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Growth Prediction in Craniofacial Complex & Its Implications in Planning an Orthodontic Treatment

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Abstract:
Orthodontic treatment usually involves a combination of tooth movement and facial growth changes. These changes may be due to natural growth or may be treatment induced. Planning out the timing of an indicative orthodontic treatment in a growing patient enhances the success of prognosis. Growth prediction forecasts the direction and amount of growth in an individual with minimal magnitude of statistical variations. This article reviews about various growth prediction parameters of craniofacial complex and its implications for planning out a successful orthodontic treatment.

Keywords: *Growth , Predictors, craniofacial, mandible,rotation*

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I. Introduction:

Prediction of facial growth has traditionally been an attractive research objective for realistic treatment planning.Kendall and Buckland defined growth prediction as the process of forecasting the magnitude of statistical variations, at some future point of time. For orthodontists, prediction involves not one, but a sequence of procedures and/or assumptions, each of which may contribute a measure of accuracy or inaccuracy to the final estimation. Despite the fact that cephalometric prediction has been championed enthusiastically for more than four decades, most orthodontists have adopted a "wait and see" attitude.In 1938, Brodie and associates concluded "There seem to be a definite correlation between success of treatment and growth.[1]

Need for growth prediction:

The desired movement of the maxilla to correct convexity depends upon the amount of convexity that the clinician estimates will be reduced naturally with future growth. Use of headgear to produce a straighter profile may be not required if considerable future horizontal growth of mandible is anticipated.

Similarly the required movements of the upper molar and incisor depends on the expected position of mandible and the lower arch at the end of the treatment. Research work by Ricketts in 1972 indicated that the probability of eruption of third molar is a predictable function of the space available at maturity from the center of the ramus (Xi) to the second molar. Hence the lower third molar may be quantitatively predicted before treatment is started.[2]

The orthodontist who uses growth forecasts begins with the cephalometric head film and draws up a proposed treatment plan, including expected growth. If the orthodontist has specifically drawn up his objective with expected growth built into it, he is better able to determine the source of problems when progress does not go according to plan. Also he can better assess the treatment methods by comparing actual results with his previously stated objective.[1]

The principal proponents of growth forecasting, notably Ricketts and Holdaway, have suggested that the major value of prediction technique is the compilation of all treatment factors (mechanics, growth, skeletal, and soft tissue) together on paper to see how they interrelate.[2]

In this review paper we will be discussing the various 'growth' prediction/ forecasting methods in the craniofacial complex from manual to computerized.

Implications of Growth predictors in the craniofacial complex.

Future size of a part:- According to Burstone, the prediction of future size is primarily a problem of predicting future increments which are to be added to a size that is already known foe e.g. predicting the length of the mandible.

Relationships of parts :- The most important prediction for the clinician is the future relationship of parts, that is the future facial pattern. Harvold has attempted to predict the maxillo-mandibular relation at one age on the basis of their relations and mandibular size at an early age.

Timing of events:- we know that growth does not proceed evenly, certain facial dimensions demonstrate marked changes in their velocity curve. These spurts of growth make prediction much more difficult.

Vectors of growth:- Rickets assumes that the morphology of the mandible is due to the future vectors of growth of the craniofacial complex. Many researchers have discussed the implications of changes in the growth vector, but no one has yet suggested a means of anticipating such change in the direction of growth in the face.

Velocity of growth:- Prediction of velocity of growth is most important during pubescent spurt and it of use to know the future expected rate of growth.[3]

Effects of orthodontic therapy on growth:-Balbach suggests that most important single factor in prediction for the orthodontist is to be able to predict what effect his therapy will have on the growing faces that are under treatment.[4]

Methods of growth prediction:-

The galacticvariability in thedirection and amount of facial growth in various subjects and its importance for the success of orthodontic treatment has been instrumental in its recognitionin dentistry over the past two decades. This has led to a marked interest in the methods of predicting the amount and direction of facial growth in the individual patient. Various methods of growth prediction are used which can be grouped under the following 4 groups:-

1) Theoretical methods 2) Regression methods
3) Experimental methods 4) Time series methods

1) **Theoretical methods**:-
A theoretical model could be constructed mathematically which might explain all the unusual activity observed and a test for hypothesis devised. Based on similar assumptions astronomers discovered planets several thousand light years away by collecting a series of random data on the behavior of celestial bodies. The model assumed the existence of this unknown planet of a certain size in a certain orbit, which was precisely in the theoretically predicted location. Theoretical models of craniofacial growth have not been defined mathematically in terms precise enough to permit the application of the method of prediction.

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

3) **Experimental methods**:-
These methods are based on the clinical experience of a single investigator who attempts to quantify his observations of practice in such a way that others can confirm them for use. For e.g. Ricketts prediction method, which utilizes means derived from a large sample of treated orthodontic patients.

