Specific masticatory characteristics of class II subdivision malocclusions

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INTRODUCTION

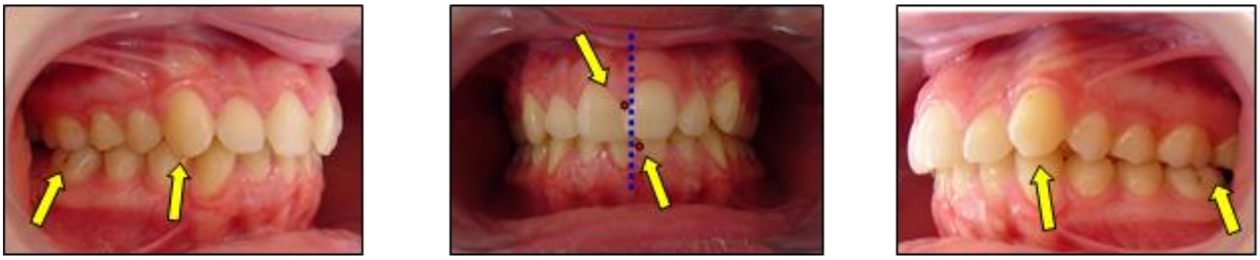
Clinically, class 2 subdivision malocclusions are frequently encountered1, though the question of their etiopathogenesis is complex. Great care and strategy are required for their correction, taking into account their tendency for relapse.

The morphological characteristics of class II subdivisions are illustrated in fig.1 by a clinical example.

At maximum intercuspation, the following clinical signs are present :

- On the right side: Normal molar and canine occlusion (fig. 1a)
- On the left side : Distal molar and canine occlusion (fig. 1c)
- Deviation from the facial midline, which is represented in fig.1b by a blue line: the maxillary midline is deviated to the right, and the mandibular midline is deviated to the left (fig. 1b).

The example in fig.2 presents a class II subdivision left malocclusion. The reversal of these signs would represent a class II subdivision right malocclusion.



a. b. c.

Fig.1: Intraoral views of a class II subdivision left, in MIP
a) right side view b) frontal view c) left side view

1- Material and Methods

The aim of our study was to explore mandibular kinematics and mastication in a sample of 26 patients with class II subdivision malocclusions using an electrognathograph (Siemens Sirognathograph), in order to determine if the morphological asymmetry present in these patients is due to a preferred chewing side and if so, which side?

The Sirognathograph® is a device which allows electrognathographic recording of mandibular movements. The main principles of operation and interpretation of this technique were published in 1985 by LEWIN2 in his work entitled: “Electrognathographics: Atlas of Diagnostic Procedures and Interpretation”.

The device is composed of several elements:

- a headgear piece

- a magnet secured to the buccal face of the mandibular incisors
- a computer, to record and treat data

The action of a Sirognathograph is based on the Hall effect (Kimmel3). The magnet is secured to the buccal face of the mandibular incisors (at the mandibular midline) during maximal intercuspidation, such as to not interfere with occlusion and mandibular movements. The magnet will, in turn, cause a three-dimensional magnetic field disruption, which is detected by two antennae fixed to the headgear (fig.3).

Fig 2

Fig 3

Fig. 2 : Magnet secured to mandibular midline
Fig.3 : Cranial headgear with right and left side antennas, of same polarity as the magnet

The magnetic waves emitted during mandibular movements are converted into an electrical signal by transducers. These signals are sent to a computer equipped with specific software capable of translating the electrical signals into digital data, which allows to represent the magnet's movements in three dimensions on a computer screen.

1-1 Sampling and inclusion criteria

Subjects were mostly dental students from **(CITY REDACTED FOR BLINDING)** Faculty of Densitry with a Class II subdivision malocclusion. We also selected orthodontic outpatients from the (**REDACTED FOR BLINDING**) University Dental Hospital.
Other than a Class II subdivision malocclusion, the selection criteria were as following:

- no history of dental extractions (except wisdom teeth)
- no ageneses
- no significant maxillary or mandibular crowding
- no unilateral maxillary molar mesioposition (primitive or secondary to maxillary second temporary molar extraction)
- no posterior sector crossbite
- no history of articular trauma or suspicion of hypercondylia
- no current complaint of dental pain or decay
- no allergies to the following substances: resin, latex, or food allergies.

