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Articular Compass: The Location of Frontal Accessories of Bioelastic Appliances

Wilma Alexandre Simões, D.D.S.

ABSTRACT: In long face syndrome with skeletal open bite, strongly associated with temporomandibular disorders (TMDs), the trajectories of an incisal point are completely different. It was demonstrated by a longitudinal study that, in these cases, the Articular Compass cephalometric analysis is helpful in the construction of bioelastic appliances to provide a better location for frontal accessories, and thereby in most cases, also provide better anchorage with proper tongue and mandible position. The Articular Compass Analysis is valid in the early diagnosis. The odds ratio of success using the Articular Compass Analysis presents a confidence rate of 95%. Moreover, it was detected that subjects by the age of six with open bite, gonial angle equal to or greater than 135 degrees, with Nasion-Gonion-Menton equal to or greater than 76 degrees are risky cases for surgical treatment. These parameters are an indication of progressive problems which, with time, can reach severe levels which involve the cervical or even the lumbar spine.

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Address for reprint requests:
Dr. Wilma Alexandre Simões
Av. Brig. Faria Lima
2894 - conj. 51
CEP: 01452-002
São Paulo, Brazil
Email: wsimoes@ibm.net

Dr. Wilma Alexandre Simões *is a 1962 graduate of the Dental Faculty, São Paulo University. She earned a certificate in orthodontics from the Federal Dental Council in 1975, authored the book "Jaw Functional Orthopedics (two editions), is editor of "TMJ Dysfunction Differential Diagnosis and Treatment," and is a contributing editor to The Journal of Clinical Pediatric Dentistry. Dr. Simões is a founding member of the Ibero-Latin American Academy of Craniomandibular Disorders and the Brazilian Academy of Cranio-Oro-Cervical Physiopathology. She is a "Doctor Honoris Causa" of C.C.B. University. Dr. Simões has taught in the postgraduate Orthopedics Program of the university and also maintains a private practice.*

Compass is an *enclosed area, circle, circumference and the limit of a space*, which includes the *space*. Compass is applied not only to space, but also to time. Furthermore, compass is an instrument for drawing *arches or circles* or for *showing direction*.[1] The Articular Compass[2-5] is related to the enclosed area of the Posselt envelope[6,7] using the incisor point trajectories in the sagittal plane and including the synchronism of the mandibular dynamics, i.e., *time and space*.

The jaw must have proportionality with the structures of the cranio-maxillomandibular-hyoid-vertebral complex in order to have a correct physiological interrelationship.

In long face syndrome with skeletal open bite, the *arch* that describes the opening/closing movements, starts at a *different place*, showing a *different direction*, with a *different length*, within a *shorter time*. Since the contacts at the maximal intercuspation position (MIP) on the posterior part of the dental arches prevent the closing movement going further, the dimension time is shorter without increase of velocity.

In such cases, it is necessary to study the beyond-certain-limits disproportion of the mandible to achieve a better diagnosis and prognosis. Bioelastic appliances[8,9] seem to be the most desirable treatment, but they require precise anchorage to provide the change of posture of the mandible by more rotation than translation. This translation is very small, compared to the greater and significant translation needed in overbite cases with large overjet.

The two circumferences that contain the circles' arches of opening mandibular movements must have a comparative relation with respect to size, radius and intersections. There must be a proper compass mastering the mandibular dynamic balance which is essential to harmonious growth. The growth of each bone must be related to the others.

The study of proportionality may help to understand why, sometimes, surgery is the only way to treat certain cases. Early treatment can preclude such a condition. However, that depends on the intensity of the growth disproportion.[2-5]

The mandibular dynamics *encompass an area* covered by the mandibular morphology while having the temporomandibular ligament limiting the extent of the rotation in the terminal hinge-axis and the stylomandibular and sphenomandibular ligaments limiting the translation.[10-14]

One of the instantaneous centers of rotation is around the center of the condyle and one of the instantaneous centers of translation is around the entrance of the Inferior Dental Canal around the lingula or spine of SPIX.[10-15] This is the geometric center of the ramus which, in cephalometry, the point is Xi.[16] The landmark Capitulare is a point at the center ofthe condyle.[17]

However, another controversial experimental point of view recently described[15] the pathway of the instantaneous axes of rotation in normal subjects as Finite Helical Axes, and on average, for each millimeter of anterior or posterior translation in opening/closing movements, the condylar rotation increases by approximately two degrees.

These statements reinforce the supposition that even if some of the instantaneous centers are not located at the center of the condyle or around the lingula, the mandible movements are still dependent on the TMJ and the neuromuscular system.

The condyle is part of the TMJ and is inferior to the lingula (attachment of the sphenomandibular ligament), and the mandibular foramen opens into the mandibular canal housing the inferior alveolar vessels and nerve. These are sites related to the neuromuscular system and are important when treatment is based on change of posture. However, radiographs show the bony contour and are a useful clinical tool. A lot of training and knowledge of landmarks is required in order to interpret cephalometric tracings.

The Articular Compass[5] can be studied using cephalometric tracings to analyze the mandibular proportionality and the relationship between upper and lower incisor position. Despite the limitations, incisors and condyles provide useful analysis for studies based on synchronic jaw motion and limits imposed by the morphology.

In order to clarify the use of the Articular Compass and cephalometric tracings for analysis, the following landmarks are defined.[16,18]

- **AR**: Articulare, the point of intersection of the inferior cranial base surface and the posterior surface of the mandibular condyle.
- **GO**: Gonion, the most distal point of the lower border of the corpus.
- **ME**: Menton, the most inferior point on the symphyseal outline coincident with the most mesial point ofthe lower border of the corpus.
- **N**: Nasion, the junction of frontonasal suture, at the most posterior point on the curve at the bridge of the nose.
- **CP**: Coronoid Process, the most superior point on the outline of the coronoid process.
- **PG**: Pogonion, the most anterior point on the contour of the chin, determined by a tangent through Nasion.
- **SYMP**: Symphyseal point, a constructed point used to determine symphyseal width at Pogonion.
- **CO**: Condylion, the most posterior and superior point on the condyle outline determined as the point of tangency to a perpendicular construction line to the anterior and posterior borders ofthe condylar head.
- **GN**: Gnathion, the most anterior and inferior point on the contour of the bony chin symphysis. This point is determined by bisecting the angle formed by the mandibular plane (GO-ME) and a line through Nasion and Pogonion.

It seems that skeletal open bites with ramus-corpus disproportion are better evaluated when the diagonal of ramus is considered. This distance is measured between the gonion (GO) and coronoid process (CP).[4] The seven key measurements to evaluate the frontiers of mandibular proportion and disproportion by Structural Articular Compass Cephalometric Analysis[2,3,5] and therefore, to provide an initial prognosis follow:

1. Gonial angle (AR-GO-ME); 2. its lower part (N-GO-ME); 3. corpus length (GO-ME); 4. ramus height (AR-GO); 5. diagonal of ramus (CP-GO); 6. mandibular diagonal (CO-GN; and 7. symphysis width (PG-SYMP), **Figure 1**.

The upper part of the gonial angle (AR-N-GO) is not measured but calculated since it is complementary to the lower part.

However, the distinct tracings of the Location Articular Compass Analysis for different open bite malocclusions are clinical tools used to better locate the frontal accessories of the appliances used as tongue grid. **Figures 2A**, **2B**, **3A**, and **3B**.