4) **Time series methods**:-
These methods are of 2 types: Time series analysis, andSmoothing methods.

Time series analysis extracts in a mathematical form of fundamental nature of process as it relater to time. 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 method.
Smoothing methods are either moving averages or exponential, which operate to give representative or average values to parameters or previously described time series equation.[3]

Johnston method: A simplified approach to prediction.Lysle E. Johnston presented a simple method based on the addition of mean increments by direct superimposition on a printed grid.[1]
The Johnston's forecast grid for points A, B and M (any point on the crown of maxillary first permanent molar) was derived on the basis of descriptive templates prepared by Harris, while points N and P (PNS) was based on Rickets studies.[4,5]Schulhof&Baghacompared various methods of growth forecasting and found that Johnston grid was almost 70% accurate for predicting growth of the nose and pogonion while 64% accurate for point A.[6]
The method involves tracing the landmarks and superimposed along S-N and registered at S. The points are then advanced downward and forward one unit per year. This way the grid was found to produce a moderate flattening of the profile and occlusal plane.[4]
In an attempt to study the points not covered in Johnston grid as well as to test the grid's applicability to a 10 year growth period, Schulhof and Bagha devised a method of prediction equivalent to the grid using the fifty case 10 year sample. Average increments for each of the points under consideration were calculated from SN with S as the origin and these increments were then used in the prediction. This way they found that this method gave a useful improvement over Johnston grid at both pogonion and point A.[6]

II. Discussion:

Genetics and Family studies to predict growth:-

Studies of parents and their adult offspring as shown by Hunter to be revealsthe genetic control of facial dimensions. Suzuki et al. indicated more precise prediction of individual growth could be made by applying genetic data obtained from similarities in craniofacial characteristics between children and their parents.[8] Studies of twins also substantiate the observation that craniofacial characteristics, are dictated by a multifactorial inheritence model. Genetic analysis of craniofacial morphology was of prime concern in the studies of twins. Anterior cranial base and mandibular length appear to be strongly controlled by genetic factors. In family studies of craniofacial forms other than on twins, only the statistically significant correlation between parents and their children was reported.

1) The craniofacial forms of children with a certain degree of bone maturity were significantly correlated with those of their parents.
2) The genetic influence of parents on their children appeared to be equal.
3) The degree of correlation of craniofacial forms between children and their parents increased from childhood to adulthood.
4) Daughters seemed to be more affected genetically than sons by there parents.[9]

So we see that parental data are useful for more precise prediction of craniofacial growth in offspring. The relationship becomes closer with growth, so it is better to use parental data than to use average growth curves when the individual growth of a child is to be determined.[10]
Also it has been shown that facial height tends to show higher heritability than facial depth, and that the father offspring relationship is stronger than the mother offspring relationship for linear measurements of skull and the mandible. Therefore, it can be concluded that the parent offspring correlation linked to be predictive formula could improve the accuracy of prediction facial growth.[8,10]

GROWTH PREDICTIONS IN CRANIOFACIAL COMPLEX:

Frontal sinus in growth prediction:-

During the last few years orthodontists have come to realize that esthetics, function, and stability of results go hand in hand. The orthodontist may eliminate many of the negative factors that could influence the stability of treatment. The size of frontal sinus on radiograph is one factor that may help the clinician to determine whether he would be able to attain stability.

The amount and direction of future facial growth are of extreme importance, especially in young child. The necessity for early diagnosis has been stressed in particular when orthopedic treatment is anticipated. Despite numerous attempts, individualized growth prediction remains uncertain. Studies have shown that frontal sinus goes hand in hand with the large mandible, irrespective of its correlation to the cranial base. The results indicate that there is a significant correlation between maxillary length, symphysis width, condylar length and frontal sinus size on a lateral cephalogram. The large frontal sinus showed a positive correlation with all parameters.[11]

Acromegaly is associated with prominent frontal sinuses and overgrowth of the jawbones, and one usually finds a Class III type prognathic mandible in such cases. The frontal sinus bud is present at birth in ethmoid region but is not evident radiographically until the age of 12 years, when they reach nearly adult size. Joffe (1964) found that frontal sinus enlargement to be associated with prognathic subjects. It was found that the main enlargement of frontal sinus ceased at 15.5 years in boys and 13.75 years in girls, which was very near to the ages at which the growth increments reached a plateau in children, suggesting that the increase in the sinuses follows the trend in growth in bone lengths very closely.[12]