For each subject, the presence of these inclusion criterea were checked with a clinical exam and a medical and dental questionnaire. Subjects with cranio- or cervico-facial malformative syndromes such as Korkaus syndrome or Goldenhar syndrome were excluded.

The sample included 26 subjects : 15 females and 11 males. The average age was 19.4 years. Among the subjects, 18 were dental students (in various years) and 8 were orthodontic outpatients.

For each subject, we identified :

- the side of distal occlusion : 17 subjects had a class II subdivision right, 9 had a class II subdivision left
- the masticatory functional angles (M.F.A., Planas[5]) by clinical examination
- instrumental examination of the M.F.As by sirognathograph
- examination of chewing cycles by having subjects chew a piece of carrot.

1-2 Study protocol

In order for subjects' behaviour to remain as natural as possible during chewing exercises, data recording, and while filling out the questionnaires, subjects were not informed of the objective of the study.

Within the sample, certain subjects were randomly chosen to return at a later stage to repeat the recordings, which were compared to the initial recordings in order to test reliability.

1-2-1 *Clinical examination of lateral mandibular movements*

Firstly, lateral movements were clinically evaluated visually, then recorded and measured with a sirognathograph.

The goal of the clinical examination was to evaluate the symmetry of lateral mandibular movements to each side. Subjects were asked to execute centrifugal lateral mandibular movements, starting at the maximum intercuspal position (MIP). Subjects were also instructed to « clench their jaws as to maintain as much intercuspal contact as possible - especially for molars - as long as possible during lateral movements ». Respecting these instructions was key to the functional significance of the examination (Raymond[4]).

From there, we were able to compare the mandibular opening amplitude during lateral movements. In the frontal plane, the movement of the mandibular midline to either side forms an angle with the horizon, named Planas' masticatory functional angle (M.F.A., Planas[5]) ; one right and one left.

Figure 4 presents left and right lateral movements originating from M.I.P in a case of normal occlusion (fig. 4b). The midline's movement to the right (fig.4a) is objectified by a line which forms the right-side M.F.A. with the horizon, as for the left side (fig.4c). In this example of normal occlusion, the left and right-side M.F.A.s are equal.

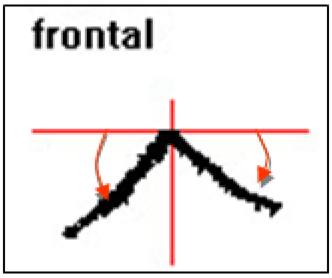
Fig.4: Lateral modement and representation of MFAs
a) right-side lateral movement and MFA b) MIP c) left-side movement and MFA

This clinical investigation prior to instrumental examination was an opportunity to advise the patient how to act during the instrumental examination. We asked subjects to perform a lateral mandibular movement while maintaining molar contact, until the mandibular buccal cusps on the working side arrived at edge-to-edge position with maxillary buccal cusps. From that position, subjects were then asked to perform the opposite movement back to M.I.P., before repeating the same cycle on the other side. All these movements were to be made while maintaining firm contact between teeth. We asked subjects to repeat movements several times consecutively in order to ensure reproducibility.

1-2-2 Instrumental examination: sirognathographic recording of M.F.As

A magnet was placed on the mandibular midline before the headgear of the Sirognathograph ® was placed on the subject. The subject then performed lateral movements, as described previously. A computer recorded the magnet's movement. Specialized software was used to display results (fig.5) : which are in the form of 3 graphs, each describing one axis. The « frontal graph » determines MFAs.