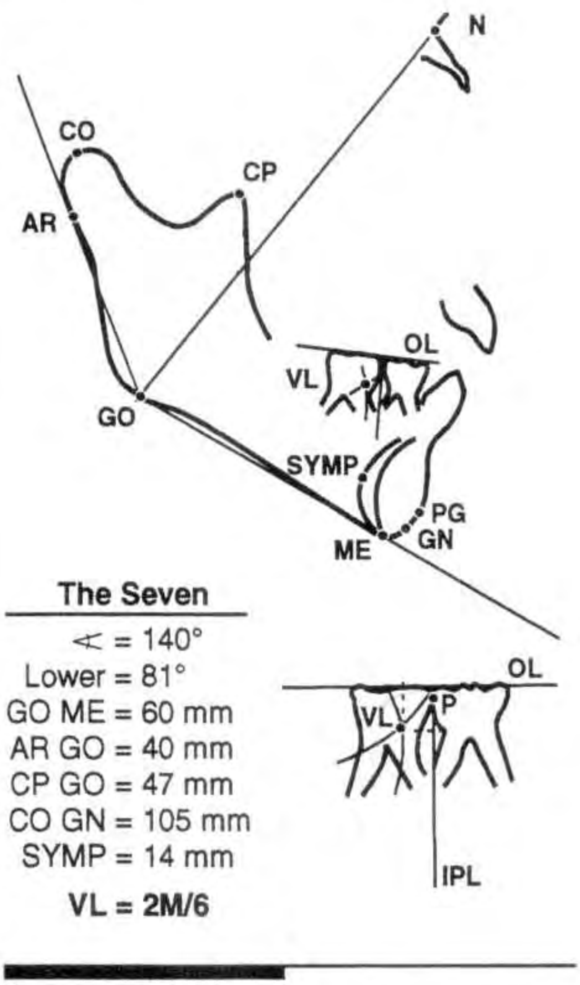


Figure 1
Structural Articular Compass Analysis: A.P.L. 6 years, Skeletal Group, with slow result. Note the high values of gonial angle in the lower part.

Figure 2A demonstrates some basic steps, where the center on H and radius CP-GO results in an upper tongue grid element. **Figure 2B** shows the location of the lower element with the center on CP and radius CP-to the end stop of the transfer, to the therapeutic axis of the distance between the upper incisor and tongue grid, measured on the guide axis.

In this way, the anterior elements of the appliances have shape/position according to individual jaw morphology and contribute to better control of the tongue-mandible-tongue posture[2-5,19] to obtain precise anchorage.[5]

Use of the Articular Compass Analysis is indicated predominantly between six to eight years of age, an important developmental stage for the architectural influence of the occlusal field on craniofacial morphology.[2,20]

The differential diagnosis of skeletal open bites can be made through a number of cephalometric and clinical features. One of the latter is protrusion of the mandible producing an increase in the space between anterior teeth that becomes even bigger when the lower incisors are under-erupted. One of the former features is the Articular Compass Analysis. Both features were used in this clinical investigation. In normal subjects during protrusion and laterotrusion, condylar rotation is not significant–close to one degree.[15]

Under-erupted incisors is one clinical sign found in a sample of adult skeletal open bite patients who were compared with control subjects used to classify the relationship between craniofacial morphology and tongue posture based on a canonical correlation analysis.[19]

It is not in the scope of this study to detail ways to transfer cephalometric findings to construction of the appliance in the laboratory. However, it is obvious that consideration of the measurements of the geometric area between incisors and grid elements provide a roadmap for laboratory transfer (**Figures 3A** and **3B**). Furthermore, it is not in the scope of this study to describe all the specific tracings for open bites, distocclusion or biprotrusion cases.

Articular Compass: Landmarks with Physiological Meaning

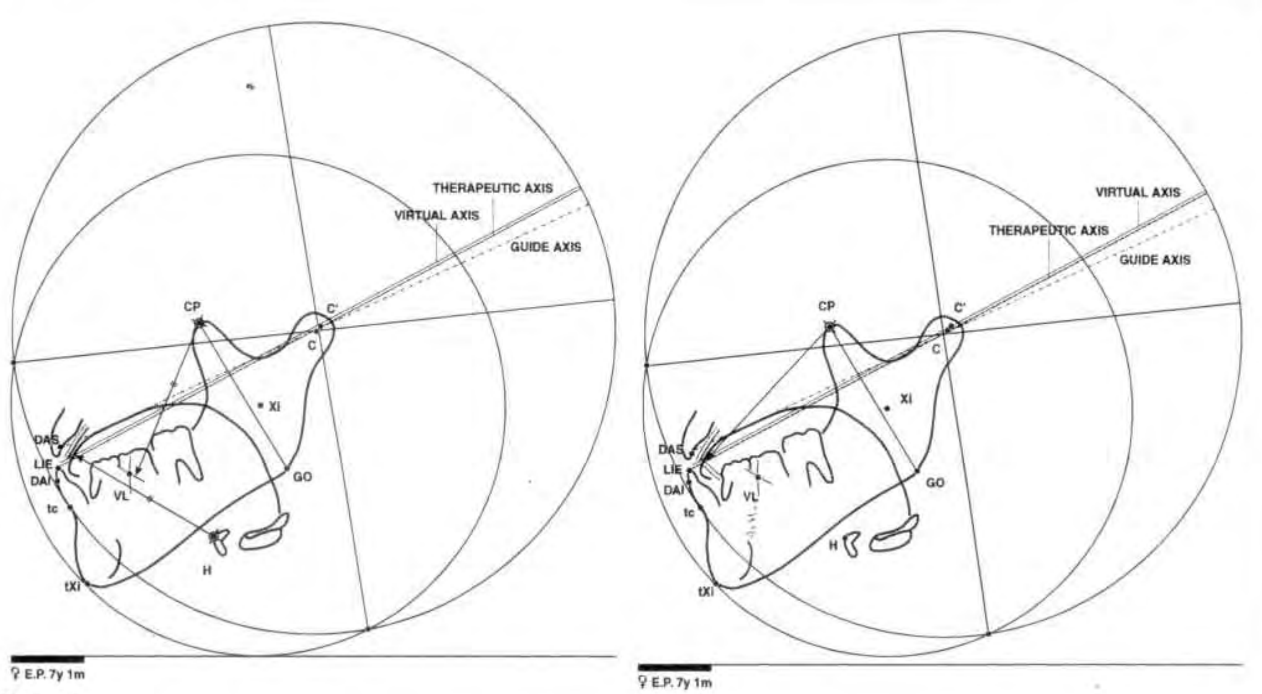
Tongue-Mandible Posture

The skeletal open bite hyperdivergent cases present different muscle position, neuromuscular activity, and tongue and lip pressure, among other alterations. Particular attention should be given to resting tongue posture, because of its relationship to changes in vertical dimension.

Bioelastic appliances[8,9] include all the elements to induce proper tongue and jaw posture and to maintain prevailing anterior mandibular rotation over translation[2-5] which is one goal of treatment. This therapeutic posture change is needed ~~to in order~~ to treat skeletal open bite.

The elevation movements of the mandible stimulate the retraction of the tongue by the principle of reciprocal innervation.[21] There is a neural and muscular intercommunication which facilitates the functional roles of the anatomic structures.[13,22-25]

Respiration cannot be interrupted for long periods of time without causing death. Sometimes it is mandatory to stop swallowing to take a breath. Therefore, there is a physiological mechanism that demands priority of one activity over another. Swallowing inhibits respiration, and airway supportive reflexes are a priority over those of mastication or swallowing. The functional priority takes



Figures 2

A(above left): E.P. 7 yr. 1m, Location Articular Compass Analysis for mesioclusion via hyoidale, direct way, locating the upper tongue grid element.
B (above right): 7 yr. 1m, Location Articular Compass Analysis for mesioclusion via hyoidale, direct way, locating the lower tongue grid element.

precedence to promote, at the proper moment, the neural action and inhibition by the shorter afferent and/or efferent ways.[24,26]

The neuromuscular system is responsible for coordination of tongue and mandibular movements involving principles of reciprocal innervation.