Growth prediction from Craniofacial & Cervical posture:-

According to a simple cybernatic model describing the influence of some functional factors on facial development, the soft tissue stretching model, a large craniocervical angle is likely to be associated with facial development in vertical direction.[13] The correlation between posture and subsequent craniofacial growth indicates that subjects with a backward inclination of the cervical column and a small craniocervical angle will exhibit reduced backward displacement of the TMJ, increased growth in the length of the maxilla, increase in maxillary and mandibular prognathism and larger than average true forward rotation of mandible. In other words, a small craniocervical angle is on the average, associated with a horizontal facial growth pattern, whereas a large craniocervical angle, on the average, is associated with a vertical facial development.[14]

Thus, there is a significant correlation between posture and subsequent facial growth, namely, between cervical inclination and craniocervical angulation and the subsequent saggital or vertical development of the face. This predictive relationship between craniocervical angle and development of lower face is in agreement with a prediction by the soft tissue stretching hypothesisby Solow and Kreiborg. According to this hypothetical model, obstruction of upper airway can lead to an increase in the craniocervical angulation to facilitate respiration. This leads to a stretching of the soft tissue layer covering the face and throat, and this stretching restricts or redirects the forward component of facial development in a more caudal direction. Huggare and co-workers have shown that in extention of the head with a large craniocervical angle, the height of the posterior arch of the atlas is reduced, and this structural feature is related to adenoid airway obstruction and a vertical facial development.[14]

Symphysis morphology - predictor of direction of mandibular growth:-

In orthodontics, knowledge of mandibular growth is highly beneficial in diagnosis and treatment planning and is critical in the development of balanced dentofacial structures.Rickets stated that symphysis morphology might be used, to predict the direction of mandibular growth. He associated a thick symphysis with anterior growth direction.

The shape and size of the symphysis of mandible is an important consideration in evaluation of orthodontic patients. With a large symphysis, more protrusion of incisors is esthetically acceptable and therefore, a greater chance of a non-extraction approach to the treatment. To define the anteriorly and posteriorly directed growth patterns, several cephalometric parameters have been suggested.[15]

Aki and Nanda et. al. developed a method to determine the symphysis dimensions. A line tangent to point B was used as the long axis of the symphysis, and a grid was formed with the lines of grid parallel and perpendicular to this constructed tangent line. The superior limit of the grid was taken at point B with the inferior, anterior and posterior limits taken at the most inferior, anterior and posterior borders of the symphysis outline, respectively. The symphysis height was defined as the distance from the anterior to the posterior limit on the grid. The Symphysis ratio was the proportioning of symphysis height to symphysis depth. The posterior-superior angle formed by the line through menton and point B and the mandibular plane determined the symphysis angle .This study showed that a large symphysis ratio i.e. height/depth is associated with a receding chin, high mandibular plane, high mandibular plane angle, large saddle, gonial and articulare angles, large anterior facial height and a large percentage of lower facial height. Also it was shown that men posses a stronger relationship between symphysis morphology and the direction of mandibular growth as compared to women, and with increasing age there was increase in symphysis ratio and decrease in symphysis angle.[16]

Antegonial notch as indicator of growth potential:-

The pressure of prominent mandibular antegonial notch is a commonly reported finding in subjects with distributed or arrested growth of mandibular condyles. In cases of unilateral condylar hypoplasia, marked mandibular notching develops only on the effected side. Bjork's implant studies illustrated apposition below the symphysis and resorption under the angle in forwardly rotating mandibles.[17] The direction of mandibular growth rotation is reflected in the location and degree of remodeling on the inferior surface of the mandible and the most pronounced area of remodeling is below the angular region. Thus, it would be reasonable to expect deep antegonial notching, a backward rotating mandibular growth pattern. Hence in a sample of persons with deep antegonial notching, a backward pattern of mandibular rotation and a vertical direction of mandibular growth should be prevalent.[18]

The study by Singer, Mamandras and Hunter (1987) clearly demonstrated decreased mandibular growth in deep notch subjects as compared with shallow notched subjects. The frequency of extraction was three times more in deep notched subjects. Therefore it can be concluded that –

- Deep notch (DN) subjects have a more retrusive mandible, with a sharper corpus, less ramus height, and a greater gonial angle than did shallow notch (SN) subjects.
- The mandibular growth direction in DN patterns is more vertically directed than for SN subjects.
- The DN subjects had longer total facial height and longer lower facial height than did the SN subjects.
- The DN subjects had a smaller saddle angle than did the SN subjects.
- Notch depth continued to increase in DN subjects, while it decreased only slightly in SN group.
- The amount of mandibular growth was less in DN sample as compared to SN sample during the period of study.

"When the growth of the mandibular condyle fails to contribute to the lowering of the mandible, the masseter and the medial pterygoid, by their continued growth, cause the bone in the region of angle to grow downward, producing antegonial notching." explains Becker et al.Inference on the association between pronounced antegonial notching and diminished mandibular growth. [19]

Therefore in summary we can say that the presence of deep mandibular antegonial notch is indicative of a diminished mandibular growth potential and a vertically directed mandibular growth pattern.

