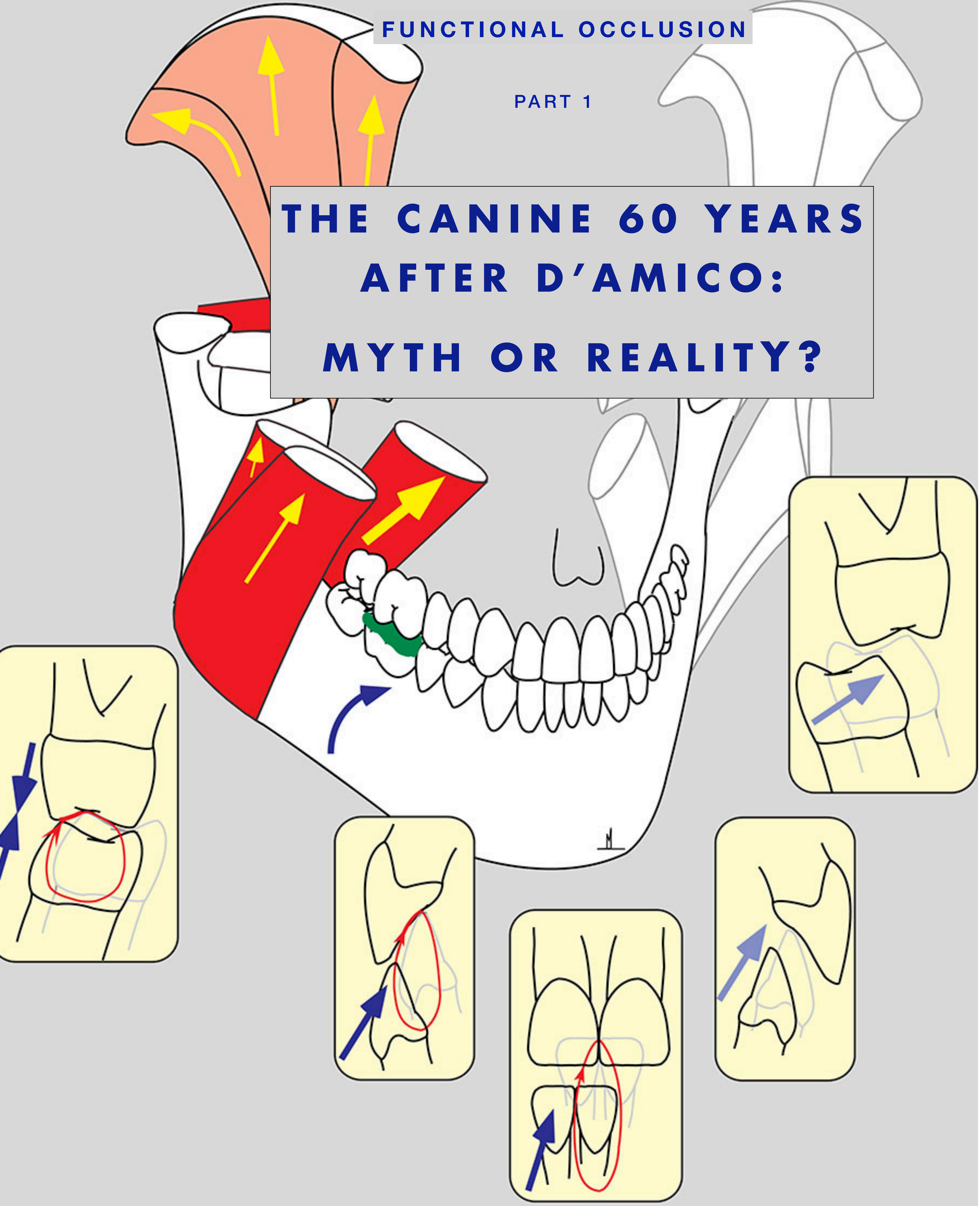
FUNCTIONAL OCCLUSION

PART 1

THE CANINE 60 YEARS AFTER D'AMICO: MYTH OR REALITY?



Marcel G. Le Gall - Roger Joerger

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THE CANINE 60 YEARS AFTER D'AMICO:

MYTH OR REALITY?

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Reading and Correction of the English edition

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FOREWORD

The online publication of this Ebook results from a reflection on the progressive evolution of our knowledge and more particularly those concerning the human masticatory apparatus. These evolutions are almost always the corollary of technological leaps due to human reflection, sometimes helped by chance.

In the nineteenth century, the invention of general anesthesia (attributed to Wells 1846) and the introduction of hygiene and aseptization during the Pastorian era led to a considerable decrease in the mortality rate of dental origin. The introduction of the first porcelain commercial teeth and the vulcanization of the rubber made it possible to produce truly functional total prostheses from impressions and plaster models mounted on the first anatomical articulators (Bonwill 1885). It is the application to these full dentures of the first concept of balanced occlusion which made them functional.

The invention of radiography in 1895 (Röntgen) and its medical and dental introduction at the beginning of the twentieth century led a little later to the emergence of the concept of Centric Relation on the first tomographies of TMJ. This manipulated CR is the founding concept of the Gnathological School (Mc Collum 1939). This reference position was initially associated with dynamic adjustment in balanced occlusion. The principle of Canine Protected Occlusion (CPO) was introduced by d'Amico in 1958 and adopted by the Gnathological School to replace the balanced occlusion on natural teeth. These concepts have been adopted by the majority of the dental profession for their apparent simplicity. They are still used and taught a lot. But very few practitioners have read the work that led to their adoption. The era was mechanistic and the articulators considered as faithful reproducers of the voluntary and functional movements of the mandible. Recording materials were non-existent and knowledge of chewing very incomplete.

The introduction of recording devices for voluntary and functional mandibular movements has led to a considerable advance in knowledge of the physiology of occlusion. The first of these materials was the Replicator®, from Lundeen and and Gibbs, in 1982, followed by Lewin's electrognathography in 1985 (Sirognatograph® from Siemens) and later by several others. They have encouraged many studies: on functional kinematics, on the role of muscles recruitment during mastication, and on the role of proprioception in muscle and kinematic regulation of masticatory cycles during food preparation.

In addition, the introduction of implantology, then more recently optical impressions, virtual articulators and more generally, Computer Assisted Design and Computer Aided Manufacturing (CADCAM), have already and continue to change durably all prosthetic protocols.

It seems appropriate to take stock of the foundations of our usual occlusal procedures and their necessary evolution.

Summary

The analysis of the founding articles of the concept of canine protection, by Angelo d'Amico in 1958 and 1961, indicates that important new works have been published since that time. They concern the physiology of chewing and swallowing, the proprioception, the role of sex selection in the size of the canines and the possibilities and limits of the reproduction of function on classical articulators. These advances in knowledge, still poorly known or ignored, between 1958 and 1961, would not allow today the publication of much of D'Amico's work on Canine Protected Occlusion. Although this principle is still widely used clinically, these new data still encourage us to question the need for a new approach to oral functions, which would be more physiological. This would remove the discredit that exists on the occlusion, following the disappointments resulting from the application of complex mechanistic concepts, far removed from chewing and swallowing, which are the natural functions of the masticatory apparatus.

Keywords: Occlusion, Tooth, Canine, Cuspid, Protection, d'Amico, Mastication, TMD Function, Guide, Chewing Cycle, Swallowing, Deglutition, Tongue, Muscle, Joint, TMJ.

INTRODUCTION

Chapter 1

From 1958 to 1961, Angelo d'Amico published a series of articles proposing, for the man, a model of dynamic occlusion, based on the concept of Canine Protected Occlusion (CPO). It is first to counterbalance Gysi's model of balanced occlusion (Gysi 1910, 1915, 1921), applied to natural teeth, that the observations of Jones (1947 p 256) resumed by d'Amico, have led to the introduction of cuspid protection. They have shown that: *"the accepted "balanced occlusion" theory to be false and contrary to the physical, biological and physiological factors involved in the process of mastication"* (d'Amico 1958 N° 1 p8). From this theory of balanced occlusion, prosthetic concepts had been developed: *"the "working" and "balancing bite". The question then is: does this theory apply to man's teeth, or is it more applicable to the teeth of the herbivores?" (D'Amico 1958 N° 1 p8).*

Jones and D'Amico are right on this point: it is clear that human teeth do not work in balanced occlusion, except when the natural functioning model is destroyed by wear

The principle of canine protection during centrifugal movements proposed by Jones and d'Amico is the antithesis of balanced occlusion. It has been accepted by the vast majority of the dental profession for its apparent simplicity of implementation. Although it does not account for chewing function, it is still widely used to balance dynamic occlusion, but with a very high risk of leaving malocclusions on the occlusal surfaces of the posterior teeth and causing bruxism to eliminate canine locking.

Sixty years after D'Amico's publications, taking into account the evolution of knowledge about the functioning of the masticatory apparatus (Lundeen and Gibbs 1982, Mongini 1986, Pröschel 1987, Lauret and Le Gall 1994, 1996, Le Gall et Lauret 2002, 2008, 2011 etc), it seems interesting to take stock, on the current level of validity of the concepts of Jones and d'Amico, which are now contested (Rinchuse et al 2007), and on the possible modifications to bring, in order to preserve them. And if that were not possible, by what new concepts should they be replaced? Knowing that any new model, compared to the previous one, should obey precise specifications. The main requirements of which would be to take into account the physiological chewing and swallowing and thus improve the functional efficiency, the prosthetic durability, with an important reduction of Temporomandibular Disorders and better stimulation of the peri-implant bone (Le Gall and Le Gall 2016), while providing a better comfort to the patient.

OCCLUSAL THEORIES (1880-1950)

Chapter 2

In the 1950s, theories on the functional relationships of human natural teeth were still inspired by concepts invented in the late nineteenth and the first half of the twentieth century. From this point of view d'Amico's articles have marked the dental profession for a long time, introducing the concept of canine protection which was the antithesis of the concepts of balanced occlusion generally taught until then.

A- BEGINNING OF SWALLOWING STUDY

Occlusodontists of the time, like Ackermann (Figure 2-1), considered that: "*Swallowing brings the mandible back into centric occlusion.*" He proposes a scheme (Ackermann 1964 p1102 fig.52) showing the vectors of action of all the retractor muscles of the mandible during swallowing. Unfortunately, the tongue does not appear in this drawing, while it's posture determines that of the mandible during swallowing (Romette 1976, Gall et al 2010, Le Gall 2013). (Fig 2-2). At the same time and a little later, some studies (Ingervall, 1964) and anatomical data (Sicher and Dubrul 1975) have begun to highlight that Maximum Intercuspation (MI) is not confused with the CR, but located forward (Posselt 1968) (This will be confirmed later by several other axiographic recordings studies (Joerger 2005, 2012).

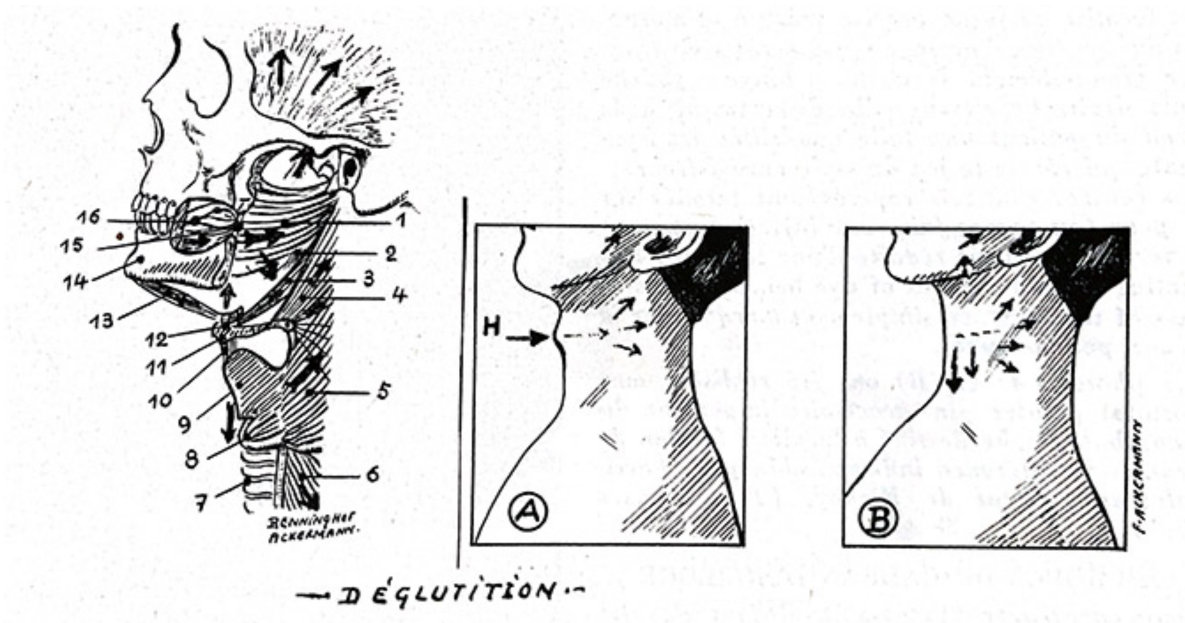


Fig 2-1: *The role of muscles during swallowing, according to Ackermann 1964. The constrictor muscles of the pharynx are all in this drawing, although their complex interactions are automated during swallowing. But the tongue, which plays a major role in the movements and positioning of the bolus during chewing and swallowing, is not included. Yet movements and mandibular posture are enslaved to those of the tongue during oral functions. Because by placing itself in support against the median anterior part of the palate, the tip of the tongue is determining of the optimal posture of the mandible during swallowing. The tongue has 17 muscles that obey a collective central programming. Only its tip can move under the control of the will. The position of its tip, through the interactions between its intrinsic muscles and the low insertions of its extrinsic muscles (Genio-glosses muscles directly, hyo-glosses and stylo-glosses indirectly) is a major determinant of the position of the mandible during swallowing. Which is not located in a centric relation, as written by Ackermann*

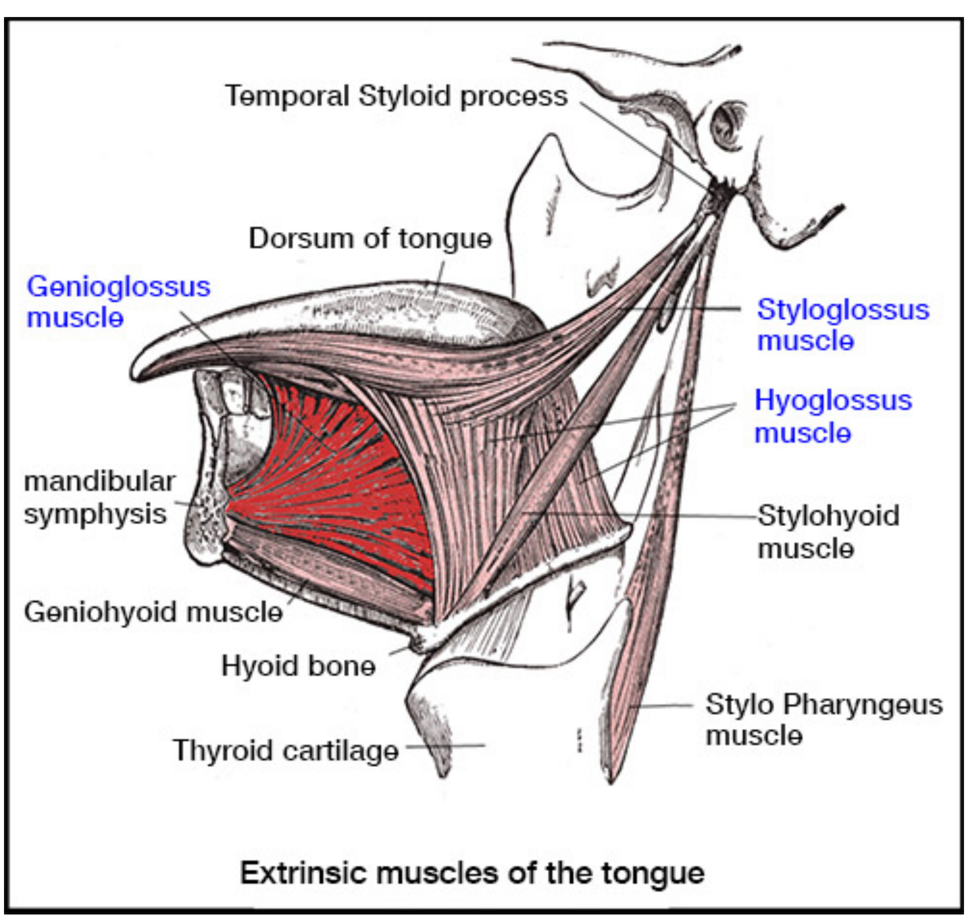


Fig 2-2: *Extrinsic muscles of the tongue (from Wikipedia). The anterior mandibular insertions of the Genio-glosses, connected to the base of the tongue, give to the movements and the posture of the tip of the tongue, a role of positioner of the jaw. If the tip of the tongue is placed in anterior support against the palate, the jaw is in a slight ante-position, as during swallowing (Genioglossus relaxed). Whereas if the tip of the tongue is moved back about 1cm, the mandible moves back slightly and if it is returned toward the soft palate, the mandible is pulled back (genioglossus, and other retractors are contracted). It is then in one of the positions of CR. The level of contraction of the genioglossus has a direct impact on the mandibular posture.*

B- BEGINNING OF MASTICATION STUDY

Several theories of mastication have been proposed, the first is that resulting from a reciprocal reflex (Sherrington 1917, Rioch 1934). It was abandoned in favour of a central control. The first known movie about chewing was made by Jones (1947). To date, it has not been possible to find this movie. The first descriptions of mastication, by Jones, are around Maximum Intercuspation, and indicate a slightly oblique cycle closure, and a vertical opening. There is confusion in the use of the word "functional", which is wrongly used for centrifugal voluntary

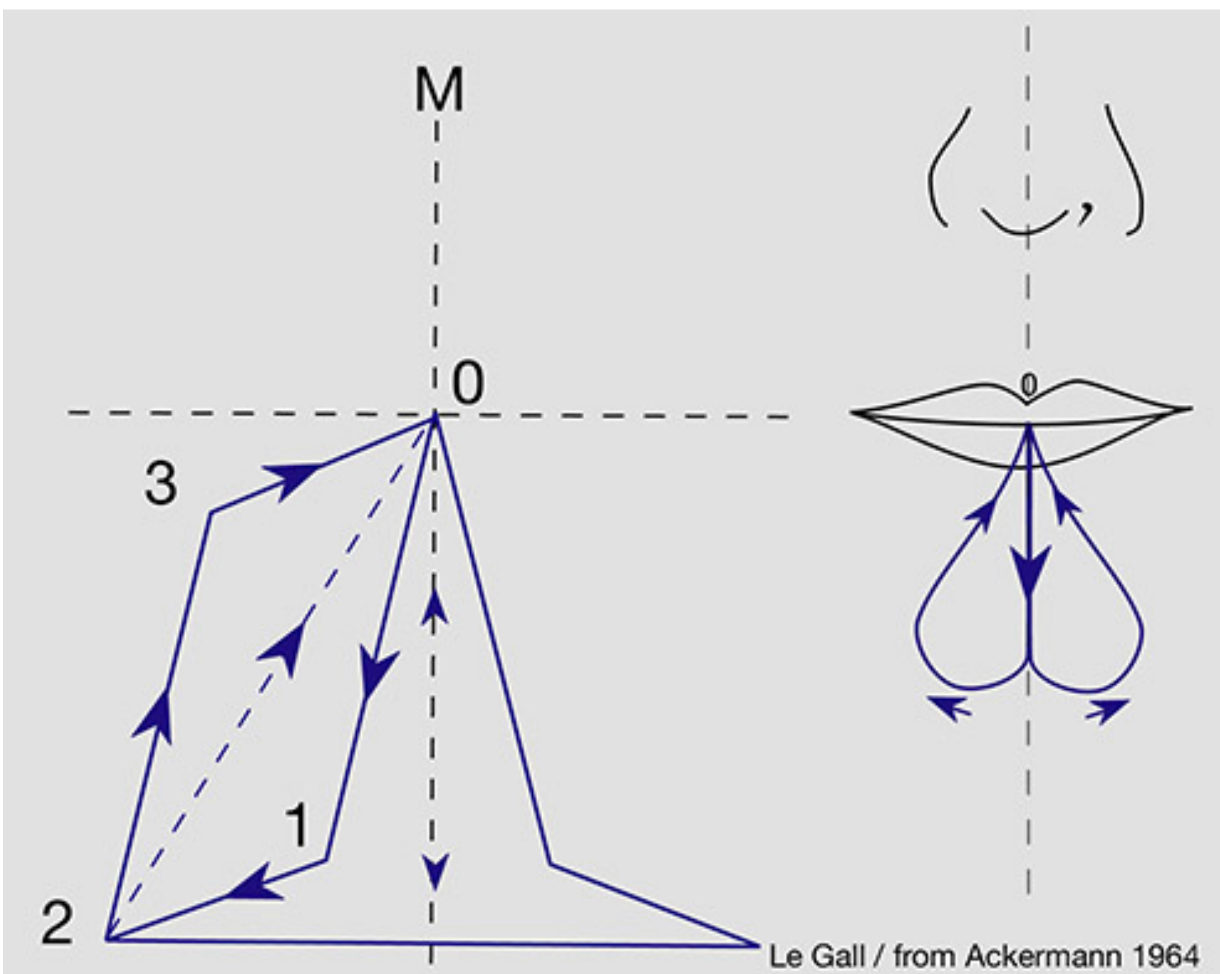


Fig 2-3 Chewing according to Ackermann 1964. Chewing cycles are very variable. The opening from 0 to 1 is initially vertical or slightly eccentric, followed by a light diduction of 1 to 2, then a centripetal closure of 2 to 3 and a return to centric occlusion, in "working" relation, from 3 to 0. Depending on the resistance of the food, the paths can be reduced to 3 essential phases and even to 2 (vertical shear). From 3 to 0 the cycle dental input (cycle-in) is centripetal in the opposite direction of the laterality movement, with contraction of the elevator muscles and sliding on the internal slopes of the maxillary buccal cusps. Gnathological occlusal equilibration (d'Amico, P.K.Thomas) aims to unload or.eliminate any friction from 3 to 0

movements, which are not functional movements, such as centripetal chewing. After *the publications of A. d'Amico (1958-1961), F. Ackermann (1964, page 1072) writes: "The incisal and masticatory cycles use their return phase, concentric functional movements. These are totally different movements from horizontal laterality movements…Chewing is mostly vertical".* He describes cycles of various pattern (Figure 2-3), whose opening is vertical with a closure going from oblique to vertical (Ackermann 1964 p.1103). He also describes a functioning model, equilibrating the forces applied by a vertical mortar-pestle effect (Figure 4),