The octagon of functional priority[9] includes the interrelation between TMJ, tongue, mandible, neck, head, vertebral column, inframandibular region (influenced by hyoid bone position) and air passage (influenced by the posterior pharyngeal wall)[19,26-34] with respect to the sequence of their physiological roles. This sequence is organized for optimum synchronism of the different functions, according to age and sex, and to mechanisms of growth and development.[2]

In cases of anterior growth rotation, orthopedic appliances change the posture of the mandible by more translation than rotation. In deep overbites with no overjet, the

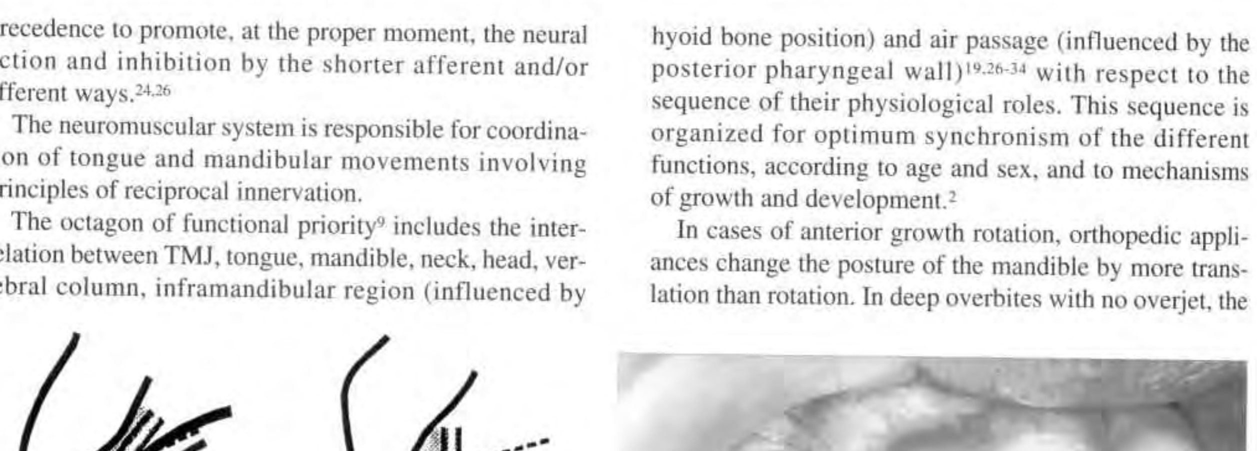


Figure 3

A (above left): E.P. 7 yr. 1m, and S.B. 7 yr 2m, patients with similar mandibular and very different tongue positions. Note the different frontal accessories location dictated by the Location Articular Compass Analysis. **B** (above right): Note the frontal accessories of the bioelastic appliance.

translation is more vertical. In such cases, the action of the muscular "envelopes" as masseter-medial pterygoid is very important for postural control.[2,9]

However, in open bite patients the muscular "reins", such as lateral pterygoid, digastric and styloglossus, are essential to make it possible for the anterior rotation to prevail over the translation.[2,9,25,35]

In all cases, the action of muscular "sheets" or muscular "cloth" (like that of a sail boat) represented, for example, by the temporal muscles, is fundamental for the final postural adjustments.[25,35]

The theory of muscular reins and the octagon of functional priority facilitate understanding of the management of bioelastic appliances which is very useful in skeletal open bite treatment.[2,9]

The Articular Compass tracing uses landmarks related to insertion of the temporal muscles, inframandibular muscles, ligaments, neuromuscular areas, the TMJ and osseous region where rotation and translation are of utmost importance.

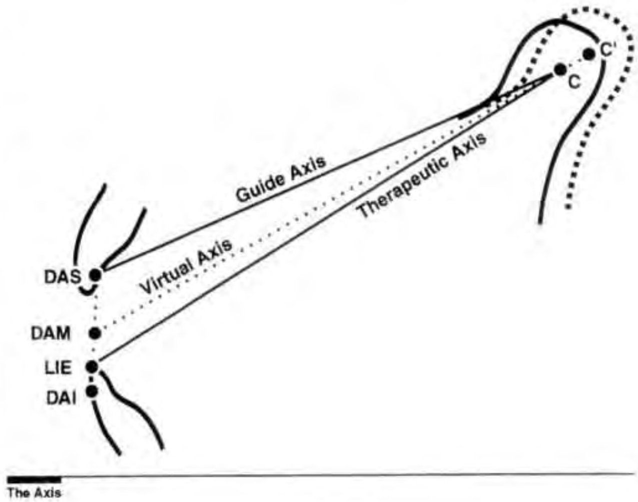


Figure 4
Note the DAS at the center of the incisal third of the upper incisor, on the palatine face equal to or greater than 2mm from the incisal edge. DAI at the same place of DAS on the buccal face of the lower incisor. DAM is at mid distance between DAS and DAI.

New Landmarks and Axes

In adult subjects, under normal physiological conditions and excluding cases with heavy medial guidances (balancing contact on the last molars), only during the lateral protrusive movements do the lower and upper incisors have contact. However, during development, there is a stage at which the occlusal plane is supported only by the permanent molars and the incisors. Later, there is no longer incisor contact at MIP.[20]

Therefore, framed by a servosystem, the biological processes as the increased static sensitivity of the receptors around the resting posture,[36] the interdental discrimination,[37] and the feedback determinant role on the mandibular movements are programmed to couple with mechanisms of incisor contact in a determined area (DA) during growth and development.[38]

The Articular Compass tracing considers some new landmarks like those in a Determined Area (DAS, DAI) of upper and lower incisors. As in open bite cases, there is no incisor contact. Another new landmark for use is DAM at the medium distance between DAS and DAI (**Figure 4**).

The Articular Compass tracing also shows a guide axis between the TMJ and the upper incisors, and a therapeutic axis situated between the TMJ and the lower incisors. When there is no incisor contact, these axes are not superposed.[5] The treatment must make these two axes overlap.

In open bites at MIP, the center of the condyles can be dislocated micra forward and upward with distoclusion, or forward and downward with mesioclusion.[39] The proper positions would be in the inverse direction. Before treatment, proper positions are virtual, not real.

Virtual Capitulare-C', considered the position goal of treatment, is a constructed point in the above-mentioned inverse direction, according to the case, at two mm maximum dislocation from the real center of the condyle, Capitulare.

Another important axis is called virtual, between virtual Capitulare and DAM, in which direction the therapeutic axis would have to move during treatment to meet the guide axis. The ideal is to get coincidence between Capitulare, C and the virtual Capitulare, C' (**Figure 4**).

VL (Vestibular-Lingual) (**Figure 5**) is a new landmark at the crossing lines of the arches of the circles with the center on CP and GO, one at a time, using the distance between CP and GO as the radius. VL is called Vestibular-Lingual since it belongs to both, the faces of teeth or mandibular bone. Cephalometry deals with 2-D parameters, but the landmarks must be based on anatomical and/or physiological meaning.

In fact, these two arches of the circles seem to enclose the measurement of one of the possible keys to understanding the mandible proportionality between the ramus and corpus relationships. CP is on the ramus, GO is on the corpus and VL is around or on the teeth.

The combined action of the elevator muscles of the mandible is fundamental for closing.[11,34] The temporal muscle inserts on the coronoid process, therefore CP is related to it. GO is on the gonial angle, at the masseter-medial pterygoid sling insertion region (**Figure 5**).

Ontogenetically, changes of VL position can be observed. It seems that from the age of six to seven years to adulthood, VL changes from the deciduous molars and/or premolar region to the symphysis and incisor region (**Figure 1**).

Since it is not possible to modify the tissue-level growth potential response to a functional or orthodontic appliance, but only to change the direction, the rate and the amount of growth,[40] it is important to know if the relationships between the occlusal plane and VL are useful when checking for possible differences or similarities achieved by treatment. The chances of modification increase based on how early the treatment begins (in preparation).

Also worthy of mention is another new landmark, H' at the intersection of the lower incisor and the arch of circle using a center on H and radius CP-GO (**Figure 6A**). H' location on the lingual surface of the lower incisor is different, depending on its inclination and the distance from the Hyoid bone. This is the starting step to use Xi as auxiliary center in order to get the lower frontal accessory location as shown in **Figure 6B**. In such cases, the upper frontal accessory location is obtained by using the same center Xi. The distance between the lower incisor and tongue grid, measured on the therapeutic axis, is transferred to the guide axis. The radius used to get the upper frontal accessory is between this point and Xi (**Figure 6C**).

Objectives

The first objective of this investigation was to find out if it was valid to use the Articular Compass tracing for the location of the frontal accessory appliances.

The second objective was to check for the possibility that these frontal accessories could provide better anchorage of the bioelastic jaw orthopedic appliance based on proper location dictated by the Location Articular Compass Analysis.