Ricketts Arcial growth principle and prediction of mandibular growth:-

Ricketts in (1972) proposed an interesting method describing the growth of mandible, known as principle of Arcial growth.The extract of the principle is as follows:- A normal human mandible grows by superior-anterior (vertical) apposition at the ramus on a curve or arch which is a segment formed from a circle. The radius of this circle is determined by using the distance from mental protruberence (Pm) to a point at the forking of the stress lines at the terminus of the oblique ridge on the mesial side of the ramus. (Eva point)

To explain the true arch of the growth of the mandible:-A point parallel to the line bisectingXi point to the sigmoid notch is selected on the anterior border of the ramus. This is called as RR point. The RR point is connected to point R3 at the depth of the sigmoid notch. 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 these two lines is called as point Eva. A third point is selected, of equal distance from Eva and Pm and is called as TR or true radius. Now using this TR point as center of the circle, an arch is scribed passing from Eva and Pm. At the point of intersection of the arch with the border of the sigmoid notch, a point is selected called Mu or Murray point. [2]

Steps in long range forecasting by using Arcialprinciple:-

1). Apposition of lower border of the symphysis occurs at about 1mm each 8 years, while from point Mu, mandible grows on the arch at the sigmoid notch about 2.5 mm each year.

2). Second step involves extending coronoid upward and outward at a rate of 0.8 mm per year. The condylar growth was found to be variable. Some condyles did not grow at all from the point Mu, while others grew significantly. The short and small condyles are given no further growth in the forecasting technique. Long necks and well formed condylar heads grow 0.5mm/year while in an average individual, the condyle is extended 0.2mm/year. It is important to note that both the coronoid and condylar process grow upward and outward in a direction essentially as a function of the original arch.

3). Thirdly with respect to gonial angle, it was reported that the gonial angle drifted posteriorly on the arch almost exactly 50% of the total mandibular growth on the arch. However, in males addition of 0.2mm/year are given.

4). Finally art work for normal contours is employed as connections are made from the projected coronoid process to the RR point on the coronoid crest. The oblique ridge of the mandible shows apposition by this method of 0.4mm/year.

Drawbacks:-

1) Employs chronological age rather than skeletal age.
2) Validity not constant in all the populations.

Bjork's Structural Method for prediction of mandibular growth:-

The growth direction of the mandible is an important factor in planning orthodontic treatment. Bjork in 1963 proposed a structural method for prediction of mandibular growth rotation based on information gained from implant studies. He proposed seven structural signs of extreme growth rotations to be considered for predicting condylar growth direction. These seven structural signs include:-

1) Inclination of condylar head.
2) Curvature of mandibular canal.
3) Shape of lower border of the mandible.
4) Inclination of symphysis.
5) Inter incisal angle.
6) Intermolar and premolar angle.
7) Lower anterior facial height.

Bjork found that a forward inclination of the condyle is related to vertical growth of the condyle with a resulting anterior rotation of the mandible. In cases with vertical growth he observed that the curvature of the mandibular canal tended to be greater than that of outline of the mandible, including the gonial angle. The opposite was found in cases with a backward shape of the condyle, characteristic of saggital growth, resulting in posterior rotation of the mandible. He also found that the shape of the lower border of the mandible reflects the direction of growth. In vertical condylar growth there was pronounced apposition below the symphysis which resulted in a thick cortical layer and anterior rounding. In saggital condylar growth the cortical layer was thin and there was no rounding. With respect to inclination of symphysis in vertical condylar growth the symphysis swung forward and resulted in a prominent chin while in saggital growth it swung backwards with a receding chin. In vertical growth, the anterior rotation will result in a relative decrease in anterior face height whereas a posterior rotation results in an increase.[20]

Bjork's implant studies based upon the centre of rotation implicated 3 types of forward and 2 types of backward rotations of mandible respectively.[21]

Type- I forward rotation: with centre of rotation at condyle resulting in deep bite.
Type- II forward rotation: with centre of rotation at incisal edges of lower anterior teeth
Type- III forward rotation: with centre of rotation displaced backwards from incisal edges to the premolars.
Type- I backward rotation: with centre of rotation in temporomandibular joint.
Type- II backward rotation: with centre of rotation at most distal occluding molars.

Besides the structural signs Odegaard (1970) also found that the size of the gonial angle was related to condylar growth direction; vertical growth results in an acute angle and saggital growth in an obtuse angle.

Wisth and Anne (1983) evaluated Bjork's method of structural growth prediction and questioned the applicability of this method in cases without marked deviation but confirmed that the structural signs introduced by Bjork are quite capable of showing mandibular growth rotation. The method should be used primarily to determine whether any typical signs of anterior or posterior growth rotations are present. [22]

Gnomonic Growth:-

The neurotrophic theory of Moss is one of the most interesting theories regarding the multiple factors effecting craniofacial growth. Literally neurotropism means nourishment from the nervous system. Moss and Salentjianalysed the foramina of the skull and the mandible through which the inferior dental nerve passes. The neurotrophic theory ascertained that the orofacial capsule responsible for translative movements of mandible creates theso-called gnomonic growth.