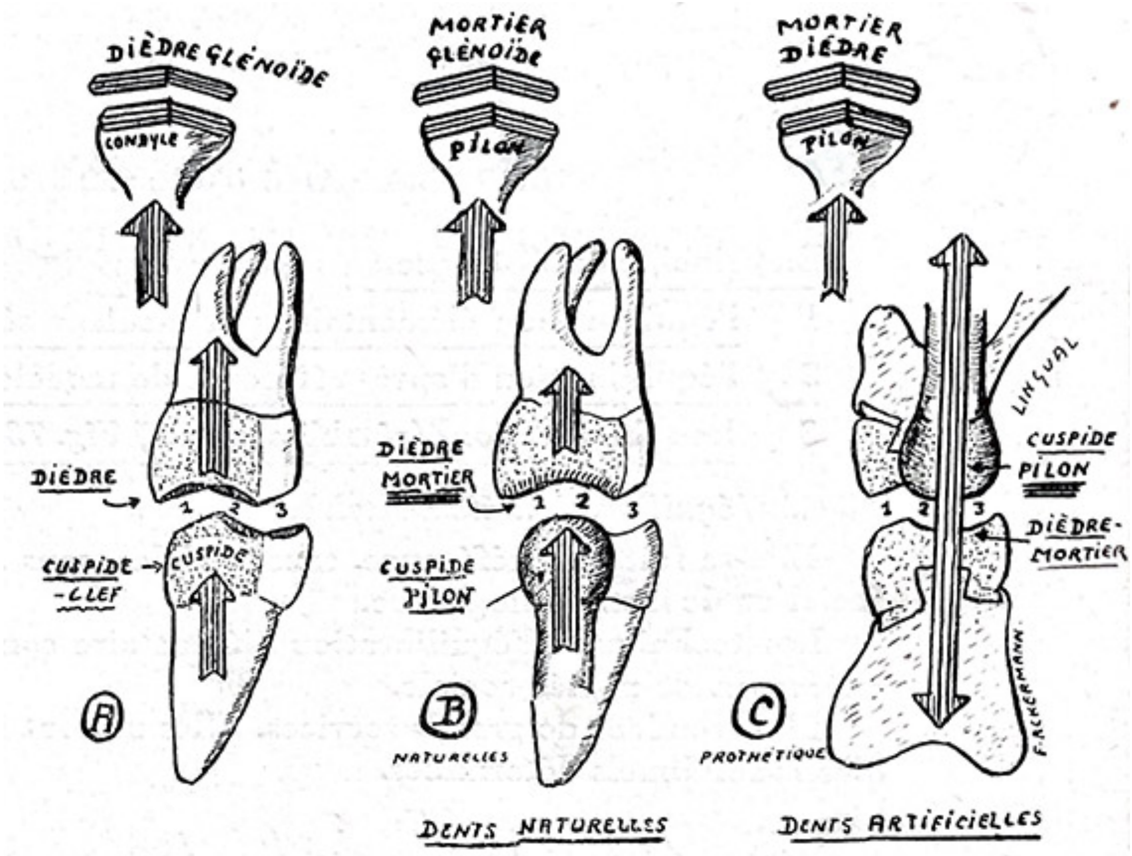


Figure 2-4: The axial distribution of natural and prosthetic forces according to Ackermann 1964. The distribution of forces is assimilated to a vertical pestle-mortar relationship.

without taking into account the transverse kinetics of the chewing cycles and the underlying root architecture; Figure 2-5 (Ackermann 1964 p. 1123 fig 71).

He describes the coronoplasties proposed by P.K.Thomas to eliminate the "exaggerated" friction during oblique closures and to restore the dominant guiding of the canine in laterality.

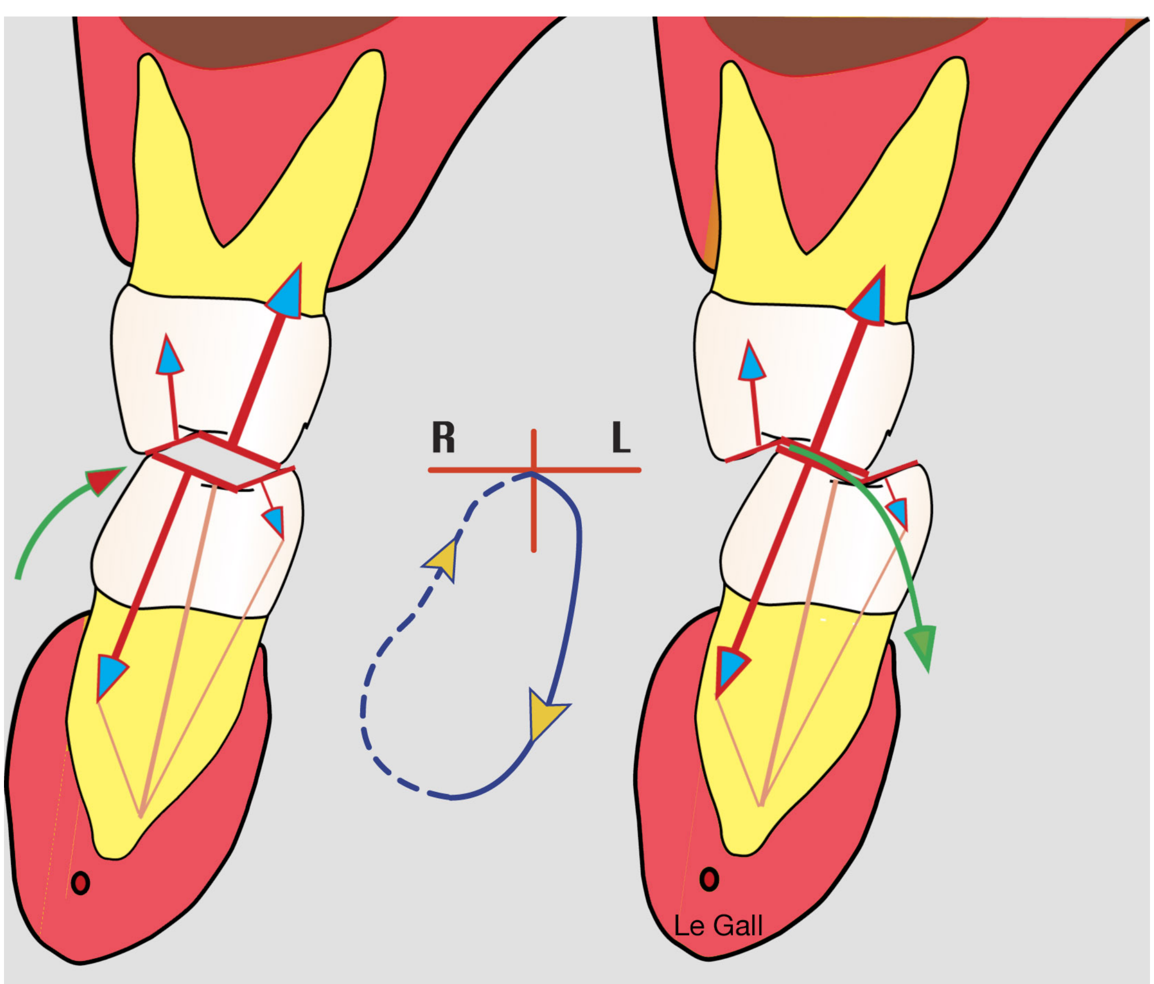


Figure 2-5: The vertical distribution of forces, according to Ackermann, does not correspond to the optimal cycle shape described today, with a transversal dynamic, dental input-output (cycle-in cycle-out), of the cycle. Under these conditions, the centripetal transverse forces are effectively dissipated by the root architecture of the M1 couples, in contact with a suitable bone bearing surface (see Fig.6) (Le Gall et al 1994

The abusive suppression of natural chewing guidances, by occlusal grinding, made in eccentric laterality, reduces chewing to a simple shear due to lack or insufficiency of proprioceptives afferences and a canine overguiding...It seems useful to point out that at that time, chewing recording devices did not exist, only direct observation was possible. It is still the immutable instrument and the eternal engine of scientific knowledge, even though today it is assisted by precise recording instruments.

C- BALANCED OCCLUSION AND SPHEROID THEORY

Since the end of the 19th century and the beginning of the 20th century, the dynamic occlusion principle applied to the full dentures, was that of Balanced Occlusion (Spee 1890, Christensen 1905, Gysi 1910). The teeth of the two lateral sectors had to slide at the same time, on each other, during transverse movements. Whereas during the antero-posterior movements, it is the anterior and posterior teeth, that had to slide simultaneously, on each other. During closure and dynamic movements, any occlusal errors were compensated by the slight displacement of the prosthetic bases, placed on soft mucosa, which made it possible to maintain the interdental contacts of the prosthetic teeth. This same principle is still applied today to full dentures.

The application to the natural teeth of this concept of Balanced Occlusion, during centrifugal movements, on articulators and in clinic, required multiple adjustments to flatten the occlusal surfaces, so that the teeth of the lateral and anterior sectors, can contact simultaneously, during the transverse and anteroposterior movements. The application of this principle was difficult, the mutilations very important and the results disappointing and irreversible.

1- To try and improve the balancing of dentate patients, Monson proposed in 1932 a geometric concept of occlusion functioning: the occlusion theory organized around a sphere 8 inches in diameter, translated clinically by principles close to balanced occlusion, during lateral movements and protrusion, and finally with similar dental mutilations (D'Amico 1958 N°1 p 8-9). This theory still defended in the 1950s has since been abandoned.

2- Several other balanced occlusion concepts, adapted from the sphere, were first proposed by Villain, then by Pankey-Mann and Schuiller (quoted by Ackermann 1964 p1137) without significant improvement, because they are too far from the natural model that on the contrary they contributed to destroy.

D- CENTRIC RELATION AND HINGE AXIS

The use of a Centric Relation of condyles in the mandibular fossae (CR), obtained by manipulation, had already been introduced in the 1930s by Mc Collum and Stallard, (Mc Collum 1939) first to locate the Mandible-Maxilla Relationship, of edentulous patients, and then of dentate subjects in CR. This is the founding concept of the Gnathological school which marks the beginning of a mechanistic era, with the search for the articular hinge axis, the recording of the condylar and facial parameters and their precise transfer to articulators, considered then as perfect simulators of static, and mandibular kinetics. The epitome of the design and sophistication of the adaptable gnathological articulators of the time is probably represented by the articulator system, introduced by Charles Stuart in 1965.

Difficulties encountered in manipulations and recordings, to apply this concept of Centric Relation to dentate subjects (whose position of the teeth is fixed) and its precise matching with the patient's Maximum Intercuspation Occlusion (MIO), have generated many clinical setbacks, giving rise to controversies that resulted in several definitions suggesting different CR positions with more or less functional play. The concept of CR has gradually opened up to additional concepts such as "short centric", "long centric", "wide centric", "freedom in centric"..., which reflect a malaise in both the conceptual and clinical. In 1964, Lucia introduced the anterior jig technique, under occlusal pressure, to obtain a mandibular recoil and find the CR by eliminating manipulation errors due to multiple operators, but the results have not brought the expected relaiability, because it is the very principle of centric relation that poses a problem. Indeed, the more the definition of this reference relationship moves away from a forced posterior position and the closer it gets to the swallowing position, a bit more anterior, the better it is accepted by the patients.

Controversies are still far from extinct today (Le Gall et al. 2010, Le Gall 2013).

MODEL OF D'AMICO

Chapter 3

G. V. Black and omnivorous human teeth

In the introduction to his "Dental Anatomy" (1890) in which he classified the teeth of mammals into three types: herbivorous, carnivorous and omnivorous, G. V. Black has written ***"that man's teeth were omnivorous, so designed as to be able to masticate all types of food."***(quoted by D'Amico N°1, 1958 P8).

This statement marks a major disagreement with Angelo d'Amico who defends another theory. Contrary to what Black has written, d'Amico considers that *"The basic or fundemental anatomical forms of the teeth have been developed for an insectivorous, frugivorous and carnivorous diet, and are quite different from the herbivorous"*(N°1, 1958 p15). Further on, he refers to Yerkes and Ada (1945) who, in their book "The Great Apes", make very interesting observations about the eating habits and diet of current chimpanzees, which he considers: *"quite pertinent to the study of function of the teeth of the anthropoids, such function being not unlike that of man"* (D'Amico N°1, 1958 p15-16).

Moreover, he totally rejects the balanced occlusion model of complete denture, when it is applied to the natural teeth of man.

A- D'AMICO: CANINE FUNCTION AND CARNIVOROUS-FRUGIVOROUS MODEL

Further on, d'Amico states that: *"Attrition of the teeth as seen in primitive man from ancient prehistoric time to récent "primitives," has led many writers in dental science to believe that man's natural mandibular movements are similar to the movements seen in the herbivores. Man* *has not specialized to the extent that herbivores have, and the morphology of his teeth remains the same as seen in Dryopithecus"* (D'Amico N°2, 1958 p 50-51)

On several occasions, relying on the opinion of other anthropologists such as:

-Theodore Mc Cown, from the University of California, who declares: *"that their primary function is for the purpose of masticating a frugivorous, carnivorous diet"* (d'Amico N°2 1958 P51)

-or Hector Jones, an anthropologist from Toowamba (Queensland, Australia) who, *"comparing the translatory mandibular movements of man and herbivores… also agrees that such horizontal movements as seen in man are not normal for his species."* (Jones quoted by d'Amico1958 N°2 P51), d'Amico states further that the man *"in the primitive state, living on rough fare, he suffers rapid occlusal attrition, the cusps being shorn completely away quite early in adult life. To put it another way, man has tended to adopt in this regard the mode of mastication of the ruminants, without possessing any form of compensatory mechanism"*. (D'Amico1958 N°2 P50-51)

He tries to prove that man is not a herbivore and *"that balanced occlusion of the natural dentition does not exist and has never existed in man".* (d'Amico1958 N°6 P199). He is right on this last point: The balanced occlusion is not the natural model of man, nor that of herbivores (see chapter 4, p.44 and following).

But he continues to say:

"All the physical evidence reviewed thus far definitely portrays nature's intention as to how the masticatory apparatus of man should function".(D'Amico1958 N°6 P200)

This is a definitive conclusion for a questionable reasoning. If nature had an intention, it would have objectives and a purpose (religious or otherwise). The hazard of mutations and the natural selection of the most suitable characters are an attempt at permanent adaptation to the changing conditions of the environment (Darwin 1859). Evolution is contingent.

To consider that this model, which has been running for more than 32 Ma, is an error of natural selection, is presumptuous to say the least.

"The morphology of the teeth of man is a modification of the teeth seen in all primates, primarily designed for the mastication of an frugivorous insectivorous, (or carnivorous) diet. All primates present prominent canine teeth modified in size according to specie. The overbite and ***interlocking relation*** *of the upper canines is the natural articulation of those teeth and common to all primates, including man. Their main function during mastication is to guide the mandible into centric relation in a medial-vertical direction, so as to prevent the contact of the remaining opposing teeth until they meet in centric occlusion"* (D'Amico N°6 1958 p 200). **This is not**

validated by clinical observations and videos of the physiology of chewing (Lundeen and Gibbs 1982, Proschel 1986, Lauret and Le Gall, Le Gall and Lauret 1994 to 2016)

"The canine teeth have always been constant in number, position and alignment in the dental arches. Also in general morphology." (D'Amico1958 N°6 p 240) In fact, it is the small size of the cuspids that allows their integration into the arcade, and their participation in mastication, as in humans, or that pushes them out, when they are too much large, to allow posterior chewing.

"The canine teeth serve to guide the mandible during eccentric movements when the opposing teeth (antagonist) *come into functional contact".*(D'Amico1958 N°6 p 240) These two previous claims are contradictory because the eccentric voluntary movements guided by the canine are in the opposite direction of the actual chewing function (Gibbs et al 1981, Pröschel 1987) with opposite muscular actions.

"The upper canine teeth, when in functional contact with the lower canines and first premolars, determine both lateral and protrusive movements of the mandible". (D'Amico1958 N°6 p 240). Lateral and protrusive eccentric movements are voluntary one's caused by the asymmetrical or symmetrical recruitment of depressor and propulsor muscles. In eccentric laterality, they are generally guided by the canine (Figure 5-59, 5D-1), and in protrusion, by the incisors, accompanied or not by the cuspids (Figure 5-51). They are of the opposite direction of the real centripetal function, which obeys a central program, and results from the action of elevator muscles.

The model of canine protection, described by d'Amico for man, is very close to that of the carnivores, but it is not the natural model of man. For example, if one tries to give a carnivore, like the dog, chewing gum, he is unable to chew it and ends up swallowing it barely dilacerated, because the vertical carnivorous teeth of the dog are missing the opposite crushing tables of the maxillary palatal and lower buccal cusps of the molars, which are present in man. These cusps are adapted and indispensable for the crushing/grinding of fruits and fibrous vegetable foods. They complement the double shearing action of maxillary buccal cusps and mandibular lingual cusps, during cycle input, even for meat !

If they can't come into contact early, well before arrival in Maximum Intercuspation , chewing cycles lose much of their functional efficiency, because they are often reduced to vertical shear, for lack of proprioceptive information transmitted by contacts and guidance of the posterior teeth (Johnsen and Trulsson 2003a p1486), through the bolus or in direct contact.

Let us recall that the mandibular movements of chewing are conditioned by two factors (Yaeger, 1978, Guichet, 1977):

• indirect **dental guidance** through the bolus and then direct, in the last cycles.

• **and central control**, that puts in harmony the muscular and articular complex with the dental guidance (see chapter C3)

B- REVIEW OF THE MODEL OF D'AMICO

In his firsts 1968 articles Angelo d'Amico has broadly defended, the interlocking relationship of the canines and their dominant guidance, during protrusion, laterality, incision and chewing (*(see the quotes from pages 14 to 17 above)*. **However "interlocking canines" come from interlock, so with locking of the occlusion at the level of the canines. It's aphysiological** (Ackermann 1964 p 1067).

D'Amico already returns to this data, page 201, in the same article N ° 6 of June 1958: *" The upper canine should have an overjet of approximately one mm. to allow a slight lateral eccentric movement even though the teeth are in full centric occlusion."* **And in the article of 1961:***"The term interlocking, when used to describe the vertical and horizontal overlap of the upper cuspids, will be misinterpreted by many dentists. They believe interlocking means that with the opposing teeth in full contact in centric occlusion, the upper cuspids will fully lock between the lower cuspids and first premolars to completely immobilize the mandible. Such is not the case. The upper cuspid should have a horizontal overlap of approximately 1 mm. to allow a slight lateral and protrusive eccentric movement when the teeth are in centric occlusion…locking causes resorption of the labial cortical plate over both upper and lower cuspids and recession of the gingivae around those teeth… Tight occlusion of incisors and cuspids that completely immobilizes the mandible…often induces bruxism"* (d'Amico JPD 1961 p.914). One mm of amplitude is an important functional play in occlusodontics. **This is the antithesis of what he defended on the previous page** (d'Amico N ° 6 1958: p 200), because in these conditions with a large horizontal clearance in laterality and protrusion the MIO is unstable. This is a fundamental contradiction with what is stated on page 200 of the N° 6 and in the previous articles of 1958.

It is a statement of failure of the concept of interlocked canine which is the foundation of the protection canine of 1958.

If D'Amico does not clearly admit to having made a mistake, his proposals are contradictory, because such a game in laterality, makes it necessary to mutilate considerably the functional surfaces of cycle inputs, of bicuspids and molars, to regain the cuspid guidance

during laterality movement. However, these proposals are still championed by practitioners who do not know chewing function.

In fact, we must not start by adjusting the canine, but first MIO and actual chewing on M1 pair, by adding , then integrate respectively to this scheme, pairs P2, P1 and canines, in their order of emergence. When this adjustment has been made in the mouth, the cuspid will naturally guide the laterality movement (recruitment of contralateral ILP muscle, lateralizer and lowerer).

