

# Feature

## Cranial Strains and Malocclusion: III Inferior Vertical Strain

*This article has been peer reviewed.*

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**Abstract:** *This article describes the Inferior Vertical Cranial Strain, one of the seven possible cranial strains that are discussed in this series of articles. Clinicians have to understand cranial strains to better treat their patients. There is a major link between the malocclusion we see and the underlying physiology of the patients. With airway restriction, it is necessary to understand the cranial, postural and facial factors as well as the soft tissue contribution for a more effective overall treatment of the patient.*

**T**he inferior vertical strain is probably the most common variation of the seven cranial strains that we examine. It can be considered the primary etiological factor in Angle Class II, division I malocclusion. It also demonstrates most vividly the link between malocclusion and the underlying physiology of the patient. The effect of the cranial strain may not be obvious when the malocclusion is mild, but where it is moderate to severe a series of adaptations become apparent. A combination of significant

airway restriction and postural factors relates back to the cranial strain. Temporomandibular joint dysfunction is also a frequent finding in Class II, division I malocclusion, even in

children.<sup>1,2</sup> This emphasizes the need to understand the cranial component of temporomandibular joint involvement.

The name of the strain describes what happens to the sphenoid at the junction of the sphenoid and the occipital bones, the spheno-basilar symphysis (S.B.S.) (Fig.1). In the inferior vertical strain the base of the sphenoid (basi-sphenoid) moves downwards and forwards at the S.B.S. in a shearing action. As it does so, it rotates around its horizontal axis in an anti-clockwise direction. The occiput is elevated at the S.B.S. and also rotates in an anti-clockwise direction.

The anti-clockwise rotation of the sphenoid results in the maxilla being drawn upwards due to the gear-like effect of the junction between the pterygoid processes and the maxillo-palatine complex. As the maxilla is drawn upwards its lateral structures are drawn towards the mid-line, i.e. an internal rotation. As the occiput rotates in an anti-clockwise movement the lateral structures of the posterior quadrants of the skull move laterally, i.e. an external rotation. This gives a distribution of Sutherland's four quadrants of the skull as seen in Figure 2. The anterior quadrants are internally rotated and the posterior quadrants are externally rotated.

Armed with this information as to the cranial relationships,

the effects on the dentition and on the face can be predicted. From the anterior aspect of the face (Fig. 3), there is reduction of inter-ocular width, constriction of the nares and a lateral contraction of the maxillary dentition often with a tendency to a high v-shaped palate. The ears are usually flared. From the lateral aspect of the face (Fig. 24b), the forward movement of the sphenoid does not necessarily result in maxillary protrusion. The lateral rotation of the posterior quadrants and the flaring of the squamous portions of the temporal bones carry the glenoid fossae distally and with them the mandible.<sup>3</sup> This

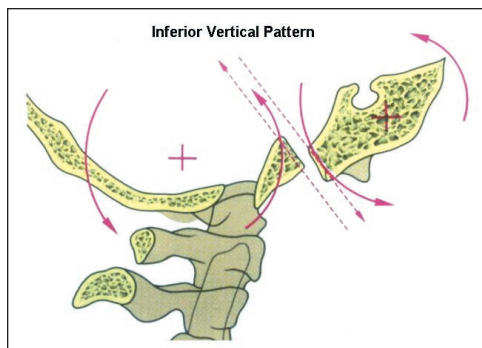


Fig. 1. Movement of Occiput and Sphenoid in Inferior Vertical Strain. Reprinted from *Orthopedic Gnathology*, Hockel, J., Ed. 1983. With permission from Quintessence Publishing Co.

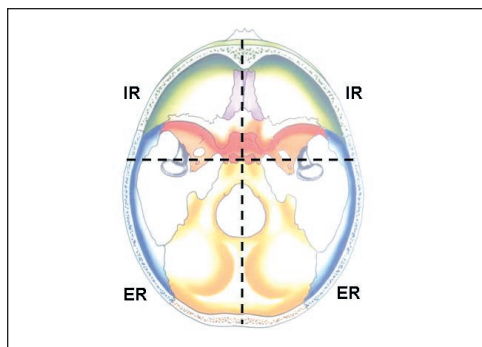


Fig. 2. Sutherland's diagram showing distribution of internal and external quadrants.