Gnomonic growth is a process in which the addition of a figure leaves the resultant figure similar to the original. Thus, gnomonic growth is characterized by increase in size without anychange in shape. The gnomonic growth, could be described, by a particular type of curve or spiral. The mandible moves down a logarithmic curve course of the inferior dental nerve. Ricketts indicated that the growth of the mandible is associated sometimes with an arch, called arcial growth and introduced a number of gnomonic figures that are related to three braches of the trigeminal nerve. Thus, he indeed recognized both the Moss neurotrophic concept as well as the logarithmic curve of the mandibular growth. The major difference is that the logarithmic curve of mandibular growth is universal, while the arcial mandibular growth is individualistic.[23, 24]

Todd's Mathematical Prediction of Craniofacial growth:-

Todd presented a mathematical model for predicting the course of craniofacial growth in an individual in an attempt to find a possible explanation for heads growing in such a globally regular manner. One hypothesis is that the overall pattern of craniofacial growth is controlled by a genetic plan.[25] Although no one could doubt that growth is effected by hereditary influences, there is considerable evidence that predispositions imposed by genetics still allow a large degree of flexibility. An alternative hypothesis more or less similar to that of D'Arcy Thompson, is that the overall pattern of craniofacial growth is primarily controlled by biomechanical influences. This hypothesis, known as Wolf's law of transformation states that once the general form of a bone is established, "The bone elements place themselves in a direction of functional pressure and increase or decrease their mass to reflect the amount of functional pressure."[26]

Now, according to Todd if biomechanical influences are to account for the global regularity of craniofacial growth, then the overall pattern of pressure and stress to which the growing material is subjected must also reflect that same regularity. Gravitational force has the obvious global influences on the biomechanics of growth. It is exerted on every point within the craniofacial complex and also providing a counter force for the muscles activity. Todd has explained this concept by considering the human skull as spherical tank filled with fluid. By applying basic hydrostatics, the amount of pressure (P) at any point (R,q) on the surface of tank is uniquely determined by its vertical distance from the top of the sphere. The direction of pressure is perpendicular to the surface at every point and the amount of pressure can be expressed as a function of position by the following equation:-

P= aR (1-Cosq)

where a, is the constant representing the product of force of gravity and density of the fluid.

Todd has oversimplified this analysis, as we know that heads are not perfectly spherical and also there are other sources of stress operating in the craniofacial complex besides the force of gravity, and the relative orientation of head does not remain absolutely fixed.

Such mathematical transformation which was derived, from the consideration of the global stresses on an idealized human head was shown to make reasonably accurate growth prediction over a span of about 10 to 15 years. However, use of such a global transformation for this purpose may add an important dimension to treatment planning because facial profiles are represented as a continuous contour rather than as a collection of independent points. [27]

Visualized Treatment Objective (VTO):

Visualized treatment objective is a visual plan to forecast the normal growth of the patient and the anticipated influences of treatment, thereby establishing the individual objectivesto achieve for that patient. Term VTO was first coined by Holdaway but used extensively by Dr. Ricketts. Treatment plan for a growing patient must be directed to the face and structures that can be anticipated in the future, instead of the skeletal structure that the patient presents initially. The treatment plan should take advantage of the beneficial aspects of growth and if possible minimize any undesirable effects of growth.

The Visual Treatment Objective is instrumental in the designing of alternative treatment plans. After the ideal alignment of teeth within the grown or anticipated facial pattern,it is up to the orthodontist to decide how far he should go with mechanics and orthopedics to achieve his possible goals and other alternatives.

Once treatment has begun, there is a continuing need for measurements and monitoring of visual goal to assess the treatment progress. By superimposing a progress tracing between the original tracing and the forecast goal, the orthodontist may evaluate progress along a definitely prescribed route. Any deviation from expected progress can be identified immediately, therebyplanning out earliest initiation of the necessary midcourse corrections.Though mostindividuals reaction ispredictable to treatment, some may deviate from the usual pattern requiring alterations in strategy. Lack of patient cooperation, variations in growth patterns and ineffective orthodontic mechanics are the different variablesresponsible for difference in response to treatment. Monitoring of these variables is important in accommodating necessary treatment to individual.[28]

The VTO forecast is blue-chip for the self-improvement of an orthodontist by permitting him to set his goals well in advance and later compare them with the results at the end of treatment. An objective picture of required improvement in the treatment plan can be obtained byIdentifying the discrepancies between goals and results of the treatment.[29]