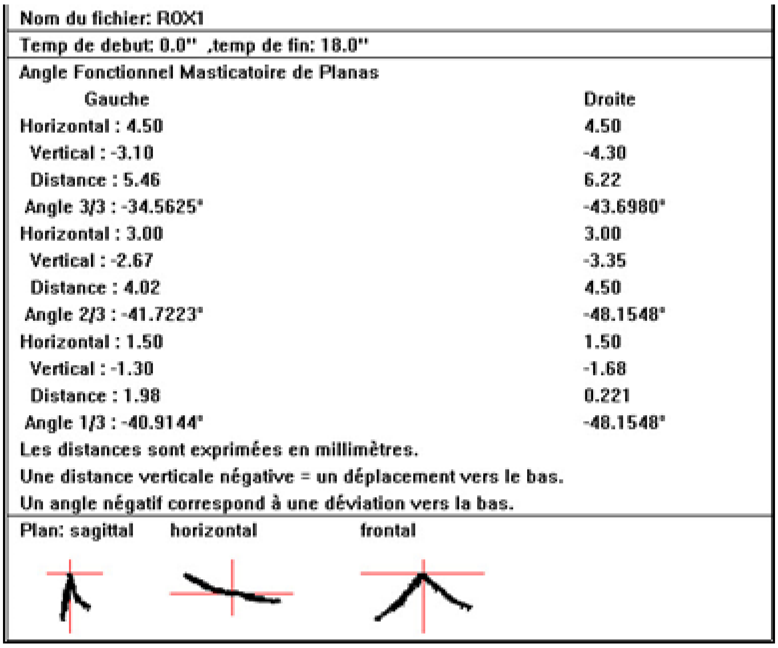
Right



Left

Fig.5: Sirognathographic recording of MFAs (left-side MFA is smaller)

The data interpretation software also allowed to fragment the movement into three equal segments, and to quantify each segment's angle with the horizon. (fig.6)



Nom du fichier: ROX1

Temp de debut: 0.0" ,temp de fin: 18.0"

Angle Fonctionnel Masticatoire de Planas

Gauche	Droite
Horizontal : 4.50	4.50
Vertical : -3.10	-4.30
Distance : 5.46	6.22
Angle 3/3 : -34.5625°	-43.6980°
Horizontal : 3.00	3.00
Vertical : -2.67	-3.35
Distance : 4.02	4.50
Angle 2/3 : -41.7223°	-48.1548°
Horizontal : 1.50	1.50
Vertical : -1.30	-1.68
Distance : 1.98	0.221
Angle 1/3 : -40.9144°	-48.1548°

Les distances sont exprimées en millimètres.
Une distance verticale négative = un déplacement vers le bas.
Un angle négatif correspond à une déviation vers la bas.

Fig.6: MFA values at three different instants of lateral movement

Fig.6 represents the numerical value of left and right MFAs obtained during recorded lateral movements of one subject. Over the masticatory sequence, the lowest recorded MFA value was 34.5645° on the left, and 43.6980° on the right. The left MFA was therefore the smallest.

1-2-3 Sirognathographic recording of mastication

After recording subject MFAs, we proceeded with a sirognathographic exploration of mastication, using a piece of raw carrot. The sirognathograph enables recording of subjects' masticatory cycles. We chose a simple and suitable food, raw carrot, whose consistency is rather hard. Carrots were cut into 2x1 cm pieces. At the beginning of the masticatory cycle, significant vertical and lateral mandibular movements were required by the subject. Moreover, pieces were to be chewed entirely before swallowing.

In this study, our focus was not to study the influence of food texture on the shape of masticatory cycles or forces generated during chewing. The sole objective was to compare the spontaneous distribution of chewing between left and right sides.

Subjects were simply asked to not move their heads or place their tongue over buccal faces during recording. No other instructions concerning chewing were given, in order not to influence subjects. The piece of carrot was placed on the dorsum of the tongue, so as not to influence the initial side of chewing. When instructed, the subject started to masticate the piece of carrot until deglutition, then return to MIP, then wink once to mark the end of the recording.

The resulting data was then analysed with data treatment software and compared to what was observed during the chewing test. We performed, in most cases, one to two more chewing tests per patient.

Results are displayed in the form of a graph describing the frontal plane. Fig.7 shows the recording of a masticatory sequence of a subject whose M.F.As are represented in figures 5 and 6. By examining fig.7, it was found that this subject performs more masticatory cycles on the left than on the right. Note that this subject's left-side M.F.A. is smaller than their right-side M.F.A. (fig.5).