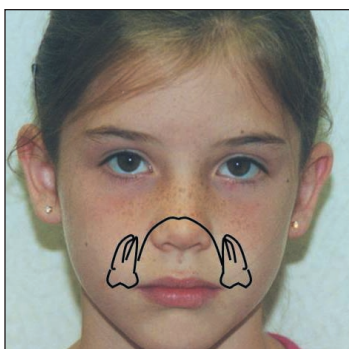


Fig. 3. Facial view, inferior vertical strain with superimposed narrow palatal vault.

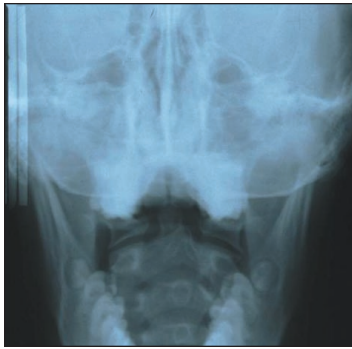


Fig. 4. P-A skull radiograph of inferior vertical strain

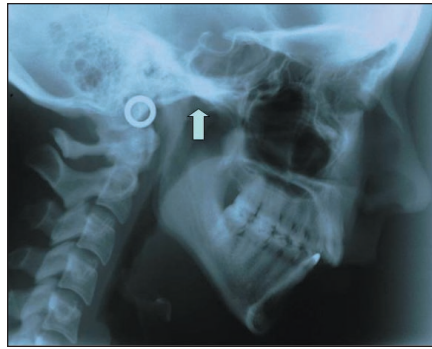


Fig. 5 Lateral head radiograph of inferior vertical strain showing step down at S.B.S. junction (arrow) and reverse curvature of cervical vertebrae.

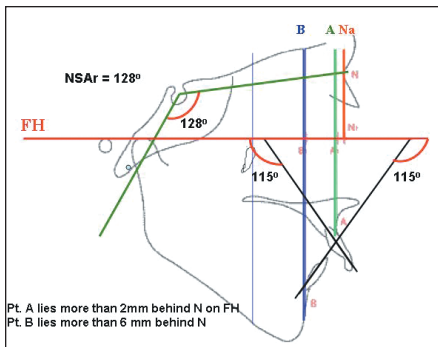
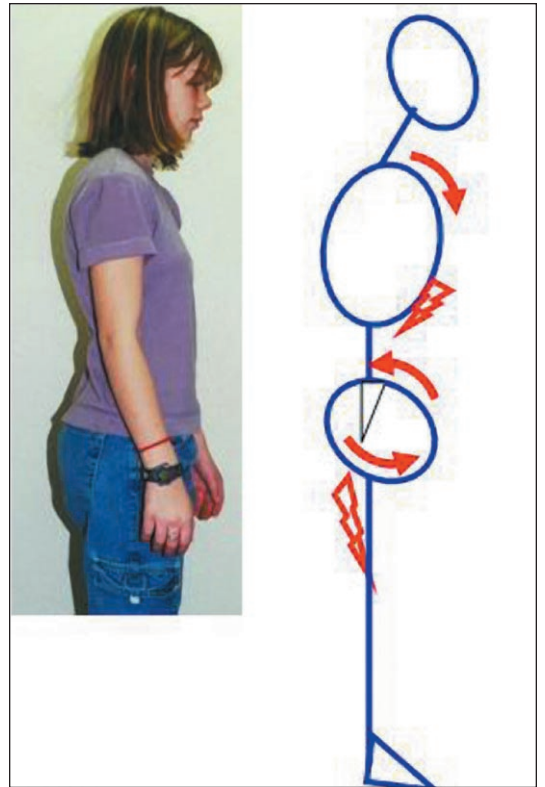


Fig. 7 Projection onto Frankfort plane for Nasion, point A and point B Template for Inferior Vertical strain.

Fig. 6 (right) Postural adaptation to Inferior Vertical Strain.

1. Forward head posture to open the lower pharyngeal airway.
2. Facial and muscular restrictions of anterior neck affect mandibular position.
3. Forward tip of torso follows the shift of center of gravity of head.
4. Pelvis rotates posteriorly and moves bodily forward due to shortness of dural sheath. Sheath attaches anterior to sacrum.
5. Hamstrings tighten to balance the pelvic shift.
6. Feet rotate outward in response to pelvic rotation.

