitization
- Ease in forming.

## Stainless Steel

**Duplex steels**

- Both austenite and ferrite grains
- Increased toughness and ductility than Ferritic steels
- Twice the yield strength of austenitic steels
- Lower nickel content
- Manufacturing low nickel attachments

## Stainless Steel

**Precipitation hardened steels**

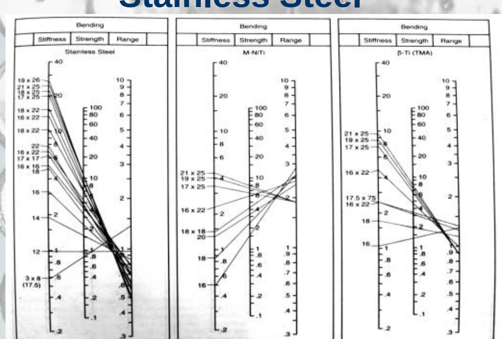
- Certain elements added to them ⇨ precipitate and increase the hardness on heat treatment.
- The strength is very high
- Resistance to corrosion is low.
- Used to make mini-brackets.

## Stainless Steel

**General properties of steel**

- Relatively stiff material

## Stainless Steel




## Stainless Steel

- Yield strength and stiffness can be varied
  - Altering the carbon content and
  - Cold working and
  - Annealing
- High forces - dissipate over a very short amount of deactivation (high load deflection rate).

## Stainless Steel

Clinical terms:-

- Loop - activated to a very small extent so as to achieve optimal force
- Deactivated by only a small amount (0.1 mm) Force level will drop tremendously
- Not physiologic
- More activations

## Stainless Steel

- Force required to engage a steel wire into a severely mal-aligned tooth.
  - Either cause the bracket to pop out,
  - Or the patient to experience pain.
- Overcome by using thinner wires, which have a lower stiffness.
- Fit poorly ⇨loss of control on the teeth.

## Stainless Steel

High stiffness ⇨

- Maintain the positions of teeth
- Hold the corrections achieved
- Begg treatment, stiff archwire, to dissipate the adverse effects of third stage auxiliaries

## Stainless Steel

- Lowest frictional resistance
- Ideal choice of wire during space closure with sliding mechanics
- Teeth be held in their corrected relation
- Minimum resistance to sliding

## Stainless Steel

- Ni is used as an austenite stabilizer.
- Not strongly bonded to produce a chemical compound.
- $\uparrow^{d}$ likelihood of slow release of Ni

## Stainless Steel

- Nickel and chromium content in the steel wires
- Cause patients to be sensitized
- Cause reactions in already sensitized patients

## Stainless Steel

- Passivating layer dissolved in areas of plaque accumulation – Crevice corrosion.
- Different degrees of cold work – Galvanic corrosion
- Different stages of regeneration of passivating layer – Galvanic corrosion
- Sensitization – Inter-granular corrosion

## High Tensile Australian Wires

<u>History</u>

- Early part of Dr. Begg's career
- Arthur Wilcock Sr.
  - Lock pins, brackets, bands, wires, etc
- Wires which would remain active for long
- No frequent visits
- This lead wilcock to develop steel wires of high tensile strength.

## High Tensile Australian Wires

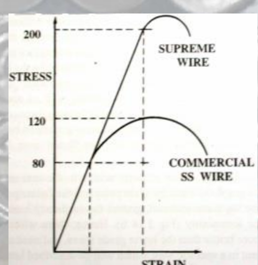
- Beginners found it difficult to use the highest tensile wires
- Grading system
- Late 1950s, the grades available were –
  - Regular
  - Regular plus
  - Special
  - Special plus

## High Tensile Australian Wires

- Newer grades were introduced after the 70s.
- Raw materials directly from the suppliers from out of Australia
- More specific ordering and obtaining better raw materials
- Higher tensile strength wires – premium

## High Tensile Australian Wires

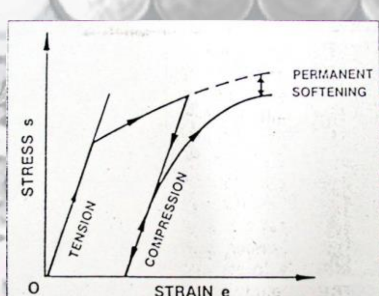
- Highly brittle, and broke easily
- Straightening the wire
  ➪ softening and loss of high tensile properties.




## High Tensile Australian Wires

- <u>Bauschinger effect</u>.
- Described by dr. Bauschinger in 1886.
- Material strained beyond its yield point in one direction,
  then strained in the reverse direction,
  its yield strength in the reverse direction is reduced.

## High Tensile Australian Wires




## High Tensile Australian Wires

- Plastic prestrain increases the elastic limit of deformation in the same direction as the prestrain.
- Plastic prestrain decreases the elastic limit of deformation in the direction opposite to the prestrain.
- If the magnitude of the prestrain is increased, the elastic limit in the reverse direction can reduce to zero.

## High Tensile Australian Wires

- Straightening a wire ⇨ pulling through a series of rollers
- Prestrain in a particular direction.
- Yield strength for bending in the opposite direction will decrease.
- Premium wire ⇨ special plus or special wire

## High Tensile Australian Wires

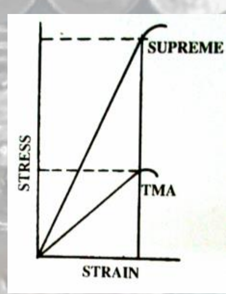
- Special pulsing process.

This method :

1. Permits the straightening of high tensile wires
2. Does not reduce the yield strength of the wire
3. Results in a smoother wire, hence less wire – bracket friction.

## High Tensile Australian Wires

- Higher yield strength ⇨ more flexible.
- Supreme grade ⇨flexibility = β-titanium.
- Higher resiliency ⇨ nearly three times.
- NiTi ⇨ higher flexibility but it lacks formability




## High Tensile Australian Wires

Mollenhauer ↴

- Supreme grade wire ⇨ faster and gentler alignment of teeth.
- Intrusion ⇨ simultaneously with the base wires
- Gingival health seemed better
- Originally in lingual orthodontics
- Equally good for labial orthodontics as well.

## High Tensile Australian Wires

Methods of increasing yield strength of Australian wires.

1. Work hardening
2. Dislocation locking
3. Solid solution strengthening
4. Grain refinement and orientation

## High Tensile Australian Wires

- Clinical significance of high yield strength.

Flexibility – $\frac{\text{Yield strength}}{\text{Elastic Modulus}}$

Resilience - $\frac{(\text{Yield strength})^2}{\text{Elastic Modulus}}$

- Plastic portion of the stress-strain graph is smaller ⇨ wires are more brittle.

## High Tensile Australian Wires

**Zero Stress Relaxation**

If a wire is deformed and held in a fixed position, the stress in the wire may diminish with time, but the strain remains constant.

Property of a wire to give constant light force, when subjected to external forces (like occlusal forces).

## High Tensile Australian Wires

external forces

⬇

particles slip over each other

⬇

activation of the wire is lost

Overcome

↙ ↘

Internal friction Between particles | ↑ yield strength

## High Tensile Australian Wires

- Zero stress relaxation in springs.
- To avoid relaxation in the wire's working stress
- Diameter of coil : Diameter of wire = 4
- smaller diameter of wires ⇨ smaller diameter springs (like the mini springs)
- Higher grade wires, ratio can be 2

## High Tensile Australian Wires

Twelftree, Cocks and Sims (AJO 1977)

- Premium plus, Premium and Special plus wires showed minimal stress relaxation.
- Special,
- Remanit,
- Yellow Elgiloy,
- Unisil.

## High Tensile Australian Wires

- Hazel, Rohan & West (1984)
  - Stress relaxation of Special plus wires after 28 days was less than Dentaurum SS and Elgiloy wires.
- Barrowes (82) & Jyothindra Kumar (89)
  - Higher working range among steel wires.

## High Tensile Australian Wires

- Pulse straightened wires – Spinner straightened (Skaria 1991)
  - Strength, stiffness and Range higher
  - Coeff. of friction higher
  - Similar surface topography, stress relaxation and Elemental makeup.

## High Tensile Australian Wires

- Anuradha Acharya (2000)
  - – Super Plus (Ortho Organizers) – between Special plus and Premium
  - – Premier (TP) – Comparable to Special
  - – Premier Plus – Special Plus
  - – Bowflex – Premium

## High Tensile Australian Wires

- Highest yield strength and ultimate tensile strength as compared to the corresponding wires.
- Higher range
- Lesser coefficient of friction
  - – Surface area seems to be rougher than that of the other manufacturers' wires.
- Lowest stress relaxation.

## High Tensile Australian Wires

<u>Fracture of wires and crack propagation</u>

Dislocation locking

⬇

High tensile wires have high density of dislocations and crystal defects

⬇

Pile up, and form a minute crack

⬇

Stress concentration

## High Tensile Australian Wires

Small stress applied with the plier beaks

⬇

Crack propagation

⬇

Elastic energy is released

⬇

Propagation accelerates to the nearest grain boundary

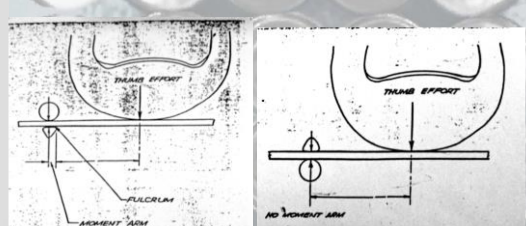
## High Tensile Australian Wires

<u>Ways of preventing fracture</u>

1. Bending the wire around the flat beak of the pliers.

   Introduces a moment about the thumb and wire gripping point, which reduces the applied stress on the wire.

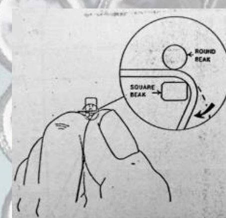
## High Tensile Australian Wires

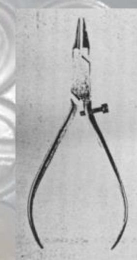


## High Tensile Australian Wires

2. The wire should not be held tightly in the beaks of the pliers.
   Area of permanent deformation to be slightly enlarged,
   Nicking and scarring avoided.
   The tips of the pliers should not be of tungsten carbide.

## High Tensile Australian Wires



## High Tensile Australian Wires

3. The edges rounded ⇨ reduce the stress concentration in the wire.

4. Ductile – brittle transition temperature slightly above room temperature.

   Wire should be warmed.

   Spools kept in oven at about 40º, so that the wire remains slightly warm.

## Multistranded Wires

- 2 or more wires of smaller diameter are twisted together/coiled around a core wire.
- Diameter - 0.0165 or 0.0175, but the stiffness is much less.
- On bending ⇨ individual strands slip over each other and the core wire, making bending easy.

## Multistranded Wires

As the diameter of a wire decreases –

- Stiffness – decreases as a function of the 4th power
- Range – increases proportionately
- Strength – decreases as a function of the 3rd power

- Multistranded wires ⇨ Small diameter wires, High strength

## Multistranded Wires

Elastic properties of multistranded archwires depend on –

1. Material parameters – Modulus of elasticity
2. Geometric factors – moment of inertia & wire dimension
3. Dimensionless constants
   – Number of strands coiled
   – Helical spring shape factor
   – Bending plane shape factor

## Multistranded Wires

Helical spring shape factor

- Coils resemble the shape of a helical spring.
- The helical spring shape factor is given as –

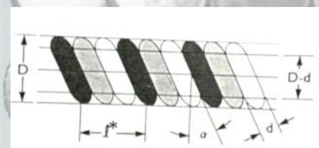
$$\frac{2\sin\alpha}{2 + v\cos\alpha}$$

α - helix angle and

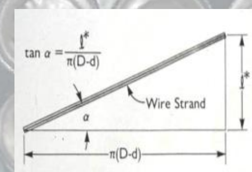
v - Poisson's ratio (lateral strain/axial strain)

Angle α can be seen in the following diagram :-

## Multistranded Wires




$$\alpha = \tan^{-1}\frac{l^*}{\pi (D-d)}$$




## Multistranded Wires

Bending shape factor

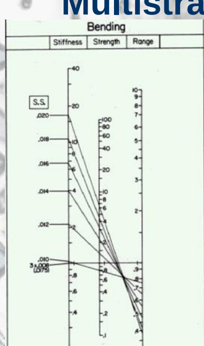
- Complex property
  - number of strands
  - orientation of the strands
  - diameter of the strands and the entire wire
  - helix angle etc.
- Different for different types of multistranded wires

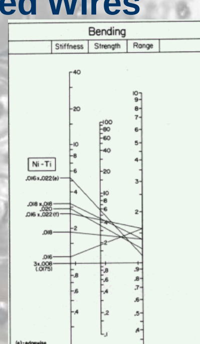
## Multistranded Wires

Kusy (AJO 1984)

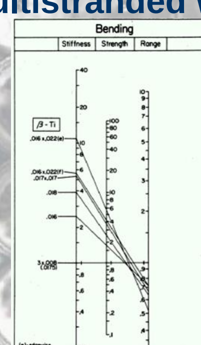
- Triple stranded 0.0175" (3x0.008") SS
- GAC's Wildcat
- Compared the results to other wires commonly used by orthodontists.