A lateral play mm is an arbitrary value that does not exist between the posterior cycle entry slopes and their opposite supports, including on the canines. In fact this functional play, immediate side shift (ISS), exists between all the teeth on the chewing side, just after the passage of the cycles by the MIO, at the beginning of the cycle output. It allows the masticatory cycles to be realized without blocking, during the passage of MIO. It is easy to observe by watching a chewing clip video, frame by frame (Figure 5B3-5). This functional game is personalized, specific to each patient and can't be replaced by an arbitrary value. Today it is still the equilibration in the mouth of the chewing and not on an articulator, that allows to adjust it precisely, which is impossible in the concept of d'Amico,which reasons in the opposite direction of the function with inverted muscular actions.

1- Joint guidance or dental guidance?

"Many writers on mandibular movements have taken the temporo-mandibular relation and condylar path as a fixed movement which can be recorded and reproduced on an articulator". (D'Amico N°1 1958 p9).

"The temporo-mandibular movement is a gliding-hinge movement, mostly gliding. The evidences does confirm the concept that the temporo-mandibular articulation does have a constant center of rotation during the vertical opening and closure of the mandible".(D'Amico N°7 1958 p 240).

"Also, as to the hinge movement, resolution of the edge-to-edge bite does support the theory that there is a fixed center of rotation or "hinge axis" in the vertical closure of the mandible." (D'Amico N°6 1958 p 200).

This is the opening, and voluntary closure, in the sagittal plane, and empty. **During the dental phase of mastication cycles, the progressive approach of the molars, up to contact through the bolus, and their oblique and transversal displacements, contradict this definition of a fixed and stable hinge axis, easy to reproduce on the articulators.**

The kinetics of TMJ is slaved to the dental guidance, it is not a simple mechanical hinge. Joint surfaces are unable to withstand stresses. The regulation of their relationships is ensured by the recruitment of capsular insertion muscles under the control of the peripheral sensory informations, which prevents any pressure from being applied to them, depending on the texture of the bolus. So there are instant adaptations, of muscular recruitment and positions, within this limited envelope of dento-articular guidance, which must be coordinated to work well, but that mechanical articulators do not know how to reproduce.

"The position of the condyles in the glenoïd fossa is the result of tooth contact and not the guide". (D'Amico1958 N°6 p 240).

In children, it is the limit envelope of dental guidance that makes it possible to finalize the shape of the TMJ. But in adults when the occlusal conditions are degraded, it is necessary that the coordination of dental contacts and guides with the limited envelope of joint kinetics, should be restored first. If this is not done, the joint-teeth complex will protect itself and will not be able to describe its limit envelope and its optimal kinetics.

2- Kinematics and compatibility of canine guidance with chewing cycles.

In humans and simians, the canine guides the eccentric laterality, while the molars guide the centripetal chewing (with all the complex: teeth, muscles, proprioception, which is inactivated in case of deficiency of only one of its determinants). In humans and anthropoids the crushing slopes, of chewing cycles output, are widely used because they have a very satisfactory functional efficiency. Provided that their occlusal anatomy has retained its integrity, and/or optimal functional characteristics.

But in the presence of a very abrasive diet (abrasives of internal and/or external origin), (Figure 3-6, 3-7), their wear is fast and responsible for their loss of effectiveness.

D'Amico concluded that:

"The morphology of the teeth of man is a modification of the teeth seen in all primates, primarily designed for the mastication of an frugivorous insectivorous, (or carnivorous) diet." (d'Amico N°6 1958 p 200) (D'Amico N°6 1958 p200). This assertion is based on the observation of rapid occlusal wear and not on criteria of functional efficacy in relation to the initial natural morphology of the teeth.

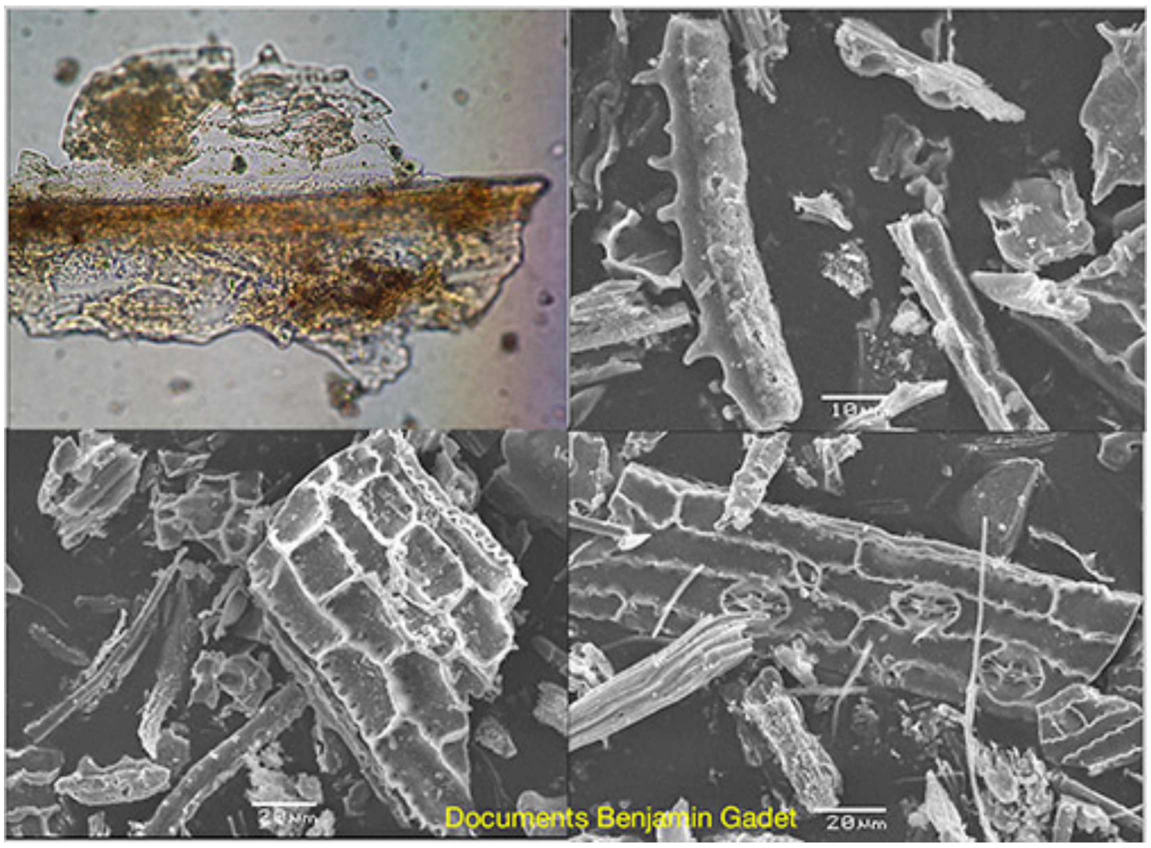


Figure 3-6: *Internal abrasives: Phytoliths. Herbal foods are fibrous and abrasive, because they contain phytoliths (plant silica) or "plant stone".-silica (in the form of opal SiO2 or opal A ((SiO2 nH2O), - or either crystals of calcium oxalate (CaC2O4). The abrasiveness of the phytolits associated with the absence of cooking is partly responsible for the rapid wear of the occlusal surfaces.*

Figure 3-7: *External abrasives: Example of a stone wheel of Roman era, coming from the marine quarry of Cap d'Ail (France), likely, by its heterogeneous composition, to release very abrasive silica particles. Poorly cleaned foods may retain abrasive soil residues on their surfaces, or may contain abrasive silica from poor quality stone grinders used to reduce cereals to flour prior to the introduction of industrial milling using metal devices. External and internal abrasives are the two main causes of attrition to which must be added the biocorrosion.*

3. Occlusal anatomy and cuspids

The occlusal anatomy of the posterior teeth of young subjects is hardly described, except for the static descriptions of the Y5 configuration by Gregory and Hellman (1939). These observations will not be taken into account next, as the role of the occlusal guidance of the molars, in relation to their occlusal relationship, which is not addressed at all.

In addition to being erroneous, from a genomic point of view, that the human tree (No. 1, p. 13) shows a direct line that leads to the "Caucasian" man, the vast majority of descriptions of Jones and D'Amico deals with the larger or smaller size of the canine and its interlocked relationship. With the aim to find the missing links of a degressive evolution of the size of the canine, in the human line: *"The literature of physical anthropology indicates the value attached to the possible discovery of an ancestral form, in which the canines differed from the canines of man, and approximated the condition seen in the anthropoid apes, interlocking canines…this feature characterized the dentition of the primitive ancestral type of early man…many physical anthropologists have learned to look for a remote human ancestor displaying relatively larger canines than exist today, with a diastema in the maxilla"* (d'Amico 1958 N°2 P.52, quoting Jones). In addition, d'Amico's observations aim to validate the guiding role of the canine. But there is a major omission in this reasoning: The variable dimorphism of canine size between males and females and whose size is in fact correlated with sexual selection parameters (Tomes 1882) (Figure: 3-8a, 3-8b, 3-9).

Sexual selection is not limited to the dimorphism of teeth, as Darwin so widely described it, in a 1871 book on "The Descent of Man, and Selection in Relation to Sex". But we will limit ourselves to dental sexual selection in the anthropoids and lineage of hominids, more fully described by Tomes, who wrote already in 1882:

"The males of many frugivorous monkeys have canine teeth much larger than those of the females; they are out late, coincidently with the attainment of sexual maturity, and are useful to their possessors as weapons in their combats with other males. ". (Tomes C 1882 p 273), then:

"It is obvious that males furnished with weapons more powerful than their fellows, will be more likely to prove victorious in their battles, to drive away the other males, to monopolise the herd of females, and so to transmit their own peculiarities to offspring, which will again be favoured in the same way".(Tomes C 1882 p 274)

“He would indeed be a rash man who ventured to assert that we had recognised all the agencies which are at work in the modelling of animal and vegetable forms ; but it is safe to say that. at the present time, we are acquainted with :

"natural selection," or "survival of the fittest," an agency by which variations beneficial to their possessors will be preserved and intensified in successive generations;

-or *"sexual selection," which operates principally by enabling those possessed of certain characters to propagate their race, while others less favoured do not get the opportunity of so doing”* (Darwin 1871; Tomes C 1882 p 277).

After quoting many relevant examples in various mammals, he writes:

Fig 3-8a, 3-8b: Female-male dimorphism in the gorilla: the canine of the male is significantly longer than that of the female. The size of the canines is related to sexual selection parameters. If the size and position of the cuspid had an effect on the shape of the masticatory cycles, the shapes of the cycles of males and females would be different. Which is not the case.

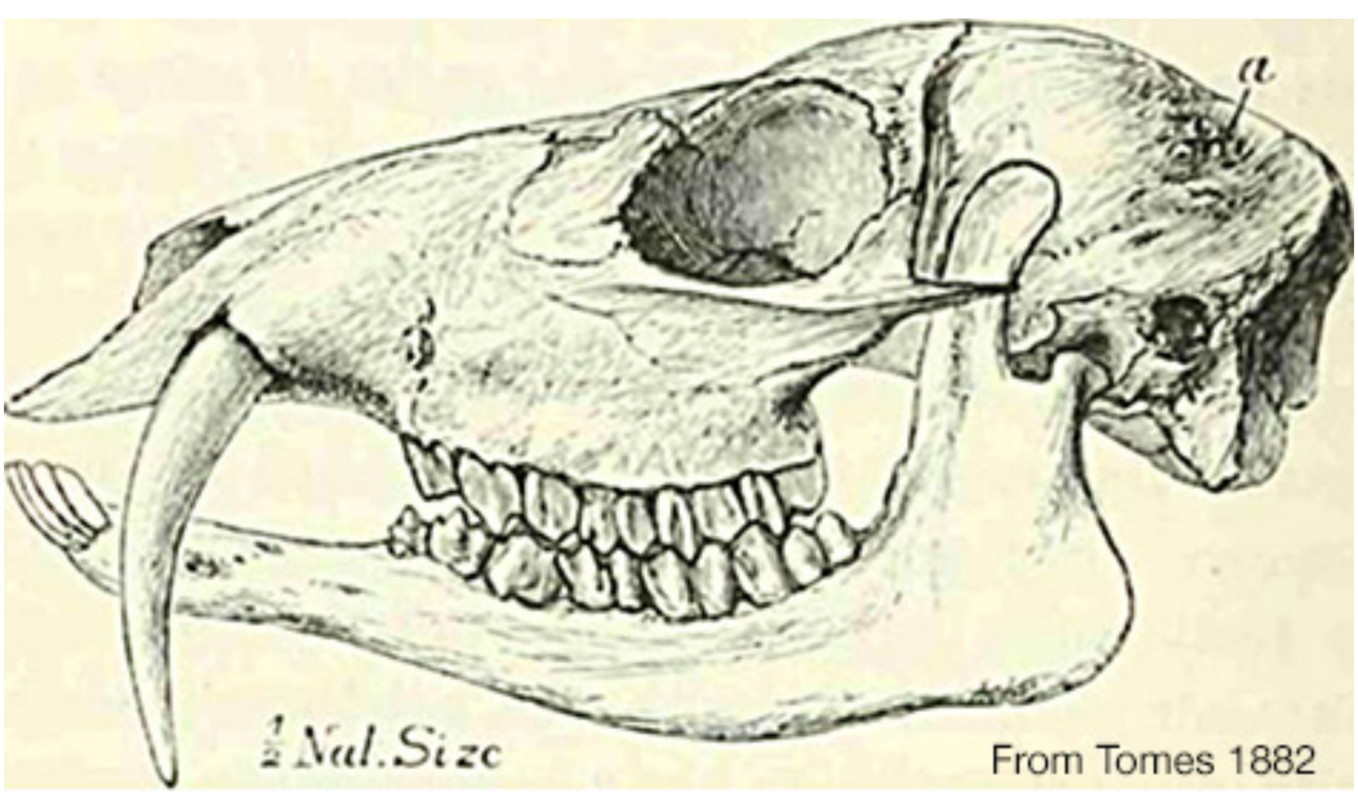


Figure 3-9: Maxillary canine of very large size in the male musk deer, devoid of antlers. The female has no canines (from Tomes 1882).

“In some of the groups no tooth has been lengthened and pointed, so as to serve as a canine ; in others it is the wrong tooth, i.e., not the same tooth as in the carnivora, or as in other Insectivora. Consequently, in the Insectivora the elevation of a tooth into caniniform length and character is a mere adaptive modification, which may affect an incisor, or a premolar, or no tooth at all”. (Tomes C 1882 p 285). (Figure 3-10, 3-11).

A more complete explanation of these relevant observations will be given much later:

In the evolutionary lineage of man, among others, the more intense is the sexual competition, the greater the dimorphism between males and females is important (Brunet M and Picq P. “The great expansion of australopithecus“ P256; in “To the origins of humanity” Coppens Y. and Picq P. Scientific Directors, Fayard ed 2001 Vol 1 (in French); Van Hoof P. “Live in a group“ p 220, 221; in: “The man's own” Picq P and Coppens Y. Scientific Directors, Fayard ed 2002 Vol 2 (in French). But the degrees of competition are variable. In species where a male is associated with several females, such as gorillas, theropithecus geladas, papio hamadrias baboon, sexual competition is permanent and strong, males are powerful, weigh usually more than twice the weight of females and have very large deterrent canines. They do not intervene in seduction, but in clashes with other males. In contrast, in monogynous species, such as gibbons, or polyanders, such as tamarinds, the competition is very weak. Males and females are the same size and their

Figure 3-10, 3-11:Perspective view of a male baboon. The very important dimorphism of the size of the canine, did not settle at the expense of chewing. There is a very important mesial diastema between maxillary canines and lateral incisors. To release the function, the mandibular P1 has tilted backwards, and the occlusal contact with the maxillary canine, is located on the bare root of mandibular P1. The manipulation simulates centripetal chewing, without any difficulty, following the residual occlusal guidance of the posterior teeth..

canines have a similar volume. Between these extremes, there are intermediate levels of competition, in species or multiple males and females coexist. In this case, the level of tolerance and the dimorphism are inversely proportional. For example, in baboons, tolerance is reduced and competition is high, resulting in a very marked dimorphism, whereas in other species, such as chimpanzees (pan troglodytes) and bonobos (pan paniscus), the level of tolerance is high. with a dimorphism of the body and canines much less important.

These data are totally ignored, in d'Amico's reflections and explanations on the size and role of the canine. All descriptions tend to make it the major key to occlusal guidance, whereas it appears late, at the time of sexual maturity: 12 years in humans before the 18th century, at the same time or after the 3rd molar in simians, when the adult occlusal scheme of the man is already installed on the first molar couples, from 6 years. Under these conditions, the canine fits into the pre-existing chewing pattern, without modifying it. If the size of the canine had any impact on the shape of masticatory cycles, the shape of the cycles of males and females would be different, and depending on the importance of dimorphism, which is not the case.

Yet Georges Tomes's book "A Manual of Dental Anatomy"(1923), is part of the bibliography of Hector Jones quoting him in his 1947 article, and later that of Angelo d'Amico:

“Turning our attention to the apes, and the other families of primates, we see interlocking canines of varied size and shape. In the males they are larger than in the females”.(Jones 1947 p 251, quotes Tomes ed.1923 Page 463) (Figures 3-8 to 3-11).

Then Jones quotes incomplete remarks from Tomes, taken from the 1923 edition. We report the complete quotations of the work of Tomes, as they have been published in the 1882 edition:

“But the most striking instance of the teeth being modified, so as to serve as weapons for sexual combat, is afforded by some members of the group of ruminants, amongst whom, as Frederic Cuvier F. long ago pointed out, (1825, 1824-1842) those which are armed with horns have no canine teeth. and vice versa, a generalisation which, although subject to slight exceptions, remains upon the whole true.

The male musk-deer (Moschus moschiferus) has canine teeth of enormous length, while it is quite without horns (figure 3-9)*; the female has no canine teeth. The male muntjak, which has very short horns, has canine teeth, but of much smaller size than those of the musk-deer”.* (Tomes C.1882 p 273).

It is astonishing that Jones and D'amico have stopped at limited excerpts, while the quotations from Tomes, reported above, show clearly and unambiguously that he considered sexual selection as a key determinant of cuspid size. It is possible that Jones as d'Amico did not adhere to the statements of Tomes, which were perhaps hypothetical at the time. **What appears today as an error that discredits their work on the size and role of the canine**.

Jones had many elements to understand dimorphism and the sexual component in the various evolutions of the canine's size:

- however, by studying the changes in the size of the lacteal canines, he moved in a direction incompatible with this hypothesis, which will nonetheless become inevitable later. (Coppens Y et Picq P: 2000; Picq P et Coppens Y: 2000, Picq 2010):

- but it correctly describes the centripetal kinetics of the human cycle input, and the first shear contacts on the inner side of upper buccal cusps, but not the second dental part of the cycle,

- then he makes a movie comparing a rhesus monkey chewing his meal, to a European, simulating chewing (It is unfortunate that the models and occlusal relationships of the two specimens are unknown). Jones finds that chewing cycles of the rhesus monkey are vertical, while those of humans are much more horizontal. He does not hesitate then to affirm p 257: *"Comparison of anatomical specimens will prove that monkeys and anthropoid apes are very different from man in the movements of the masticatory machinery,..and the difference can all be laid at the door of the canines. These practically prevent lateral movement of the mandible".*(A comparison between only 2 specimens is not relevant, given the variability of the cycles shapes, related with occlusal relationships, that were still unknown. These data could never be confirmed and for good reason, the model of functioning of the man and the anthropoids is similar since more than 32My. (Le Gall and Lauret 2008, 2011…, Picq 2007, 2010).
- And then p 257: "*Should we compare the dentition of the apes and monkeys with the dentition of the Australian aboriginal, we cannot but be forcibly impressed by the fact that, under attrition, the cusps of the human teeth are completely worn away and present a flat surface..".* And p 258: "*…Since the cusp formation, which exist at tooth eruption, tends to persist much longer under attrition in the anthropoid"…*(this is not what is observed on the contemporary specimens of Figures 4-34 to 4-44, whose longevity is much less than that of the current man)*…we should be justified in assuming that the mode of mastication and the mandibular movements seen in them are the more primitive. Man alone of the primates, has learned to incorporate the* (transverse) *shearing stress into his masticatory apparatus.* (Man is very far from being the only descendant of primates who masticates and uses his cycle outputs. Chewing does not require learning, it is a primary function related to the presence and balance of posterior occlusal guidance).*"The result is that in the primitive state,*

living on rough fare, he suffers rapid occlusal attrition, the cusps being shorn completely away quite early in adult life…man has tended to adopt in this regard the mode of mastication of the ruminants, without possessing any form of compensatory mechanism" (p 258). He considers this wear to be abnormal for man, compared to that of other simians. And he thinks that in anthropoids it is the canines that limit the amplitude of cycles and that they are likely to do the same in man (this is only true when the molars have worn out too quickly).

- and he then embarks on an uncertain comparison with the lacteal teeth, to look for primitive characters and missing links of intermediate size, to validate his hypothesis on the canine.