The postural changes and the patient's compensation to maintain an airway feed into each other and both are consequences of the cranial strain.



contributes to the convexity of the facial profile.

The significance of the airway has been of much interest in orthodontics for many years.<sup>4,5</sup> The contribution made by unfavourable soft tissue mass and behavior patterns is well understood.<sup>6</sup> There is a cause and effect relationship between the skeletal structures and soft tissue patterns. The lateral constriction of the maxilla can create significant airway blockage through the nares (Fig. 4). The compression of the turbinate bones against the nasal septum can also cause interference with drainage of the maxillary sinuses. The upward and backward positioning of the maxillary complex can reduce the superior pharyngeal space and thus create stagnation areas. Swollen adenoid tissue is commonly found. This in turn can lead to blockage of the Eustachian tubes at their lower end due to the swollen adenoid tissue, with subsequent otalgic problems due to the lack of drainage or to infection tracking up the tubes. The combination of blocked nares, stagnation through the superior pharynx and lateral constriction of the palate leads to a low tongue position to allow for mouth breathing. An anterior tongue thrust may be present due to posterior blockage by enlarged tonsils. The patient uses a lower lip/tongue combination to produce an oral seal. Allergic tendencies may contribute to the airway problem.

As Angle recognized, a key component in the Class II, division I malocclusion is the retruded position of the mandible. This can be compounded by restriction of forward development of the mandible due to a tight lower lip and the need to drop the mandible down to improve the airway. The distal position of the mandible also encroaches on the airway, especially if tonsils are enlarged. This leads to a forward head posture (Fig. 5), which opens up the lower pharynx, but at the price of loss of primary curvature of the cervical vertebrae.

Some of these airway impediments have been identified and discussed elsewhere in the literature.<sup>7</sup> There has been less recognition that there is often a significant postural change. To help the reader understand the postural factors, we have illustrated the adaptations (Fig. 6).

The postural changes and the patient's compensation to maintain an airway feed into each other and both are consequences of the cranial strain. With advancement of the head its weight is effectively doubled. The result is often increased thoracic and lumbar curvature and a forward position of the pelvis to support the forward head position. Where there are airway problems, the sternocleidomastoid muscles, which elevate the thorax, may be involved to compensate for restriction in breathing.

## Radiographic Evidence

There are several distinctive features usually found in the lateral cephalometric radiograph of an inferior vertical strain patient. Typically, there is a step at the lower border of the S.B.S. (Fig. 5), caused by the downward positioning of the basi-sphenoid. As the occiput rotates in an anti-clockwise direction, it carries the occipital condyles forward, which in turn contributes to loss of the primary curvature of the cervical vertebrae. This is compounded by the forward head position.

In terms of actual measurements, the cranial base angle in a Class II, division I malocclusion, when recorded as Nasion-Sella-Articulare, averages  $128^{\circ}$ .<sup>8</sup> This reflects the distal position of the glenoid fossae. Logically, the downward and forward positioning of the basi-sphenoid would seem to dictate a forward position of the maxilla. Due to the gear effect of the sphenoid against the maxilla, the maxilla is actually rotated up and back as was discussed earlier. When projections are made from point A, representing the maxillary position and from Nasion onto the Frankfort horizontal (Fig. 7), McNamara<sup>9</sup> has pointed out that 25% of Class II, division I malocclusions actually have a retruded maxilla, that is point A is more than 2mm behind Nasion. Only 10% have protrusion of the maxilla. The relative size of the maxilla, when assessed by a cephalometric analysis such as that of McNamara<sup>7</sup> or Bimler,<sup>10</sup> is often small.

When the incisor angulations are examined, McNamara's figures show that only 20% of Class II, division I patients have a dento-alveolar protrusion. This is contrary to the commonly held view that protrusion of the maxillary anterior teeth is a predominant feature of a Class II, division I malocclusion. A useful diagnostic procedure during assessment is to correct the incisor angulations on the tracing to the theoretical values of  $115^{\circ}$  of the maxillary incisors to the FH and  $115^{\circ}$  in the mandible relative to the FH. By eliminating the dental compensations, a better indication is obtained as to the extent of the skeletal discrepancy.