## Multistranded Wires




## Multistranded Wires



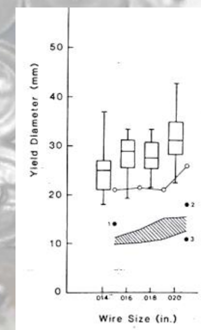
## Multistranded Wires

- Did not resemble the 0.018” SS wire except -
- Size
- Wire-bracket relation.

## Multistranded Wires

Ingram, Gipe and Smith (AJO 86)

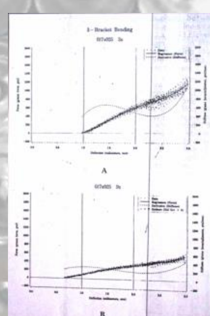
- Range independent of wire size
- Consistent for different configurations of wires.
- For round as well as rectangular multistranded wires.




## Multistranded Wires

Nanda et al (AO 97)

- Increase in No. of strands ↓ stiffness
- Unlike single stranded wires
  - stiffness varied as deflection varied.

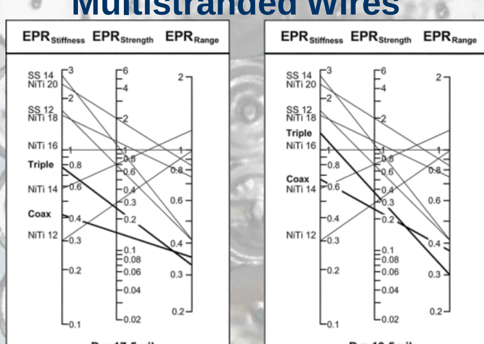


## Multistranded Wires

Kusy (AO 2002)

- Interaction between individual strands was negligible.
- Range and strength ⇨Triple stranded ≡ Co-axial (six stranded)
- Stiffness ⇨ Coaxial < Triple stranded
- Range of small dimension single stranded SS wire was similar.

## Multistranded Wires




## Friction

- Two bodies in contact,
- Relative motion

2 components :-

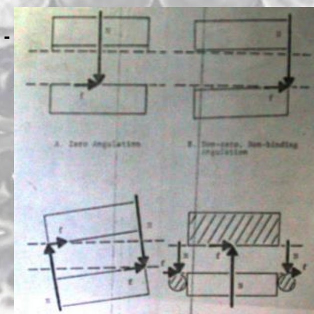
- Frictional force –contact force between the sliding surfaces and is opposite to it.
- Normal (perpendicular force) – forces that arise which are normal (perpendicular) to the two surfaces in contact

## Friction

- Frictional force = Coefficient of friction x normal force.
- Coefficient of friction
  – static
  – kinetic

## Friction

- Normal Force -



## Friction

- Friction is determined by the relative roughness of the two materials in contact. This depends on :-

1. The material itself
2. manufacturing process (polishing, heat treatment etc.)
3. Shelf and/or use time.(due to corrosion, creep etc)

## Friction

- Normal force –

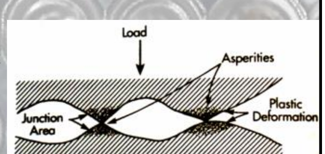
1. Stiffness of the wire in bending.

## Friction

- Friction is independent of the area of contact

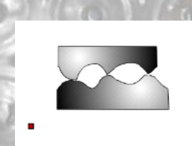
  \- Proffit

- Rough at molecular level – Asperities
- *Real contact* only at these spots.




## Friction

- Light loads can cause plastic deformation.
- Shearing of asperities.
- "Stick-slip" phenomenon.
- Interlocking of asperities.
- Harder materials plow into softer materials.



## Friction

Frank and Nikoli (AJO-1980)

- Friction depends on wire bracket angulation
  - At lower angulations ⇨surface
  - Higher angulations ⇨Normal force

## Friction

- Rectangular wires > Round wires
  - Greater area of contact.
- At higher angulations ⇨ 0.020" higher friction than some rectangular wires (17x25)

## Friction

Influence of wire material

- NiTi wires - rougher surface than steel or Elgiloy – more friction at low angulations
- at high angulations - normal force
  - NiTi ⇨ lower stiffness than steel or Elgiloy ⇨ lower frictional resistance.

## Friction

Stannard et al (AJO 1986)

- surface layer of oxides - harder than the material on the interior
- unpredictability of the exact area of contact
- Friction cannot be determined accurately every time.

## Friction

Before and after sliding-

- SS had a smooth and polished structure before sliding & surface roughness and wear tracks were seen after sliding
- β titanium had a grainy surface before and a smoother surface after sliding.
- NiTi and cobalt chrome had a fibrous surface before and no change after sliding.

## Friction

Dry and wet conditions

- Wet condition ↑ the coefficient of friction
- Except cobalt chromium
- Liquid ↑ the adhesion b/w molecules of the wire and bracket
- Saliva does not act as a lubricant

## Friction

- Stainless steel and β titanium - lowest friction.
- NiTi
- Cobalt Chrome. - Highest

## Friction

Tidy (AJO 1989)

- stainless steel - lowest friction
- NiTi second
- TMA
- TMA 5 times > stainless steel

## Friction

- At high wire bracket angulations – normal force more important.
  - Initial stages – High friction of steel wires
  - NiTi and β titanium have lower friction. (lower stiffness)
- After alignment, surface characteristics more important
  - Steel has smoother surface.

## Friction

- Round or Rectangular for sliding?
  - After alignment, difference is negligible.
  - Rect. Wire ⇨Better torque control

➔Leave rect. Wire in place for final corrections

➔Start sliding after 1 visit.

## Welding of Steel

- 3 useful properties –

1. Comparatively low melting point,
2. High electrical resistance and
3. Low conductivity of heat.

## Welding of Steel

- Important to
  - minimize the time of passing the current
  - minimize the area of heating
- Sensitization - between 400 and 900°C
- Chromium carbides need time for their formation.

## Welding of Steel

- Join two thin sheets of metal
- Same thickness
- Joining tubes, wires and springs, soldering is generally recommended.
- Electrodes - small tips, not exceeding 1 mm in diameter.

## Cobalt Chromium

- 1950s the Elgin Watch
- Rocky Mountain Orthodontics
- Elgiloy
- CoCr alloys - satellite alloys
  - superior resistance to corrosion, comparable to that of gold alloys.

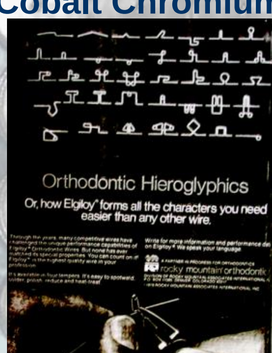
## Cobalt Chromium

- Cobalt – 40-45%
- Chromium – 15-22%
- Nickel – for strength and ductility
- Iron, molybdenum, tungsten and titanium to form stable carbides and enhance hardenability.

## Cobalt Chromium

- Strength and formability modified by heat treatment.
- The alloy is highly formable, and can be easily shaped.
- Heat treated.
  - Strength ↑
  - Formability ↓

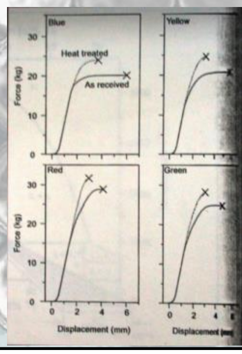
## Cobalt Chromium




## Cobalt Chromium

- Heat treated at 482ºc for 7 to 12 mins
- Precipitation hardening
  - ↑ ultimate tensile strength of the alloy, without hampering the resilience.
- After heat treatment, elgiloy had elastic properties similar to steel.

## Cobalt Chromium




## Cobalt Chromium

- Blue – soft
- Yellow – ductile
- Green – semiresilient
- Red – resilient

## Cobalt Chromium

- Blue ⇨considerable bending, soldering or welding
- Red ⇨ most resilient and best used for springs
  - difficult to form, (brittle)
  - After heat treatment , no adjustments can be made to the wire, and it becomes extremely resilient.

## Cobalt Chromium

After heat treatment ⇨

- Blue and yellow ≡ normal steel wire
- Green and red tempers ≡ higher grade steel

## Cobalt Chromium

- Heating above 650ºC
  - partial annealing, and softening of the wire
- Optimum heat treatment ⇨ dark straw color of the wire
- advantage of Co-Cr over SS is –
  - Greater resistance to fatigue and distortion
  - longer function as a resilient spring

## Cobalt Chromium

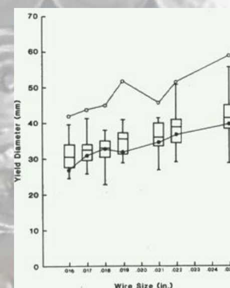
- Properties of Co-Cr are very similar to that of stainless steel.
- Force
  - 2x of β titanium and
  - 1/4th of niti.

## Cobalt Chromium

- Frank and Nikoli (1980)
  - Co-Cr alloys ≡ stainless steel.
- Stannard et al (AJO 1986)
  - Co-Cr highest frictional resistance in wet and dry conditions.

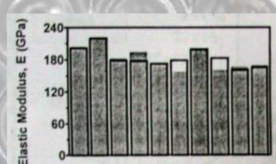
## Cobalt Chromium

- Ingram Gipe and Smith (AJO 86)
- Non heat treated
  - Range < stainless steel of comparable sizes
- But after heat treatment, the range was considerably increased.



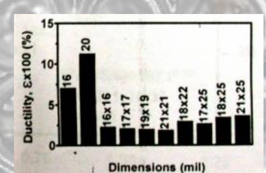

## Cobalt Chromium

- Kusy et al (AJO 2001)
- The elastic modulus did not vary appreciably ⇨ edgewise or ribbon-wise configurations.



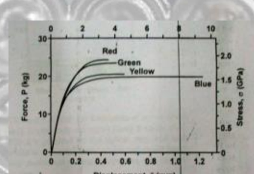

## Cobalt Chromium

- Round wires ⇨ higher ductility than square or rectangular wires.




## Cobalt Chromium

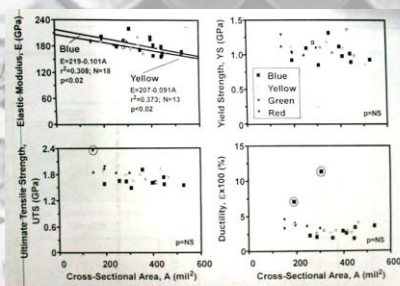
- As expected, the modulus of elasticity was independent of temper of the wire.




## Cobalt Chromium

- Elastic properties (yield strength and ultimate tensile strength and ductility) were quite similar for different cross sectional areas and tempers.
- This does not seem to agree with what is expected of the wires.

## Cobalt Chromium




## Cobalt Chromium

- Different tempers with different physical properties – attractive
- More care taken during the manufacture of the wires.

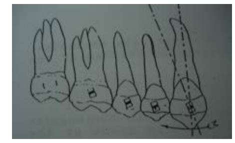
# Andrew’s straight wire appliance (SWA)

Presented by:
Dr. Kamal Bajaj
Professor and Head,
Department of Orthodontics and Dentofacial Orthopedics,
MG Dental college and Hospital
Jaipur

## History

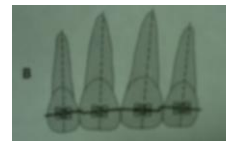
ANGLE (1929)

- ✓ ANGULATED BRACKETS TO PRODUCE TIPPING
- ✓ ANGULATED POSTERIOR BRACKETS FOR ROOT MOVEMENTS



TWEED (1941)

- ✓ “ARTISTIC POSITIONING BENDS” IN WIRES FOR CORRECT AXIAL RELATIONSHIPS



Am J Orthod Dentofacial Orthop
2015;147:654-62

HOLDAWAY (1952)

PUBLISHED A LANDMARK ARTICLE IN 1952 DESCRIBED 3 USES OF BRACKET ANGULATION

- AIDS IN PARALLELING ROOTS ADJACENT TO EXTRACTION SITES
- METHOD OF SETTING UP POSTERIOR ANCHORAGE
- TO OBTAIN CORRECT AXIAL INLINATIONS.