The third objective was to find out if the Articular Compass could show, in advance, if treatment would be in the range of orthopedics and/or orthodontics or if it would suggest that surgery was a better option, and to see if the Articular Compass could be used as a tool to indicate a need for surgery in severe cases where orthopedic appliance treatment would be unsuccessful.

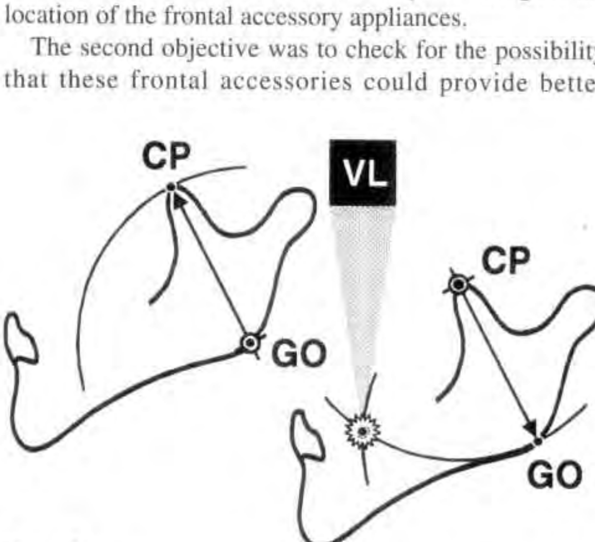


Figure 5
VL (vestibular lingual) is a very useful landmark to study the ramus-corpus proportionality.

Materials and Methods

Subjects

The sample included 105 subjects, 41 boys and 64 girls, ranging in age from four to eight years. Only 87 subjects, 33 boys and 54 girls, followed this longitudinal study because of many factors: three subjects had insufficient reliable measurements available on a sequential set of radiographs; 12 subjects did not follow the experimental process; and another three, in accordance with the third stage of development[20,41] showed complete deciduous dentition but with no eruption of the first molar.

Of the 87 subjects who participated, 85 were between the ages of five and eight years. Additionally, all 87 subjects were between the fourth and seventh stages of their development.[38] The initial predominant age range was between six and seven years and/or corresponded to the fifth and sixth stage of development.

Among the boys, the youngest was four and one-half years old, and among the girls, the youngest was four years and nine months old. However, both of these subjects presented with the first molars fully erupted placing them in the fourth stage of development.[20,41]

Follow-up was for a minimum of three years (excluding one patient with only two years and four months of follow-up—enough time to obtain pertinent research results of incisor contact) to a maximum of 22 years and seven months. The medium time for follow-up was to be the same for the all four groups (**Table 1**).

Criteria

All the subjects had open bite and a gonial angle with a minimum of 130 degrees in which the lower part had a minimum of 76 degrees. In the subjects with gonial angle equal to or greater than 135 degrees, it was not considered a minimum value for the lower part (**Figures 7**, **8** and **9**).

Functional orthopedic appliances, predominantly bioelastic, were used. No fixed appliances were used, except in those cases where the incisor contact could not be achieved and then later had to be prepared for surgery.

Ontogenetically, changes of VL position can be observed. It seems that from the age of six to seven years to adulthood, VL changes from the deciduous molars and/or premolar region to the symphysis and incisor region (**Figure 1**).

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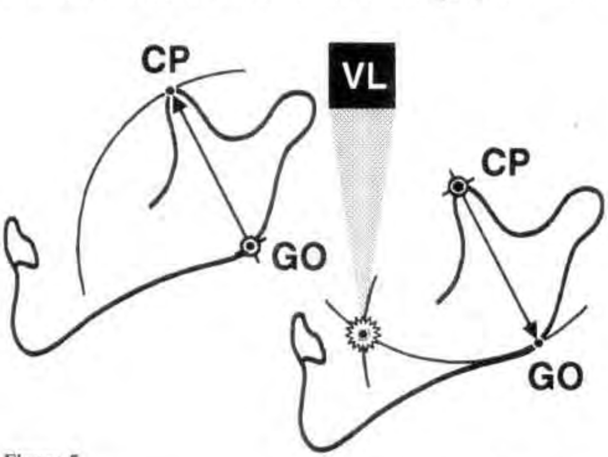

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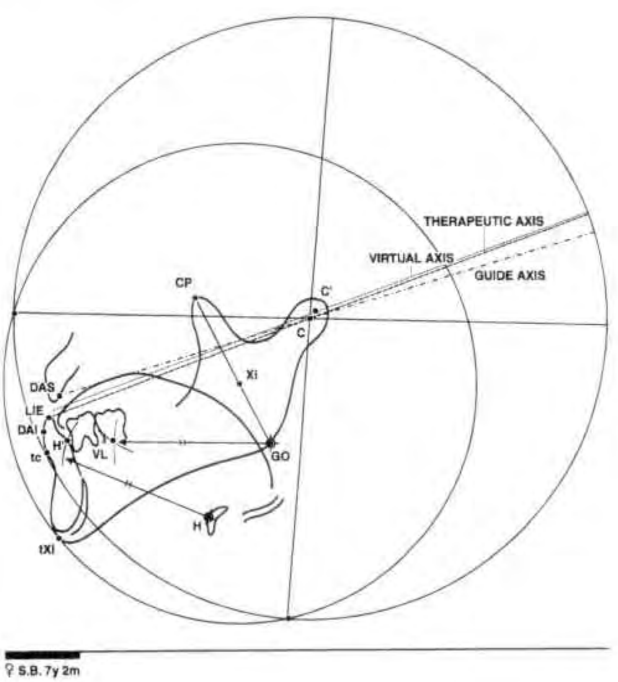


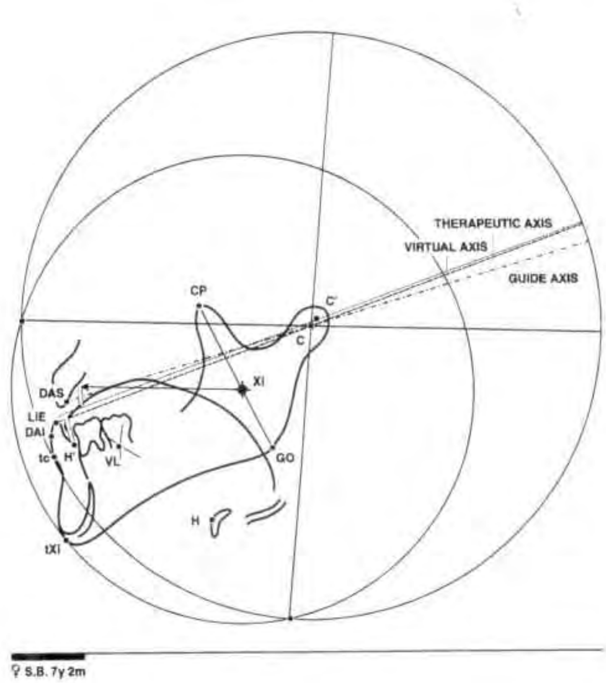
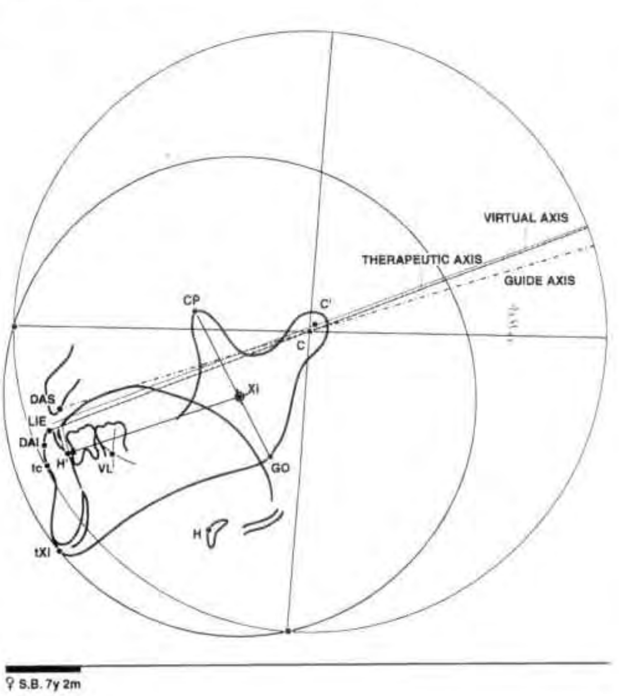


Figure 6
A (above left) and **B** (below): S.B. 7 yr. 2m, Location Articular Compass Analysis for mesioclusion, via hyoidale, indirect way, locating the lower tongue grid element. **C** (above right): S.B. 7 yr. 2m, Location Articular Compass Analysis for mesioclusion, via hyoidale, indirect way, locating the upper tongue grid element.