Regarding the mandible, the inferior vertical strain results in distal positioning of the mandible. That is, when point B is projected onto the FH it lies more than 6mm behind Nasion. In a more severe Class II, division I problem, the mandible like the maxilla, is often small. A high Frankfort mandibular plane angle can compound the appearance of mandibular retrusion with the chin going down and back.

The P-A radiograph (Fig. 4) is helpful in identifying the degree of maxillary constriction and possible deflection of the nasal septum. Partial or complete blockage of the nares can be seen. Asymmetries in the level of the occlusal plane, the nasal floor and the bony orbits are also visible. On a good radiograph the condylar outlines are usually identifiable.

## Treatment

It is important to approach the treatment of an Angle Class II, division I malocclusion by seeing it as an integral part of an inferior vertical strain. To identify the problem primarily in dental terms is to limit treatment possibilities. With an understanding of the anatomy and physiology underlying the inferior vertical strain, we can avoid the possibility of inadvertently worsening the malocclusion through inappropriate treatment. **If a dental solution is forcibly imposed without recognition of the cranial strain it may actually worsen the strain. Relapse becomes a strong probability, as the cranial strain will re-express itself. This is discussed in more detail later in the article.**

We have listed the factors we look for which are associated with an inferior vertical strain. All of them are not necessarily present in any one individual. The more severe the malocclusion the more likely it is that these factors will be present. They can be seen almost as a syndrome. They are as follows:

- Downward step of basi-sphenoid at the S.B.S.
- Lateral constriction of the maxilla.
- Shortening of the maxilla in an a-p plane.
- Distal placement of the maxilla.
- Retruded position of the mandible.
- Reduced size of the mandible.
- Compensatory inclination of the maxillary and mandibular incisors.
- Temporomandibular joint dysfunction.
- Postural adaptation and airway restriction.
- Soft tissue mass and behavior pattern.

Two patients are presented to illustrate this approach.

## Patient K. M. Age 10 years

Prior to treatment, there was a history of snoring, repeated sinus infections and mouth breathing. Adenoids were removed at age 9 years.

## Pre-treatment Status

The full-face and profile views (Figs. 8a, b) show the reduced inter-ocular width, the narrow nares and the constricted lateral facial dimensions. The lower lip lies behind the maxillary incisors. There is lack of development of the malar processes in the infra-orbital region. In profile view the retruded position of the maxilla is demonstrated by the flatness of the infra orbital region. This is a key point in making a diagnosis as to the position of the maxillae. The mandible is severely retruded and small. From a postural aspect (Figs. 9a, b), although the profile photo does not show the whole body, there is a forward head posture, the shoulders are rotated forward and there is increased kyphosis and lordosis.

The lateral skull radiograph (Fig. 10) shows some loss of primary curvature of the vertebrae and it also demonstrates the step created by the downward movement of the basi-sphenoid. When the cephalometric evaluation is applied (Fig. 11), the cranial base angle is actually on aver-





Fig. 8 a. b. Inferior vertical strain patient. Facial and profile photographs, pretreatment. Severe maxillary and mandibular retrusion. Patient KM.



Fig. 9 a. b. Inferior vertical strain patient. Note poor posture, head forward, shoulders rolled forward. Incompetent upper lip. Patient KM.

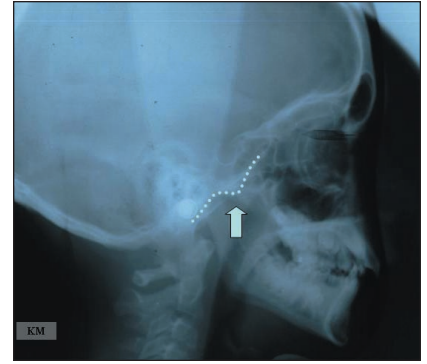


Fig. 10 Note the step down at the basi-sphenoid (arrow) and loss of primary cervical curvature. Patient KM.

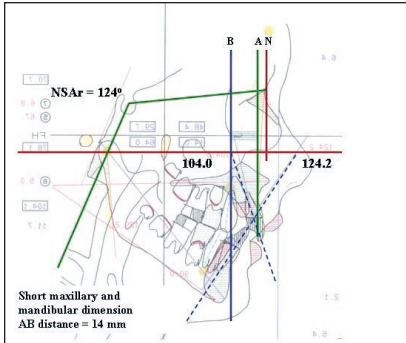


Fig. 11 Cephalometric tracing — Patient KM.