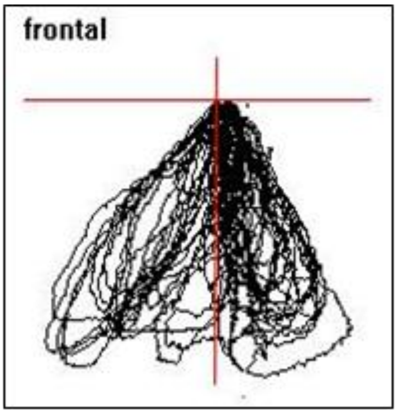


Fig.7: Recording of masticatory sequence of a piece of carrot; *a higher number of cycles on the left side is remarked.*

During several recordings, especially in subjects with a pronounced overbite, the magnet became detatched. In these cases, we reattached the magnet and continued the recording, while ensuring the magnet remained in place.

Once the recordings were finished and verified, the magnet was detached and teeth were carefully cleaned.

2- <u>Results</u>

Fig.8 offers an overview of the results for all 26 subjects. Data for each subject is provided in the "Tables" section. Each column represents one of the subjects of the sample, numbered from 1 to 26. For each column, we checked boxes designating:

- side of distoclusion
- side with smallest M.F.A. recorded during clinical examination
- side with smallest M.F.A. recorded during sirognathographic examination
- preferred chewing side revealed by sirognathographic examination

	1		2		3		4		5		6		7		8		9	
	D	G	D	G	D	G	D	G	D	G	D	G	D	G	D	G	D	G
côté en distocclusion		X	X			X	X		X		X		X			X	X	
AFMP + petit explo clinique		X	X			X	X		X		X		X			X	X	
AFMP + petit explo instrum.		X	X			X	X		X		X		X			X	X	
côté de mastication préf.		X	X			X	X		X		X		X			X	X	

	10		11		12		13		14		15		16		17		18	
	D	G	D	G	D	G	D	G	D	G	D	G	D	G	D	G	D	G
côté en distocclusion	X		X			X	X			X	X			X		X	X	
AFMP + petit explo clinique	X		X			X	X			X	X			X		X	X	
AFMP + petit explo instrum.	X		X			X	X			X	X			X		X	X	
côté de mastication préf.	X		X			X	X		X		X			X		X	X	

	19		20		21		22		23		24		25		26	
	D	G	D	G	D	G	D	G	D	G	D	G	D	G	D	G
côté en distocclusion	X		X			X	X		X			X	X		X	
AFMP + petit explo. Clinique	X		X			X	X		X			X	X		X	
AFMP + petit explo. Instrum.	X		X			X	X		X			X	X		X	
côté de mastication préf.	X		X			X	X		X			X	X		X	

Fig.8: Summary table of experiment results for each subject (all present a class II subdivision malocclusion). For each subject, the side of distoclusion, the side of smallest MFA determined clinically, and instrumentally, is indicated.

To check the experiment’s reproducibility, we asked two random subjects to return at a later date to perform the experiment again. No explanation other than the scientific necessity to repeat the experiment was given to the two subjects (numbers 2 and 4). These repeat tests produced the same results as the initial recordings.

Fig. 8 : Representation of results in the form of a table allows fast and clear reading. Instrumental analysis - in this case sirognathographic – provided results perfectly matching the clinical examination. In other terms, a simple clinical examination of M.F.A.s is, when correctly performed, reliable and fit for use in daily practice.

2-1 Correlation between side of distoclusion and side of smallest MFA

When combining morphological and functional caracteristics of each subject, a strong correlation is noted between the side of distoclusion and the side presenting the smallest M.F.A. The intraoral view of a class II subdivision right subject (Fig.9), who is subject number 4 in Fig.8, illustrates these findings.

The lateral movements of this same subject, illustrated in Fig.10, allow a visual assesment of MFAs. During a left-side lateral movement, mandibular depression results in a greater disclusion than for a right-side lateral movement, thus a greater

MFA is observed on the left side. Finally, the subject's sirognathographic recording (Fig.11) shows a smaller MFA on the right side compared to the left side.

Fig.9: Intraoral views in MIP of subject number 4, *class II subdivision right.*

Fig.10: Still frame images of right and left-side lateral movements of subject number 4. Mandibular depression is of smaller amplitude during right-side lateral movements (fig.10-3), which results in a smaller MFA on the right side versus the left side.