Ricketts VTO:

VTO construction is a step by step procedure in the undermentioned sequence considering an average growth for a two-year period of active treatment, keeping in mind the objectives that we want to achieve with our mechanics:[30]

1) Prediction of the cranial base prediction
2) Prediction of the mandibular growth
3) Prediction of the maxillary growth
4) Positioning of the occlusal plane
5) Location of the dentition
6) Softtissue of the face

Fine Element Method Modelling Of Craniofacial Growth (FEM)

Finite element modeling are able to provide absolute quantitative description of cranial skeleton size and shape change with local growth significance, independent of any external frame of reference.It is assumed that identical growth occurs within a given finite element. Hence accordingly FEM analysis of craniofacial growth gains in accuracy as the numbers of finite element studies are increased and there size decreases.[31]

Finite element fundamentally attributes its ability to discretize structures or bodies into large number of continuous 2-3 dimensional elements each called finite element. While the FEM describes only the mean growth behaviours in each element, in practice the smaller the individual finite element and more of them in a given body, the more closely the resulting numerical result will approximate the reality of growth behaviours at each point.[32]

The force per unit area required to produce a strain is termed as stress and is the measure of the internal resistance of the body to deformation. Cell division, cell growth and production of extracellular matrices are responsible for the growth deformations not stress. A growth strain is the measurable deformation of a biologic body resulting from its growth. It is assumed that the growth description of any single element is valid for all of the points within the continuum of that same element in the present study of skulls.

The continuum viewpoint suggests that the fundamental effects in growth are the local extensions in the vicinity of any point. The growth stains are distributed by the growth tensor in each point. Tensors in general are abstract mathematical entities that cannot be visualized.[33]

Growth tensors are by definition independent of the body registration methods and define growth changes locally. If that growth process is prescribed by specifying growth tensors at every point of the body, then assuming that the growth strains are compatible and that the initial shape of the body is given the FEM is capable of predicting the shape of the body at any subsequent time during its growth.[32,33]

Skeletal maturation evaluation using cervical vertebrae by (Brunt Hassel and Allen Farman):

The first-string objective of this study was to create a method of evaluating the skeletal maturation of the orthodontic patient with the cephalometric radiograph that is routinely taken with pretreatment records. Cervical vertebrae (C2, C3, C4) predicts the growth under 6 stages: *Initiation, Acceleration, Transition, Deacceleration, Maturation and Completion.*

Correlations were made between cervical vertebrae maturation and the skeletal maturation of the hand wrist cervical vertebrae maturation indicators or CVMI as stated below.[34]

1) Initiation stage: Here very significant amount of adolescent growth is expected. C2, C3, C4 inferior vertebral body borders are flat
2) Acceleration stage: Significant amount of adolescent growth expected. Concavities start developing in the lower border of C2 and C3 while Lower border of C4 vertebral body is flat .C3 and C4 are more rectangular in shape
3) Transition stage: Moderate amount of adolescent growth expected. Distinct concavities seen in lower borders of C2 and C3. A developing concavity seen in lower border of the C4 vertebral body
4) Deacceleration stage: Small amount of adolescent growth is expected. Distinct concavities seen in lower borders of C2, C3 and C4. C3 and C4 vertebral bodies are nearly square in shape.
5) Maturation stage: Insignificant amount of adolescent growth is expected.Accentuated concavities seen in the inferior vertebral body borders of C2, C3 and C4.C3 and C4 vertebral bodies are square in shape.
6) Completion stage: Adolescent growth is completed. Deep concavities are present for inferior vertebral body borders of C2, C3 and C4.

III. Conclusion:

Growth prediction is a vital cog for a successful orthodontic treatment in a growing patient. Though there is a slight variability of growth in between individuals, our knowledge of various growth prediction methods can aid us in determining the right time to intervene for a successful orthodontic treatment rather acting blindly on it.