Fig. 12 Intra-oral photographs. Patient KM. Note mandibular anterior crowding and lack of space for three cuspids.



Fig. 13 a. A.L.F. appliances. Class III intra-oral elastics. Reverse pull elastic attachment to first bicuspids. left photo Fig. 13 b. Lateral and A-P expansion with elastic attachment for reverse pull facemask. right photo.

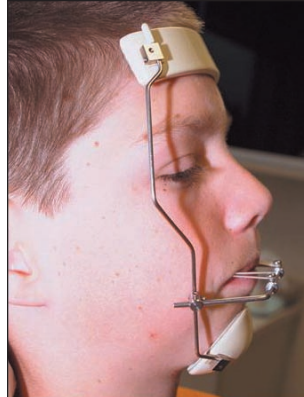


Fig. 14 Reverse pull facemask to maxillary A.L.F.

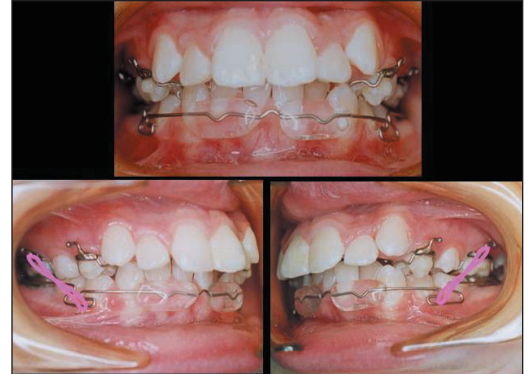


Fig. 15 Note space development for erupting cuspids and Class III elastics to lip bumper. Patient KM.



Fig. 16 OMNI 2 appliance to advance mandible. Note flanges to allow lateral movement. Lingual apron spring to align lower incisors.



Fig. 17 OMNI 2 appliance Intra-oral view. Patient KM.

age at value  $124^\circ$ . The A point lies only slightly behind Nasion, but the maxillary incisors are at  $104^\circ$ , i.e. retroclined. Correction of the angulation to  $115^\circ$  would carry the A point more distally. Similarly, correction of the mandibular incisor inclination from  $124^\circ$  to  $115^\circ$  would retrocline these teeth. The A-B distance on F.H. is 14mm which is excessive. Both the maxilla and the mandible are small relative to the cranium.

Dentally (Fig. 12), the shortness of the maxilla and the mandible contributes to severe crowding with three cuspids being blocked out of the arch. There is also thinning of the labial mucosa on the mandibular left central incisor. The molar relationship is a full unit Class II.

## Treatment

Treatment was begun using Applied Lightwire Functional (A.L.F.) appliances (Figs. 13a, b). In the maxilla the incisors were proclined and the arch was developed laterally. In the mandible, while the arch was being developed, there were also Class III elastics from the maxilla to the mandible to start advancement of the maxilla. Forward movement of the maxilla was supplemented by a reverse pull headgear (Fig. 14). This would seem to fly in the face of logic if the malocclusion is considered in dental terms only. From a mechanical point of view, Class III elastics and reverse pull facemask will worsen the overjet. From a biological point of view, the Class III traction has a favorable effect on reducing the cranial strain. Patients have to be advised that the overjet will worsen initially.

As space was gained in the maxilla the cuspids began to erupt (Fig. 15). The mandibular appliance was changed to a lip bumper to help gain space in the mandibular arch. Class III elastics were continued to the lip bumper. Having created an increased overjet and accommodated the teeth, a Nordstrom Omni 2 appliance was inserted (Figs. 16, 17). This appliance develops a forward position of the mandible while holding the maxillary anterior teeth forward. The flanges allow for more lateral movement of the mandible than is possible with a twin block appliance. Fixed appliances were then placed for final positioning with Class II elastics (Fig. 18). Figure 19 shows the final occlusion. Figures 20a, b and 21a, b show the improved overall facial balance. In particular, note the development of the malar processes. There is still a mild mandibular retrusion, but as the patient is only 14 years, further development of the mandible can be anticipated. Note also (Figs. 22a, b, 23a, b) the change in posture. The shoulder

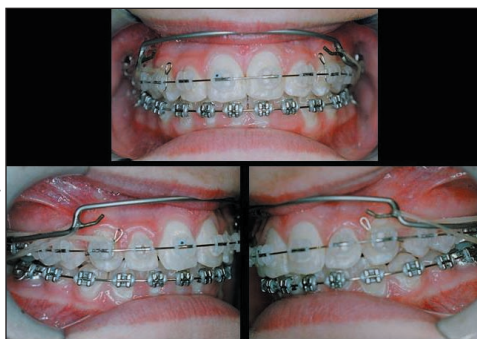


Fig. 18 Fixed appliances Class II elastics. Patient KM.