Jones published his unfinalized work in 1947, where he laid the foundations for an incomplete functioning model. T**his work based on the guidance of the canine was then taken up by d'Amico**, but **always avoiding the work of Tomes on the dimorphism and the directing role of the posterior teeth, which come progressively into contact, during the chewing of food.** (Figures 3-13 to 3-16, 5C-3 to 5C-5) . Similarly mastery of fire, evolution of the food diet, its level of abrasiveness (Figure 2-6, 2-7) and the psychosocial component of human nutrition have not been addressed. If today the wear of comminution tables has slowed down considerably, the life expectancy has greatly increased. In addition, it is now possible to build again lost volumes and restore the optimal functional efficiency of chewing (Figure 7-1). *Vidéo YouTube:* https://youtu.be/IOLxqQ2uYC8).

But neither Gregory Hellman, nor Jones, nor d'Amico had a complete knowledge of the functional anatomy and chewing kinetics of a young adult. **D'Amico therefore took over Jones' incomplete data on the canine, ignoring the role of the occlusal anatomy of the posterior teeth, which already guides the chewing, alone, several years before the canines appeared within the arcade.** With the agreement of many other paleo-anthropologists of the time, he finally took into account, only worn mouths, whose functioning model was already destroyed by an abrasive diet, and from which he has drawn erroneous conclusions about the guidance role of the cuspid, while chewing.

There seems to be a great vagueness in d'Amico's thinking, directly inspired by that of Jones, which describes on the one hand the posterior disclusion by the canine during the laterality and on the other hand very incompletely describes the contacts, between the posterior teeth. While maintaining the notion of hinge axis, during mastication, and the prominence of canine guidance till the maximum intercuspation, during latero-medial chewing movement, as on the articulators. In fact, considering the recruitment and the situation of the elevator muscles, the closing up of the posterior teeth during the mastication cycles, which occurs in the mouth, is not compatible, with the very concept of the unique hinge axis of the articulators, which does not allow it. (d'Amico N°5,6 1958)

Indeed he writes at the end of the article N°5 1958 p 182:

"…The length of the roots of the canines and their interlocking position are definitely for the purpose of limiting lateral excursions of the mandible. This relationship restores the désirable hinge movement of the mandible when the opposing teeth come into functional contact, and the normal shearing and cutting action of the cusps of the premolars and molars which is typical of the frugivorous-carnivorous species. There is no doubt in my mind that previous writers on normal occlusion have been guided in their theories by what they saw in primitive specimens. As a result of this, we have been trying to reproduce in man an abnormal functional relationship of the opposing teeth, a relationship typical of the herbivor or ruminant in contrast to the normal relation and function of the frugivorous carnivorous primate. This theory (of bilateral balanced occlusion) appears to be contrary to all physical evidence available and submitted by the writer relating to the origin and évolution of the natural dentition of man". D'Amico is right to criticize the concept of balanced occlusion and the very mutilating grinding techniques he advocates on natural teeth. However, But, it does not make any difference, between the lateroclusion movement with disclusion of the premolars and molars, and the centripetal chewing movement, under pressure of the elevator muscles, when on chewing side, the posterior occlusal surfaces show dynamic, balanced contacts.

In the current Indians Maidu, D'Amico also considers that the canines systematically put the posterior teeth in disclusion during all of the diduction movements.

He continues to show that balanced occlusion is not the human model, without understanding that the occlusal model of man is much more complex than the simplistic model, which he proposes, with over-guiding canines, which deprive the posterior teeth of sensory inputs which are determinant, of the power, shape and optimal efficiency of mastication cycles.

Some other quotes from D'Amico's articles about the canine:

"The strong development of the canine teeth in the adult would seem to indicate a carnivorous propensity, but they do not manifest it, in any case except during domestication". (D'Amico 1958 N°1 p 16). There is an error on the functional role of the canine and on the omnivorous capacity, which adapts to the available diet.

Or in a chapter devoted to captive monkeys and apes:

"…At first they reject flesh, but easily acquire a fondness for it. The canines are early developed, and evidently designed to act the important part of weapons of defence. When in contact with

man, almost the first effort of the animal is to bite". (d'Amico 1958 N°1 p 16: This paragraph is quoted by Yerkes as coming from Savage and Wyman). This is incorrect, the date of eruption of the cuspids is late. In simians it is simultaneous with that of the third molars and in humans it is around 12 years..

"Normally, in the deciduous and successive dentitions, the upper canine teeth are the last to erupt." (D'Amico fixed partial dentures 1961 p 901)

That's right, but the opposite of what is said above , about the eruption of the canines. (d'Amico 1958 N°1 p 16 quoting Yerkes).

D'Amico also writes (N°4 1958 p.127):

"Most (of the authors) seem to agree that the canines in man appear to be casualties of évolution".

An accident of evolution that is not adapted to the environment, always ends up being eliminated. The decrease in the size of the human canine is linked to the loss of its part in sexual selection, there are about 2My (Picq 2010). This has nothing in common with an accident of evolution.

4. Role and importance of proprioception

It is recognized today that, during chewing, central control supplants reflex phenomena (Lund 1983, Campbell 1985, Taylor 1983) and that it is the peripheral sensory information, mainly that emanating from periodontal mechanoreceptors (Anderson et al. 1970, Mei et al.,1975),that allow instantaneous adaptation of kinematics to sensory events encountered during chewing. (Steiner et al 1974; Gibbs 1981; Nakamura et al. 1989). The center of chewing is a central generator of engrams, responsible for the rhythm and duration of functional movements. (Delow et Lund 1971; Sessle 1976).

D'Amico writes that: *"The canine teeth also have a unique function. They are extremely sensitive organs. When their opponents come in contact during attempted eccentric movements of the mandible they transmit in a greater degree than any other teeth the desirable periodontal proprioceptor impulses to the muscles of mastication, reducing muscular tension and thereby reducing the magnitude of the applied force"* (D'Amico1958 N°6 p 240). It's incomplete and largely inaccurate because *"Human periodontal afferents signal detailed information about spatial changes of tooth loads and contribute to the spatial control of mastication… Receptor field properties of human periodontal afferents are similar on anterior and posterior teeth"*(Johnsen and Trulsson 2003a; Trulsson and Johansson 1996b, Türker 2002).

There is no primacy to the canine.

More *"A recent study from our laboratory has demonstrated that the receptive field properties of human periodontal afferents of anterior and posterior teeth are similar. However, analyses of the population responses made it clear that periodontal afferents supplying anterior and posterior teeth differ in their capacity to signal horizontal and vertical forces"* (Johnsen and Trulsson, 2005 p1889). *"During chewing, when food particles are ground into smaller pieces, strong axial and, in particular, horizontal forces are exerted onto the premolar and molar teeth. The periodontal receptors at premolars and molars are well suited to encode in detail the temporal and spatial changes of these tooth loads"* (Johnsen SE and Trulsson M. 2003a p1486)

From the age of 6, the periodontal afferents of the first molar couples are the only ones to fulfil this role completely. Later on the incisors and canines will also provide vertical incision and accompaniment of chewing, Mei et al .1975, Johnsen and Trulsson, 2005). If the cuspids are interlocked, their over-guidance, during cycle inputs and outputs, will prevent the contacts, between the posterior teeth. There will be a loss of proprioceptive information (direct or indirect) and disorganization of the kinetics of chewing. Indeed:

"The absence of sensory input results in reduced masticatory force and distorted spatial control of jaw movements during chewing" (Inoue et al.,1989, Lavigne et al., 1987, quoted by Johnsen SE and Trulsson M. 2003a p1486). In other words, poor coordination of the posterior chewing occlusal surfaces, modifies, reduces or removes the underlying sensory inputs, resulting in decreased masticatory forces and reduced amplitude and / or modified shape of the masticatory cycles. **This results in a significant reduction in their functional efficiency.**

The importance of chewing in nutrition and digestion is now much better known. Numerous evaluation studies have shown that masticatory impairments modify the diet and can have serious consequences on health (N'gom et al 2010; Lexomboon et al. 2012).

For more than 25 years, in clinical practice, (iconographed with photos and/or video recordings), **we regularly observe cycles whose envelope is deformed and sometimes reduced to a simple vertical shear. We can say that this situation is reversible, because when the functional equilibrium of the occlusal surfaces is restored (by addition) and the sensory inputs reestablished and balanced, the cycles instantly find again their optimal kinetics and their crushing power, without any learning.** (Le Gall and Lauret 1998, www.mastication-ppp.net). **It is clinically indisputable.** (vidéo YouTube: https://youtu.be/Heo8c8KM4WY).

But these data are interdependent on several other parameters such as: the number of mechanoreceptors relative to the root-bearing surface, which itself has a relationship with the forces supported by the different teeth, depending on their position within the arch, their clinical mobility, their root architecture, and the properties of the supporting bone.

1- It is necessary to apply a force 4 times higher on the molars to have the same level of discrimination as at the incisor level (Johnsen and Trulsson, 2005), but by a phenomenon of leverage taking into account the situation of the elevator muscles, the forces developed on the anterior teeth are 8 to 10 times lower than on the posterior teeth (Fontenelle et Woda; in Chateau 1993). (at the level of the cuspid it is likely that this range of applied forces is between 6 to 8 times less than at the molar level). The forces applied on the molars are much stronger than on the anterior teeth, there is a plethora of information, the discrimination of the pressure information is facilitated and requires the activation of less mechano-receptors than when these forces are less important, as on the anterior ones, so that the level of perception of information is equivalent between the incisors, the canines and the molars.

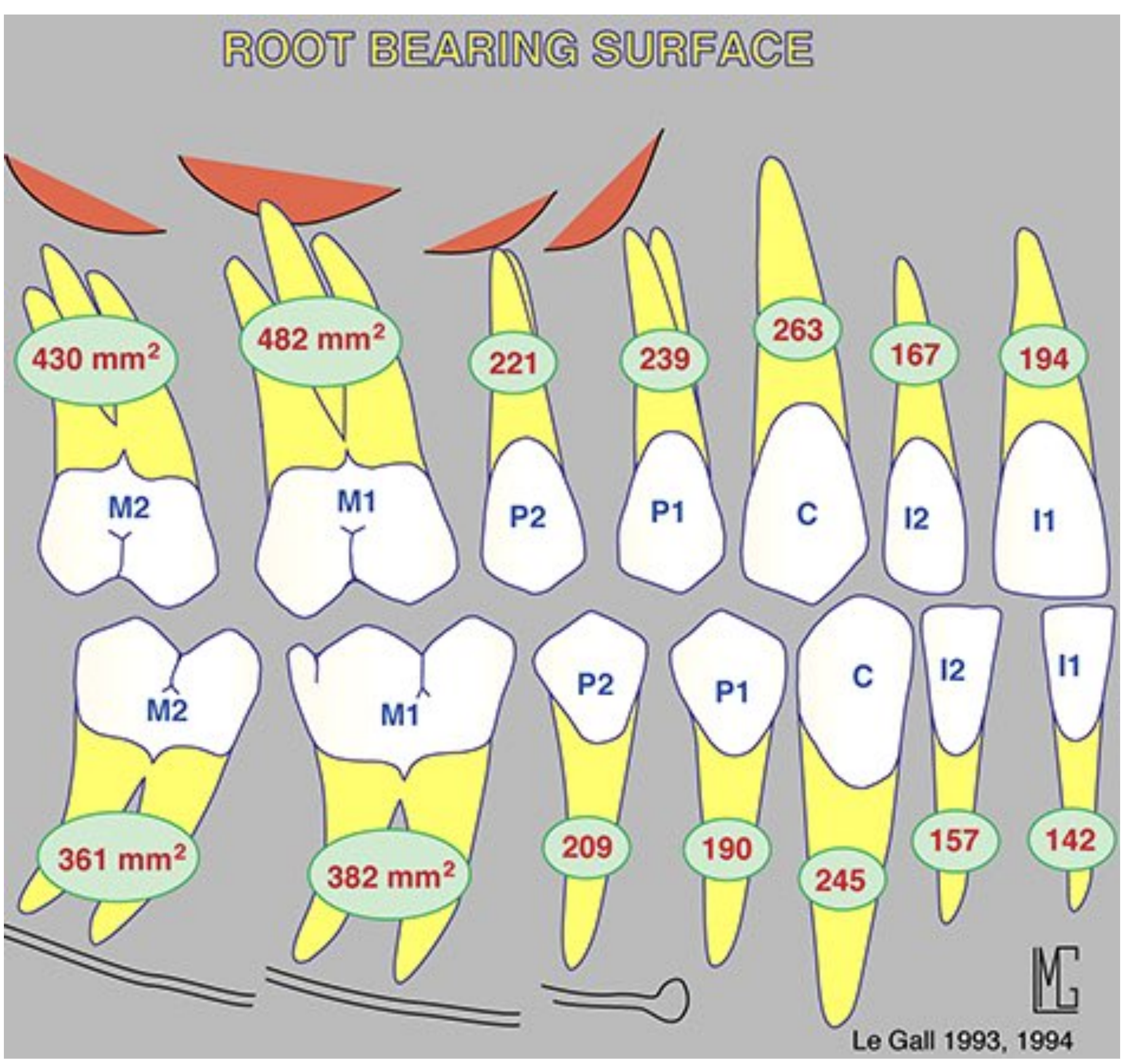


Figure 3-12:Root bearing surfaces is adapted to the functional loads supported by the tooth, depending on the quality of the support bone, and its position on the arcade.

2- The study by Parfitt (1960) indicates that the average transverse physiological mobility of the maxilla first molars is 56 micrometers versus 64 µm for the maxillary cuspid and 108 µm for the central incisor (for mobility teeth 1). These figures are corroborated by the root architecture of

Figure 3-13: 28 year old man. Right medio-lateral movement in the mouth. This movement is achieved with anterior guidance on the canine like on the articulator (fig.3-18).There is no posterior contact.

Figure 3-14: Simulation of latero-medial movement of right chewing, in the mouth. The situation is totally different. These are all internal slopes of the buccal cusps, on the chewing side, which support the cycle input guides. This is a fundamental difference with the articulator that can not reproduce this movement (fig.18). The human joint does not function as a hinge articulator axis, during chewing.

these teeth and their surface developed according to the mechanical qualities of the supporting bone (Le Gall et Saadoun 1993). As an example, the maxillary M1 has 480mm2 of developed roots surface against 380mm2 for the mandibular M1 and 263 and 245mm2 respectively for the superior and inferior canine, with an extremely thin buccal bone cortical. (Figure 3-12).

In this context, the biomechanical characteristics of the canines do not appear to be as exceptional as D'Amico claims in the conclusion of his 6th article of 1958 and are exceeded by those of the first molars from and around which the adult occlusal pattern was installed.

The position of the latter, their very limited mobility, their double guidances of cycle input, and their tripod like roots, allow them to support alone the most important chewing forces with

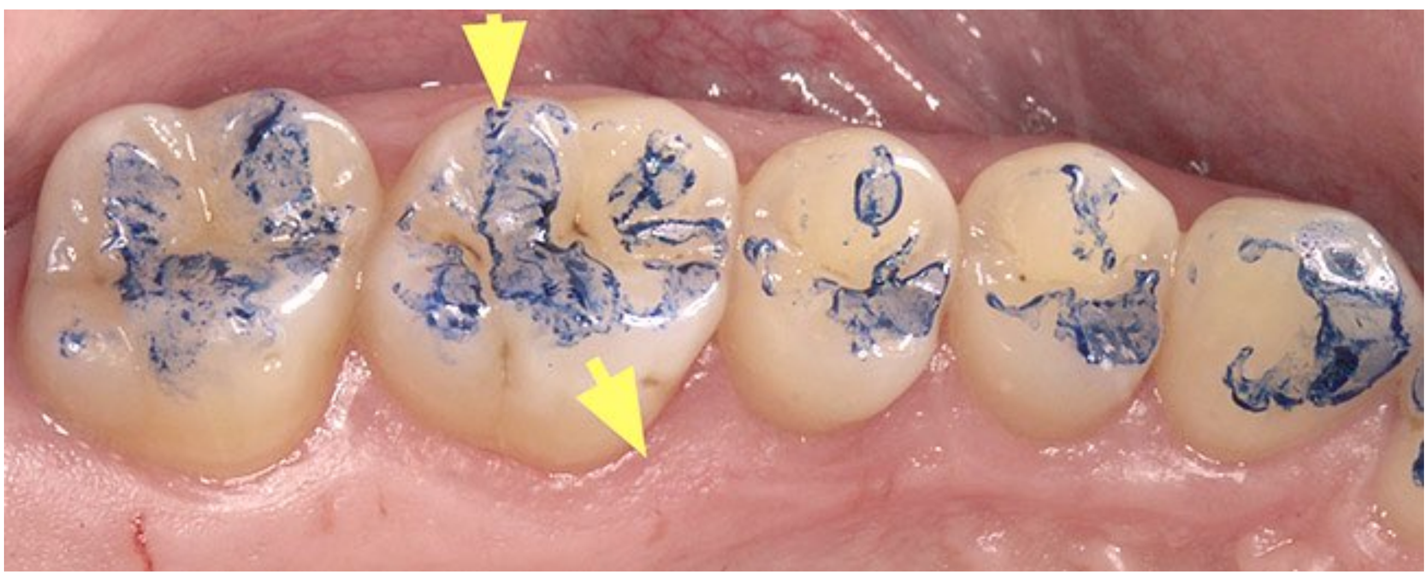


Figure 3-15: View of the dental guide boundary envelope, intermaxillary, on the maxilla chewing side. The mandibular movement has a centripetal orientation, and contacts and guidances are present throughout the occlusal surfaces, during cycle-in and cycle-out (on so-called "working" slopes, as on so-called "non-working" slopes).

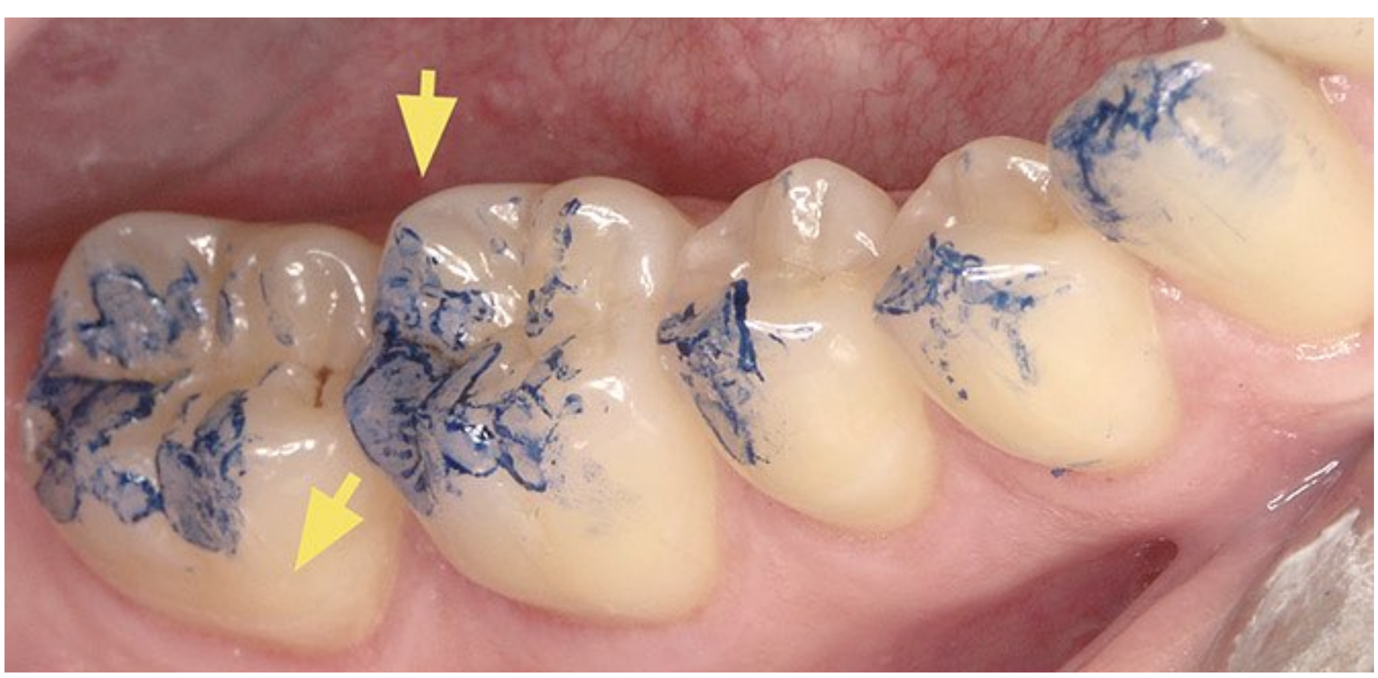


Figure 3-16: View of the dental guide boundary envelope, at the mandible, on the chewing side. The mandibular movement has a centripetal orientation, but the guides are read from the lingual side and are finely paired with their maxillary antagonists. These contacts are not visible during the laterality movement guided by the canine.

dominant guides. This does not confirm the inference on the *"resolution of opposing forces"* (d'Amico,

Article No. 6,1958), which are simplistically limited to axial forces alone. The cuspid arrives tardily on the arch and it's position is imposed by the preexisting chewing pattern, which means that a sufficient functional play is kept, with her contacting teeth, for the mastication to retain the pre-existing kinetics, and impose it to the cuspid. As a result, this supports much lower forces, but by its position, participates in incision and chewing while generally guiding the movement of laterality alone. Given the muscle mainly recruited to perform this movement: the contro-lateral lower head of the lateral Pterygoid muscle which is acting by depressing and moving forwards and laterally the condyle, transverse forces applied to the tooth during this movement are low, which helps to understand why the maxillary canine can withstand them, with such a thin buccal cortical. Even in case of bruxism, the distant position from the elevator muscles and the lever arm, does not allow the development at the anterior level of forces as high as at the level of the molars.