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FIGURE- 1: FRONTAL SINUS IN GROWTH PREDICTION

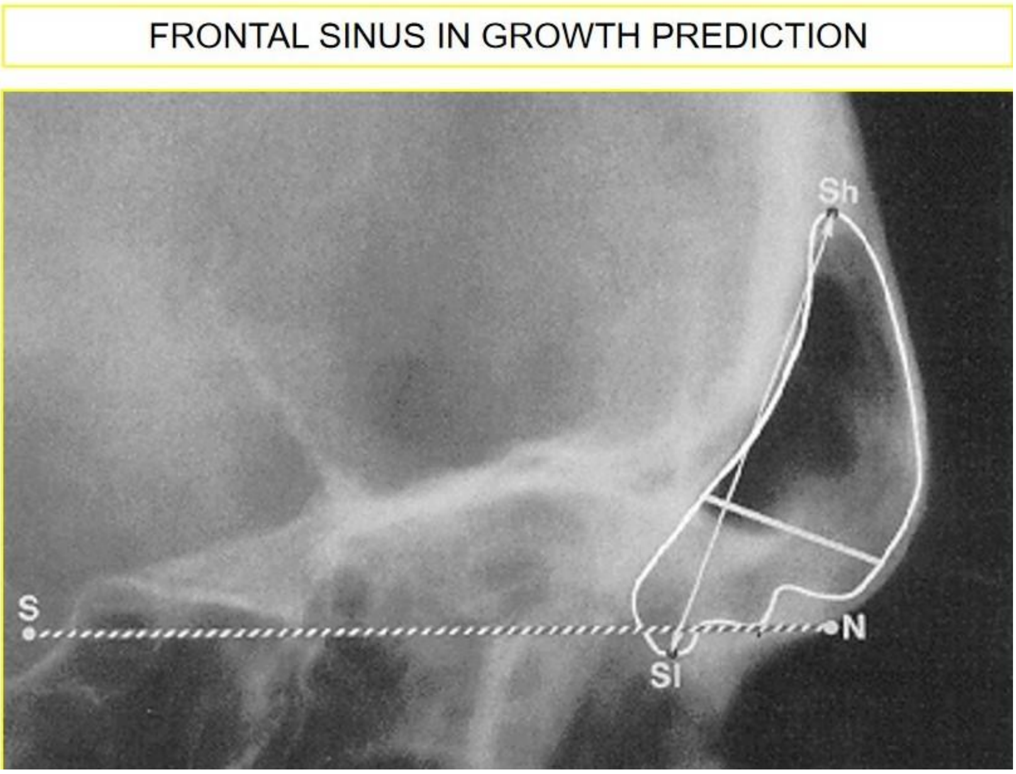


FIGURE- 2: BJORKS METHOD OF GROWTH PREDICTION IN HORIZONTALLY & VERTICALLY GROWING MANDIBLE

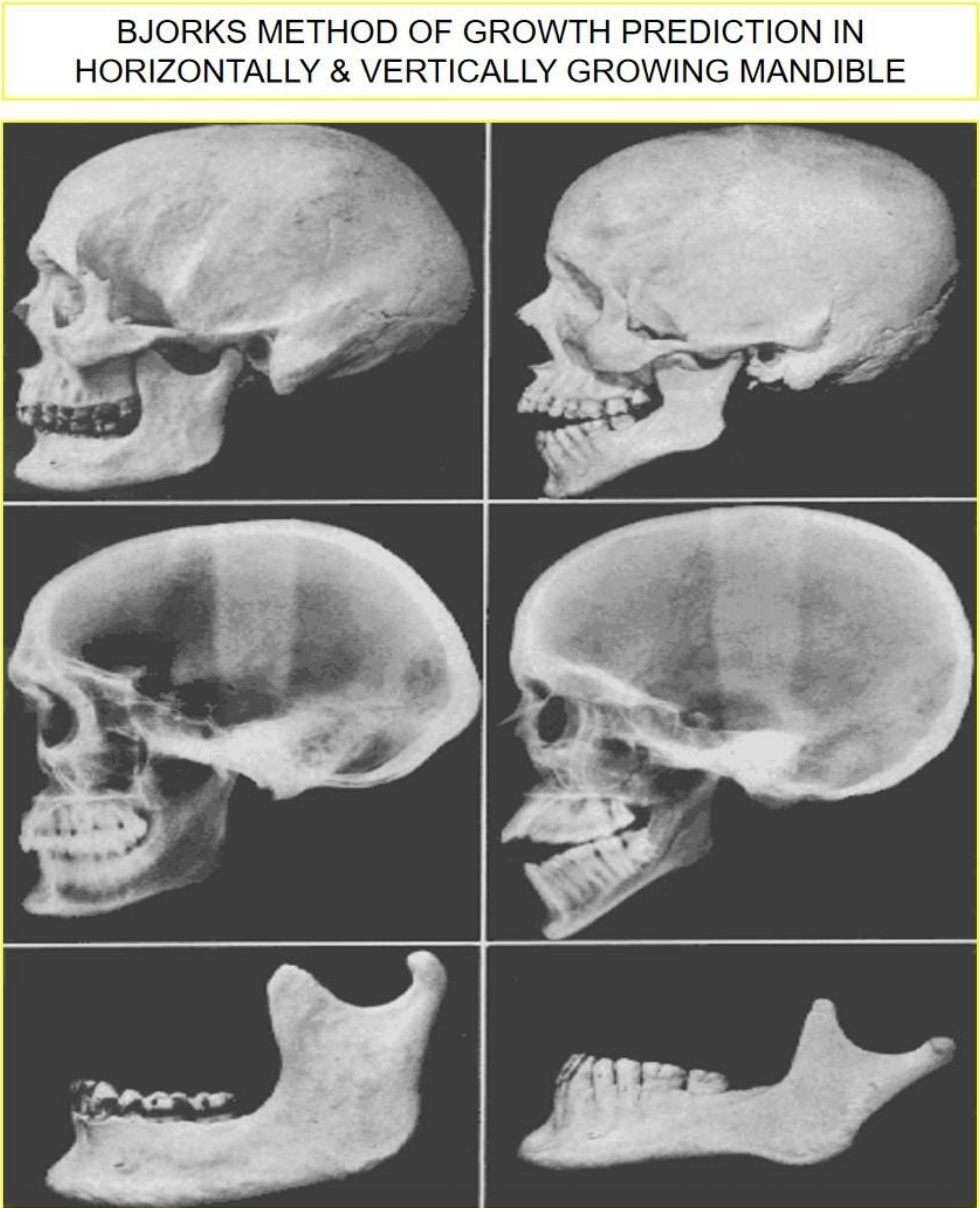