The subjects were separated by sex and according to the presence of the clinical signs of free protrusion, that is a straightforward protrusion line of movement. This was called the Protrusion Group.

Other subjects, describing a downward protrusion movement caused by occlusal, articular, muscular or vascular interference, were separated into Skeletal Groups and their movement was named *broken protrusion*.

In some cases, the mandible described, firstly, a straightforward protrusion, but at a second phase, the movement was broken, by some interference and the mandible moved downward. This combined effect was considered to be the Skeletal Group.

Therefore, the broken protrusion movement of the Skeletal Group produced an increase in the space measured between anterior teeth, which became even bigger when the lower incisors were under-erupted. However, when the interference was on deciduous teeth and could be removed, allowing the incisor contact, the case was selected for the Protrusion Group.

Therefore, the subjects were separated in 4 groups: Protrusion Group Female (PRF); Protrusion Group Male (PRM); Skeletal Group Female (SKF) and Skeletal Group Male (SKM), **Table 2**.

Methods of Registration and Analysis

Standardized procedures were used to take lateral cephalometric radiographs for assessment of morphologic features. Lateral cephalograms were traced and 87 longitudinal series were available. There was no correc-

Table 1
Descriptive Analysis of Follow-up

Descriptive measurements	GROUP PRF		PRM		SKF		SKM		Total		Comparative test
	Yrs.	Mos.	Yrs.	Mos.	Yrs.	Mos.	Yrs.	Mos.	Yrs.	Mos.	
Mean	8	7	6	10	9	3	8	2	8	4	
Standard deviation	4	11	2	9	4	3	4	7	4	4	
Median	7	3	6	4	8	3	7	6	7	10	$p^1 = 0.351$
Minimum	3	4	3	0	3	1	2	4	2	4	
Maximum	26	1	11	8	22	7	19	9	26	1	

1. Variance Analysis

Table 2
Frequency Distribution of Groups

Group	n	%
PRF	23	26.4
PRM	16	18.5
SKF	31	35.6
SKM	17	19.5
Total	87	100.0

tion for distortion, which is the result of projecting lateral structures on a midsagittal plane. All the radiographs were taken using the same equipment, at the same place with the patient at MIP, in the natural head position.[18]

The main approaches of this study used tracing, measuring and correlation of cephalometric headfilms and were: 1. Treatment outcome, with and without the Location Articular Compass; and 2. Analysis, a study of mandibular morphology proportion using the Structural Articular Compass Analysis related to treatment outcome.

The treatment outcome classification, according to time used to achieve the incisal contact in a determined area, was: DAVF = 6 months (DA very fast); DAF = 12 months (DA fast); DASL = 18 months (DA slow); DAVSL = 24 months (DA very slow); EDGE = edge-to-edge contact was the maximum achieved; NODA = no contact could be achieved. EDGE and NODA were considered treatment failures and when appropriate, subjects were referred for fixed orthodontics/surgery.

AC was another variable taken into consideration when the Articular Compass Analysis was used, or not, corresponding to IN or OUT, respectively.

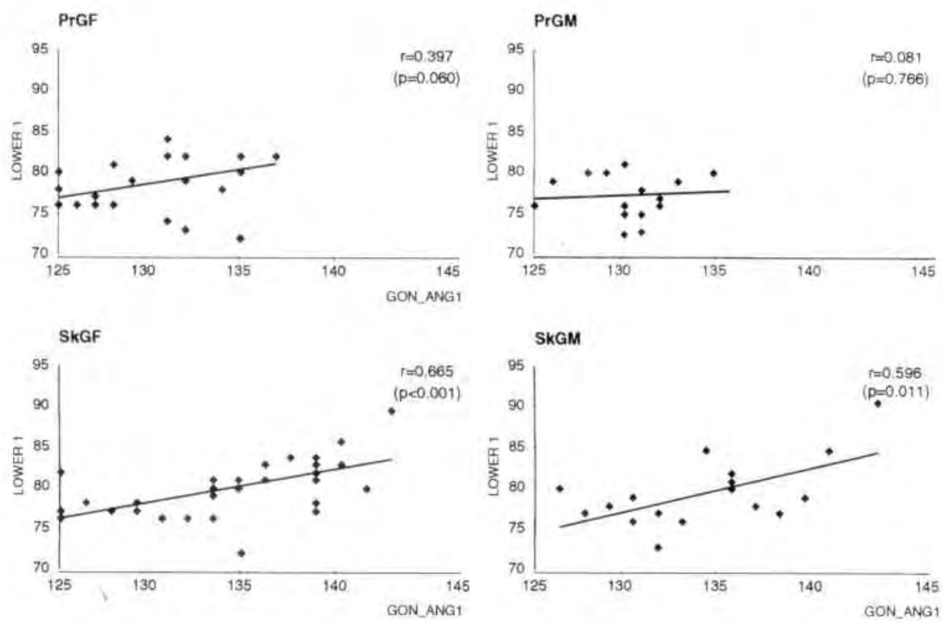


Figure 7
Gonial angle and its lower part at the beginning of treatment.

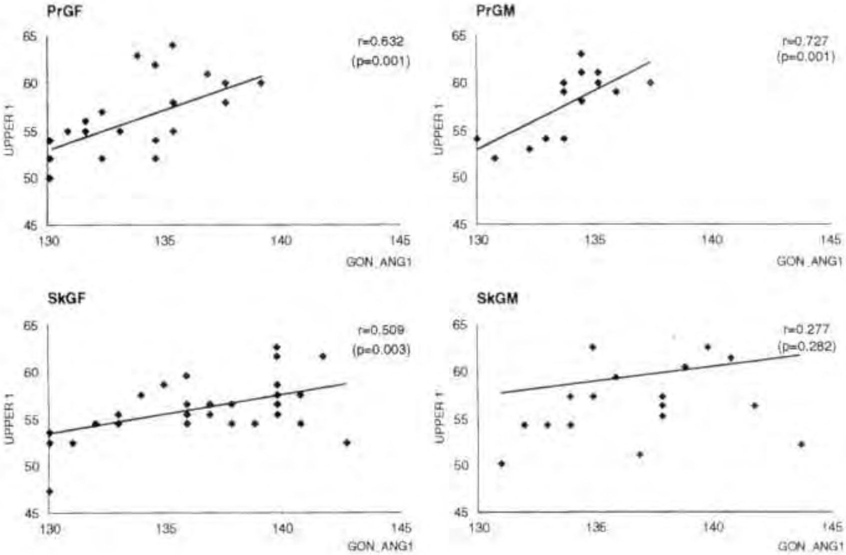


Figure 8
Gonial angle and its upper part at the beginning of treatment.

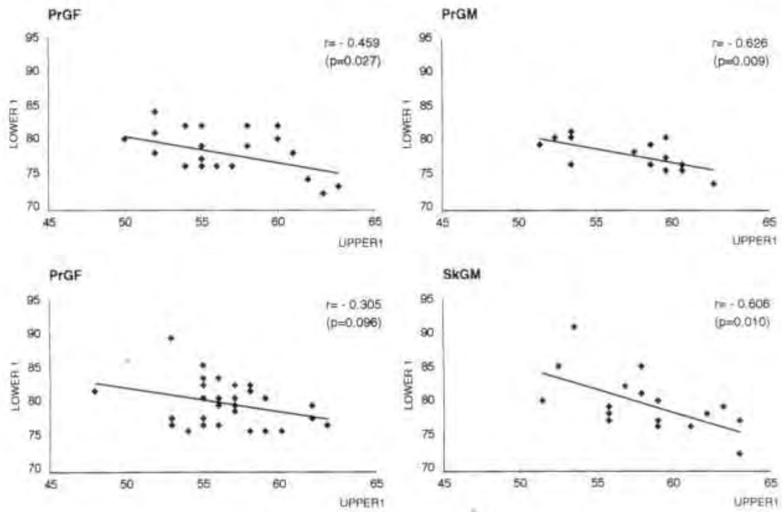


Figure 9
Lower and upper part of the gonial angle at the beginning of treatment.