5. Mechanical articulators and reproduction of the human function

The era was mechanistic with the concept of CR, and joint hinge axis *"The evidence does confirm the concept that the temporo-mandibular articulation does have a constant center of rotation during the vertical opening and closure of the mandible."* D'Amico n°6 1958 p240).
Practically all the mechanical articulators, have been designed according to this principle of fixed hinge axis and considered as faithful reproducers of joint and mandibular kinetics.
It is therefore not surprising to see the validation of the Canine Protection, performed on models mounted on an articulator (D'Amico n°6 1958 p 205-206).
The concept of hinge axis is now disputed by the fact that the articular surfaces come closer during chewing (Gallo L 2005, Palla S et al 2003, Jaisson et coll. 2011). This allows the occlusal surfaces of masticating molars to crush the food, gradually getting closer to their antagonists, depending on the state of crushing the bolus. When direct interdental contacts occur through the bolus in the last cycles, this is a strong signal for triggering swallowing.. (Figures 13 to 16). However, this vertical resilience is impossible to simulate on conventional mechanical articulators having, a simplified and non-compressible, hinge axis. See video YouTube: https://youtu.be/jiZD7JppW3w

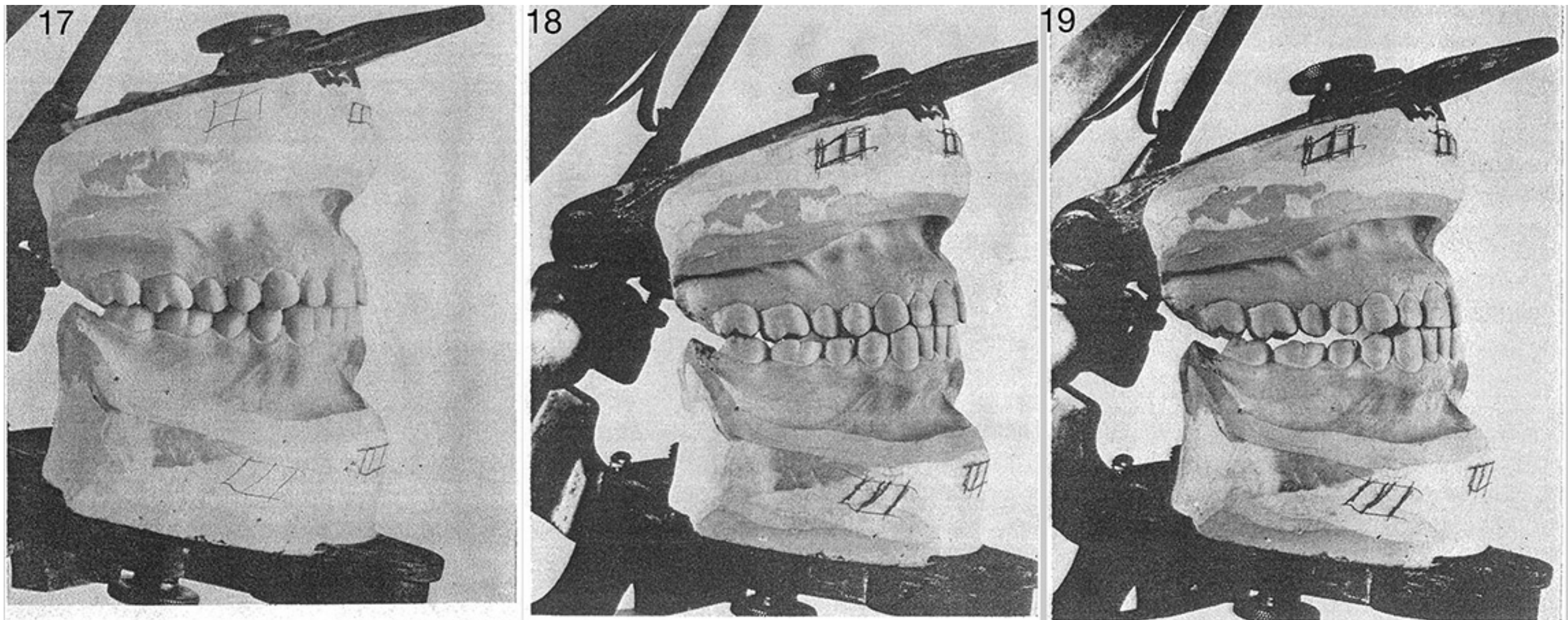


Figure 69. Upper and lower models illustrated in Figure 68 mounted in centric occlusion. Female, age 54.

Figure 70. "Working" side of specimen illustrated in Figures 68 and 69. Female, age 54.

Figure 71. "Balancing" side of specimen illustrated in Figures 68, 69 and 70. Female, age 54.

Figure 3-17, 3-18, 3-19 Clinical case of A. d'Amico (1958 N°6 P. 205 Fig 69, 70, 71) mounted on a conventional articulator. 3-17- View of models mounted in Maximum Intercuspation, "centric occlusion" 3-18- View of the medio-lateral right movement on articulator. This movement of laterality is realized, in anterior guidance, on the cuspid. There is not any posterior contact. The latero-medial return path on the articulator is identical to the previous, with the anterior guidance of the canine, without posterior contact, before arrival in Maximum Intercuspation. While, during chewing, there are contacts and posterior guidances. 3-19- View of the lateral movement of the contralateral lateral side on the articulator. There is disclusion on the right side (not working).

D'Amico writes about this in article N ° 6 p 205,: "…In all three of the preceding cases, the functional relationship is identical, all possessing an interlocking relation of the canines. During lateral excursions of the mandible, (on articulator Figures 3-17 to 3-19) none of the cusps or inclined planes of the opposing premolars and molars make contact until the mandible has returned to centric relation with dentition in centric occlusion. In such a functional relation none of the applied force of the Temporal and Masseter muscles can be directed at an angle to the long axis of the teeth".

This demonstration on the articulator, of the Canine Protection "during mastication", is fundamentally wrong, because, this canine protection, does not exist naturally when real chewing is observed, or recorded on videoclip (Figures 3-13 to 3-16, 5B3-1 A,B, 5B3-2 A,B).

Too much data were lacking on the physiology of mastication, the role of elevator muscles, and the functional relationships of the occlusal surfaces of posterior teeth, still poorly described at this time, to allow this pseudo demonstration, because:

- **On the articulator,** the medio-lateral movement and latero-medial movement, are guided by the canine on the same side and there is disclusion of the posterior teeth on the two sides. Nevertheless, compared to the mouth, when the posterior wall of the articular cases are straight, the disclusion of the posterior teeth, is often slightly amplified, during laterality movement on an articulator, since the angulation of the Bennett movement is not adjustable beyond 17°.
- **In the patient's mouth, the medio-lateral movement** is guided by the canine and there is a disclusion of the posterior teeth, on the two side. Because this movement is induced by the contraction of the contralateral Lower Lateral Pterygoid muscle, which is depressor and lateralizer and without real action, of the elevator muscles.
- **In the mouth, during a mastication cycle**, on the same side. The movement is centripetal, latero-medial during the cycle input, followed, after the passage of the maximum intercuspation, by a continuous displacement, in the same orientation during cycle output (in limit movement, guidance exists on all posterior occlusal surfaces, on this chewing side). This movement is realized with the strong contraction of the muscles Temporal, Masseter (elevators muscles) and Medial Pterygoid (elevator and lateralizer muscles) on the same side. Under these conditions, the articular surfaces and posterior teeth on the chewing side come closer vertically (Gallo L. 2005, Palla S et al 2003), as the bolus size reduces, and until the teeth start to contact, in the last chewing cycles before swallowing. The contact between the teeth determines the limiting guide envelope of the chewing cycles on this side (Figures 3-23, 5C-1 , 5C-2).
- The reproduction of this chewing cycle with **the posterior teeth, is impossible for** the totality of **mechanical articulators** whose joint cases are not compressible. It is achievable on the virtual articulators in CADCAM. It is a fundamental error of d'Amico, who imagined, for the man, a model copied on that of the articulator and not on the observation of the real kinetics of chewing, in the mouths of the patients. This error irremediably condemns the concept of Canine Protection as proposed by d'Amico. **The functional model of man is not that of an articulator of the twentieth century.**
- Possibilities and limitations of current mechanical articulators. Even today, mechanical articulators are reliable and often indispensable in static occlusion. In this context, articulator mounting may be useful or necessary for occlusal analysis, for the choice of vertical dimension, for the determination of a gnathological or physiological intermaxillary relationship, the balancing of Maximum Intercuspation, on natural teeth, and prostheses on

implants, teeth or dentures. But as far as dynamic movements are concerned, classical articulators, operating according to the gnathological model, could not be sufficiently improved to correctly simulate chewing. The final equilibration must always be checked and finalized in the patient's mouth by simulating chewing, because fixed restorations balanced on articulator during workflow, almost always have functional malocclusions, during the placement,, which can only be balanced in the mouth of the patient and consequences are particularly amplified in implantology.

The only old attempt at "functional" recording of laterality is the FGP technique, or “Functional Generated Path”, (Meyers 1934, Dawson 1974) which consists of recording the palatal face of the cuspid up to the limit of its laterality movement , on a plastic material (wax or others) placed on the frame of a small-scaled restoration. This technique allows adjustment of the cuspid and anterior teeth in laterality movement. It can also be adapted to the actual function, by asking the patient to chew on a plastic material, at the level of the molars, provided that they are functionally balanced. In this case there is ambiguity about the use of the term "functional" for the recording of the voluntary movement of laterality, without posterior contacts, while chewing obeys a central program, with contacts and centripetal guidance between the posterior teeth. Therefore, to avoid confusion in CADCAM, we propose to use the term CGP (Chewing Generated Path), or CGS (Chewing Guiding Surface), when it comes to simulation of the real chewing between the posterior teeth.

6. Current possibilities of virtual articulators and CADCAM

- A CADCAM system is composed of three parts:
  - A first unit takes the 3D optical recording. Optical impression of teeth, and arches is extremely accurate and reliable, with still disparities between the available cameras. It allows us to realize a virtual model in three dimensions, faithful, manipulatable and orientable in all the positions. This type of recording makes it possible to eliminate practically all the risks of errors related to conventional impression taking, the casting of models and mounting on a mechanical articulator. It must be performed in the mouth and not on plaster castings with almost all distortions and inaccuracies.
  - A second unit performs the digital processing of the virtual impression obtained. The latter is associated with a gnathological virtual articulator and prosthetic design software. The data is then transmitted to the manufacturing unit, usually in STL format

- **A third unit is responsible for prosthetic realization.** The prosthetic restoration is performed either by subtraction on a machining device or by addition to a 3D printer.

- **CADCAM techniques are still evolving rapidly.** Currently, the unit responsible for the treatment of occlusal relationships, functional kinetics and prosthetic design is the one that is is evolving very rapidly:
  - At present, virtual articulators were all digitized copies of gnathological articulators, which were not designed and are still unable to simulate chewing. In order to get closer to it, some of their operating parameters can be modified manually but with limits. Recording and use of a complete chewing cycle for occlusal reconstruction is impossible on this type of material,
  - The exact recording of the occlusal surfaces is totally controlled and can be used as a basis for their reproduction, provided that they are well balanced.
  - If the functional occlusal anatomy of the tooth to be covered is reestablished on a temporary crown, an optical impression of its occlusal surface can be taken and replicated by CADCAM.
  - When the occlusal anatomy of neighbouring teeth is unbalanced or lost, the functional anatomy of these teeth must first be reconstructed and their optimal cycle restored in the patient mouth, before taking their chewing guiding surface as a model (CGS).
  - Unlike mechanical articulators, virtualization gives the possibility of bringing the posterior sectors closer to the chewing side, and sliding them on one another to perform an approximate simulation of the mastication, following the chewing guiding surfaces(CGS), as some prosthetists do by removing the models from the gnathological articulators and manually fitting them. This allows for similar guidance to neighbouring teeth on the prosthesis being designed.
  - The occlusal anatomy of the future restoration, often manually adapted to the screen, is first validated. Then the virtual models are placed in occlusion on the screen to record the occlusal relationship with the camera, before being transmitted to the manufacturing unit. This phase is essential and delicate. The final adjustment will be realized in the mouth, with a possible return to the laboratory for occlusal additions.
  - Since the operating model of virtual articulators is a copy of mechanical articulators, it remains to optimize the possibilities of adjusting certain values, to obtain an acceptable reproduction of chewing. Particularly the orientation of the cycle input that it is not always possible to obtain (Figure 3-20), because on the gnathological articulators, the adjustment

of the angulation of the movement of Bennett, of opposite direction of chewing, is usually limited to about 17°. The adjustment should be extended to approximately 50°, in order to obtain in all cases a correct angulation of the cycle entry which follows well the enamel bridge rail of the maxillary M_1, because the "condylar" ball of mechanical articulators is not compressible, unlike the human joint, it is necessary to display a much larger angular value to simulate the cycle-in, and compensate for this deficiency. This is probably a minor software modification to be made, taking into account: the vertical approximation of the mandibular teeth and the angulation of their displacement, when they follow the maxillary M1 cycle input rail. This change has not been made yet.

See the chapter about CADCAM on: www.mastication-ppp.net

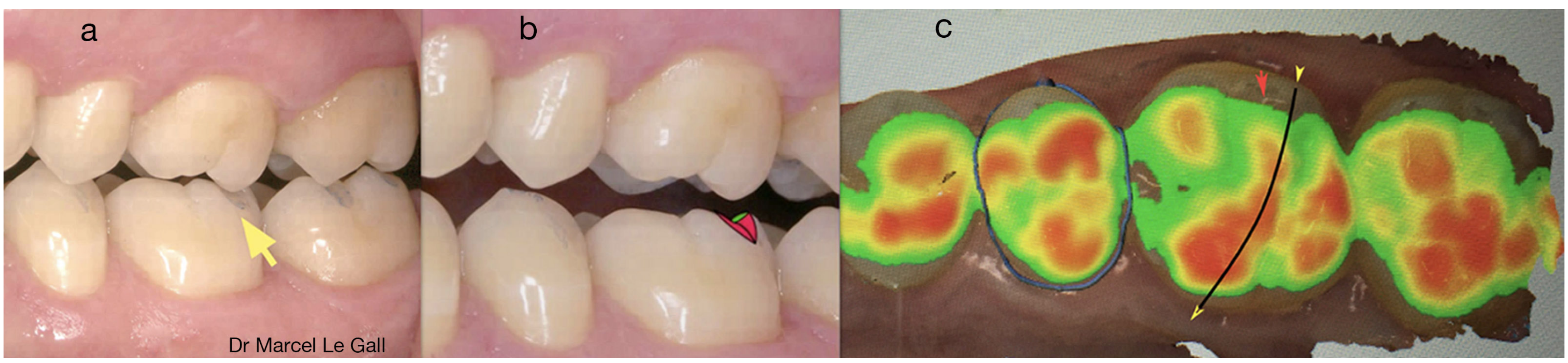


Figure 3-20(c): Occlusal view of the simulation of chewing on a virtual articulator 3shape ©. The angulation of the cycle input on maxillary M1, is too anterior (red arrow), compared to the optimal angulation of the enamel bridge rail (black line yellow arrows). This angulation does not allow the maxillary rail to position itself in the V-shaped receptacle located between the centro-buccal and disto-buccal cusp of jaw M1 (a, b).

7. Reproduction of Mastication: Contribution of the virtual 4D

Systems for analyzing and recording mandibular movements using classical or optical external sensors, have been now presented. They can record masticatory cycles when dissociated from their gnathological articulator, which restricts the possibilities of movement and whose functioning is not conducive to the reproduction of chewing. Their operation, taking into account the current technologies, is then, in the right line, of the first simulators of mastication: Replicator®, Sirognatograh®, whose ability to move in space was not limited by the restrictions of a primitive mechanic simulator..

There are several devices of this type whose latest developments quickly bring them closer to an optimal reproduction of chewing:

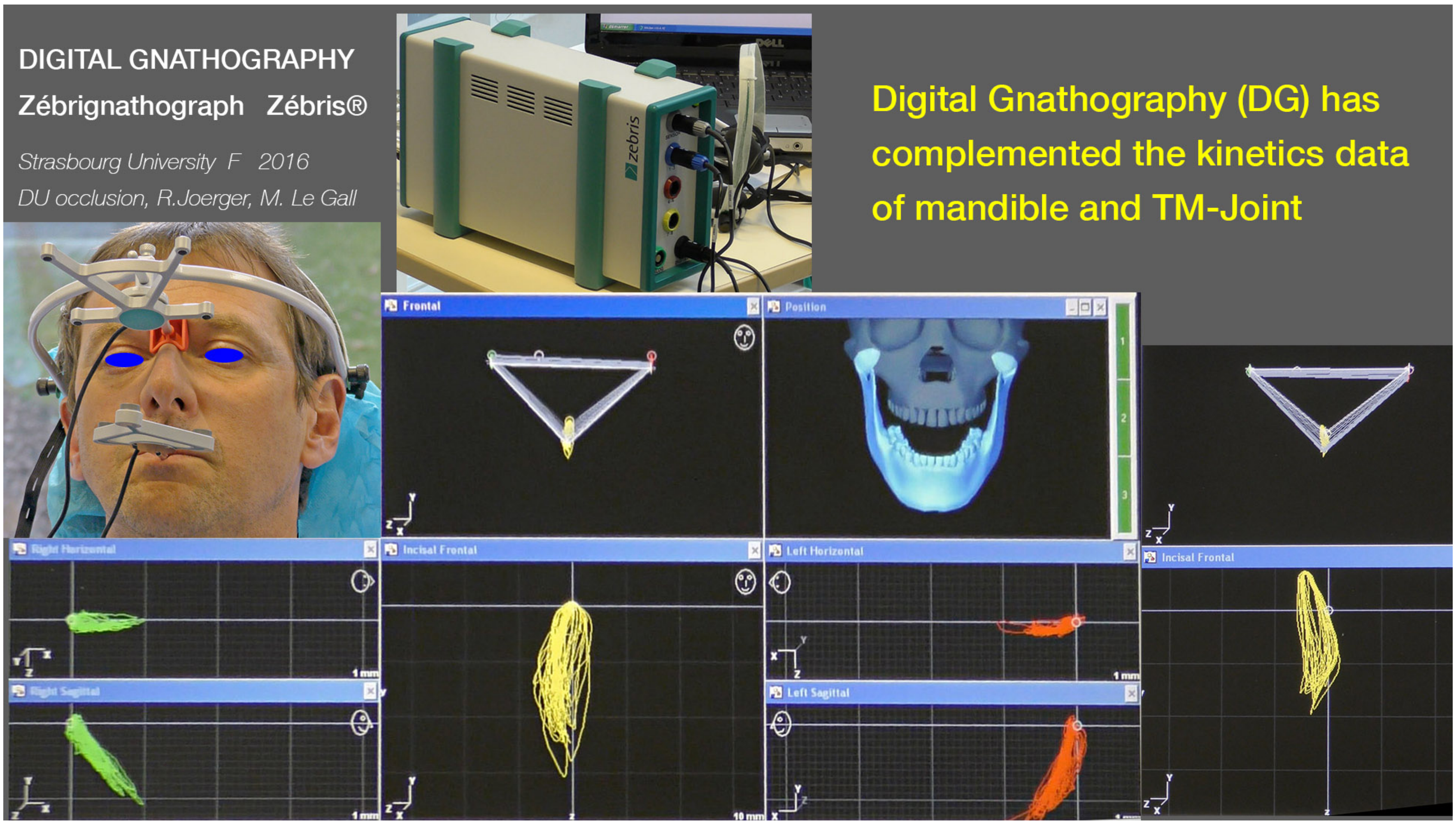


Figure 3-21 The Zébris® is a masticatory kinetic recording device consisting of a frontal bow supporting 4 horizontal sensors interacting with 3 lower sensors supported by a sealed fork on the buccal surfaces of the mandibular teeth. It is a tool for diagnosis and control of the evolution of the initial and final shape of the cycles during a treatment. The interactions of their shape with the dynamic equilibrium of the occlusal faces and kinetics and joint pathologies can be visualized and recorded. It looks like a very improved version of the sirognathograph © that we used in 1985.