Am J Orthod Dentofacial Orthop
2015;147:654-62

JOHN STIFTER (1958)

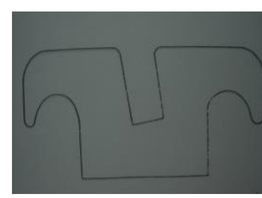
BRACKETS WITH MALE AND FEMALE ATTACHMENT

IVAN LEE(1960)

BRACKETS OF UPPER ANTERIORS AND LOWER POSTERIORS HAD TORQUED SLOTS

JARABACK (1962)

SUGGESTED THAT UPPER ANTERIORS BE TORQUED AND ANGULATED



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IN 1960’S MANUFACTURERS-

- ✓ RAISED THE BASE OF UPPER LATERAL INCISORS TO ELIMINATE LATERAL OFFSET
- ✓ MOLAR TUBES WITH 10° OFFSET AND TORQUE FOR ROTATIONAL CONTROL

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LAWRENCE F. ANDREWS’ STRAIGHT WIRE APPLIANCE (1976)

2 PRESCRIPTIONS

- ➢ STANDARD (NON EXTRACTION)
- ➢ TRANSLATION (EXTRACTION)

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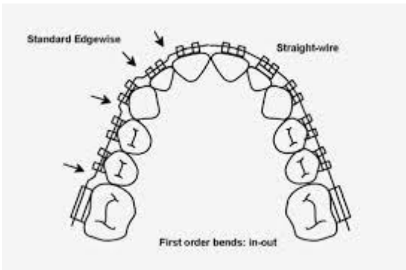
'a sophisticated edgewise appliance'.




Lawrence F. Andrews D.D.S. (1979) The Straight-Wire Appliance, British



## Qualities:

- Customized brackets for individual tooth.
  - Size of teeth
  - Gingival and hygienic factors
  - Ease of clinical use
  - Patient comfort
  - Reduction of occlusal interference

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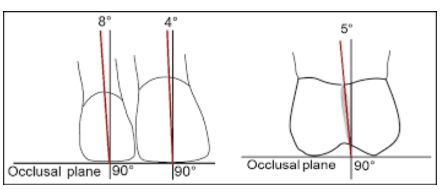
- Pre-angulated slots for mesiodistal tooth tip

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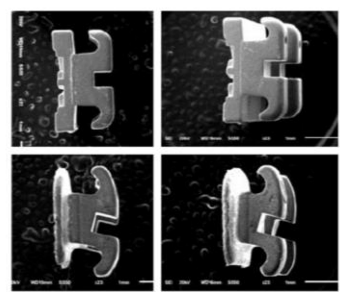
- The bases of the brackets are inclined for each tooth type, to achieve proper tooth 'torque'



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- SWA bases are contoured vertically as well as horizontally
- The distance from the base of the slot to the base of the bracket varies for each tooth type.

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- The guidance features are preprogrammed to reflect research findings that are consistent with the requirements of functional occlusion.
- Extraction Brackets were available, and provided anti-tip and anti-rotation features which promote bodily movement.

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## The story behind SWA

- Eleven hundred and fifty models of patients treated by orthodontists were studied from 1965 to 1971
- Later, compared with 120 models of paients with minimal or no requirement of orthodontic therapy.

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## Six keys of occlusion

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## Key 1

- *Molar relationship.*
- The distal surface of the distal marginal ridge of the upper first permanent molar contacts and occludes with the mesial surface of the mesial marginal ridge of the lower second molar.

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- The mesio-buccal cusp of the upper first permanent molar falls within the groove between the mesial and middle cusps of the lower first permanent molar.
- The mesio-lingual cusp of the upper first molar seats in the central fossa of the lower first molar.

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## Key 2

- *Crown angulation - the mesio-distal 'tip'.*
- In normally occluded teeth, the gingival portion of the long axis of each crown is distal to the occlusal portion of that axis. The degree of tip varies with each tooth type.

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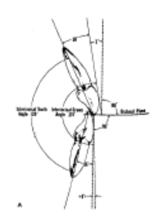
## Key 3

- *Crown inclination, the labio-lingual or buccolingual 'torque'.*
- Crown inclination is the angle between a line 90 degrees to the occlusal plane, and a line tangent to the middle of the labial or buccal clinical crown.



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## Key 4

- *Rotations.*
- Teeth should be free of undesirable rotations.

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## Key 5

- *Tight contacts.*
- In the absence of such abnormalities as genuine tooth-size discrepancies, contact points should be tight.

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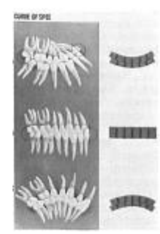
## Key 6

- *Curve of Spee.*
- A flat occlusal plane should be a treatment goal as a form of overtreatment. Measured from the most prominent cusp of the lower second molar to the lower central incisor, no curve was deeper than 1·5 mm in the non-orthodontic normals.



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## Seventh key

- *Boltons tooth size ratio*
- In order for maxillary teeth to fit well with the mandibular teeth, for esthetics, occlusal stability and functional harmony there must be a definite proportionality of tooth size.
- Bolton proposed the inter-maxillary ratio to aid in determining disproportion in size between maxillary and mandibular teeth.

Bolton W. A. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Ortho 1958; 28:113-

23

## Why was a new appliance needed?

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## Individual tooth prescription!

- Although innovations had come to help avoid first, second and third order bends ; a prescription was needed which would have a defined set of dimensions for individual teeth.



## Torque more than 5°?

- It was not possible to inculcate more than 5° torque in face of the bracket which made it complicated for the clinician.



## Wagon wheel effect

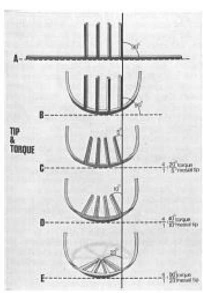
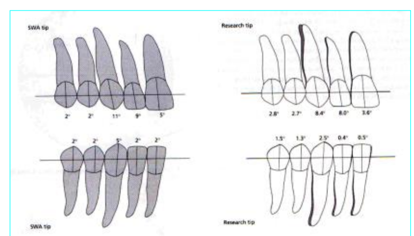



Fig. 1. The wagon wheel. Anterior archwire torque negates archwire tip in a ratio of 4:1. Clinical result is that the gingival portions of the crowns converge 1° for each 4° of lingual torque placed in the wire.

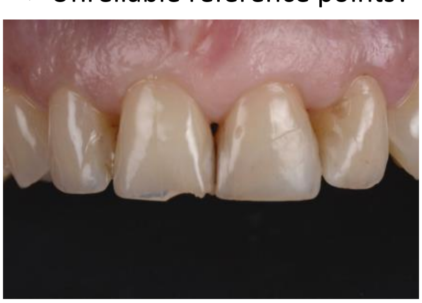


## Tip in Andrew's SWA






## Banding of all teeth on arbitary points? => Unreliable reference points?





## How did reference points change in SWA?

- *The long axis of the clinical crown (LACC)*

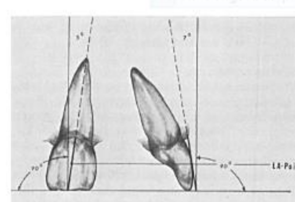



Fig. 2. The long axis of the clinical crown, and the LA-point.

- Viewed from the buccolabial perspective:
- For molars the LACC is identified by the dominant vertical groove on the buccal surface.
- For all other teeth it is at the vertical mid-developmental ridge, the most prominent portion in the central area of the buccolabial surface.



- Viewed from mesiodistal perspective, the LACC is represented by a line tangent to the middle of the crown's labial or buccal surface.
- For molars it parallels the dominant groove.
- For all other teeth, it parallels the mid-developmental ridge



# The LA-point

- We can measure from the cemento-enamel junction when establishing the midpoint of the clinical crown.

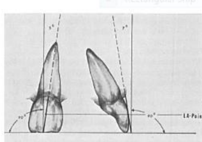


Fig. 2. The long axis of the clinical crown, and the LA-point.



# Terminology related to SWA brackets

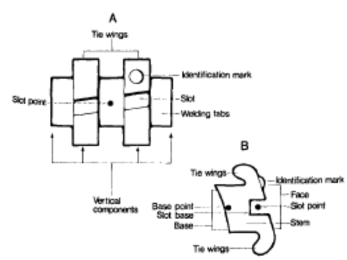


Fig. 3. Bracket components.



# The Andrews Plane

Assuming no curve of Spee, an imaginary plane that would intersect the crowns of properly positioned teeth at their LA- points, separating the occlusal and gingival portions of each crown.

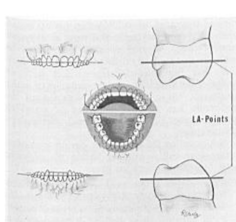


Fig. 4. Andrews Plane and the LA-point.



# Crown Angulation

The degree of crown tip is the angle formed by the long axis of the clinical crown (as viewed from labial or buccal perspective) and a line perpendicular to the occlusal plane.
•Plus – gingival portion distal to occlusal
•Minus – gingival portion mesial to occlusal

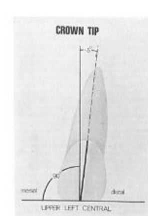


Fig. 5. Crown angulation or 'tip'.

## Crown Inclination

•Plus- gingival portion of the crown is lingual to the occlusal portion

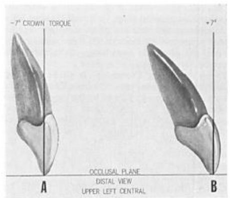



Fig. 6. Crown inclination or 'torque'.

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## SWA Design

- Pretorqued brackets

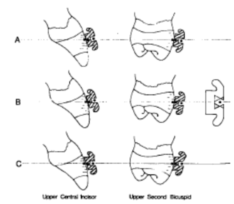


Fig. 8. (A) Untorqued edgewise brackets located at LA-point. (B) Pretorqued edgewise brackets located at LA-point; and (far right) two such brackets superimposed. (C) Straight-Wire brackets on the LA-point.

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## Torque in base

Pre-torqued edgewise brackets


SWA brackets

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- Curved base of the bracket

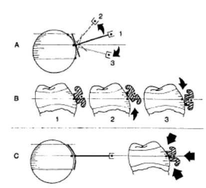


Fig. 7. (A) Rolling potential of a flat-base bracket on curved surface of a crown, indicating effects on torque, on height of slot, and on horizontal distance of slot from intended bracket site—which affects in/out requirements. (B) Three of the possible bracket positions inherent in the rolling potential described above. (C) Bracket with vertically curved base eliminates the rolling potential, assuring consistent location of slot in relation to bracket site.

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## Effect of flat base on torque

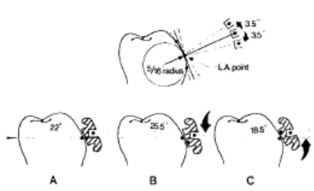


Fig. 10. Effect on torque of flat-base bracket's rolling potential.

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## Effect of flat base on tip

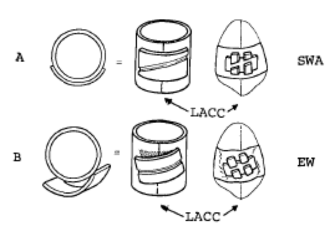


Fig. 11. (A) When tip is built into the slot, the bracket can mate solidly with the tooth. (B) When bracket is angulated on tooth to accomplish tip, a rocking potential is created.

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## In/Out and molar Offset

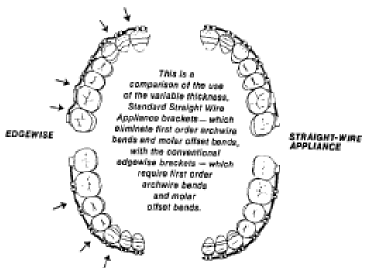
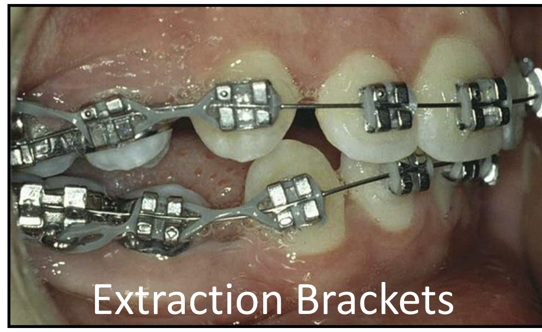
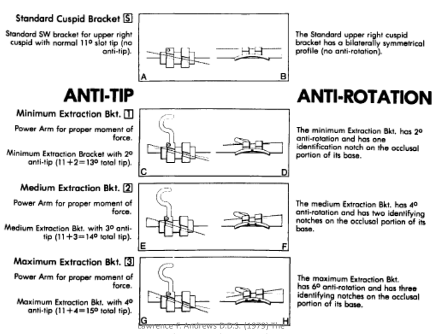



Fig. 12. In/out and upper molar offsets in the SWA.