The cooperation in the use of appliances and in the attendance of patients at appointments were split into two categories: E = Excellent and I = Irregular.

Also taken into account was the variable with regard to whether the appliance provided enough Anchorage (A) or not (NA). For statistical analysis the Chi-square and Fisher exact tests were applied and a logistic regression was employed.

Results

The distribution of stage of development and use of the appliances was similar across the four groups with a predominance of the sixth initial stage followed by the fifth in all groups. There appeared to be a high percentage of excellent use in all groups (**Table 3**).

However, anchorage was not distributed in a similar way among all groups. There was a significant difference between sexes in the Skeletal Group. Also, in the female groups there were differences illustrated (**Tables 4** and **5**).

The evaluation of treatment outcome and the variables according to group, sex, stage of development, anchorage and use is described in **Table 6**.

There was no significant differences based on sex when comparing outcome treatment. However, there was a higher percentage of better results, DAVF and DAF, within the Protrusion Group. Within the Skeletal Group, there was also a higher percentage of results as DASL, DAVSL, EDGE, NODA. The initial stage of development appears to be related to treatment outcome.

The highest percentage of patients with results DAF,

Table 3
Descriptive Analysis of Stage of Development, Anchorage and Use Per Group

Variable	Category	PRF n	PRF %	PRM n	PRM %	SKF n	SKF %	SKM n	SKM %	Total n	Total %	Comparative Test
STAGE	4	1	4.4	1	6.2	2	6.5	2	11.8	6	6.9	
	5	5	21.7	5	31.3	9	29.0	7	41.2	26	29.9	
	6	15	65.2	9	56.3	20	64.5	8	47.0	52	59.8	p[1] = 0.770
	7	2	8.7	1	6.2	0	0.0	0	0.0	3	3.4	
	Total	23	100	16	100	31	100	17	100	87	100	
ANCH	A	23	100	14	87.5	19	61.3	16	94.1	72	82.7	
	NA	0	0.0	2	12.5	12	38.7	1	5.9	15	17.2	p[2] **<0.001**
	Total	23	100	16	100	31	100	17	100	87	100	
USE	E	14	60.9	8	50.0	20	64.5	14	82.3	56	64.3	
	I	9	39.1	8	50.0	11	35.5	3	17.7	31	35.7	p[1] = 0.266
	Total	23	100	16	100	31	100	17	100	87	100	

1. Chi-square test
2. Fisher exact test

Table 4
Frequency Distribution of Anchorage Per Group for Each Sex

Sex	Variable	Category	Protrusion n	Protrusion %	Skeletal n	Skeletal %	Total n	Total %	Comparative Test
Female	ANCH	A	23	100	19	61.3	42	77.8	
		NA	0	0.0	12	38.7	12	22.2	p[1] = 0.001
		Total	23	100	31	100	54	100	
Male	ANCH	A	14	87.5	16	94.1	30	90.9	
		NA	2	12.5	1	5.9	3	9.1	p[2] = 0.601
		Total	16	100	17	100	33	100	

1. Chi-square test
2. Fisher exact test

Table 5
Frequency Distribution of Anchorage Per Sex for Each Group

Group	Variable	Category	Female n	Female %	Male n	Male %	Total n	Total %	Comparative Test
Protrusion	ANCH	A	23	100	14	87.5	37	94.8	
		NA	0	0.0	2	12.5	2	5.2	p[2] = 0.162
		Total	23	100	16	100	39	100	
Skeletal	ANCH	A	19	61.3	16	94.1	35	72.9	
		NA	12	38.7	1	5.9	13	27.1	p[2] = 0.018
		Total	31	100	17	100	48	100	

1. Chi-square test
2. Fisher exact test

Table 6
Descriptive Analysis of Group, Sex, Stage and Use Per Treatment Outcome

		TREATMENT OUTCOME												
		DAVF		DAF		DASL		DAVSL		EDGE		NODA		Comparative
Variable	Category	n	%	n	%	n	%	n	%	n	%	n	%	Test
	Protrusion	2	100	18	69.2	9	34.6	9	39.1	0	0.0	1	16.7	
Group	Skeletal	0	0.0	8	30.8	17	65.4	14	60.9	4	100	5	83.3	p^2 = **0.001**
	Total	2	100	26	100	26	100	23	100	4	100	6	100	
	Female	2	100	14	53.8	16	61.5	15	65.2	3	75.0	4	66.7	
Sex	Male	0	0.0	12	46.2	10	38.5	8	34.8	1	25.0	2	33.3	p^2 = 0.876
	Total	2	100	26	100	26	100	23	100	4	100	6	100	
Stage	≤ 5	0	0.0	4	15.4	15	57.7	8	34.8	3	75.0	2	33.3	
	≥ 6	2	100	22	84.6	11	42.3	15	65.2	1	25.0	4	66.7	p^2 = **0.011**
	Total	2	100	26	100	26	100	23	100	4	100	6	100	
ANCH	A	2	100	26	100	24	92.3	17	73.9	1	25.0	2	33.3	
	NA	0	0.0	0	0.0	2	7.7	6	26.1	3	75.0	4	66.7	p^2 < **0.001**
	Total	2	100	26	100	26	100	23	100	4	100	6	100	
USE	E	1	50.0	19	73.1	21	80.8	12	52.2	2	50.0	1	16.7	
	I	1	50.0	7	26.9	5	19.2	11	47.8	2	50.0	5	83.3	p^2 = **0.021**
	Total	2	100	26	100	26	100	23	100	4	100	6	100	

1. Chi-square test
2. Fisher exact test

DASL, DAVSL, had excellent use. Irregular use on the contrary was seen frequently on patients with results EDGE and NODA.

The evaluation of mandibular morphology was calculated using the interval between the final measurements on the last radiography minus the measurements on the initial one (**Table 7**).

There were insignificant differences in the four groups in most variables, for example, the treatment effect was almost the same across the groups. However, significant differences were found in the variables GO-ME and SYMP. The study looked at differences between the sexes and then groups within the sexes to find significant differences.

The analysis of variance for GO-ME showed that within the group SKG, males showed significant differences from the females ($p = 0.002$), and that there was a significant difference between the PrG and SKG, for males ($p = 0.003$). For the variable SYMP, the study found within the SKG a significant difference between the sexes ($p = 0.016$) (**Table 7**).

The evaluation of the variables for each treatment outcome is described in **Tables 8-13**. The treatment outcome showed a significative increase of AR-GO, CP-GO and CO-GN, except for DAVF.

The GONIAL ANGLE decreased significantly when the result was DAF, DASL and DAVSL. However, no significance was found in this angle, including the upper and lower parts, when the treatment outcome was EDGE. There was a significant increase of the lower part with the result DAVSL.

In all cases, there was also a significant increase of GO-ME, except for the group SKGF where the result was DAF. SYMP did not have a significant modification for the group PRG with DAVSL; also for the group PRGF with result DASL; and, no significant changes for the males within the two groups PRGM and SKGM and the SKGF with result DAF (**Tables 14-18**).

The distribution of the variable AC was similar for both sexes, in the SKG. There was a higher percentage of DAF and DASL among the patients with the variable AC-IN and DAVSL, and EDGE and NODA among those with AC-OUT. **Tables 19** and **20**.

It was possible to study the distribution of the frequency of these effects based on sex and AC. There was a higher percentage of success in both sexes. Although in the SKG this percentage was even higher, no significance differences were found. There was a higher percentage of success among the AC-IN than that found among AC-OUT (**Tables 21** and **22**).

The successful cases were considered linked with AC-IN and the failed cases to those with AC-OUT. It was possible to estimate the probability of success since AC-IN was 0.96 and failure since AC-OUT was 0.40.