- The Zebris® which has a very good ability to reproduce and record chewing cycles and which is used in the University Diploma of functional occlusion of Strasbourg France (Fig 3-21). The used version serves as a tool for recording cycles and diagnosing occlusal imbalances and pathologies of the disc and joint kinetics, in addition to or instead of magnetic resonance imaging (MRI) examinations. This version is not usable in CADCAM. Innovations follow one another quickly and costly equipment often outdated at the same pace, sometimes wrongly.
- The Modjaw® of which we had a clinical demonstration by Maxime Jaisson, the designer of this solution (Fig 3-22, 3-23). This recent system (Felenc and Jaisson 2018), more evolved and open, must first be associated with a 3D optical recording unit, then after validation of the prosthetic project, to a machining or 3D printing machine, for its realization. Its extensive possibilities make it a promising solution, because from the arch records, saved as an open STL file, it is possible:

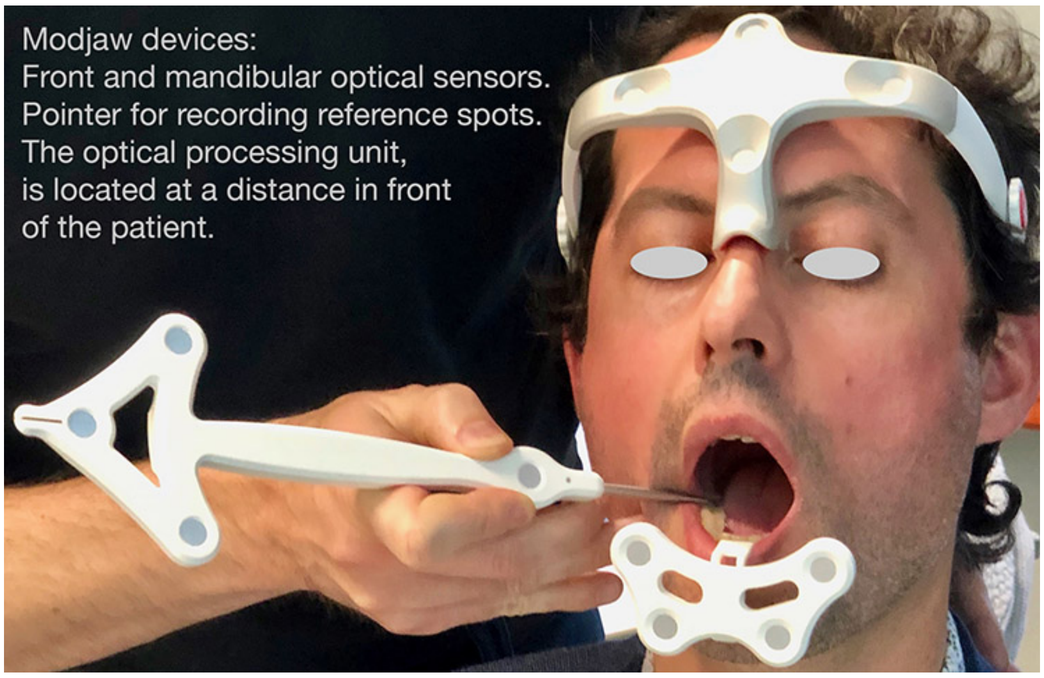


Fig. 3-22: This system is composed of optical sensors, wireless, cranial and mandibular frontal orientation, associated with dental and mucosal reference spots by an optical pointer. These sensors are connected to the independent and mobile treatment unit located facing the patient. This complete unit combines two optical sensors with a computer and a screen facing the patient, which can follow the recording Fig. 3-23.

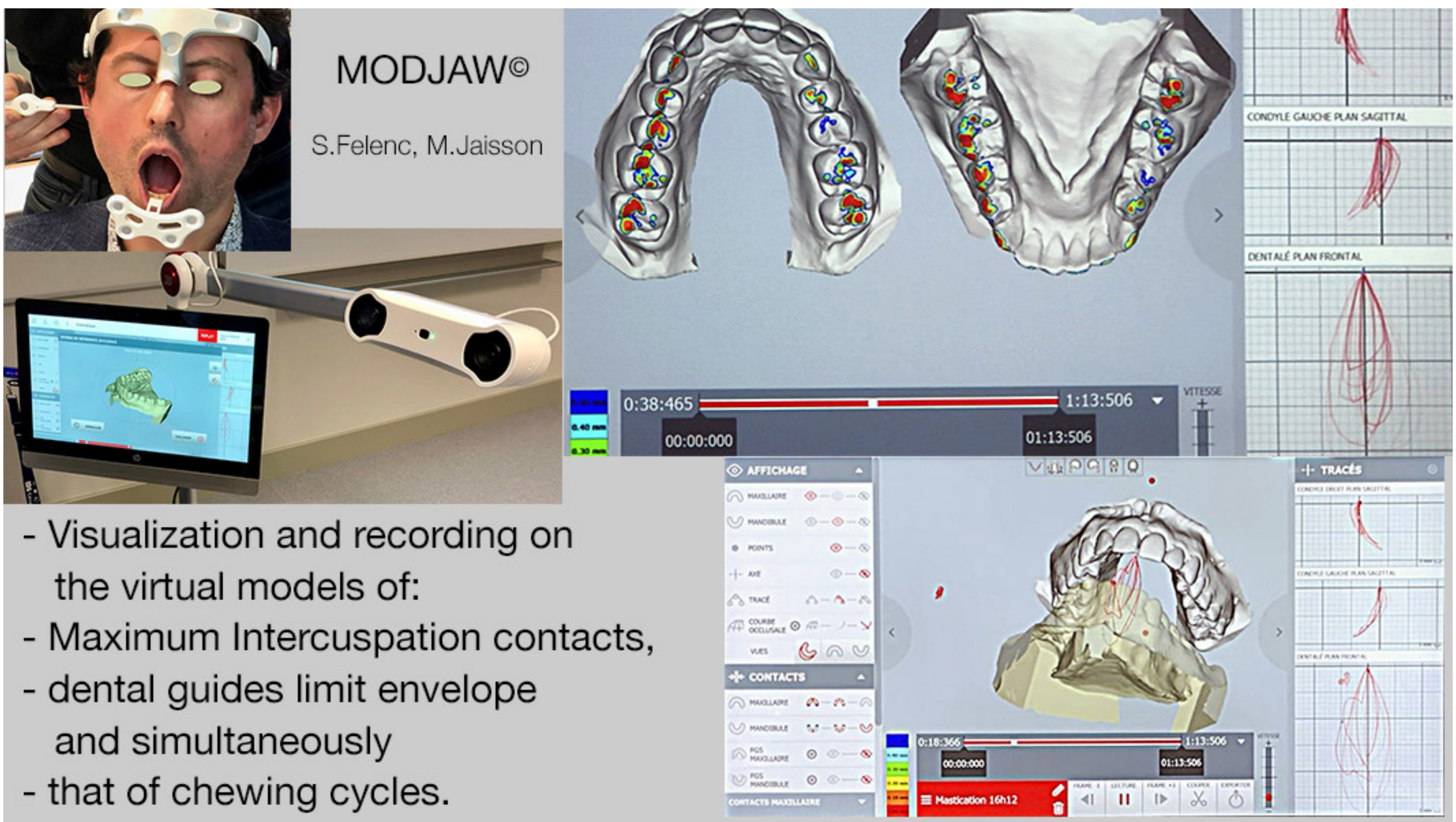


Figure 3-23: The Modjaw© allows the recording of mastication cycles and the simultaneous visualization of the chewing guiding envelope on the posterior teeth, which opens up new diagnostic and therapeutic possibilities of occlusal reconstruction.

- thanks to the reference points, to use it as a facebow to position the maxillary virtual model, and then see all the contacts of Maximum Intercuspation on the screen,
- probably to be able to associate the wearing of a specifically adapted maxillary anterior jig, in order to analyze the closure path with the tip of the tongue in swallowing position and to be able to objectify a possible premature contact on the virtual models of the arcades.

- and most importantly, to simulate, visualising and recording the patient's chewing cycles, either to the right or to the left, and to simultaneously observe the movements of the virtual mandibular model that reproduces the chewing cycles with the maxillary, without the limitations of a gnathological articulator. The dynamic interdental contacts and guidance are materialized in color and become visible on virtual models, outside the patient's mouth. They can be associated to the form of the cycles. Analysis of the distribution, insufficiency, excess or balance of Chewing Guidance Surfaces (CGS) can be done without having to interpose marker paper, colored films or other devices between teeth. This is also interesting on the non-chewing side, where the mere interposition of a film can trigger parasitic muscular contractions.

This virtual CGS can be recorded, exported in STL format and used to establish a diagnosis and achieve various objectives: surgical, occlusal, prosthetic, aesthetic or other.

We will limit ourselves to functional occlusal aspects:

- This virtual model can be used directly to create a diagnostic model and then, in case of balance of neighbouring dental guidings, a therapeutic model, thanks to a virtual wax-up,
- or exported to a manufacturing unit and printed to have models
- There is, still a problem. To use the Chewing Guides Surfaces as a reference and a model for the realization of a therapeutic guide, they must be balanced and cycles must have optimal kinematics (which does not always appear on videos of mastication cycles presented). However, to date, we do not have yet the possibility of making a reliable predictive analysis of the optimal shape of a patient's masticatory cycles. When the occlusal anatomy is lost, we are always obliged to go through the step of adding composite made in the mouth, starting with the couples of first molars, to gradually bring into harmony the kinetics of chewing of these teeth with that of TMJ. Then we gradually see the shape of the cycle change and find its optimal amplitude and functional efficiency. This allows us to have the patient's dynamic model of chewing. From this registered CGS, it is possible to realize the patient's own functional therapeutic model and to reconstruct its neighbouring functional occlusal surfaces
- The accuracy of all these potentialities will of course have to be validated clinically.
- Nevertheless, this situation could change if the physiological functional parameters of the teeth and the entire masticatory apparatus could be integrated into the computer software to create the diagnosis model first and then the therapeutic model.

- The first step could be to create a kind of "**generic avatar**" of the couple of first molars that would retain the memory of their occluso-masticatory characteristics, while being susceptible to adaptive deformations to the morphology and to the specific characteristics of different patients teeth, which would allow their integration in their arcades. This personalized avatar would then serve as a model for the functional reconstruction of neighbouring teeth on the arcades. Which parameters to remember? The descriptive and functional anatomy, but with the most extreme reservations for the usual model of which we know that the reference of Intermaxillary Relationship and the dynamic part are unfounded (chapter 5). By functional anatomy we mean the natural model of man based on swallowing and chewing. Locally it will be necessary to determine which parameters determining the static and dynamic occlusion, will be used. For mastication, it will certainly be necessary to start by relying on our current knowledge of the functional occlusal anatomy of the couples of first molar, since it is from their anatomical and functional characteristics that the adult occlusal pattern was established. In Angle's class1 occlusion these teeth are the 3D image inverted from each other and located at the frontal centre of gravity of the arcades. Figures 5-69 to 5-71 show the first parameters to be taken into account: the occlusal surfaces of entry and exit of chewing cycles and the guide rails that they have, which channel and orient their movements during that dental phase, such as the enamel bridge of maxillary M1 and its mandibular antagonists, in inverted volume etc. The second step would be to integrate this avatar, in the virtual dental arcades from the patient, its dental and facial typology, its cranio-facial parameters, the shape of its TMJ etc. The ultimate goal is to find the optimal characteristics of its chewing cycles and their maximum effectiveness.
- It is artificial intelligence (AI) and the power of its algorithms, which would make this modeling possible. Its gradual improvement, thanks to the capacity of learning and self-adaptation of the AI, would be made as the number of clinical parameters recorded in the bank of data increase. In medicine the analysis of these massive volumes of data (Big Data) is already made possible by new ways to treat them because the conventional means do not know how to manage them. There is still a lot of work to do to finalize and optimize these possibilities. but we are on the right track …

MAMMALS: MORPHOLOGY AND FUNCTION

Chapter 4

At the beginning of the first article (Amico 1958 No.1), there appeared a point of disagreement between G. Black and A. d'Amico on human functioning model, either omnivorous for Black, or carnivorous frugivorous for d'Amico.

To try to determine who is right, it seems useful to recall the main models of dento-articular functioning of mammals and to make a comparison with that of anthropoids and hominids. By taking into account:

- the ability to prepare the bolus in the oral cavity, then to digest, and assimilate it in the digestive tract,
- and how these models have been selected by the evolution since the Cretaceous-Tertiary crisis.

It has been possible to propose a coherent and reasoned explanation to the outbreak of the Cretaceous-Tertiary crisis, there are 65.5 My. It was mainly caused by the fall of a meteorite more than 10 km in diameter, whose impact power has projected into the upper atmosphere an enormous amount of matter, responsible for a temporary, almost total, limitation of photosynthesis. This caused a massive extinction of marine and terrestrial species depending on photosynthesis. The dust particles gradually fell and settled over the entire land surface, forming a layer of clay (K-T limit) with a high and abnormal rate of iridium, characteristic of this meteorite. Biodiversity is present in the previous layer, but there is not any fossil in this boundary layer and in the next upper layer. The enormous kinetic energy released during the impact weakened and cracked the earth's crust and was probably responsible for a very significant upsurge in volcanism, partially responsible of the disappearance of approximately 75% of the species.

As a result of this crisis, which caused the extinction of the great dinosaurs, a new evolutionary diversity was established from small species. As for surviving mammals, they have diversified from small placental, nocturnal mammals with 44 teeth. These small modern mammals of the size of a mouse, were able to survive thanks to their omnivorous capacity, because they could eat the grass, in the niches left free by the brutal disappearance of the large herbivorous dinosaurs, followed by that of the carnivores. Sigogneau-Russel (1991) describes the dental formula of Kennalestes Asiorictes, one of those omnivorous species with 44 teeth, 3 I, 1 C, 4 P, 3 M. In this regard, Granat (2001) writes that this dental formula is at the origin of all current placental mammals, and thus of primates.

A second phase of radiation-diversification occurred about 34 My (Sherwood-Romer 2009) at the time of “ La Grande Coupure“ (major climate crisis that saw the separation of the Antarctic continent from Australia and South America). This crisis has caused the selection of the majority of species still present today.

Species that have kept tribosphenic molars have generally retained omnivorous characteristics. Others have evolved towards strictly carnivorous, herbivorous or rodent models, or with intermediate characteristics according to the ecological niches they occupied or still occupy today. (Le Gall et Lauret 2008, 2011, Chap 3):

- carnivores, with vertical functional field and 1 degree of joint freedom

- herbivores, with frontal functional field and 2 degrees of joint freedom,

- rodents, with sagittal functional field and 2 degrees of joint freedom,

- omnivorous models, including those with tribosphenic molars, with cusps, and 3 degrees of articular freedom, optimized by the presence of a hand, capable of bringing food to the mouth and introducing it, thank's to a specific incision.

- **However, numerous functioning models exist and have intermediate characteristics**. Some have been eliminated and then re-selected in other lines and / or at different times (eg, the teeth of some herbivorous dinosaurs that are similar to those of current herbivores).

A- CARNIVORES

1. Joint Kinetics

Carnivorous mammals have only one degree of freedom, tooth / joint, allowing only the vertical opening and closing of the oral cavity. The articulations are elongated transversely and allow only rotation (Figure 4-22)

2. Dental morphology and model specificities (Figure 4-20, 4-21)

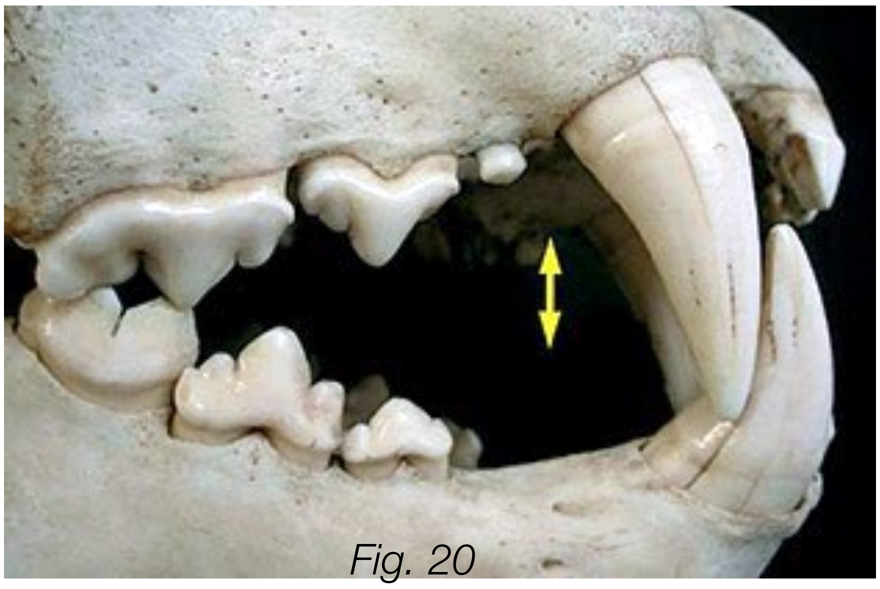


Figure 4-20, 4-21 Dento-articular system of a young lioness (Collection de Ramecourt, Le Gall)
Figure 4-20 The canines behave first, like hooks capture and killing of the prey, and then allow, the dismemberment summary, aided by the action of carnivorous teeth whose effectiveness is formidable..
Figure 4-21 (from Le Gall et Lauret 2008, 2011) We can see the opposite guidance and self-sharpening of carnivorous teeth, with a powerful cut, similar to that of scissors.

The anteroposterior limitation is ensured by:

- hinge joints,
- the anterior locking of the mandibular canines against the maxillary lateral incisors:

The transversal limitation is ensured by:

Figure 4-22 (from Le Gall and Lauret 2008-2011). The joints can only perform a pure rotation. The opening and closing are maintained in the sagittal plane by a vertical dental determinant and by the transverse elongation of the two joints (like door hinges), which prohibit any diagonal transversal movement. Figure 4-22b: It's a real hinge axis, not like in man.

- On the one hand, the very early closure of the canines and especially the interlocked occlusion of carnivorous teeth and canines, which forbid all transversal movements..

- and on the other hand the two transversely elongated articular hinges axis, that prohibit diagonal movements.

This sharp teeth apparatus is suitable for catching and holding live fleeing preys, and killing them with very long and pointed canines, behaving like real prehensile hooks. The dismemberment, tearing and brutal shredding of the victims and pieces of meat are ensured by the canines but especially by the vertical shear of carnivorous teeth acting like scissors blades. Their effectiveness is amplified by the confrontation of the cusp points, in the form of triangular blades, facing each other and sliding diagonally, in the sagittal plane.

The physical preparation of the food is reduced and fast without proper chewing before swallowing, to avoid the greed of other predators. Most of its digestion is chemical, it is facilitated by the presence of powerful gastric juices, whose PH is of the order of 1, less than 2.

We note the presence of interlocked wear facets between lateral incisor and upper canines. The vertical sliding zones of the opposite carnivorous teeth, indicate a functional self-sharpening of the latter (Figure 4-21).

The shearing action of carnivorous teeth is extremely effective. Some carnivores like hyenas can even break bones, with them.

This model, very specialized, efficient and fast, is not suitable for chewing or oral preparation of fibrous, abrasive and low-protein plant foods, because there are no transverse tables, able to grind the cellulose wall of the cells before digesting the contents. Even the digestion of polysaccharides, such as raw starch, is incomplete and difficult in domestic carnivorous mammals, such as dogs (Champ Martine 1985, Grancher Denis 2009). On the other hand, it is not the only model that allows the preparation, ingestion and digestion of meat-based foods. Meat is a food easily digested by a non-specialized digestive system.

B- HERBIVORES

1. Joint Kinetics

Herbivorous mammals have two degrees of dento-articular freedom, allowing the opening and closing of the oral cavity, as well as transverse movements. In the herbivore model, anteroposterior movements are not possible.

2. Dental morphology and model specificities

Example: model of functioning of equines Figures 4-23 to 4-26 (horse from Poitou France):

The anteroposterior limitation is ensured by:

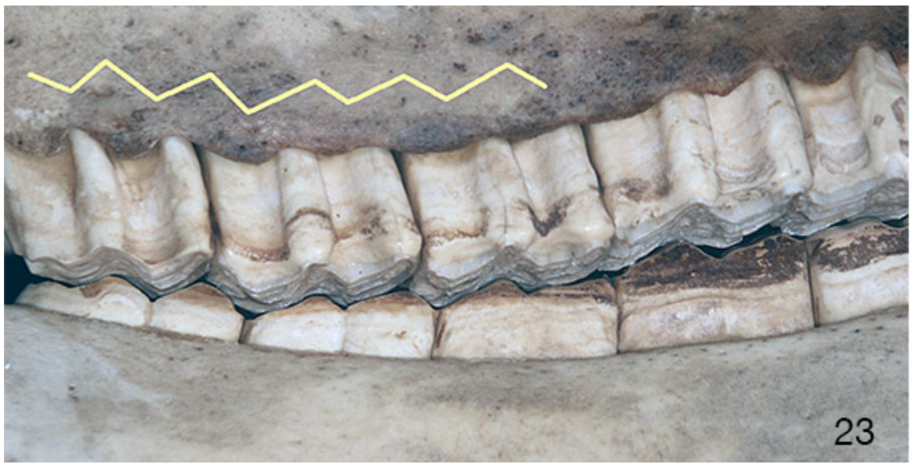
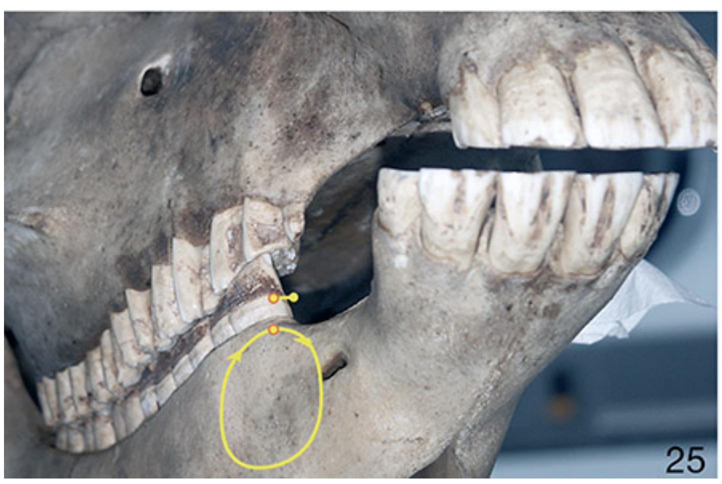


Figure 4-23,) In the sagittal plane, note the zig-zag aspect of occlusal relations which prohibit any antero-posterior movement. *Figure 4-24: In centric closure position, the mandible, of reduced width, is medially offset. When closing, the incisors have a marked edge to edge relationship, but the contacts are reduced, between the lateral sectors. Dento-articular horse system (from Le Gall and Lauret 2008-2011).*



Figures 4-25, 4-26 (from Le Gall and Lauret 2008-2011)
A slight centrifugal displacement puts the molars on the triturating side in a position of maximum unilateral intercuspation by causing the disinoculation of the incisors and premolars and molars on the non-triturating side. It is around this "lateral centric occlusion" that masticatory cycles develop, without "balancing" occlusal contacts on the non-chewing side.