Fig. 19 Final dental result. Patient KM.



Fig. 20 a. b. Pre- and post treatment facial view.



Fig. 21 a. b. Pre- and post treatment profile.

rotation is corrected, the head position with the body's center of gravity and the forward head posture have been resolved. The patient no longer has airway restrictions.

By any standards this is a severe malocclusion with a very unfavorable skeletal discrepancy. Conventional orthodontic thought would almost certainly have considered extraction of teeth. Given the severity of the a-p discrepancy, eventual mandibular advancement by orthognathic surgery would have been a possible option. The changes achieved in this treatment were by understanding the contribution of the inferior vertical strain and by the use of light forces compatible with cranial movement. This demonstrates the value of the cranial diagnostic approach.



Fig. 22 a. b. Pre- and post treatment standing front posture. Note postural changes.



Fig. 23 a. b. Pre- and post treatment profile.



## Patient E. G. Age 11 years:

This patient (Figs. 24a, b) had very little of note in her pretreatment history, except some minor neck problems at age of eight years. Her parents' concerns were regarding the facial appearance primarily and the dental appearance as a secondary factor. Even allowing for the forward head tilt, the profile outline and full-face view with flaring of the ears would suggest a significant mandibular retrusion with a forward head posture.

The dental picture (Fig. 25) is a Class I relationship of both molar and cuspids. There is an increased overjet and overbite, but the dental findings do not seem to reflect the facial appearance. The lateral skull radiograph (Fig. 26) shows only a mild step down of the basi-sphenoid. The cervical vertebral curvature is close to normal. Actual measurements (Fig. 27) show that the cranial base angle at 125° is close to the average of 124°. Similarly, maxillary incisor protrusion at 115° is balanced. Point A is set back only slightly from Nasion on Frankfort Horizontal but the maxilla is small in a-p dimension. The main factor contributing to the configuration is a small mandible with compensatory mandibular incisor proclination.

Given the Class I molar and cuspid relationship, treatment could have been directed at lateral development of the maxilla with reorganization of the overjet and overbite, i.e. a dental correction only. In fact, A.L.F. appliances were used (Fig. 28). In the maxilla, the arch was developed laterally while the lateral incisors were proclined. In the mandible the incisors were retroclined. Class III elastics were used to advance the maxilla as a whole. As with the previous patient, the overjet was increased to allow for forward development of the mandible.

After the overjet was increased, bionator treatment was instituted. Figure 29 is the result of bionator treatment. Fixed appliances were placed (Fig. 30) for detail finishing. Figure 31 shows the final dental results. What is of particular interest is the change in the face, particularly from a profile point of view (Figs. 32a, b, 33a, b). The forward head posture has also resolved. This was a mild malocclusion in dental terms and the inferior vertical strain characteristics were less obvious. However, by recognizing the cranial strain pattern, rather than just the dental picture, a more effective result was achieved.

## Adult Treatment

Obviously, lacking the possibilities offered by further growth, treatment of an inferior vertical strain in adults has to be modified. The fact that cranial movement continues throughout life implies at least some flexibility of the sphenomaxillary structures. That can be turned to advantage. For example, lateral development of the maxillary arch with very light force can achieve substantial improvement in width with good long-term stability.

Another factor, which can be utilized in adult treatment,

is adaptation of the temporomandibular joints. The most common pathology observed in adults with a Class II, division I malocclusion is distal placement of the condyles within the fossae, with the discs being displaced anteriorly and mesially. As McNamara et al recognized,<sup>7</sup> development of the maxillary arch may allow some spontaneous forward positioning of the mandible. In practice this is usually accompanied by improvement in the condyle/disc relationship. Advancement of the mandible to help stabilize the condyle/disc position can be effective, but is of limited value in adults. Over-advancement of the mandible may pull the condyles out of the fossae and create an inherently unstable position. Mandibular positioning has to be considered in the context of the whole stomatognathic system. This includes the temporomandibular joints, the cranial architecture and the overall body posture.