## Anti-torque

- Upper molars are the only three rooted teeth and they require special consideration when they are moved mesially. Their dominant lingual root causes their buccal surfaces to rotate not only mesially but also to rotate gingivally.



- This gingival rotation intrudes the buccal cusps and extrudes the lingual cusps, resulting in potential lateral excursion interferences.
- The amount of anti-torque for the minimum Extraction Bracket is 4° (4+9= 13 total degrees), 5° for the medium (5+9= 14°), and 6° for the maximum (6+9= 15°).



## Class II molar brackets

- An upper bicuspid only extraction case or congenitally missing upper laterals would be examples of this situation.
- In this position, the long axis of the upper molar crowns should be upright and no distal buccal offset is needed. Class II molar brackets meet this need with 9° torque but no tip and no molar offset.

# Incisor Bracket Sets

**Incisor bracket sets***

| | | | | |
|---|---|---|---|---|
| **Set A**[1] | | | | |
| Upper torque | −2° | 2° | 2° | −2° |
| Lower torque | 4° | 4° | 4° | 4° |
| **Set S (Standard)**[2] | | | | |
| Upper torque | 3° | 7° | 7° | 3° |
| Lower torque | −1° | −1° | −1° | −1° |
| **Set C**[3] | | | | |
| Upper torque | 8° | 12° | 12° | 8° |
| Lower torque | −6° | −6° | −6° | −6° |

* All sets have standard amounts of tip.
[1] Recommended for Class II skeletal tendencies.
[2] Recommended for Class I skeletal relationships.
[3] Recommended for Class III skeletal tendencies.



# Advantages of having a straight wire

- A flexed archwire provides force only until it returns to its original passive form. When it stops working, its passivity is a signal that the goals are reached.
- Even if a patient misses an appointment, no unplanned overtreatment occurs, because the appliance is self-limiting.
- The angulations, the inclinations, the bracket sitings, the built-in treatment process itself - all are referenced to the same known point



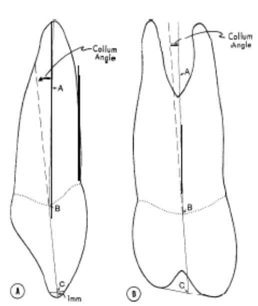
# Disadvantages of Andrew’s system

- Facial surface contours are not consistent among teeth of the same type. Standard deviations ranged from +- 2.6 ° to 6.4 ° for the point studied.
- This variability increases progressively between teeth from anterior to posterior in both the upper and the lower arches.
- Facial surface contours do vary but not in a regular manner from incisal/occlusal to gingival areas. Vertical placement errors of 1 mm can alter torque values present by up to 10° for the points studied.



- Faciolingual tooth position is controlled by several biologic morphologic variables in addition to bracket slot positioning.
- Use of a prescribed bracket torque may improve care of some patients but not of others.






Variation in the long axis of the crown to the long axis of the root (collum angle) necessarily results in different faciolingual root positions in spite of constant crown positions.



# Appliances inspired by SWA

- Roth
- MBT
- STb Light Lingual System
- Orapix-a straight wire lingual technique

## Conclusion

- The SWA is programmed to deliver treatment to optimum end results with few if any archwire bends.

Lawrence F. Andrews D.D.S. (1979) The Straight-Wire Appliance, British

# THEORIES OF GROWTH

Presented by:
Dr. Kamal Bajaj
Professor and Head,
Department of Orthodontics and Dentofacial Orthopedics,
MG Dental college and Hospital
Jaipur

Sound knowledge of growth and development is essential for successful orthodontic treatment.

**DEFINATION:**

- Self multiplication of living substance–**J.S. HUXLEY**
- Increase in size, change in proportion and progressive complexity– **KROGMAN**
- An increase in size – **TODD**
- Entire series of sequential anatomic and physiologic changes taking place from the beginning of prenatal life to senility. – **MERIDITH**
- Quantitative aspect of biologic development per unit of time. – **MOYERS**
- Change in any morphological parameter which is measurable - **MOSS**

**Various theories of growth were proposed.**

- **Genetic theory**
- **Sutural theory**
- **Cartilaginous theory**
- **Functional matrix concept**
- **Multifactorial theory**
- **V principle and remodelling pattern theory**
- **Enlows counterpart principle**
- **Neurotrophic process theory**

**GENETIC THEORY:**

- **Genes are exclusive determinants of all growth parameter, including regional growth amount velocities and minute details of regional configuration.**
- **Genes are indeed a basic participant in the operation of any given cells organelles leading to the organelles leading to the expression of that cells function.**

**APPROVAL:**

**Role of genetic preprogramming has been presumed by many to have a fundamental and overriding influence in establishing basic facial pattern and the features upon which internal and external environment then begin to play.**

**SUTURAL THEORY:**
**Given by "SICHER"**

**According to sutural theory paired parallel sutures that attached facial areas to the skull and the cranial base region push the nasomaxillary complex forward to pace its growth with that of mandible.**

## DISAPPROVAL:

Suture is essentially ***A Tension Adapted Tissue***. The sutural membrane cannot with stand any undue amount of compression because pressure affects its vascular and cellular components.

- So stimulus for sutural bone growth is the tension produced by the displacement of that bone, rather than the *force* it causes it.
- When an area of the suture is transplanted to another location the tissue does not continue to grow. Thus indicating *lack of innate growth potential* of suture.
- Growth takes place in untreated cases of cleft palate even in absence of suture.
- Microcephaly and hydrocephaly raised doubts about the intrinsic genetic stimulus of suture.

## EXPERIMENTS TO PROVE DISAPPROVAL

1. *KOSKI'S EXPERIMENT* – He observed that the trabecular pattern of bone at suture changes with age probably indicating changes in direction of growth and it is difficult to believe that sutural tissue itself could alter that direction of growth.

   Change in trabecular pattern with age changes in direction of growth

2. *WATENBE et al 1957*– He did an experiment in which zygomaticomaxillary suture was auto transplanted in abdominal wall of a guinea pig. He placed metallic implant an either side of sutures. He observed gradual narrowing and final obliteration of suture.

   Then he concluded that there in no autonomous growth potential in the suture tissue

## EXPERIMENTS TO PROVE DISAPPROVAL

*SARNAT (AO56)* – Extirpation of facial sutures have no effect on dimensional growth.

*MOSS* – He showed that the shape of suture is dependent on functional stimuli.

It is possible to bring the sutural growth to half. Such mechanical forces as metal clips applied across sutures or bridge in the sutures.

From above it is clear that suture tissue *do not have an independent growth potential*. Sutures do not have tissue separating force and therefore are *not comparable to growth centre*.

## CARTILAGINOUS THEORY:

Put forward by "JAMES SCOTT"

- According to cartilaginous theory, cartilage is specifically adapted to certain pressure related growth sites, because
- it is a special tissue uniquely structured to provide the *capacity for growth in field of compression.*
- Intrinsic growth controlling factors are present in cartilage and periosteum, with sutures being only secondary.
- Cartilaginous sites through out the skull as *primary centres of growth*. For example Growth of maxilla is attributed to the *Nasal Septal Cartilage.*

## APPROVAL :

- Pressure accommodating expansion of the cartilage in the nasal septum provides a source for the physical force that displaces the maxilla anteriorly and inferiorly. This sets up the *fields of tension in all maxillary sutures.*

  The *bones then secondarily* but almost simultaneously *enlarge at their suture* in response to the tension created by the displacement process.
- Nasal septal cartilage and epiphyseal plate shows innate growth potential on being transplanted to another site.
- If nasal septal cartilage is removed then midface development is retarded.

## DISAPPROVAL:

- Maxillary displacement is probably *multifactorial* in nature other factors probably control as well.
- During surgical deletion of cartilage to test the nature of their functional roles in growth destruction of tissues like blood vessels and nerves also occur and *variables are introduced in experimental procedure.*

FUNCTIONAL MATRIX CONCEPT:

Put forward by "MELVIN MOSS"

- States that any given bone grows in response to functional relationship established by the sum of the soft tissues operating in association with that bone.

- The functional matrix hypothesis claims that the origin form position growth and maintenance of all skeletal tissues and organ are always *secondary compensatory and necessary responses* to chronologically and morphologically prior events or processes that occur in specifically related *non skeletal tissues organs and functioning spaces.*

- Bone itself does not regulate the rate and direction of its own growth. *Functional matrix concept is the actual determinant.*

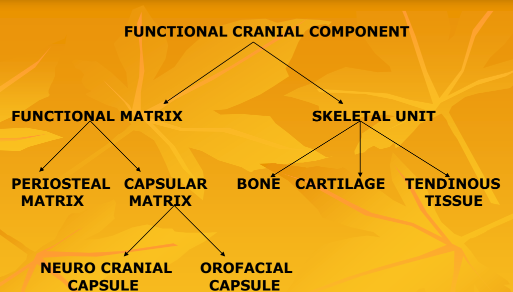
- Course and extent of bone growth are secondarily dependent upon the growth and functioning of pace making soft tissue.
  Bone and cartilage are also involved. They participate in giving *essential feed back information to soft tissue.*

This causes soft tissues to inhibit or accelerate the rate and amount of subsequent bone growth activity depending on the status of functional mechanical *equilibrium between bone and its soft tissue matrix.*

Thus for nasamaxillary complex the growth expansion of facial muscles the subcutaneous and submucosal connective tissues oral and nasal epithelial lining the spaces the vessels and nerves *combine to move facial bone passively* along with them as they grow. This places each bone in correct anatomic position to carry out its function.

- According to functional matrix theory relatively independent functions are carried out by their respective "FUNCTIONAL CRANIAL COMPONENT"

Concept of functional cranial component was given by "VAN DER KLAAUS"




Each functional cranial component consists of *tissues, organ spaces and skeletal parts* necessary to carry out a given function.

THE FUNCTIONAL MATRIX:

- Consists of muscles, glands nerves, vessels, fat, teeth and functioning spaces divided into
- Periosteal matrix
- Capsular matrix

PERIOSTEAL MATRIX:

- Act *directly and actively* upon related skeletal unit.
- Alteration in functional demand produce a *secondary transformation* of the *size and shape* of skeletal unit.
- Transformation brought about by process of bone deposition and resorption.
- Periosteal matrix include muscles, blood vessels, nerves, glands etc.

CAPSULAR MATRIX:

- Act *indirectly and passively* on their related skeletal units.
- Produces *secondary translation in space.*
- Transformation brought about by the *expansion of the orofacial* capsule within which facial bones arise grow and maintained.
- Examples are *neuro- cranial and orofacial capsule.*
- Capsule is an envelop and contain series of functional cranial component like in neuro cranial capsule, cover consists of skin and duramater.
  In orofacial capsule the skin and mucosa forms the covering.

SKELETAL MATRIX:

- All skeletal tissues associates c a single function are called as "THE SKELETAL UNIT"
- When bone is comprised of several contiguous skeletal units they are termed as "MICRO SKELETAL UNIT"
- For example, orbital, pneumatic palatal, basal are micro skeletal units of MAXILLA.
- Alveolar, angular, condylar, gonial, mental, coronoid and basal are micro skeletal units of MANDIBLE.
- Functional matrix theory attempts to *comprehend* the relationship between *from and function.*

MULTIFACTORIAL THEORY:

Put forward by " VAN LIMBORGH'S" IN 1970

- Multifactorial theory have led to *combination* of various growth control theories in attempt to confront and account for the many complexities embodied in regulating growth.
- Each theory contains *elements of significance* that cannot be denied.

Multifactorial theory supports.

- Functional matrix theory of MOSS
- Sutural theory of SICHER
- Genetic blue print theory.
  - Chondrocranial and desmocranial growth are controlled by genetic factor.
  - Cartilaginous part of skull are growth centre.
  - Sutural growth is secondary to cartilaginous and adjacent skull structure.
  - Periosteal growth depends on adjacent structure and some non genetic environmental influence.

According to Van Limborgh 5 factors controls growth.