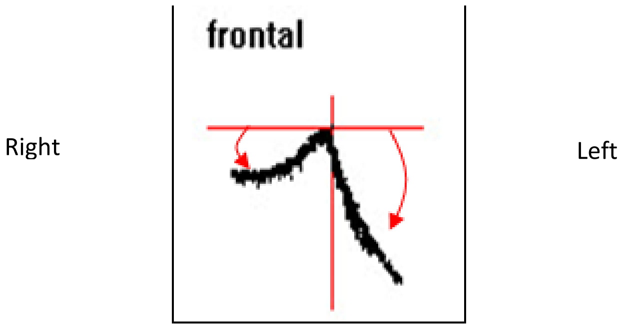


Fig.11: Sirognathographic recording of subject 4's MFAs (frontal view) showing a smaller MFA on the right side.

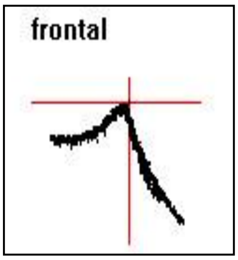
Analysis of Fig.8 shows firstly, a complete correlation between clinical examination of MFAs and sirognathographic recording and interpretation of MFAs. Secondly, for all 26 subjects of the study, the side of distoclusion matches the side of smallest MFA ; as shown in the three upper columns of the table.

Cohen's kappa coefficient was used for statistical analysis. It is a statistic test which measures inter-rater or inter-method agreement for qualitative items. It allows to minimize the observer bias between different methods of analysis that were employed. In a case of absolute correlation this coefficiant is equal to 1, which is the case for the correlation observed between side of smallest MFA and side of distoclusion. These results lead to believe that, in a case of class II subdivision malocclusion, the side of distoclusion corresponds to the side of smallest MFA.

2-2 Correlation between smallest MFA and preferred chewing side

Analysis of Fig.8 suggests a third correlation that is illustrated in Fig.12 by the mastication recording of subject number 4 (class II subdivision right), whose intraoral views and lateral movements are shown in Figs. 9, 10, 11. Subject number 4 performs masticatory cycles solely on the right side. Chewing is therefore preferred (in this case, is exclusively so) on the side of the smallest MFA.
All subjects of the study except subject number 14 (25 out of 26) prefer chewing on the side of the smallest MFA ; without necessarily being an exclusive preference as for subject 4.

Droite
Right

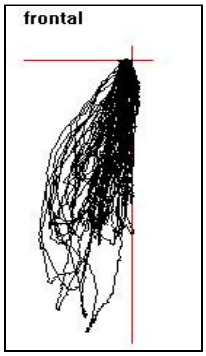


Gauche
Left

a.

Fig.12 a

Droite
Right



Gauche
Left

b.

Fig. 12 b

Fig.12a: Sirognathographic recording of MFAs (frontal view) showing a smaller MFA on the right side.
Fig.12b: Sirognathographic recording of carrot piece mastication (performed by subject 4) showing a high proportion of masticatory cycles on the right side.

Statistically, Cohen's kappa coefficiant is 0.9127517, this corresponds to a very high level of correlation, and gives a certain degree of significance to this study, despite a rather wide bootstrapp confidence interval of [0,5942 - 1,0000], due to the low number of subjects.

These results may well confirm the hypothesis that individuals with a class II subdivision malocclusion masticate preferentially on the side of the smallest MFA, which is also the side of distoclusion.

3- Discussion

This study raises several questions which can be discussed, notably the choice of food type or selection of the sample. But the most interesting of these – due to its diagnostic and therapeutic potential – is the question of the etiopathogenesis of class II subdivision malocclusions.
Before going into detail, it is important to assess the usual chewing mode.

3-1 Chewing pattern

According to Planas[5], physiological mastication (alternate unilateral mastication) is performed indistinctely, and alternately, on both sides; lateral mandibular movements produce an equal amplitude of mandibular depression on either side, thus left and right MFAs are equal. Although if mandibular depression is asymmetrical, chewing will be preferred on the side where the depression is minimal, that is, the side of the smallest MFA.

According to PROESCHEL[6], children with « normal » occlusion perform uniform movements during mastication, while those presenting a malocclusion perform more irregular movements. This leads to say that « normal masticatory function is associated with normal masticatory movements » , thus symmetrical and alternate.

For PEYRON and WODA[7], subjects do not perform identical mandibular movements during mastication, regardless of analysis method. For any given test food, observed differences concern the number of chewing cycles during the sequence, vertical and lateral movement amplitude, and opening/closing speed. However they underline that there exists a reproducibility inherent to each subject.