Table 7
Descriptive Analysis of the Interval Between the First and Last Cephalogram for the Seven Mandibular Measurements (upper is calculated) in Each Group

Variable	Group	Mean	SD	Median	Minimum	Maximum	N	Comparative Test
	PRF	-3.30	2.87	-3.00	-12.00	1.00	23	
GON-ANG	PRM	-2.50	3.12	-2.00	-8.00	2.00	16	
	SKF	-2.48	3.38	-3.00	-12.00	3.00	31	p = 0.340
	SKM	-4.29	4.81	-4.00	-16.00	4.00	17	
	PRF	-3.48	1.90	-4.00	-6.00	0.00	23	
UPPER	PRM	-3.06	2.11	-2.50	-8.00	0.00	16	p = 0.366
	SKF	-2.90	3.03	-3.00	-10.00	3.00	31	
	SKM	-4.29	3.29	-4.00	-12.00	0.00	17	
	PRF	0.17	2.62	0.00	-6.00	5.00	23	
LOWER	PRM	0.56	2.42	0.00	-4.00	4.00	16	p = 0.930
	SKF	0.42	2.98	1.00	-7.00	8.00	31	
	SKM	0.00	2.87	0.00	-6.00	5.00	17	
	PRF	8.78	3.67	9.00	0.00	16.00	23	
GO-ME	PRM	9.63	3.61	9.50	2.00	16.00	16	**p = 0.001**
	SKF	10.23	4.22	10.00	3.00	23.00	31	
	SKM	14.41	6.35	16.00	3.00	24.00	17	
	PRF	8.13	3.32	9.00	1.00	13.00	23	
AR-GO	PRM	8.75	5.78	9.00	1.00	21.00	16	p = 0.873
	SKF	8.52	3.24	8.00	2.00	15.00	31	
	SKM	7.65	5.18	8.00	0.00	16.00	17	
	PRF	0.87	1.29	1.00	-1.00	5.00	23	
SYMP	PRM	1.19	1.11	1.00	0.00	3.00	16	**p = 0.026**
	SKF	1.13	0.81	1.00	0.00	3.00	31	
	SKM	2.00	1.58	2.00	0.00	6.00	17	
	PRF	9.26	5.24	9.00	0.00	19.00	23	
CP-GO	PRM	11.13	6.54	10.00	3.00	26.00	16	p = 0.319
	SKF	10.32	4.36	10.00	1.00	20.00	31	
	SKM	12.59	7.35	13.00	0.00	23.00	17	
	PRF	16.04	4.54	15.00	7.00	26.00	23	
CO-GN	PRM	18.31	7.73	18.50	5.00	30.00	16	p = 0.109
	SKF	19.71	6.44	21.00	0.00	30.00	31	
	SKM	21.12	9.15	25.00	4.00	32.00	17	

*Variance Analysis

Table 8
Value of the Intervals Between the First and the Last cephalogram for the Seven Mandibular Measurements (upper is calculated) for the Two Subjects of the PRGF Where the Result Was Very Fast

Variable	Subject 1	Subject 2
GON-ANG	-3.00	-7.00
UPPER	-2.00	-5.00
LOWER	-1.00	-2.00
AR-GO	10.00	8.00
GO-ME	10.00	16.00
SYMP	1.00	2.00
CP-GO	2.00	18.00
CO-GN	15.00	22.00

The logistic regression was applied to relate sex and AC to the probability of success in the group SKG (**Table 23**). The probability of success was 2.58 times higher in males which was not significant. The probability of success in patients in which the Articular Compass Anaylsis treatment was used (AC-IN) was 19.02 times higher than those in which it was not used (AC-OUT).

Discussion

The study demonstrated that in this homogeneous sample, early treatment and anchorage are important for good results when treating skeletal open bite.

Reasonable care was taken to minimize any misleading interpretation of the results in this study. In cases which resulted in EDGE and NODA where there were more

Table 9
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Is No Difference Between Groups and the Result Was Fast

Variable	Mean	SD	Median	Minimum	Maximum	N	Test of significance
GON-ANG	-4.08	4.07	-3.50	-16.00	3.00	26	p < **0.001**
UPPER	-3.81	2.62	-4.00	-10.00	3.00	26	p < **0.001**
LOWER	-0.27	2.96	0.00	-6.00	5.00	26	p = 0.647
AR-GO	8.88	4.62	9.00	0.00	19.00	26	p < **0.001**
CP-GO	11.00	6.17	10.00	1.00	23.00	26	p < **0.001**
CO-GN	17.88	8.36	18.50	0.00	32.00	26	p < **0.001**

Table 10
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Is No Difference Between Groups and the Result Was Slow

Variable	Mean	SD	Median	Minimum	Maximum	N	Test of significance
GON-ANG	-3.12	3.34	-3.00	-12.00	2.00	26	p < **0.001**
UPPER	-3.04	3.29	-3.00	-12.00	3.00	26	p < **0.001**
LOWER	-0.08	2.62	0.00	-7.00	5.00	26	p = 0.882
AR-GO	7.31	4.56	7.50	1.00	21.00	26	p < **0.001**
CP-GO	9.92	6.04	9.00	0.00	26.00	26	p < **0.001**
CO-GN	16.62	6.33	17.00	4.00	29.00	26	p < **0.001**

Table 11
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Is No Difference Between Groups and the Result Was Very Slow

Variable	Mean	SD	Median	Minimum	Maximum	N	Test of significance
GON-ANG	-1.83	3.05	-1.00	-8.00	4.00	23	p = **0.009**
UPPER	-3.48	2.17	-3.00	-7.00	0.00	23	p < **0.001**
LOWER	1.65	2.50	1.00	-4.00	8.00	23	p = **0.004**
AR-GO	8.04	3.52	9.00	1.00	15.00	23	p < **0.001**
CP-GO	9.96	4.59	10.00	0.00	18.00	23	p < **0.001**
CO-GN	20.48	6.24	21.00	11.00	30.00	23	p < **0.001**

Table 12
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Is No Difference Between Groups and the Treatment Outcome Was Incisor Contact On Edge-to-Edge

Variable	Mean	SD	Median	Minimum	Maximum	N	Test of significance
GON-ANG	-3.75	3.40	-4.50	-7.00	1.00	4	p = 0.115
UPPER	-2.00	2.94	-2.00	-5.00	1.00	4	p = 0.267
LOWER	-1.75	2.06	-1.50	-4.00	0.00	4	p = 0.188
AR-GO	10.00	3.37	10.00	6.00	14.00	4	p = **0.009**
CP-GO	13.50	6.45	12.00	8.00	22.00	4	p = **0.025**
CO-GN	23.00	5.77	23.00	16.00	30.00	4	p = **0.004**

Table 13
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where ThereIs No Difference Between Groups and the Treatment Outcome Was No Incisor Contact

Variable	Mean	SD	Median	Minimum	Maximum	N	Test of significance
GON-ANG	-2.00	3.52	-2.00	-7.00	2.00	6	p = 0.223
UPPER	-3.17	2.23	-4.00	-6.00	0.00	6	p = **0.017**
LOWER	1.17	1.83	1.00	-1.00	4.00	6	p = 0.180
AR-GO	9.50	4.09	11.00	2.00	13.00	6	p = **0.002**
CP-GO	13.00	4.94	12.50	7.00	20.00	6	p = **0.001**
CO-GN	22.50	5.17	23.00	15.00	30.00	6	p < **0.001**

Table 14
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Was Difference Between Groups and the Result Was Fast

Variable	Group	Mean	SD	Median	Minimum	Maximum	N	Test of Significance
GO-ME	PRF	9.09	3.24	9.00	4.00	16.00	11	p < **0.001**
	PRM	8.86	3.98	10.00	2.00	13.00	7	p = **0.001**
	SKF	5.33	3.21	4.00	3.00	9.00	3	p = 0.103
	SKM	17.60	4.39	17.00	12.00	24.00	5	p < **0.001**
SYMP	PRF	1.27	1.56	1.00	0.00	5.00	11	p = **0.022**
	PRM	0.71	1.11	0.00	0.00	3.00	7	p = 0.140
	SKF	1.00	0.00	1.00	1.00	1.00	3	—
	SKM	2.20	2.39	1.00	0.00	6.00	5	p = 0.108

Table 15
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Was Difference Between Groups and the Result Was Slow

Variable	Group	Mean	SD	Median	Minimum	Maximum	N	Test of Significance
GO-ME	PRF	6.50	4.46	7.00	0.00	12.00	6	p = **0.016**
	PRM	8.67	2.52	9.00	6.00	11.00	3	p = **0.027**
	SKF	10.90	3.21	11.50	7.00	17.00	10	p < **0.001**
	SKM	11.00	7.33	11.00	3.00	23.00	7	p = **0.007**
SYMP	PRF	0.00	0.63	0.00	-1.00	1.00	6	p = 1.000
	PRM	1.33	0.58	1.00	1.00	2.00	3	p = **0.057**
	SKF	1.10	0.99	1.00	0.00	3.00	10	p = **0.007**
	SKM	1.43	1.27	1.00	0.00	3.00	7	p = **0.025**

problems with the appliances and with anchorage (NA), the outcome of the treatment worsened, probably because the subject found the appliance less comfortable to use.