- INTRINSIC GENETIC FACTOR:
  - Genetic control of skeletal unit.
- LOCAL EPIGENETIC FACTOR :-
  - Genetic control originating from adjacent structures like BRAIN, EYES,
-

- **GENERAL EPIGENETIC FACTOR :-**

  ➢ **Genetic Factors determining growth from distant structures like SEX HORMONE, GROWTH HORMONE.**

- **LOCAL ENVIRONMENTAL FACTOR :-**

  ➢ **Non genetic factors from local external environment like HABITS, MUSCLE FORCE.**

- **GENERAL ENVIRONMENTAL FACTOR:**

  ➢ **Non genetic influences such as nutrition. OXYGEN**

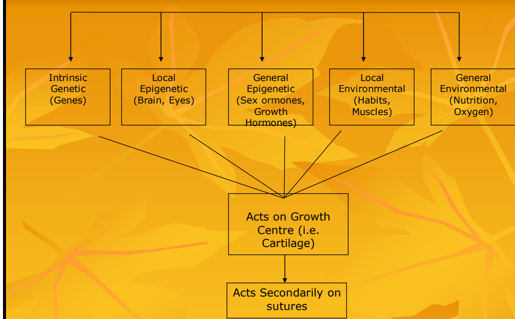



**DIAGRAM DEPICTING MULTIPLE FACTORS CONTROLLING GROWTH**

**REMODELLING PATTERN THEORY / EXPANDING V PRINCIPLE**

**PUT FORWARD BY " ENLOW"**

- **Concept is that many facial and cranial bones or parts of bones have V shaped configuration.**
  **Bone deposition occurs on inner side of v and bone resorption on outer side of wide ends of V.**
  **Differential bone deposition occurs on outer side of narrow part of V and resorption on inner side.**
- **Simultaneous growth movement and enlargement occurs by addition of bone an the inside and removal from outside.**
- **V pattern of growth occurs in *base of mandible, end of long bones mandibular body, palate.***

**V SHAPED CONFIGURATION SHOWING DIFFERENTIAL GROWTH PATTERN:**

**GROWTH PATTERN OF MANDIBLE BY SELECTIVE BONE DEPOSITION AND RESORPTION**

**ENLOWS COUNTERPART PRINCIPLE**

- **States that growth of any given facial or cranial part relates specifically to other structural and geometric counterpart in the face and cranium.**
- **If regional part and its particular counterpart enlarge to the same extend balanced growth occur. Imbalances occurs because of differences between amount direction and time of growth between counterpart.**

**Different parts and counterpart are.**

1. **Nasomaxillary complex relates to anterior cranial fossa.**
2. **Horizontal dimension of pharyngeal space relates to middle cranial fossa.**
3. **Maxillary and mandible are mutual counterparl**

## NEUROTROPHIC PROCESS CONCEPT

- Neurotrophism is a non impulse transmitting neural function that involves axoplasmic transport and provides for long term interaction between neurons and innervalated tissues that homeostatically regulates morphological, compositional and functional integrity of those tissues.

Different types of neurotrophic mechanisms are.

- Neuro epithelial trophism
- Neuro visceral trophism
- Neuro muscular trophism

## NEURO EPITHELIAL TROPHISM :

NERVE SYNAPSE

Release of neurotrophic Substance → Normal epithelial Growth → Epithelial mitosis and synthesis

Lacking neurotrophic Substance. → Abnormal Epithelial Growth → Orofacial hypoplasia & Malformation

For example:

Taste buds → If deinnervated → Becomes atrophic thereby epithelial cells also become atrophic

## NEURO MUSCULAR TROPHISM.

Muscles at myoblast stage → If distorted innervation and trophic control. → Discontinued myogenesis

NEURO –VISCERAL TROPHISM :

Salivary glands & fat tissue are tropically regulated

"You may only get one chance to do your orthodontics the right way."

THANK YOU

# GROWTH AND DEVELOPMENT – Theories of Growth

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Jaipur



## Contents



## Evolution of Theories

## Craniofacial biology as "Normal Science"

***David S. Carlson***

*The Structure of Scientific Revolutions* – *Thomas Kuhn (1970)*

**Normal Science – the norm :**

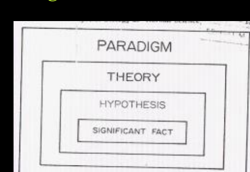
"Research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges as supplying the foundation for its further practice."

or

"research findings generally agreed to be basic to a scientific field."

## Paradigm (Model or Pattern)

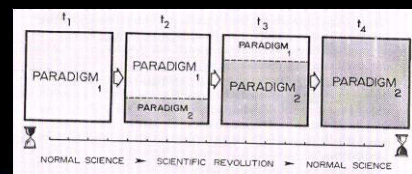
- Current conceptual framework of a scientific field.
- A conceptual scheme that encompasses individual theories and is accepted by a scientific community as a model and foundation for further research.
- *Paradigms change…..!!*

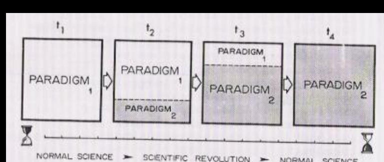


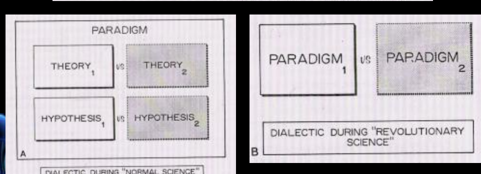
- ***Scientific Community*** – is a group characterized by its consensus about a paradigm & commitment to relate that paradigm to the rest of the natural world.
- Conflict between scientific communities – ***Scientific Revolution***

## *Scientific Revolution*

- A Change in paradigm brought about by inconsistencies within the old scheme or by technologic developments that permit scientist to ask new questions & gain new data is called *Scientific Revolution*




## *Paradigms in Craniofacial Biology*

***Craniofacial Biology*** *– the study of the growth, function, and adaptation, both phylogenetically and ontogenetically, of the craniofacial skeleton and related structures.*

- Genetic predetermination – middle of 20th century
- Functional factors
- Epigenesis – current focus

## *1920-1940*

- Study of structure of craniofacial skeleton with no consideration to **function** –
  - Anthropologic craniometry
- - Krogman(1974) - 'static approach' – 'standards,' 'norms'
- Moss(1982) - subdivided
  1. Pre-radiologic phase - craniometry
  2. Radiologic phase – no conceptual change

- Studies based on –
  Comparative anatomy,
  Craniometrics,
  Radiographic cephalometrics
- Anatomic intuition & extrapolation from other parts of body- ***growth immutable & genetically pre-determined.***
- **Moss- "Classic Triad"**
  1. ***Sutures** are primary **growth sites***
  2. *Growth of the cranial vault occurs only by periosteal deposition and endosteal resorption.*
  3. *All cephalic cartilages are primary growth centers under direct genetic control*

## *Genomic paradigm*

- Craniofacial growth - **heredity**
- Genetically determined – so growth pattern invariant.
- "norms" or "standards"
- Treatment of bones of face ignored – heredity & un-modifiable
- Focus on the more plastic dentoalveolar area.
- If not alter facial growth – strive for an acceptable dental alignment.

## *1940-1960*

- Increase in experimental animal research.
- **Methodologic change -** Technological developments:-
  1. Use of Radio-opaque Implants.
  2. Vital Dyes.
  3. Autoradiography.
  4. In-vivo and In-vitro transplantations.
- Mid to late 1950s - PRE-REVOLUTIONARY

- The end of 1950's – 2 approaches within **genomic paradigm** (Krogman – 1974) –

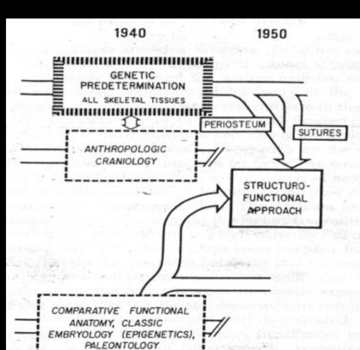
1. COMPREHENSIVE APPROACH
2. STRUCTUROFUNTIONAL APPROACH

Comprehensive approach:

- descriptive
- continued craniometrics with more sophisticated hardware -radiographs, cephalostats and software (statistical models).

Structurofunctional Approach:

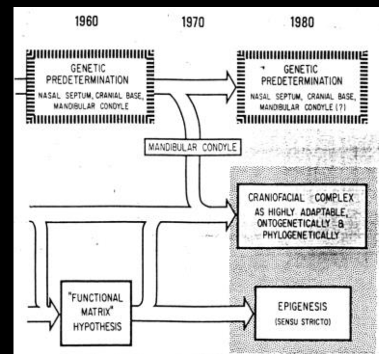
- Experimental & analytic
- Concentrated more on "cause and effect relationships"
- Effect of altered or abnormal function on form




- The end of 1950's - **genomic paradigm** put into question
- Periosteal and sutural bone growth - removed from genomic paradigm - given the status of secondary, compensatory or adaptive phenomena
- Lack of evidence - genomic paradigm remained dominant
- Alternative view - **"Function"** plays a major role - continued to gather momentum.

## *1960-1980*

- Early 1960s- 'period of Scientific Revolution'.
- Development of alternative paradigm mostly associated with – Melvin Moss
- **'Functional Matrix Hypothesis'**- some consider it to be an alternative paradigm itself.
- David Carlson- major component of 'FUNCTIONAL PARADIGM'
- Daniels & Kremanak – "has probably both stimulated & inhibited thinking & experimentation. It may be harmful in thinking."




- "Functional Matrix Hypothesis"- a topic of theoretical debate involving people like-
  Moorrees(1972)
  Koski(1972)
  Wayne Watson(1982)
  Johnston(1976)

- Alexander Petrovic and associates(1975) - proposed the **'Cybernetic theory'.**

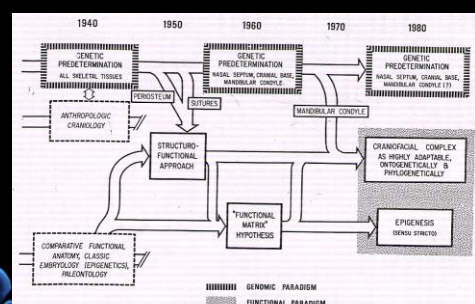


Fig. 2-6. Summary of the development of competing paradigms within craniofacial biology from 1940 through the present.

## *2 Paradigms*

1. Genomic ("nature-nurture") - Exists primarily on the strength of the belief that facial growth and form should be encoded genetically.
2. Functional ("intrinsic-extrinsic") - Includes the Functional Matrix Hypothesis and its extension - The epigenetic hypothesis

- At present - a conflict of these two paradigms is seen until a new one is proposed...

## *Theories of growth*

- Different theories differ in the location at which genetic control is established.

## *Growth site vs Growth centre*

**Cranial growth centers: Facts or fallacies? –**
Koski *AJO-DO 1968*
*Aug (566-583)*

**BAUME:**

**Growth Centre-** site of endochondral ossification with *tissue-separating capability,* contributing to the increase of skeletal mass.

i.e. location at which independent (genetically controlled) growth occurs.

**Growth site:** regions of periosteal or sutural bone formation and modeling resorption adaptive to *environmental influences.*

i.e. merely location at which growth occurs, but as a secondary, compensatory effect.

## *Genetic Theory*

- Assumed that craniofacial growth is largely inherited, intrinsically regulated, and **genetically predetermined**
- It was more assumed than proven
- The assumption was made that the *cartilages and facial sutures were under genetic control* and that brain determined the vault dimensions.

(which meant vault sutures were passive while *facial sutures were actively forcing bones apart* – Wendell Wylie – "Orthodontic Calvinism")

## *Early Concept (circa 1800-1940)*

- First rigorous scientific research on craniofacial growth – Sir John Hunter in 18th century(1771)
- Growth of maxilla and mandible – primarily by means of the addition of bone to their posterior aspects.
- Rational – issue of interstitial vs appositional bone growth.
- It was accepted that *bone as a tissue does not grow interstitially, but grows **only** appositionally at bone surfaces.*

## *Remodeling Theory*

- First general theory of craniofacial growth
- The Principlal scientific basis –
  - *Bone only grows appositionally at surfaces;*
  - *Growth of the jaws is characterized by deposition of bone at the posterior surfaces of the maxilla and mandible; and*
  - *Calvarial growth occurs via deposition of bone on the ectocranial surface of the cranial vault and resorption of bone endocranially.*

David S Carlson – Growth Modification: From molecules to Mandibles. Craniofacial Growth Series 35, Ann Arbor,1999.