FIGURE-3 : FORWARD ROTATION OF MANDIBLE BY BJORK

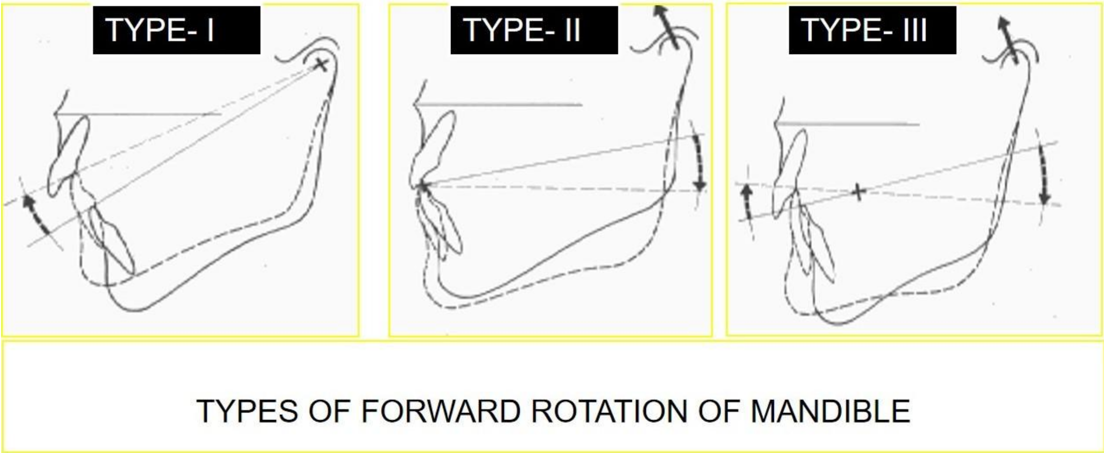
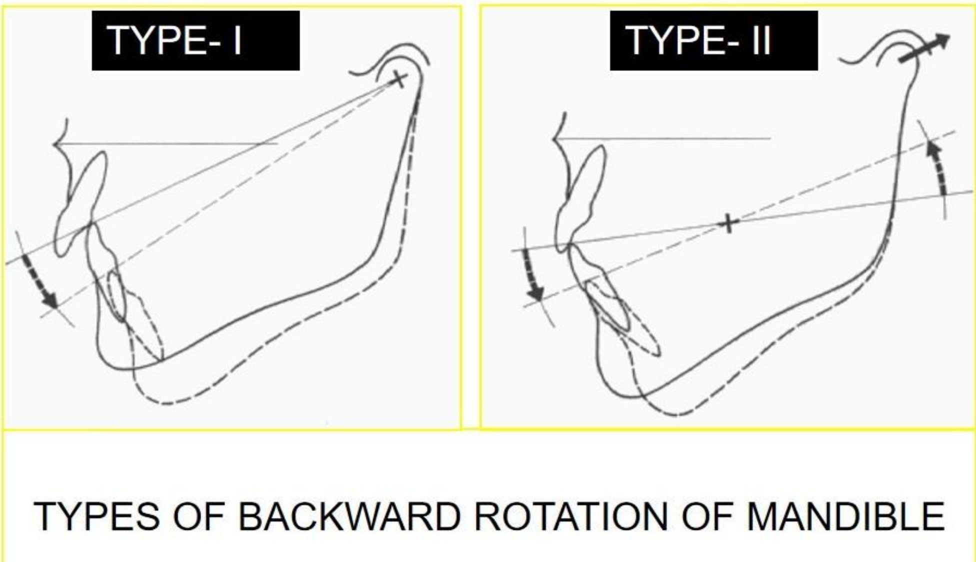


FIGURE-4: BACKWARD ROTATION OF MANDIBLE BY BJORK



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