The implication of not being able to advance the mandible in an adult beyond a certain point means that in a severe Class II, division I malocclusion, a residual overjet may have to be accepted. Alternatively, advancement of the mandible by orthognathic surgery may be appropriate. On occasion a severe Class II, division I malocclusion may be resolved completely by conservative means in adults. However, in most severe cases, limited objectives, maintained by retainers may be more realistic.

Throughout this series of articles we have touched on the need to apply treatment principles which recognize the existence of cranial movement. The goal is always to enhance, or at least not to overwhelm this physiological process. Several commonly used treatment techniques have the potential for iatrogenic damage. This is particularly true in the case of an inferior vertical strain.

Rapid palatal expansion, usually with fixed appliances, has long been a staple in orthodontics.<sup>11</sup> Although the rate of expansion may vary, the effect is a rigid locking of the two halves of the maxilla with the goal being forcible splitting of the palatal suture. The two maxillae pivot out against the resistance offered through zygomatic and frontal bones. We no longer use this technique for several reasons. It can severely distort the cranial/facial bones and jam the entire cranial/facial complex, with subsequent restriction of cranial movement. The expansion is prone to relapse, hence the general recommendation to over-expand the arch in anticipation of this. In most patients, no matter what the strain pattern is, one half of the maxilla tends to move more readily than the other. This reflects an underlying asymmetry present in the great majority of individuals. For preference asymmetry should be corrected with the use of A.L.F. appliances and light forces.

The use of a neck strap also introduces unfavorable forces. It drives the occiput forward and upward into even more flexion, thus aggravating the original distortion. It can compress C1, C2 and C3 vertebrae forwards creating an unfavorable postural problem. A high pull headgear can



Fig. 24 a. b. Full face and profile. Patient EG.



Fig. 25 Pretreatment photographs. Class II Div i - Inferior vertical strain molar and cuspid relationship is Class I. Patient EG.

**Patient E. G.  
Age 11 years**



Fig. 26 Lateral skull radiograph. Patient EG.

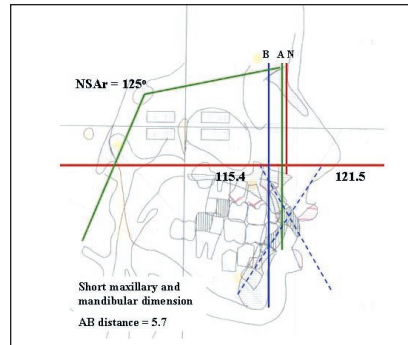


Fig. 27 Cephalometric tracing — Patient EG.



Fig. 28 A.L.F. appliance to develop maxillary arch laterally. Mandibular appliance to retract mandibular incisors and CI III elastics to bring maxilla bodily forward.



Fig. 29 Mandibular position after bionator. Patient EG.



Fig. 30 Fixed appliances. Patient EG.



Fig. 31 Final dental result. Patient EG.



compress most of the sutures of the cranium and depress the normal physiological rhythm. With both neck strap and high pull headgear distal movement of the maxilla and the maxillary dentition is usually the objective. As we have demonstrated, this is generally the opposite of what is needed in an inferior vertical strain.

Throughout this article we have described the structural features of inferior vertical strain which predispose to restriction of the airway. The internal rotation of the maxillae causes lateral constriction of the nares. The anti-clockwise rotation of sphenoid displaces the maxillae upwards and posteriorly as well as narrowing them laterally. These factors cause restriction through the upper pharyngeal space. The flexion of the occiput brings about a retruded position of the mandible, thus encroaching on the lower pharyngeal space.

There is another cranial strain, which can bring about similar adaptation.<sup>12</sup> The hyperextension strain also has anti-clockwise rotation of the sphenoid with a very similar internal rotation of the maxillae. The maxillae are also displaced more upwards and posteriorly in this strain. The result is an even greater encroachment on the upper pharyngeal space, but the prognathism of the mandible caused by the internal rotation of the occiput minimizes lower pharyngeal problems.