- It was postulated that –
- ***All of craniofacial skeletal growth occurs exclusively by selective addition and resorption of bone at its surfaces;*** such structures as sutures and the cartilages of the craniofacial skeleton have little or no major role in the growth of the craniofacial skeleton

- *Remodeling theory* – differential deposition and resorption of bone to account for growth
- Fundamental concern – role of sutures, cranial base, synchondroses, and the mandibular condyle..?
- If these obvious sites of bone growth are **not** essential for normal craniofacial growth, then why are they present at all…..?????

## *Sutural dominance theory*

- ***SICHER(1947)*** **–** studies using vital dyes – *sutures caused much of growth*
- "….the primary event in sutural growth is the proliferation of the connective tissue between the two bones. If the sutural connective tissue proliferates it creates the space for oppositional growth at the borders of the two bones."
- Connective tissue in sutures of nasomaxillary complex & vault – separated bones like synchondrosis & epiphyseal plates

- Growth in the sutures is controlled by the intrinsic genetic makeup of the tissue.
- Imp. Sites for growth of maxillary complex – along 4 parallel sutures – downward and forward displacement
  - Fronto-maxillary,
  - Zygomatico-temporal,
  - Pterygo-palatine, and
  - Zygomatico-maxillary

- Sicher ascribes equal value – osteogenic tissues, cartilage, sutures & periosteum.

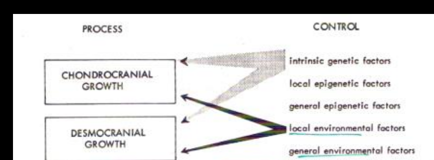
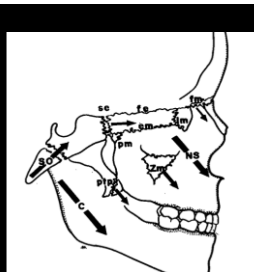



*Figure 2–15* Diagram showing the classic view on the control of skull growth. (From Limborgh, J. V.: A new view on the control of the morphogenesis of the skull. Acta Morph. Neer-Scand., 8:143–160, 1970.)




- **"expanding V "** – cranial portion moves upwards and forwards and the *facial portion downward and forward.*

## *Three-layer structure:*

- Connective tissue between the two bones - same as cartilage at the base of the skull, epiphyses, and articular surfaces of long bones

- "spreading" of the suture, initiated by the proliferation of the *middle layer cells* of the sutural tissue.

-"tissue-separating force" in the sutural tissue.

## *Evidence against sutural theory*

1. Subcutaneous autotransplants of the zygomaticomaxillary suture area in the guinea pig have not been found to grow – *lack of innate growth potential.*
2. Growth of sutures – respond to external stimuli.
3. Extirpation of facial sutures - no appreciable effect on growth of the skeleton.
4. Shape of sutures - depends on functional stimuli
5. Closure of sutures -extrinsically determined.
6. Sites of sutures - not predetermined .

CONCLUSION:

- Sutures are growth sites **not centres.**
- Adaptive, compensatory or secondary growth.
- The sutural connective tissue is **not** adapted to a pressure related growth process. The suture is essentially a **tension adapted** tissue.

## *Cartilaginous theory*

SCOTT'S HYPOTHESIS:

- Intrinsic growth - controlling factors in **cartilage & periosteum.**
- Sutures are secondary & dependent on extra-sutural influences.
- Cartilaginous part of skull must be recognised as primary centres of growth, with **nasal septum** being a major contributor in maxillary growth, *per se.*
- Sutural growth – responsive to synchondrosis proliferation & local environmental factors.

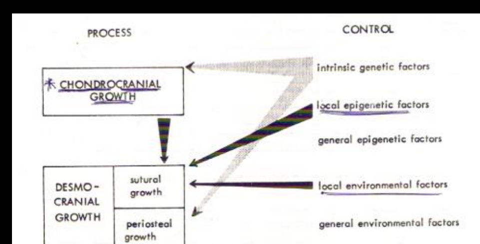
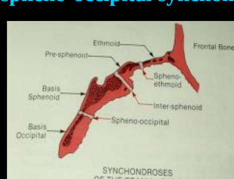


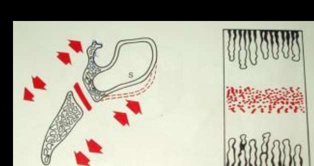

*Figure 2–16* Diagram showing Scott's view on the control of skull growth. (From Limborgh, J. V.: A new view on the control of the morphogenesis of the skull. Acta Morph. Neer-Scand., 8:143–160, 1970.)

## *Cranial base synchondroses*

- The cranial base synchondroses, which are analogous to epiphyseal growth plates, were thought to have a longer-lasting effect on craniofacial growth, through at least 7 years of age for the spheno-ethmoidal synchondrosis and until puberty for the **spheno-occipital synchondrosis.**




- Endochondral cranial base – lesser response to brain growth than intramembranous cranial vault.
- Primary centres of growth – Sarnat, Burdi, Baume, Petrovic & others.



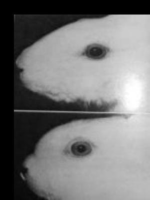
- Cranial base – single bone with multiple epiphyseal plate-like synchondrosis.
- Endochondral ossification at the synchondroses - only a response to external stimuli..?
- Cartilage - lacks same amount of independent growth potential as transplants of epiphyseal cartilage under similar experimental conditions.

## *Nasal septal cartilage*

- Nasal septum – **most active and important** for craniofacial skeletal growth prenatally and post-natally
- The anterior-inferior expansive growth of the nasal septal cartilage, which is buttressed against the cranial base posteriorly, **"drives"** midface downward and forward.

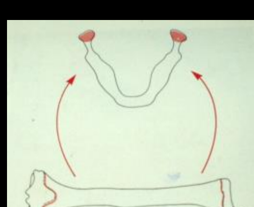
- **Latham**- ligament extending from nasal septal cartilage to anterior premaxillary region – ***Septo-premaxillary ligament.***
- This is an important relation between midfacial & nasal septal growth – especially before birth.

- Experimental excision of the nasal septum affects the growth of the upper face considerably - due to trauma.
- Nasal septum - central support for the upper facial area, and its loss results in a predictable collapse in the area.



## *Condylar cartilage*

- Growth of the condylar cartilage is responsible for the anteroposterior growth of the mandible - primary growth centre.



- Scott- growth of the condylar cartilage enables the condyle "to grow upwards and backwards so as to maintain the contact at the temporomandibular joint as the mandible is carried downwards and forwards by the growth of the upper facial skeleton."
- If the condylar cartilage is transplanted to a relatively nonfunctional site, such as the subcutaneous or brain tissue, it **does not** maintain its structure and **does not** behave like the condylar cartilage in situ.
- Bilateral condylectomy, congenital absence of the rami- no appreciable effect on the growth of the rest of the mandible in humans.

- Studies involving the use of metallic implants - actual growth of the condyle is sometimes upward and backward and sometimes upward and forward.

## Van Limborgh's theory:

- A multi-factorial theory was put forward by **Van Limborgh** in 1970.
- Van Limborgh explains the process of growth and development in a view that *combines all the three existing theories.*

G Gola, K Zarrinnia, E Kravitz – Nutrition in Basic and Craniofacial Development. Basic and Craniofacial Development

Van Limborgh has suggested the following *five factors* that he believed controls growth-

1. **Intrinsic genetic factors :** They are the genetic control of the skeletal units themselves.
2. **Local epigenetic factors :** Bone growth is determined by genetic control originating from adjacent structures like brain, eyes etc.
3. **General epigenetic factors:** They are the genetic factors determining growth from distant structures. Ex.growth hormones, sex hormones.
4. **Local environment factors:** They are non-genetic factors from local external environment. Ex: Habits, muscle force, etc.
5. **General environment factors:** They are general non-genetic influences such as nutrition, oxygen.

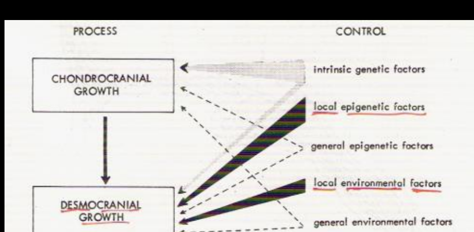



*Figure 2–20* Diagram showing the new view on the control of skull growth. (From Limborgh, J. V.: A new view on the control of the morphogenesis of the skull. Acta Morph. Neer-Scand., 8:143–160, 1970.)

The views expressed by Van Limborgh can be summarized in the following six points:

a. Chondrocranial growth is controlled mainly by the intrinsic Genetic factors.

b. Desmocranial growth is controlled by any few intrinsic genetic factors.

c. The cartilaginous part of the skull must be considered as growth centers.

d. Sutural growth controlled mainly by influences originating from the skull cartilages and from other adjacent skull structures.

e. Periosteal growth largely depends upon growth of adjacent structures.

f. Sutural and perisoteal growth are additionally governed by local Non-genetic environmental influence.

## *Gnomic growth and logrithmic spiral*

- What is gnomic growth?
- The process where upon the addition to a body leaves the resultant body similar to the original is called **gnomic growth.**
- D'Arcy Thompson classified the sea shells in accordance to their pattern of enlargement and developed an equation.

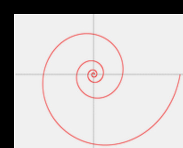
M L Moss, L Salentijn – Differences b/n the functional matrices in anterior open-bite and in deep overbite. Am J Orthod, vol.60, no.3, sept 1971, 264-280.

- The Nautilus offers 2 fundamental characterstics-
- 1. The shell grows in size but does **not** change its shape

new growth

- 2. Its gnomic growth can be described by a particular kind of curve- ***the logarithmic or equiangular spiral.***

- The spiral is characterized by the movement of a point away from the pole along the radius vector with a velocity increasing as its distance from the pole

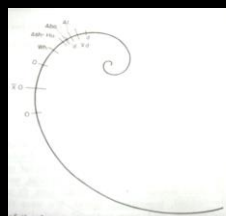


## *Logarithmic growth of human mandible*

- There are several functional conditions which are not violated during orofacial growth- one of these is *neural innervations* which must ***never*** be subjected to *external loading.*
- Craniometric studies were performed on American Indian skull .they are representative of mandible with fetal, deciduous, mixed and adult dentition.
- Small lead shots were fixed to foramen ovale. Mandibular foramen & foramen mental.

- Lateral x-rays effectively outlined the pathway of the Inf. Alveolar nerve.
- All the 3 neural foramina at all ages fit precisely upon a single mathematically defined, logarithmic spiral (Moss,1970).

- Another longitudinal and cross sectional clinical growth data showed that *these foramina moved along the same logarithmic spiral in geometric fashion, with the gradient of motion directly increasing with the distance of the foramina from the cranial base.* ie mental foramen moves most and the foramen ovale least.



- In the fetal period the 3 foramina are relatively near the origin of the spiral and at the same time they are placed nearer to each other than at later stage. This produces a flatter curvature hence gonial angle is relatively flat

- With growth due to increase in distance ramus becomes straight relative to corpus and gonial angle acute.

- During all stages of development the corpus stays in essentially a horizontal position. At the same time the mandible curves down the logarithmic spiral course of the inferior alveolar nerve.

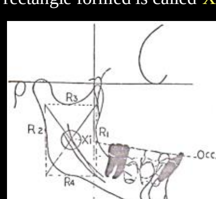
## *Arcial growth*

- **Ricketts in 1972** developed a method to determine the arc of growth of the mandible.
- Principle - A normal human mandible grows by superior anterior apposition at the ramus on a curve or arc which is a segment formed from a circle. The radius of this circle is determined by using the distance from mental protruberance (Pm) to a point at the forking of the stress lines at the terminus of the oblique ridge on the medial side of the ramus (point Eva).

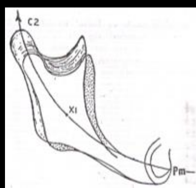
R M Ricketts – A Principle of Arcial Growth of the Mandible, Angle Orthod vol.42, no.4, oct 1972, 368-386.

**Landmarks:** **Xi point-**

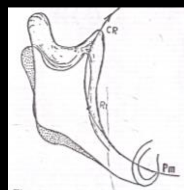
- The deepest point on the subcoronoid is selected as R1.
- R2 is selected directly opposite to it on post border of ramus.
- R3 is selected at the depth of the sigmoid notch.
- R4 is directly on the lower border of ramus.
- The centroid of the rectangle formed is called Xi point.