-Posterior occlusal tables showing, in the sagittal plane, an occlusal relationship in accordion, blocking the anteroposterior movements and channeling the transversal movements of masticatory cycles.

In the closed position, one can note the frontal shift of the intermaxillary relations, the mandible being shifted internally position with well marked incisor edge to edge relation.

-The temporal joints have an accentuated "dome" shape that does not allow anteroposterior displacements, but they are released transversely with, in the case of the horse, a limited vertical opening.

This dental system is suitable for the complete tearing and grinding of herbaceous foods that are low in protein and, moreover, abrasive (the cuticle contains phytoliths). The accelerated wear of the occlusal surfaces is compensated by the presence of continuously growing teeth.

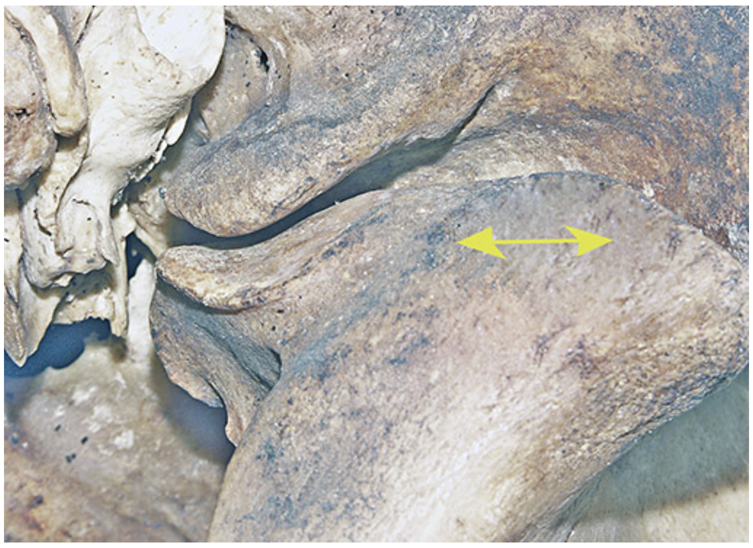


Figure 4-26b Dome-shaped joints, channel movements in the frontal plane

The antero-posterior incision movement is not possible, the grasping of the grass is carried out by a direct section-tearing of the blades of grass by the incisors (a lateral displacement would put them immediately in disclusion).

The originality of this model lies in the fact that, in the “centric“ sagittal closure position, the lower occlusal tables are in marked medial shift with their maxillary antagonists (Figure 4-24). During chewing, a small medio-lateral displacement of the mandible towards the chewing side places the occlusal tables in a maximum unilateral occlusion and causes the disocclusion of the teeth on the non-chewing side and anterior teeth. Figures 4-25, 4-26 . It is around this laterally shifted position that the mastication cycles take place, with no contact between the molars on the non-chewing side and between the incisors. Posterior occlusal tables present enamel convolutions, with various patterns, separated by areas of dentine which wear out more quickly by attrition and biocorrosion. This configuration, whose differential wear is self-sustained by continuous growth, allows the teeth to behave like very abrasive rasps that break and crush the cellulose fibers and the cell walls, to facilitate the digestion of their contents. (Chapter 3).

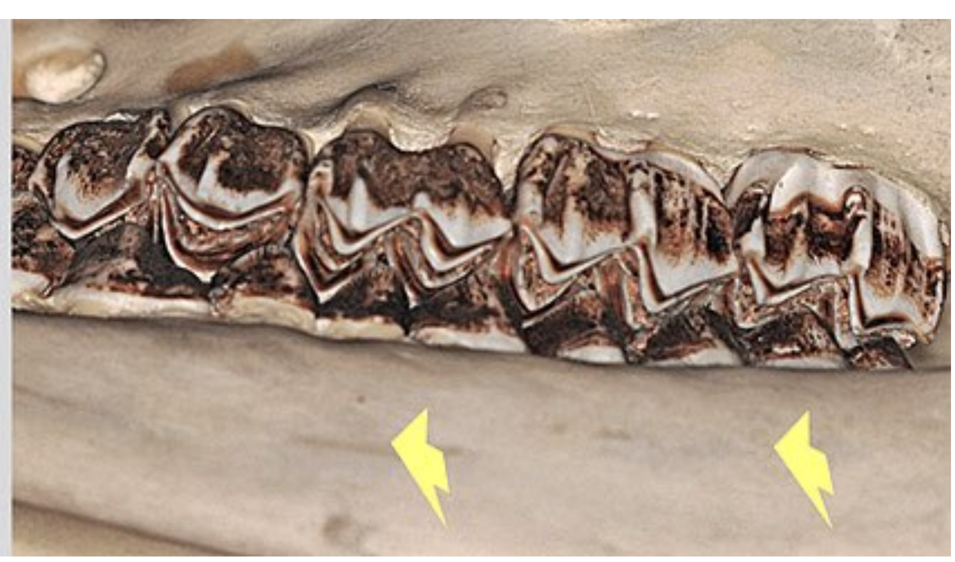


Figure 4-27a: View of a related configuration in a cervid. The rails have a triangular section.
Figure 4-27b: (Zoological Museum, Strasbourg France) Perspective view of the sliding of the mandibular rails, in "accordion", in their maxillary antagonists. It is this dynamic relation, indirect then direct through the bolus, which gives its efficiency to the model.

Some herbivores are grazers (white rhinoceros), others are folivores (gray rhinoceros). There are a large number of related models (Figure 4-27).

Others, like the current African savannah elephants, have several replacement germs, when the occlusal table of their single molar is worn out.

Carbohydrate digestion, like starch, is usually done by endogenous enzymes. In the case of cellulose, it is the exogenous enzymes of a specific microflora that ensure its degradation-digestion (Champ M., 1985). Not all herbivores have the ability to digest cellulose directly. In the monogastric, it's prior degradation, which is long and energy consuming, is reserved for certain specifically adapted herbivores, such as the sloth and the panda. In ruminants, such as cattle, the immediate ingestion of the grass in a specific organ, the rumen, allows the faster degradation of the cellulose, before its regurgitation and its secondary chewing (rumination), followed by its digestion in the usual digestive system.

C- RODENTS

1. Joint Kinetics

Rodents are part of the group of Glires, with the Lagomorphs. Glires usually have a double capacity. In addition to opening and closing, they can be either rodent in anteroposterior

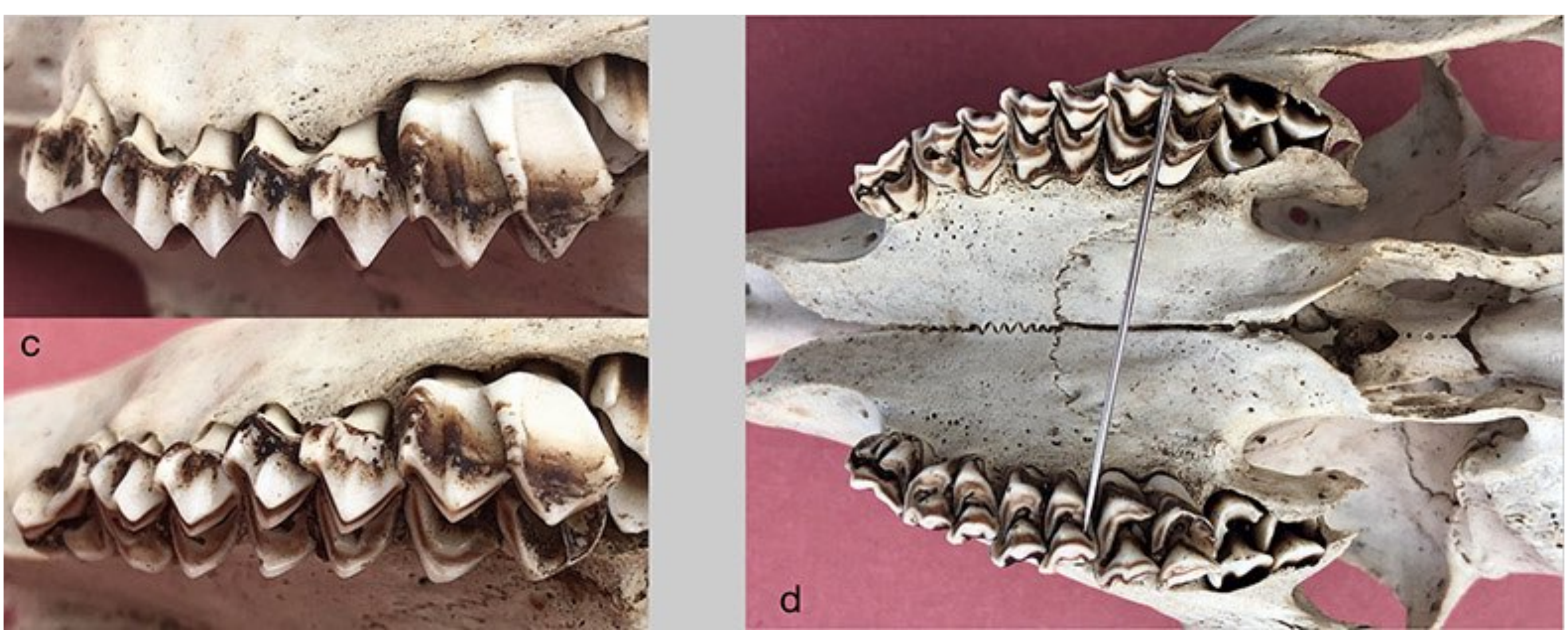


Figure 4-27c, (European Roe (Kerven, 29140 Melgven France) The alignment of the guide surfaces which constitute the rails is noticeable in axial view and in perspective.

Figure 4-27d: The rails on the same side are parallel and rectilinear with a frontal orientation, more or less diagonal, depending on the species. Even in this case, where the angulation is small, the rails of the chewing and non-chewing sides can not be engaged simultaneously. So the chewing is unilateral and is not done in balanced occlusion.

movements, or herbivorous in transverse movements, but not simultaneously. They have articular surfaces often more complex, because they adapted to this dual possibility.

2. Dental morphology and model specificities

The preparation of very hard plant foods is facilitated by the ability to gnaw, which is also used for other purposes, such as beavers for cutting wood or moles to dig its galleries.

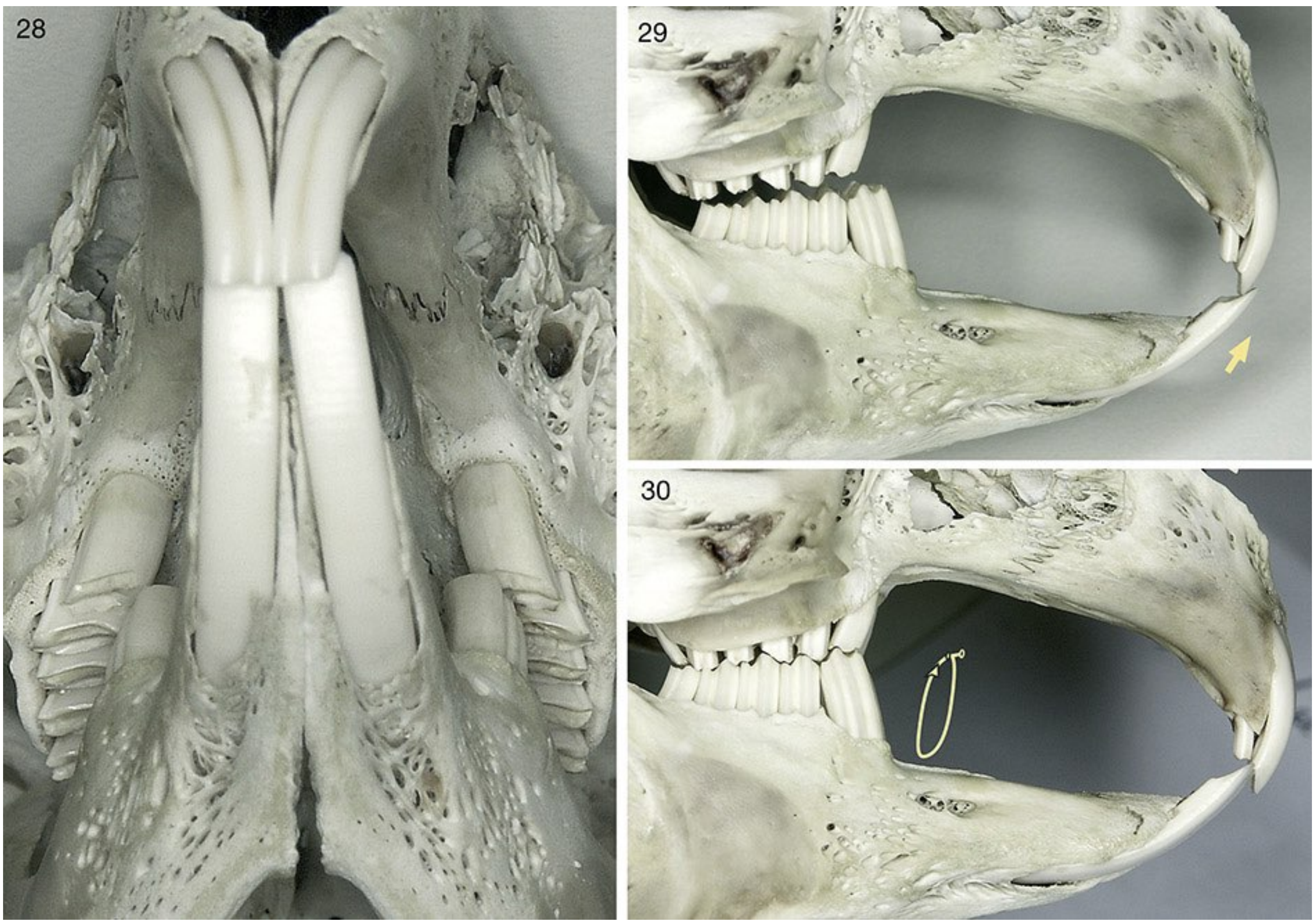


Figure 4-28 (from Le Gall and Lauret 2008-2011): The mandibular condyles are oriented longitudinally. The maxillary articular surface is reduced to a simple arcuate support. Note the external offset of maxillary molars compared to mandibular sagittal occlusion. This makes it possible, in herbivore mode, to shift the mandible towards the chewing side and to put in occlusion on the non-chewing side.The incisors are supported, but the contacts of the posterior teeth are relatively reduced in Maximum Intercuspation Occlusion (MIO).

Figure 4-29: The gnawing takes place in a protrusion position, in inverted incisal relationships or not. This anteposition puts the molars into in occlusion during the gnawing done by the incisors.

Figure 4-30: During chewing, the mandible recoils and can become unilateral occlusion shifted either to the right or to the left (like the horse). Under these conditions the non-chewing side goes into disocclusion and mastication can be done without contact on the not chewing side. In the rabbit, during chewing there is anterior guidance, at the 2 palatal incisors and cingulum of the 2 buccal incisors.

Figure 4-29b: During gnawing, in ante position, transverse movements are not possible. The longitudinal rear part of the mandibular condyle slides against the transverse root of the zygomatic arch whose shape channels its displacement in the sagittal plane.
Figure 4-30b: During herbivorous frontal chewing, the mandible is in a retracted position. And it is the anterior part of the articular surface of the jaw condyle, leaning against the back of the zygoma, which accompanies the transverse molar occlusion relations, accordion-like. This coordination prohibits any movement of propulsion during mastication.

About the rabbit, the position of sagittal occlusion places the arcades in occlusal relationships shifted in the frontal plane, as for horses (Figure 4-28). From this position, two types of functional programs are possible, but can not be realized simultaneously:

- Opening and protrusion/incision of the mandible, to perform the gnawing in incisal relation, inverted or not (Figure 4-29). This function is performed by sliding and friction between the two maxillary central incisors and their two antagonists, continuous growth. These alternative sagittal movements are accompanied by the displacement of the posterior part of the condylar heads elongated in the sagittal plane. In this function, transverse movements are not possible. The gnawing is very often associated with the herbivore capacity, as it is the case for

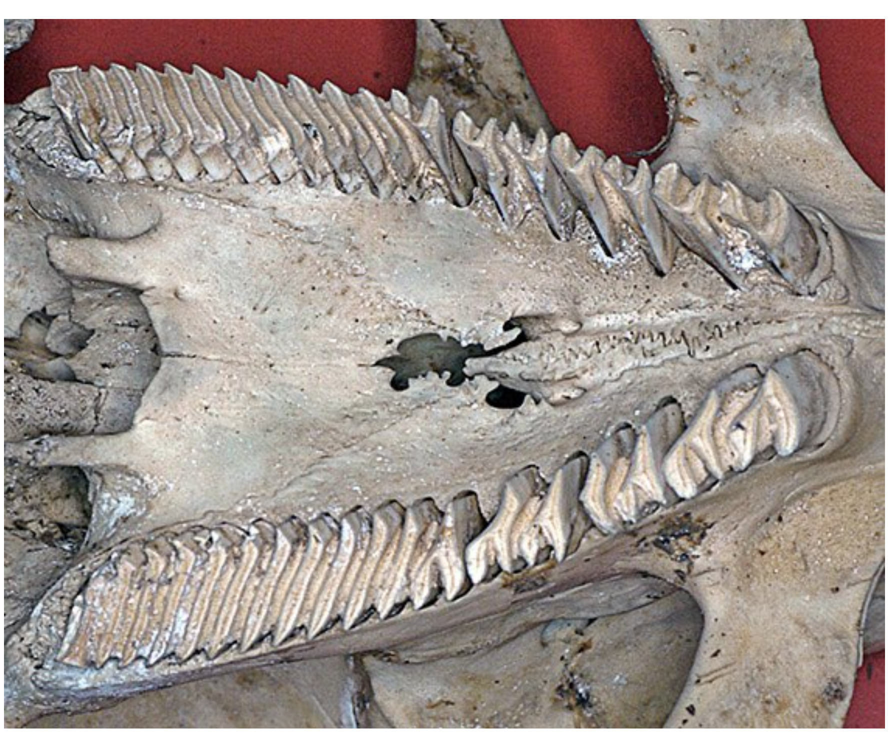


Figure 4-31 Agoutis:
- *rodent in anteroposterior functioning,*
- *herbivorous in posterior transverse functioning*
- *The posterior occlusal rails are not parallels, they have a marked diagonal orientation and can't function in balanced occlusion, with the rails engaged simultaneously on both sides (This could only happen if the teeth were worn flat, without rails and / or did not benefit from continuous growth, as are sometimes human teeth whose occlusal faces have progressively degraded and flattened).*

the domestic rabbit (lagomorph: rodent possessing 2 additional central incisors, in palatal position).

• Orpening and transverse shifting of the mandible towards the chewing side, in order to place this posterior sector in maximum unilateral intercuspation (Figure 4-30) and the contralateral sector in disclusion. From this position, chewing, guided by the transverse rails of the molars, becomes possible on this side, with a frontal sliding between the incisors. The transverse guidances, prohibit antero-posterior movements and contacts on the non-chewing side, because the rails on both sides are not parallel. In this situation, it is the anterior part of the condyle, shaped like a rounded "Chinese hat", which accompanies the transversal movement of the mastication cycles.

The model of the domestic rabbit illustrates in a very demonstrative way the adaptation of the anatomy and the articular movements to the functional kinematics imposed by the shape of the teeth. The condyle of the temporal is reduced to a simple transverse arch, in rounded circumflex accent, constituted by the transverse root of the zygomatic process. It thus responds, all along its length, to the rounded form of the mandibular condyle.

A different and adapted form of joint therefore corresponds to each of the two dental functions. During gnawing, it is the posterior portion of the narrow, sagittally elongated mandibular condyle that moves longitudinally in the uppermost part of the temporal condyle). During chewing, it is the anterior part of the broad, frontally developed condyle that moves transversely along the posterior portion of the temporal arch (in Le Gall and Lauret 2011 p 137-138).