3-2 Food type

Different « test » food types exist according to PEYRON and WODA[7]

- Non-edible products (elastomers, waxes) which present the advantage of being non-perishable, but cannot be swallowed, which may influence mastication.

- Natural foods (nuts, coffee grains, carrot, cheese, meat...) which can be chosen for their consistency or for their prevalence in an everyday diet.

- Artificial foods, edible products based on hydrocolloids of standardized texture.

In this study, we wanted to employ an easy to use and natural food in order to « trivialize » the experiment for the subjects, and to be able to simply and quickly perform the test without influencing subjects' normal behaviour.

We chose carrots for several reasons.

Carrots enabled our study's objectives of revealing the general aspect of masticatory sequences and their distribution between left and right sides. This was not however a study of masticatory efficiency and performance in relation to food consistency, in which case artificial foods are preferable (Buschang[8]).

Carrots are a familiar and well tolerated food, can be eaten raw, and are easy to separate into identical pieces.

Size of the test food piece is important, as it influences the aspect of masticatory cycles.

Bhatka[9] considers that masticatory adaptation to increased food size is achieved by an increase in the perimeter and speed of cycles, while maintaining their original shape.

Consequently, the hardness of carrot pieces seems appropriate to make the neuromuscular system perform the most self-stabilising movement possible, therefore revealing if a preferred chewing side – on which a larger number of cycles are performed – exists.

It could be of interest to perform the same tests with test foods of various consistencies. Peyron and Woda[7] noted the parameters caracterising mandibular movement amplitude increase with thickness of the test food morsel, independently of texture. One can assume that the harder the test food, the more a preferred chewing side will reveal itself (if one exists) by increased use. Thus one can assume that, for softer test foods, results would be less contrasted than those of our study ; as for using test foods as hard, or harder than in our study, results would be comparable or more contrasted.

3-3 Sample size and representativity

Our study's sample population consisted of 26 subjects presenting a class II subdivision malocclusion.

At no moment were subjects informed on the aim of our clinical research so as to preserve objectivity.

One may raise the question of dental students' knowledge of mastication physiology, and the possible influence this may have on their behaviour during chewing tests.

In order to minimize this possible source of bias, we mainly included students in their first, second and third years of dental studies, whose knowledge of mastication was thefore limited.

Furthermore, students of fourth or fifth year included in the study who had already been educated on the clinical exploration of masticatory function were not aware of the exact nature of our study; more precisely the possibility of a prefered chewing side being related to their malocclusion.
The distribution of class II subdivisions in our sample is striking. 9 are class II subdivision left while 17 are class II subdivison right - almost twice as many.

It may be interesting to discuss, given the prevalence in the general population of right-handed versus left-handed people, a possible correlation. We regret not asking subjects if they were right or left-handed, as a possible correlation could have been studied.

3-4 Hypothesis of the etiopathogenesis of class II subdivision malocclusions

In this study, we aimed to establish if particular chewing patterns existed in cases of class II subdivision malocclusions. The results corroborate this hypothesis : **the side of distoclusion is the preferred chewing side .**

The confirmed existence of a relation between asymmetry of dental arches and preferential unilateral mastication on the side of the malocclusion raises, understandably, the question of etiopathogenesis of this unique form of malocclusion.

This raises two points :

1 – Does masticatory function influence maxillo-mandibular development ?

2 – If this is the case, can the functional anomaly at the origin of this malocclusion be incriminated to dental arch asymmetry, and by what mechanism ?

Serveral studies have proven the influence of mastication on bone and dental arch growth.
The effect of mastication on sutural growth was established by Katsaros[10,11], among others, who studied internasal, nasopremaxillary and interpremaxillary sutures in rats. They found that all sutures are significantly narrower in hypofunctional animals, who were fed a soft diet.
Furthermore, study of bone apposition in these sutures shows - despite apposition being a varying phenomenon between sutures – a significantly lower level of growth in the hypofunctional group: up to 25% for the nasopremaxillary suture.

These results show a decrease in sutural activity, therefore a decrease in growth.