- **Suprapogonion** (Pm - protuberance menti) **-** It is a point located at the superior aspect of symphysis.
- Substantiated as a reference point because-
  - Located at approximately a stress center (Ricketts)
  - It is the site of a reversal line (Enlow)
  - Stable unchanging bone in this area of chin (Bjork)
- **Point Dc** – It is a point at the bisection of condyle neck

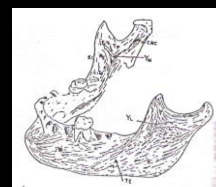


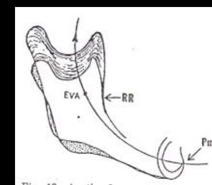

Not enough bending




Too much bending

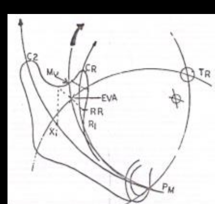
- These findings suggested that the **true arc** of growth of mandible lay somewhere b/n the Xi point and the anterior border of the ramus and b/n the condylar and coronoid processess.





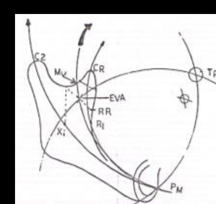

- **Point Eva-** it is a biologic point as it is located over the point of forking of the stress line in the ramus.

- Ramus reference point (RR): A line from point Xi to R3 is bisected and a parallel point on the anterior border of the ramus is the RR point.
- Point RR & R3 are connected. *This line is crossed by a second line selected from a point midway of the base of the coronoid process to the Xi point.* The crossing of two lines is the **point Eva**




*True Arc*

- Take pt Eva–Pm as radius - circle is drawn-
  taking eva as a centre,
  taking Pm as a centre.
- The point of intersection is TR (True radius), taking this as a centre an arc **(true arc)** is drawn from pogonion through Eva.
- Where this arc crosses sigmoid notch is called **Murray point.**



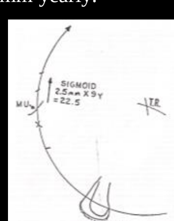

**Steps in growth prediction**

Step 1 : amount of growth on arc - 2.5mm

From pt Mu the mandible is grown out on the arc at the sigmoid notch about 2.5mm yearly.

cutoff for males = 19yrs

females = 14.5yrs



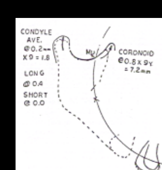

Step 2

Coronoid –

upwards & outwards – 0.8mm/yr

Condyle -

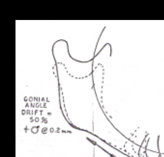
upward & backward - 0.2 mm / yr




Step 3 - Drift of gonial angle

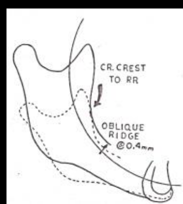
Females- no addition

Males - 0.2 mm / yr



- Step 4 complete forcasting of the mandibular form

Connections from coronoid process –RR – 0.4mm/yr determine space available for 3rd molar




- By constructing the growth arc, growing the mandible on the arc, extending and drifting the angular process, this forecasting technique is tested.

## Drawbacks of arcial growth prediction

- It relies heavily on the operators skill in tracing the cephalogram.
- Mitchell & Jordan (1975) concluded Ricketts uses chronological age rather than the skeletal age. If the patient is in a growth spurt or lag phase it will alter the result.
- The growth increments constants are for a fixed population.

## *Conclusion*

- Everything is not yet known and much research is yet to be done , but clinicians must treat patients with *working hypothesis* of growth in mind while issues are being resolved by craniofacial biologists in their minds and laboratories.

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thank you..

## *ROLE OF TONGUE IN CAUSING & MAINTAINING MALOCCLUSION*

Presented by:
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## INTRODUCTION

The morphology of the craniofacial complex, the dynamics of the stomatognathic system & the arrangement of the dentition is an integrated functioning unit.

Muscles are potent force, whether they are in active function or at rest. The teeth & supporting structure are constantly under the influence of the contiguous musculature.

## TONGUE

- Muscular organ
- Situated in the floor of the mouth
- Associated with the functions of
  - Speech
  - Mastication
  - Deglutition
- Essential in maintaining the arch form & position of teeth.

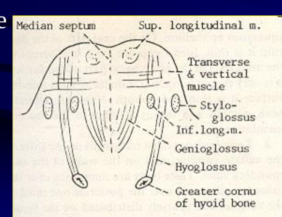
## MUSCLES OF THE TONGUE

**INTRINSIC**

- Superior longitidinal
- Inferior longitidinal
- Transverse
- Vertical

**EXTRINSIC**

- Genioglossus
- Hyoglossus
- Styloglossus
- Palatoglossus




- SUPERIOR LONGITIDINAL MUSCLE

Shortens the tongue & makes the dorsum concave

- INFERIOR LONGITIDINAL MUSCLE

Shortens the tongue & makes the dorsum convex

## TRANSVERSE MUSCLE

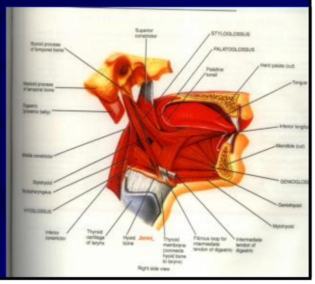
Makes the tongue narrow & elongated

## VERTICAL MUSCLES

Makes the tongue broad & flattened

## EXTRINSIC MUSCLES

- Genioglossus - Mandible
- Hyoglossus - Hyoid bone
- Styloglossus - Styloid process
- Palatoglossus - Palate



Hyoglossus – depresses the tongue

Styloglossus - pulls it upward & backward

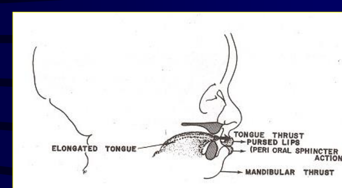
Genioglossus – Protrudes the tongue out of the mouth by pulling the posterior part forwards

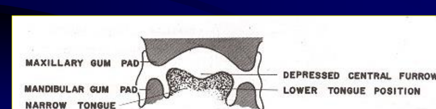
Palatoglossus – brings the palatoglossal arches together, thus shutting the oral cavity from the oropharynx

## DEGLUTITION

- Infantile swallow ( visceral swallow)
- Mature swallow ( somatic swallow)

## INFANTILE (VISCERAL) SWALLOW




## CHARACTERISTICS OF INFANTILE SWALLOW

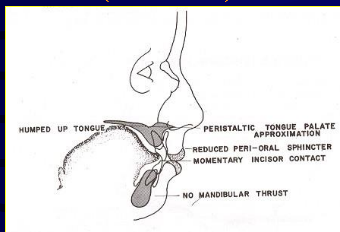
- The jaws are apart, with the tongue between the gum pads
- The mandible is stabilized by contraction of the muscles of the 7th cranial nerve & the interposed tongue.
- The swallow is guided, & to a great extent controlled by sensory interchange between the lips & the tongue.

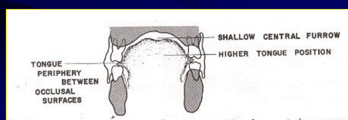
## TRANSITION PERIOD

At about the 5 to 6th month of age, as the incisors begin to erupt, certain proprioceptive impulses come into play & the peripheral portions of the tongue starts to spread laterally.

An average infant would show a dominant & exclusive thrusting swallow for the first 6 months of life,a transitional thrusting & lateral spread of tongue during the next year & a dominant somatic swallow thereafter.

## MATURE ( SOMATIC) SWALLOW




## CHARACTERISTICS OF MATURE SWALLOW

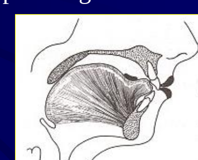
- The teeth are together
- The mandible is stabilized by contraction of the mandibular elevators,which are primarily 5th cranial nerve muscles
- The tongue tip is held against the palate, above & behind the incisors
- There are minimal contractions of the lips during the mature swallow.

## DEGLUTITION CYCLE

1. Preparatory swallow
2. Oral phase of swallowing
3. Pharyngeal phase of swallowing
4. Esophageal phase of swallowing

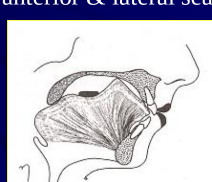
## PREPARATORY SWALLOW

- Starts as soon as liquids are taken in, or after the bolus has been masticated
- The liquid or bolus is then in a swallow-preparatory position on the dorsum of the tongue.
- The oral cavity is sealed by lip & tongue.



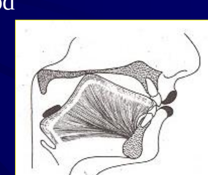
## Oral phase of swallowing

- Soft palate moves upward & the tongue drops downward & backward
- Larynx & hyoid bone move upward
- Smooth path for the bolus as it is pushed from the oral cavity by the wave like rippling of the tongue
- Oral cavity is stabilized by the muscles of mastication, & maintains the anterior & lateral seal



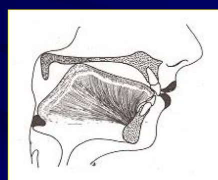
## Pharyngeal phase of swallowing

- Begins as the bolus passes through the fauces
- The pharyngeal tube is raised upward en masse
- Nasopharynx is sealed off by closure of the soft palate against the posterior pharyngeal wall
- Hyoid bone & base of tongue move forward as the pharynx & tongue continue their peristaltic – like movement of the bolus of the food



## Esophageal phase of swallowing

- Commences as the food passes the cricopharyngeal sphincter
- While peristaltic movement carries the food through the esophagus, the hyoid bone , palate & tongue return to their original positions



# DIAGNOSIS

## EXAMINATION OF THE TONGUE

1. Morphological examination
2. Functional examination

Morphological examination:

The tongue should be examined for size & shape

Macroglossia:

Scalloping on the lateral borders

Microglossia:

Severe crowding & collapsed dental arch

## SHAPE OF THE TONGUE

ASYMMETRY OF THE TONGUE:

Functional

Morphological

- Ask the patient to protrude the tongue, & note the symmetry in this position
- Then ask the patient to relax the tongue, allowing it to drape over the lower lip

## FUNCTIONAL EXAMINATION OF THE TONGUE

- Observe the posture of the tongue while the mandible is in postural rest position

  Ceph taken at the mandibular postural position

  Examination of the tongue with patient in upright position

- During mandibular posture, dorsum touches the palate lightly & the tip is in the lingual fossa or at the crevices of mandibular incisors

## Observe the tongue in various swallows

- Patient should be in upright position with the vertebral column vertical & FHP parallel to the plane
- Observe several unconscious swallows
- Place small amount of water beneath the patients tongue tip & ask him to swallow & note mandibular movements

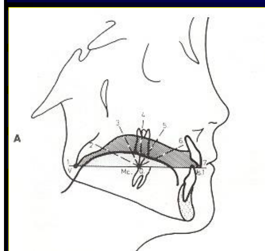
  Mature swallow – mandible rises, lips touch lightly with very minimal contraction

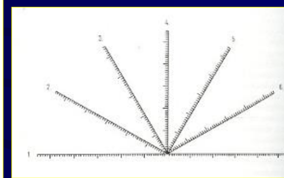
❖Place the hand over the temporal muscle,pressing lightly with finger tips

❖Give the patient more water & ask for a repeat swallow & feel for temporal muscle contraction

❖Place a tongue depressor or mouth mirror on the lower lip & ask the patient to swallow

## CEPHALOMETRIC EVALUATION OF TONGUE POSTURE & VOLUME





## PALATOGRAPHIC EXAMINATION OF THE TONGUE

❖Permits tongue function to be observed during swallowing & speaking

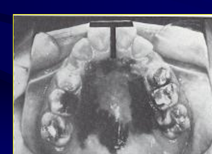
❖Direct & indirect methods

## DIRECT METHOD

➢First described by Oakley Coles in 1872

➢Gum Arabic & flour were mixed & painted on the tongue

➢After selected functional exercises – contacts on the palate were transferred onto the cast & evaluated



## INDIRECT PALATOGRAPHIC TECHNIQUE

✓First used by Kingsley in 1880

✓Upper plate – black india rubber

✓Covered the tongue with mixture of chalk & alcohol

✓The contacts seen on the palatal rubber plate were then transferred onto the cast

## CURRENT DIRECT METHOD

▪Superior surface of the tongue is covered with a precise impression material ( Imprex )

▪After functional exercises an instant (Polaroid) print is made of the palatal region

▪Evaluation of the palatogram is possible by direct measurement on the picture

## EVALUATION OF TONGUE MOVEMENTS

- Electro platography
- Cineradiography
- Computer tomography
- Magnetic resonance imaging
- Electromagnetic articulography
- Ultrasonography
- Cinefluoroscopy

## TONGUE THRUST

DEFINITION

The forward movement of the tongue tip between the teeth to meet the lower lip in deglutition and in sounds of speech so that the tongue becomes interdental.