The comparison made in **Table 7** roughly represents treatment consequences for each variable; the role of growth in these consequence should be noted. The shorter the time period of growth in which to compensate for the disproportion, the slower the response to treatment with appliances becomes as in cases of DASL and DAVSL.

When analyzing the behavior of EDGE and NODA, it becomes easier to understand why at times it was really impossible to overcome the strong influence of mandibular ramus-corpus disproportion, and consequently, facial masks and surgery are sometimes necessary.

Subjects with a gonial angle equal to or greater than 135 degrees with the lower part equal to or greater than

Table 16
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Was Difference Between Groups and the Result Was Very Slow

Variable	Group	Mean	SD	Median	Minimum	Maximum	N	Test of Significance
GO-ME	PRF	9.25	1.26	9.00	8.00	11.00	4	p < **0.001**
	PRM	11.40	4.04	11.00	7.00	16.00	5	p = **0.003**
	SKF	8.82	3.34	9.00	3.00	14.00	11	p < **0.001**
	SKM	16.33	5.51	19.00	10.00	20.00	3	p = **0.036**
SYMP	PRF	0.75	0.96	0.50	0.00	2.00	4	p = 0.215
	PRM	1.40	1.14	1.00	0.00	3.00	5	p = 0.051
	SKF	1.27	0.90	1.00	0.00	3.00	11	p < 0.001
	SKM	3.00	1.00	3.00	2.00	4.00	3	p = **0.035**

Table 17
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Was Difference Between Groups and the Treatment Outcome Was Incisor Contact on Edge-to-Edge

Variable	Group	Mean	SD	Median	Minimum	Maximum	N	Test of Significance
GO-ME	SKF	11.33	2.08	12.00	9.00	13.00	3	p = **0.011**
	SKM	20.00		20.00	20.00	20.00	1	—
SYMP	SKF	1.00	1.00	1.00	0.00	2.00	3	p = 0.225
	SKM	2.00		2.00	2.00	2.00	1	—

Table 18
Descriptive Analysis of the Interval Between the First and Last Cephalograms for the Variables of Mandibular Measurements Where There Was Difference Between Groups and the Treatment Outcome Was No Incisor Contact

Variable	Group	Mean	SD	Median	Minimum	Maximum	N	Test of Significance
GO-ME	PRM	9.00		9.00	9.00	9.00	1	—
	SKF	15.25	5.74	14.00	10.00	23.00	4	p = **0.013**
	SKM	11.00		11.00	11.00	11.00	1	—
SYMP	PRM	3.00		3.00	3.00	3.00	1	—
	SKF	1.00	0.00	1.00	1.00	1.00	4	—
	SKM	2.00		2.00	2.00	2.00	1	—

76 degrees required more proportionality of mandibular growth than the did others. These cases are at risk for surgical treatment.

However, measurements taken in other areas of the craniofacial complex must be taken into consideration in order to accomplish treatment within reasonable time limits.

The frontal accessories are probably linked to comfort when using an appliance and certainly to the maintenance of a proper therapeutic change of posture. Deductively, one can assume that they facilitate anchorage and the use of an appliance resulting in satifactory treatment results. Based on our study we believe the use of the Location Articular Compass Analysis is valid.

It appears that the clinical sign which identifies the SKG, i.e., interference increasing the upper and lower incisal distance, makes it more difficult to achieve treatment goals.

Growth disproportionality within or beyond the limits of treatment control is the supreme determinant of results.

Table 19
Descriptive Analysis of Location Articular Compass Per Sex for the Skeletal Group

		SEX						
		Female		Male		Total		Comparative test
Variable	Category	n	%	n	%	n	%	
AC	IN	18	58.1	10	58.8	28	58.3	$p^1 = 0.959$
	OUT	13	41.9	7	41.2	20	41.7	
	Total	31	100	17	100	48	100	

1. Chi-square test
2. Fisher exact test

Table 20
Descriptive Analysis of Location Articular Compass Per Result for the Skeletal Group

		OUTCOME														
		DAVF		DAF		DASL		DAVSL		EDGE		NODA		Total		Comparative test
Variable	Category	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
AC	IN	–	–	6	21.4	16	57.1	5	17.9	0	0.0	1	3.6	28	100	$p^2 < 0.001$
	OUT	–	–	2	10.0	1	5.0	9	45.0	4	20.0	4	20.0	20	100	
	Total	–	–	8		17		14		4		5		48		

1. Chi-square test
2. Fisher exact test

Table 21
Frequency Distribution of Sex Per Sucess

		SEX						
		Female		Male		Total		Comparative test
Variable	Category	n	%	n	%	n	%	
Effect	Success	24	77.4	15	88.2	39	81.3	$p^2 = 0.460$
	Failure	7	22.6	2	11.8	9	18.7	
	Total	31	100	17	100	48	100	

1. Chi-square test
2. Fisher exact test

Table 22
Frequency Distribution of Location Articular Compass Analysis Per Success

		AC						
		IN		OUT		Total		Comparative test
Variable	Category	n	%	n	%	n	%	
Effect	Success	27	96.4	12	60.0	39	81.3	$p^2 < 0.001$
	Failure	1	3.6	8	40.0	9	18.7	
	Total	28	100	20	100	48	100	

1. Chi-square test
2. Fisher exact test

Therefore, the initial stage of development is not always related to treatment outcome. Nevertheless, it is still better to start treatment earlier, since growth rate cannot be predicted, and it is always better to diminish the risks of failure by early detection of disproportion.

When the rate, direction and amount of growth favors the gonial angle closing, it also favors the open bite closing. When the growth favors the increase of the lower part of gonial angle, the result becomes slower (DAVSL).

Mandibular corpus length (GO-ME) and symphysis

Table 23
Logistic Regression
Summary of the Odds Ratio of Success and Respective Interval with 95% of Confidence

Factor	Odds ratio	C.I. 95%
Sex	2.58	[0.40; 16.77]
AC	19.02	[2.10; 172.01]

must be treated in order to close the bite. However, treatment control is limited by the rate of growth. Furthermore, these limits depend on the proportion of measurements of other craniofacial sites.

Finally, the longer the ramus (AR-GO) in the group PRGF at the beginning of treatment, the longer the time to reach a treatment goal. The explanation based on comparison of the behavior of the diagonal ramus was interesting. In this context, when referring to ramus height, it must be considered the diagonal. AR-GO and CP-GO seem to be the focus of the ramus proportionality regulation, and consequently, also the focus of the proportion relation between ramus and corpus.

The study demonstrated that in the treatment of open bite cases, the Articular Compass Analysis is a resource for consideration in diagnosis, prognosis and when constructing bioelastic orthopedic appliances. Further studies are necessary to give more credence to its clinical use.

Last but not least, one must emphasize that no result is possible if there is not enough tissue-level growth potential responsiveness to control disproportions.[40] However, it is important to try to improve the treatment of skeletal open bites, since they can be later associated with temporomandibular disorders.[42]

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