Moreover, Yamamoto[12] studied the effect of diet consistency on bone apposition in maxillary growth sites, particularly the palatine region. In hypofunctional rats, a protrusive direction of growth was observed in the lower maxilla and premaxilla regions.
By studying the relationship between masticatory function and internal structure of the mandible by computed tomography, Sato et al.[13] obtained findings resembling those of Yamamoto. They observed, this time in humans, a decrease in goniac angle and FMA angle ; in other words, a decreased anterior facial height.
In this same study, authors observed a decreased bone density starting four weeks after the beginning of the study. These results confirm the authors' hypothesis that an adaptative tissular response in the mandible to the mechanical stimulus of masticatory function happens not only at muscle attachment sites, but also in the alveolar bone of the molar region.

Mavropoulos[14,15] and Ödman[16] come to an identical verdict. Masticatory hypofunction :
- reduces alveolar process volume and height
- reduces bone densiometric indices
- therefore causes a significant loss of quantity and quality of alveolar process bone.

They also found that hypofunctional rats present a lower mineralisation rate, regardless of the mandibular region studied.
Other authors, K.Takada[17], J.Ahlgren[18], B.Ingervall[19,20] obtained similar results.
All these studies, which focus either on occlusal structures in their entirety or on symmetrical sutures, demonstrate the impact of masticatory function on craniofacial development, and answer our first question: does masticatory function influence maxillo-mandibular development?
To answer our second question, one must refer to work such as that of Delaire[21], on the « posterior maxillary suture system ». Hence, the anterior section of the lateral maxillopalatine suture (which extends from the transverse palatine suture) is firstly oblique before becoming almost sagittal.
In 16 year olds, its anterior section is markedly sagittal although its posterior section is oblique. The stimulation of this sutural complex results in anterior growth and widening of the affected dental quadrant.
Muscular forces delivered preferentially to the chewing side affected by masticatory dysfunction therefore perfectly explain the anterior growth of the stimulated maxillary quadrant, thus the emergence of a homolateral class II malocclusion and controlateral displacement of the maxillary midline.

Conversely, mandibular movement, also asymetrical, results in a preferential growth of the controlateral mandibular body (hemi-mandible engaged in movement during chewing cycles). This contributes to displacement of the mandibular midline towards the preferred chewing side.

Other hypotheses have been advanced. Rose[22] stated, by analysing submentovertex views, that mandibular position relative to the base of the skull may not be abnormal, nor may any skeletal asymetry be present ; therefore that subdivisions are of dentoalveolar origin, due to a distal position of the mandibular first molar. However, this study does not exclude the possibility of a maxillary skeletal or dentoalveolar assymetry.

Azevedo[1] considers the origin of asymmetry to be dentoalveolar, the most important factor being a distal position of the mandibular first molar, and secondly a mesial position of the maxillary first molar. According to Janson[23,24], this results in more frequent mandibular midline deviations towards the side of the class II malocclusion, rather than a deviation od the maxillary midline towards the side of normal occlusion.

Although, for these authors, distoclusion of a mandibular molar seems to initiate the class II subdivision malocclusion, no hypotheses are advanced about the origin of this molar distoclusion.

It was noted that once the class II subdivision is in place, the malocclusion affects masticatory function, making a spontaneous correction or « auto-rehabilitation » near impossible. It would seem that the dysfunction is « incorporated » into the malocclusion which it created. This phenomenon is characteristic of *complex systems* known under the term « law of recursion » (Raymond & Kolf[25]).

Thus, there are many reasons to think that non-alternate, repeated unilateral mastication may be at the origin of class II subdivision malocclusions. To eliminate doubts about this hypothesis, it may be of interest to carry out a longitudinal study following a large number of children, from a young age – 3 years (end of temporary dentition) – until 13 years (end of permanent dentition). Such a study would be difficult, but not impossible, to perform. We hope such a study will be undertaken in the near future.

Conclusion

This study consisted in studying the chewing mode of 26 individuals presenting a class II subdivision maloclusion, in order to determine if a masticatory function specific to class II subdivision malocclusions exists.

Results showed that among the 26 subjects included in the study, all presented a smaller M.F.A (masticatory functional angle) on the side of the class II malocclusion, and that 25 of 26 subjects showed a preference for chewing on the side of molar distoclusion. Therefore, it would appear that morphological asymmetry carries with it a « functional masticatory assymetry », which may be at the origin of this type of malocclusion.

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