CLASSIFICATION

According to Moyers,

- ✓ Simple tongue thrust swallow
- ✓ Complex tongue thrust swallow
- ✓ Retained infantile swallow / tongue sucking

## SIMPLE TONGUE THRUST SWALLOW

- Tongue thrust with a teeth together swallow
- Malocclusion:

  Well circumscribed anterior open bite

  Posterior teeth in perfect occlusion
- Open bite has definite beginning & an ending
- Usually associated with digit sucking, since it is necessary for the tongue to thrust forward into the open bite to maintain the anterior seal during swallow.

## Complex tongue thrust swallow

- Tongue thrust with teeth apart swallow
- Malocclusion:

  Poor occlusal fit – prompts a slide into occlusion

  Generalized anterior open bite
- Mandibular elevators don't contract during swallowing, & mandible is stabilized by tongue & inframandibular muscle contractions
- Usually associated with chronic resp. distress, mouth breathing, tonsillitis & pharyngitis.

## Retained infantile swallow / tongue sucking

- Undue persistence of the infantile swallow well past the normal time for its departure
- Teeth occlude on only one molar in each quadrant
- Strong contractions of the facial muscles during swallowing
- Patients will have expressionless faces, since the muscles of the 7th cranial nerve are being used for stabilization of the mandible
- Difficulties in mastication & low gag threshold

## CLASSIFICATION OF TONGUE THRUST

According to Brauer & Holt, AO-1965

Type I – Non deforming tongue thrust

Type II- Deforming anterior tongue thrust

Subgroup 1 - Anterior open bite

Subgroup 2 – Associated procumbency of anteriors

Subgroup 3 – Associated posterior cross bite

Type III – Deforming lateral tongue thrust

Subgroup 1 – Posterior open bite

Subgroup 2 – Posterior cross bite

Subgroup 3 – Deep overbite

Type IV – Deforming ant & lateral tongue thrust

Subgroup 1 – Anterior & posterior open bite

Subgroup 2 – Associated procumbency of anteriors

Subgroup 3 - Associated posterior cross bite

## EFFECTS OF TONGUE THRUSTING

Thumb sucking + Tongue thrusting:

If the finger displaces the maxillary incisors labially, the tongue thrusts forward to maintain lip seal

✓Accentuates the open bite tendency & prevents the incisors from erupting & forces them labially

✓Lips become more hypotonic & no longer contact each other during rest

✓Mouth breathing is aggravated

✓Increased over jet – lower lip cushions to the lingual of the maxillary incisors

✓Mentalis muscle activity increases – puckering of the chin

✓Tongue drops lower in the mouth & no longer approximates the palate

✓Tongue elongates in shape

✓Balancing effect on the buccal segment is decreased

✓Lateral peripheral portions no longer overlie the occlusal surfaces of posteriors

✓Net effect:

Narrowing of the maxillary arch

Over eruption of the posteriors

Inter occlusal space is eliminated

Posterior cross bite

## TONGUE THRUST -TREATMENT

SIMPLE TONGUE THRUST

Should not be started before correction of incisor proclination

**STEPS IN THE Rx:**

**STEP I**

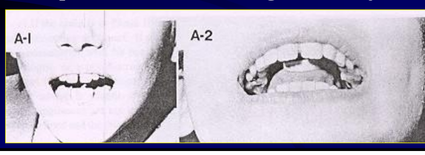
❖ **Patient is instructed to swallow by holding the tongue tip against the junction of hard & soft palate**

❖**To practice correct swallowing at least 40 times/day**

❖**Small elastics can be held by the tongue tip against the palate**

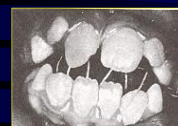

## STEP II

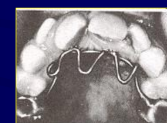
- Reinforce the new swallowing pattern subconsciously
- Flat, sugarless fruit drops can be used
- To place the drop on the tip of the tongue & hold it against the palate until the candy has dissolved completely
- Have the patient time how long the candy is held in place




## STEP III

- Well adapted lingual arch wire with short 2mm, sharp, strategically placed spurs can be given
- Should not be placed as the first appliance





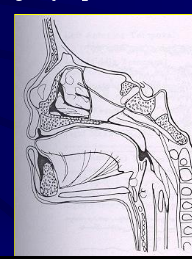
## COMPLEX TONGUE THRUST

- To treat the occlusion first
- Muscle training should be started when the ortho Rx is in finishing stages
- Instruct the patient to keep the teeth together during step I
- Step III is must
- Maxillary retention appliance should have spurs incorporated in it

## TONGUE POSTURE

NEONATES

- Tongue is postured forward & touches the lips while the gum pads are held slightly apart

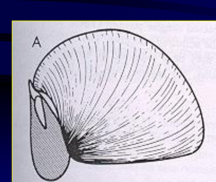


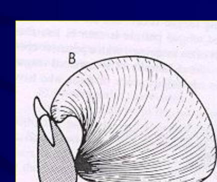
## INFANTILE TO MATURE TONGUE POSTURE

1. Eruption of incisors
2. Downward & forward growth of the mandible – increases the intraoral volume
3. Growth of the alveolar process in vertical direction

## MATURE TONGUE POSTURE

- During mandibular posture, the dorsum touches the palate slightly and the tongue tip normally is at rest in the lingual fossa or at the crevices of the mandibular incisors.



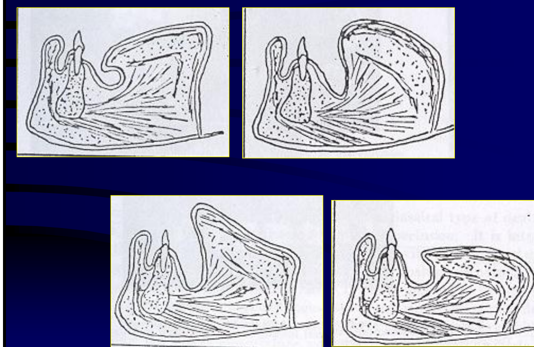
## ABNORMAL TONGUE POSTURE

1. Retracted tongue posture
2. Protracted tongue posture( Retained infantile tongue posture)

Endogenous

Acquired adaptive

## Retracted tongue posture



## MALOCCLUSION ASSOCIATED WITH RETRACTED POSTURE

- ✓Crowded mandibular incisors with lingual tipping & rotation
- ✓Excessive overclosure
- ✓Distoocclusion
- ✓Posterior open bite

## PROTRACTED TONGUE POSTURE

ENDOGENOUS PROTRACTED POSTURE:

- ❖Retention of infantile tongue posture
- ❖Adaptation to excessive anterior facial height

ACQUIRED PROTRACTED POSTURE:

- ❖Transitory adaptation to enlarged tonsil, pharyngitis o tonsillitis

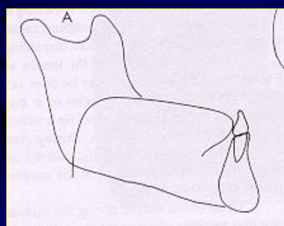
# TONGUE POSTURE IN VARIOUS MALOCCLUSIONS

## CLASS II MALOCCLUSION

- ➢ Retracted and low
- ➢Buccinator force is not balanced by the tongue & this leads to narrow, ‘V’ shaped maxillary arch

## CLASS III MALOCCLUSION:

- The tongue tends to lie lower in the floor of the mouth below the occlusal plane




Chia fen, AJO-2002

Examined the relationship between tongue movements during swallowing & dentofacial morphology with

Ultrasonography

Cephalometric radiography

Dental casts

- Movements of tongue during swallowing are related to dentofacial morphology

- Arch length increased with prolonged duration of swallowing
- Those who have longer duration of swallowing appear to have increased gonial angles, steep mandibular planes, increased body & ramus lengths, raised anterior lower facial heights, lingually inclined lower incisors,increased arch lengths
- Size, posture,& function of the tongue are significantly correlated with dentofacial morphology, including jaw relations, abnormality of dental arch form & abnormal tooth position or malocclusion.

## ABNORMAL SIZE OF THE TONGUE

MACROGLOSSIA

Pseudomacroglossia | True macroglossia

1. Habitual posturing
2. Hypertrophied tonsil/ adenoid
3. Low palatal vault
4. Severe mandibular deficiency

## TRUE MACROGLOSSIA

CONGENITAL

- Muscular hypertrophy
- Glandular hyperplasia
- Hemangioma
- Lymphangioma
- Downs syndrome

ACQUIRED

- Acromegaly
- Cretinism/Myxedema
- Amyloidosis
- Cysts/tumor
- Tertiary syphilis

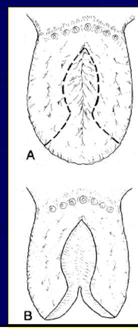
## CLINICAL FEATURES OF MACROGLOSSIA

- The oral cavity is filled by the tongue mass
- Epipharynx is narrow
- Patient is able extend the tongue to the nose tip / chin
- Indentations are evident on the tongue periphery
- Generalized spacing between the teeth
- Procumbent anteriors
- Open bite
- Treatment

  Surgical trimming of the tongue

## METHODS OF REDUCING THE TONGUE

1. midline wedge resection with the base in the anterior tongue,
2. midline elliptical excision,
3. marginal excision,
4. the "keyhole" or midline elliptical excision combined with an anterior wedge resection,




## MICROGLOSSIA OR HYPOGLOSSIA

- Rare condition
- Protruded tongue tip reaches the lower incisors at best
- Floor of the mouth is elevated & visible on each side of the diminutive tongue
- Dental arch is collapsed & reduced with extreme crowding in the premolar area
- Severe class II malocclusion
- Impacted III molars

## ROLE OF TONGUE IN SPEECH

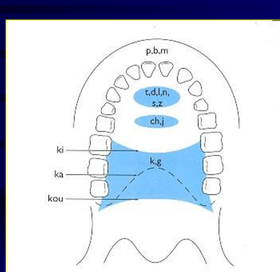
Speech production requires

1. Pulmonary bellow -provide an air steam that is under pressure during the phase of exhalation
2. Larynx – where sounds originate
3. Organs of speech ( articulators )

## ROLE OF TONGUE

- The articulators modify the shape, volume & cross section of the opening in the oral resonating cavity
- The tongue can divide the oral space into a double cavity, which multiplies the possible types of resonance and creates the range of vowels.

## ZONES OF CONTACT BETWEEN THE TONGUE & PALATE




## SPEECH DIFFICULTIES RELATED TO MALOCCLUSION

s,z (sibilants) - Ant. Open bite, large gap b/w incisors

t,d (Linguoalveolar stops) - Irregular incisors

f,v(Labiodental fricatives) - Skeletal class III

th,sh,ch(lin.dental fricatives) - Anterior open bite

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# FUNCTIONAL APPLIANCES

&

TONGUE

## BIONATOR

- Functional space for the tongue is essential to the normal development of the orofacial system
- Discoordination of tongue function can lead to abnormal growth & actual deformation
- Mandible is postured anteriorly with the incisors in an edge to edge relation

  Enlarged the oral space

  Allows the normal action of the tongue

# ROLE OF TONGUE IN MAINTAINING MALOCCLUSION

## TONGUE ADAPTATIONS FOLLOWING SURGERY

MANDIBULAR SETBACK:

- Maintenance of respiration
- Wedge reduction of tongue
- Postural adaptation of tongue
- Downward movement of hyoid bone & changes in the soft tissue contour – Double chin

Mary V. Andianopolos et al, AO-1987

Patients with persistent tongue thrust habit was significantly related to the amount of relapse & patients who underwent Rx for tongue thrusting & who are not currently tongue thrusting are positively related to a smaller overjet relapse

Greg.Haang, et al, AO-1990

Tongue crib therapy significantly reduced the post treatment relapse of open bite.

Larry.M. Wolford,AJO-1996

If the openbite is not due to macroglossia, correction will allow a normal tongue, which is a very adaptable organ, to readjust to the oral cavity little tendency towards relapse.

If the macroglossia is present with the openbite, then instability of the orthodontics & orthognathic surgery may likely occur with a tendency for the openbite to return.

## CONCLUSION

Retaining the achieved results is a major challenge faced by every orthodontist. Not only esthetically pleasing arch form & occlusion but positioning the teeth where muscular forces ( intra & extra oral ) are balanced should be aimed at right from the day one of the treatment.

# THANK U