Woodside and Linder-Aronson have documented<sup>6</sup> the effects of naso and oral pharyngeal obstruction. They have also shown the change in mandibular growth from a vertical to a more anterior direction following removal of these various obstructions. While they recognize that cranial based factors are contributory, their main focus has been on soft tissue effects. It is our contention that the two cranial patterns, inferior vertical strain and hyperextension, are the principal factors leading to airway obstruction. This is because of the anatomical and physiological limitation imposed by the strains. The result is a lack of oxygenation, stagnation and subsequent hypertrophy of the soft tissues through the nares and pharynx.

Recognition of the contribution of the two cranial strains promotes a much more sophisticated understanding of airway problems. An early and effective approach to soft tissue management is fully appropriate in order to achieve maximum benefit. Identification of the cranial architecture of these two strains permits a more specific orthopedic and orthodontic type of intervention, which embraces the entire physiology of the body.

## Conclusions

In our previous articles we discussed the need to recognize rhythmic cranial movement as a normal physiological process throughout life. In this article we have tried to show that treatment must allow for the characteristics of the particular cranial strain being treated. Malocclusion is part of a total body picture and should not be seen in isolation.



Fig. 32 a. b. Front facial photographs pretreatment and post-treatment. Upper face is wider. Head tilt to the left is corrected. Increased lower facial height.



Fig. 33 a. b. Profile photographs, pretreatment and post-treatment. Note mandibular development. More favorable soft tissue profile. Patient EG.

This is particularly true where there are airway restrictions. It is necessary to understand the cranial, postural and facial factors as well as the soft tissue contribution.

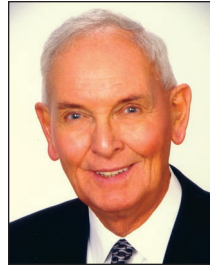
The two cases presented in this article demonstrate the value of this approach. They also indicate the need to work with other health disciplines such as an ear, nose and throat surgeon, osteopaths or physiotherapists in order to achieve optimum long-term health for our patients.

## References

1. Schellas, K.P., Pollei, S.R., Wilkes, C.H. "Pediatric internal derangements of the temporomandibular joint: Effect on facial development." *Am. J. Orthodont.* 104: 1: pgs. 51-59: 1993.
2. Pahkala, R., Overstrom, M., "Can temporomandibular dysfunction signs be predicted by early morphological or functional variables?" *Eur. J. Orthodont.* 26: 4: pgs. 369-373: 2004.
3. James, G.A., Strokon D., "Cranial strains and malocclusion: A rationale for a new diagnostic and treatment approach." *Int. J. Orthodont.* 16: 2: pgs. 25-29: 2005.
4. O'Ryan, F.S., Gallagher, D.M., LaBanc, J.P., Epker, B.N., "The relation between nasorespiratory function and dentofacial morphology: a review." *Am. J. Orthodont.* 82: pgs. 483-410: 1982.
5. Duchateaux, C. "Nasal ventilation and orthodontics." *Int. J. Orthodont.* 15: 1: pgs. 27-29: 2004.
6. Linder-Aronson, S., Woodside, D.G., *Excess Face Height Malocclusion*. Quintessence pub. Co.: 2000.
7. McNamara, J.A., Brudon, W.L., *Orthodontic and orthopedic*



- treatment in the mixed dentition. Pub. Needham Press: 1995.
8. Hopkin, G.M., Houston, W.J.m James, G.A., "The cranial base as an etiological factor in malocclusion." *Angle Ortho*, 38: pgs. 250-255: 1968.
  9. McNamara, J.A., "Components of Class II malocclusion in children 8 – 10 years of age." *Angle Ortho*, 51: pgs. 177-202: 1981.
  10. *Bimler Cephalometric Analysis*. Pub. By Clinical Foundation of Orthopedics and Orthodontics. P.O. Box 695, Gainsville TX 76241.
  11. Lima, A.L., "Long-term clinical outcome of rapid palatal expansion as the only treatment performed in Class I malocclusion." *Angle Ortho*. 75: 3: 2005.
  12. James, G.A., Strokon D., "Cranial Strains and Malocclusion II Hyperextension and Superior Vertical Strain," *Int J Orthodont*, 16:3 pgs. 15-19:2005.



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