Accelerated wear of functional tooth surfaces is compensated for by continuous teeth growth.

The agoutis is a similar rodent with double capacity:

- gnawing in the sagittal plane with anteposition of the mandibular incisors.
- while the posterior teeth have a unilateral mode of transverse chewing, herbivorous type. The simple observation of the occlusal surfaces clearly shows that the occlusal guide rails of mastication are not parallel between the two sides. Their diagonal orientation clearly indicates that they can't function in "balanced" occlusion with the rails engaged simultaneously on both sides (Figure 4- 31).

D- OMNIVORES AND THEIR EVOLUTION

Some species have diverged from the original model, others have more or less retained or improved the omnivorous features inherited from the ancestral model. We will limit ourselves to an example before addressing hominids

1- Non tribosphenic, warthogs (Figures 4-32, 4-33)

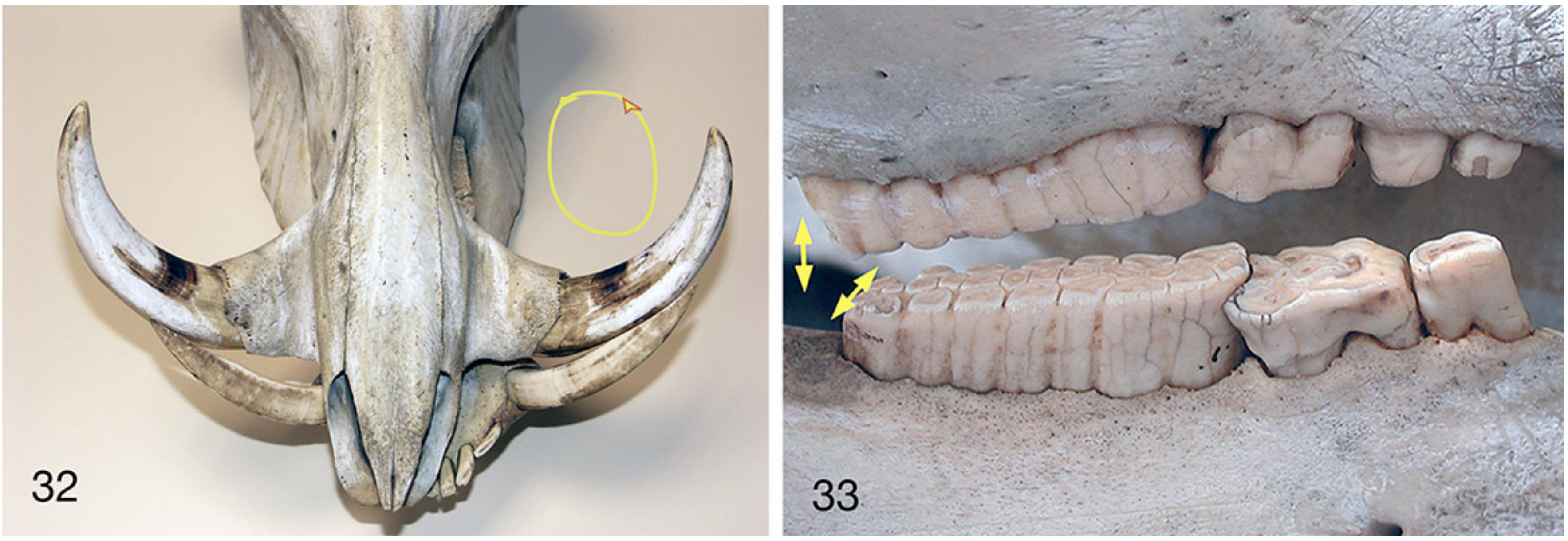


Figure 4-32: Male warthog. The warthog's mandibular canines are sharpened by functional sliding against the maxillary canines, prohibiting the mandibular recoil.
4-33: The occlusal surfaces, of continuous growth molars, are flat with differential wear between enamel and dentin. (Collection De Ramecourt, Le Gall)

a. Dental morphology and model specificities

The omnivorous warthog model is interesting. It does not have tribosphenic molars, but has occlusal tables of herbivore, which are flat, because without transversal guide rails, with two degrees of dento-articular freedom. In the absence of posterior canalization, the canines alone inevitably delimit the rear of the transverse functional field (retrusive limit), while achieving self-sharpening of the mandibular cusids. These last are sharpened and cutting like a razor, allowing them to defend in case of attack and the search for buried food. On the other hand, they do not play the role of retentive hooks, as in carnivores. They can defend, but not capture live and escaping preys. There is a marked dimorphism between males and females.

b. Joint Kinetics and specificities

There is no cranial articular cavity, the functional surface is totally flat and transversely elongated (Chapt.3, in Le Gall and Lauret(†) 2011). Their digestive tract allows the digestion of an omnivorous diet. This simple model, with flat occlusal faces, benefits from a good regeneration. It works in canine protection, but it is not the functioning model of hominids that is much more complex.

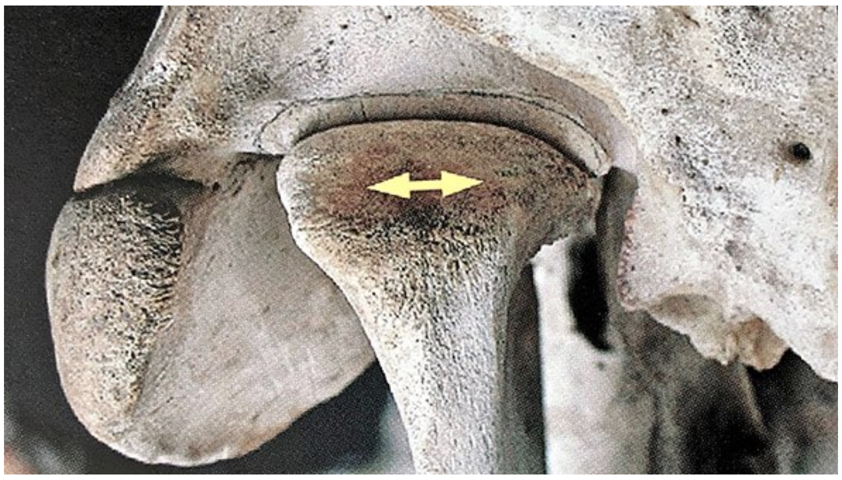


Figure 4-33b: The maxillary articular fossa is non-existent and the transverse articular surface is flat. All transverse guidance is provided by the maxillary canines. The mandibular canines slide against them during chewing, self-sharpening. They are used to search the soil for food and weapons of defence.

2- Tribosphenic:

a- Generality simians

Simians, and more particularly tribosphenic molar hominids, have retained the omnivorous capacity of the ancestral mammal of 65.5 million years. For more than 32 million years, they associate a toothing with 2 times 16 teeth to the presence of a prehensile hand able to seize,, prepare and place the food in the oral cavity.(Coppens, Picq et coll 2000,(1). This hand, capable of also providing defence and replacing the direct grasping of the food by the snout, is certainly a determining factor in its progressive disappearance, whereas the enlargement of the brain of the human line has changed the facial equilibrium. Hominids have the omnivorous capacity: the great apes and especially the man whose basicranium has adapted to the various functional demands of which it is the object (Picq and Lemire 2002): adaptation to vertical posture, walking, development of the skull, breathing, speech, communicative mimicry, but also in its nutritional mode. Men and chimpanzees eat meat, gorillas are more vegetarian, but eat meat if necessary. The share of meat in their diet is therefore very different and according on the resources of the ecosystem, men are a little more carnivorous than chimpanzees and much more than gorillas.

The highly variable importance of feeding meat in the nutritional repertoire of humans is part of their survival and expansion strategies, but not of chimpanzees and gorillas (Coppens et al 2000, Picq and Lemire2002). Their digestive system is capable of digesting meat and its glycogen, but not the bones, only digested by carnivores whose gastric pH is of the order of 1. Similarly, they digest fruits, plant foods and starch (with cooking for some) , but not cellulose, requiring the enzymes of a specific external flora installed early in the digestive tract, or the presence of a rumen dedicated to its degradation.

The dento-articular systems of hominids: gorillas, chimpanzees, bonobos, humans (phylogenetic systematics of Hennig.1966) derive from the same omnivorous common ancestor, living more than 7 million years ago, in the savannah of Africa (Picq and Lemire 2002). Since speciation, their parallel evolutions have been expressed by certain differences in their anatomical and functional characteristics..

We will study a system, comparing it to the human model (Figure 13 to 17 in Le Gall and Lauret(†) 2011).

b- **Tribosphenics: Gorilla** (Figures 4-34 to 4-39

-Joint Kinetics

The articular anatomy is quite close to the human anatomy with three degrees of freedom, but with a posterior process partially limiting the back of the functional field (Figure3-15a in Le Gall and Lauret 2011).

-Dental morphology and model specificities

The gorilla has arcades rectangular shaped, sagittally elongated. The muzzle is still present, it facilitates the olfaction and the direct grip of food.

The canines positioned in the corners, are located outside the arch. They have a reduced functional role in occlusion and dental kinematics, as in other apes and monkeys, they have a role of prehension, defence and intimidation. They're a very large size in polygamous male anthropoïds, with marked dimorphism (Figure 2-8) which decreases considerably in

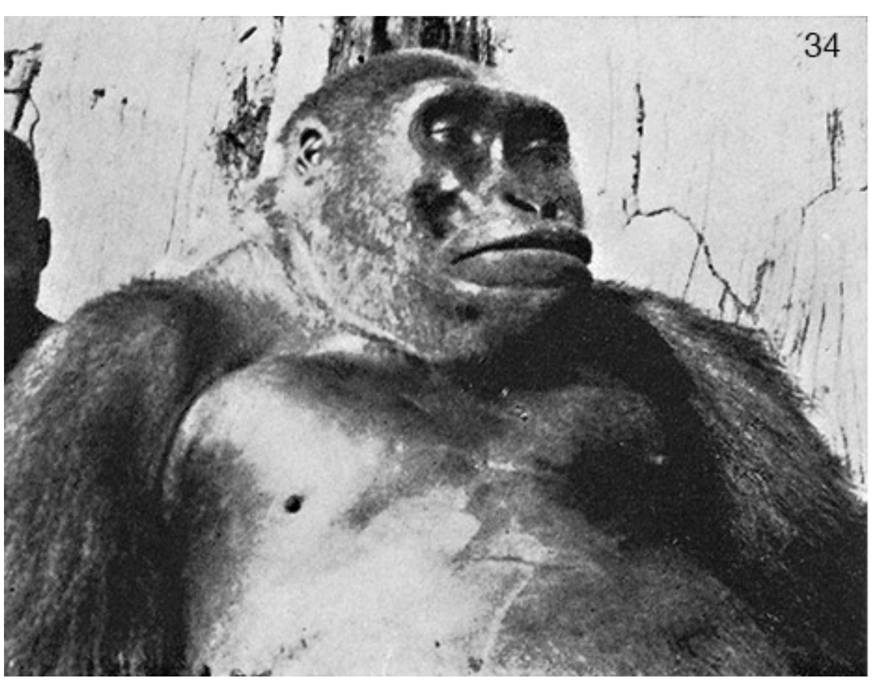


Figure 4-34: The photo and skull of this elderly gorilla, killed in 1930, come from the collection of hunting trophies by Gabriel De Ramecourt (1970). The estimated age of this specimen, by the natives, is a hundred years. In reality, it's probably less.

Figure 4-35: The maxillary arch is rectangular in shape. Functional abrasions of all teeth are very severe. The pulp chambers are open, with apical pathologies on many teeth.

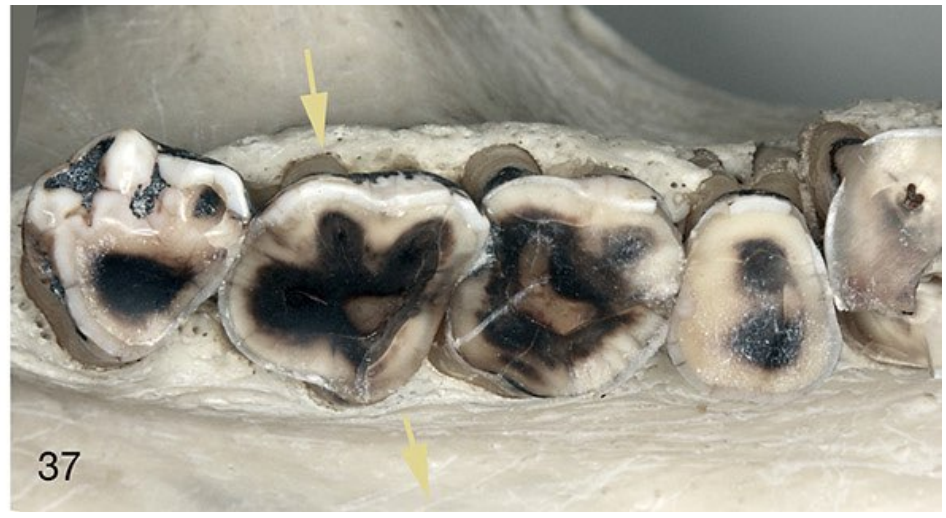
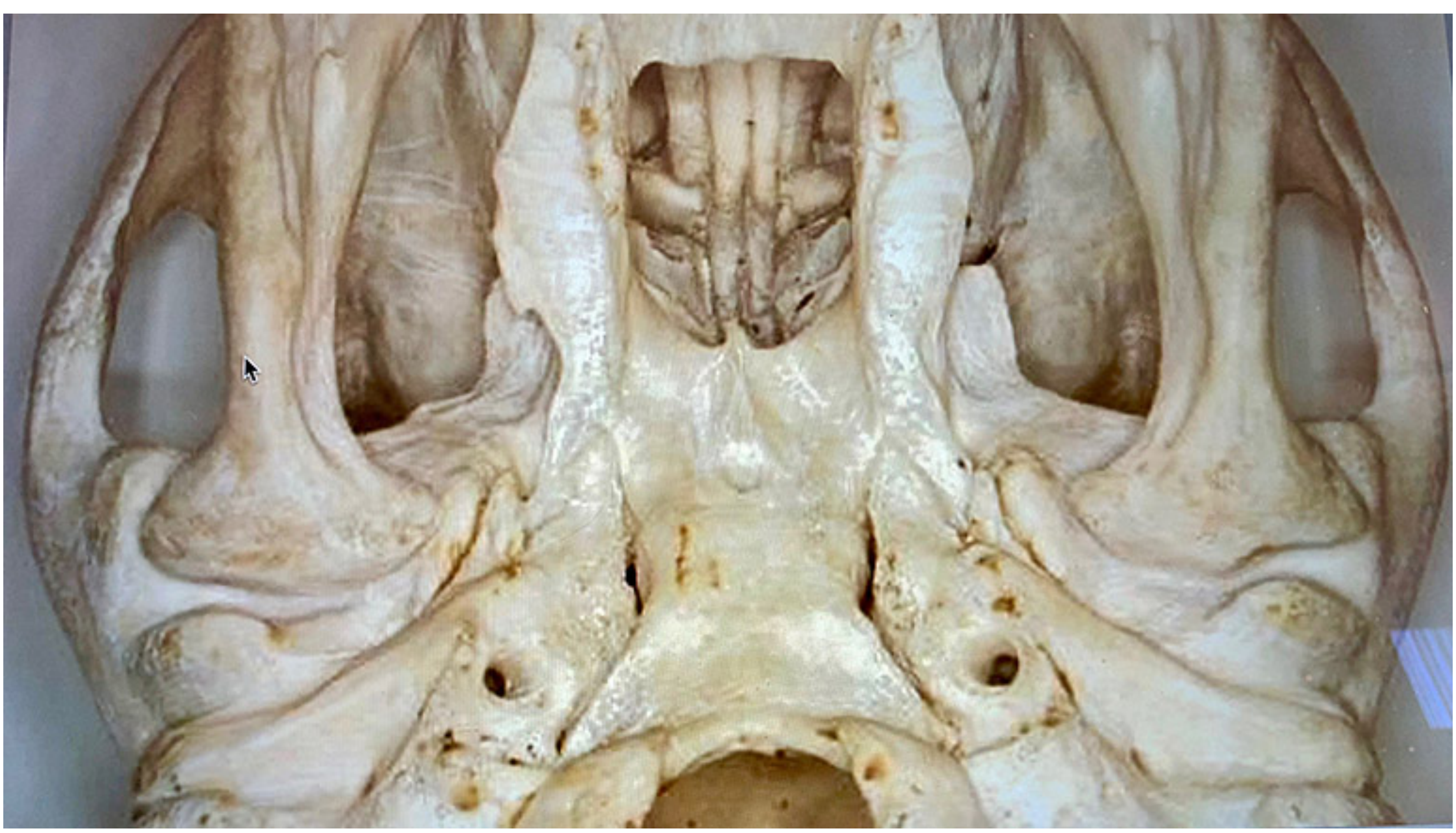


Figure 4-36: *The abraded posterior surfaces co-adapted well during the simulation of masticatory movements. They are resulting from a long use and are very similar to those encountered in the current human species, in some elderly subjects.*

Figure 4-37: *These attrition abrasions exhibit a smooth appearance, indicating direct contact wear and functional slippage between the antagonists .*

Figure 4-38 *The anterior incisor edges are not coadapted, they result from old fractures for the canines and the interposition of foreign bodies or hard food between the incisors.*

Figure 4-38b *The posterior part of the temporal fossae presents a posterior processus limiting the chewing cycle input. The totally worn dental guides no longer make it possible to protect the articular surfaces. There is a large bone lesion resulting from the direct contact between this processus and the back of the left condylar head.*



monogamous monkeys, with a very low dimorphism. Their size is the consequence of their associated role in sexual competition with other males (Tomes 1882, Coppens, Picq et al 2000 ; (2), Picq 2010).

Molars have a complex occlusal anatomy, slightly different from human anatomy. The very old male specimen of our collection, (Figure 4-34), shows an extremely important occlusal attrition, resulting from sliding occlusal contacts, with the antagonists. The dynamic relation of the posterior sectors, show a functional kinematics of human type, frontalised with a diagonal resultant whose tracks wear and show the orientation (Figures 4-35 to 4-37). This is probablyproof that, this forest specimen, is not limited to the consumption of fruits, which is minimally abrasive, but has also eaten a lot of herbaceous and / or very abrasive leaves.

The abrasions of the anterior sector, have not found any explanation, by direct dental wear, because the facets do not coadapt (Figure 38). Their convex and smooth appearance suggests the interposition of abrasive and hard vegetable foods. Or, like the very old fractures of the mandibular canines, they probably result from fights, followed by secondary wear.

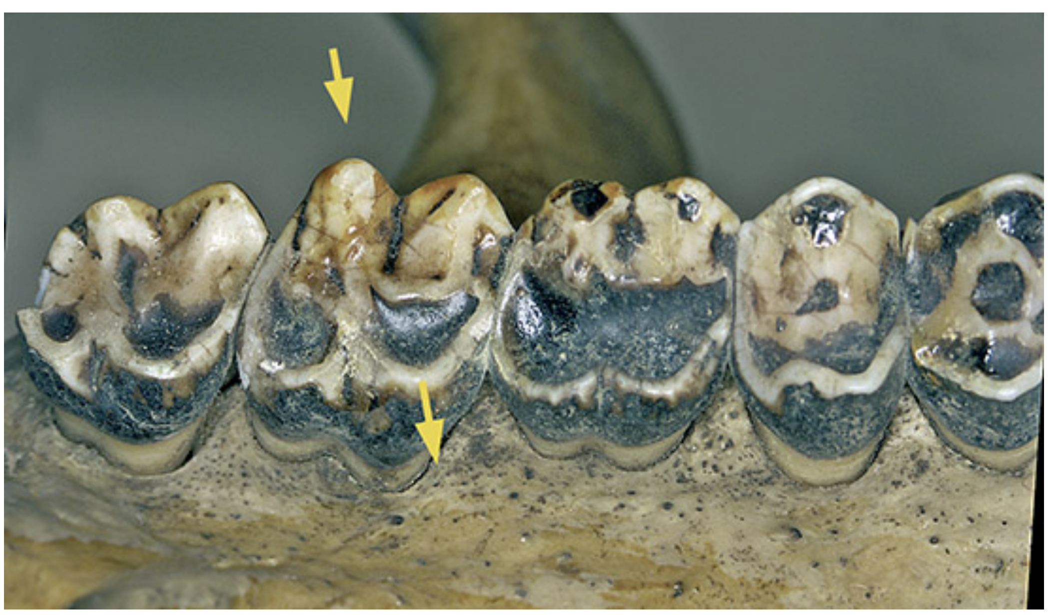


Figure 4-39 *Dental inputs and outputs of the right chewing cycles in another older gorilla. On the maxillary cusps, the internal slopes of cycle inputs, show a significant attrition on M1, P1 and P2, while the palatal output of M1, have a lacunar and concave appearance resulting from a strong biocorrosion, having followed a prior attrition. This type of erosion is also present on cycle outputs of M2, M3 and P2, P1.*

We have a second gorilla skull whose shape is significantly different from the previous one. It has large male canines and a female skull shape. Maybe it belongs to a different specie. The observation of the teeth, shows transversal guidances close to the human type, with a moderate attrition of the cycle input slopes and a particularly important biocorrosion, on the crushing tables, of cycle output (Figure 39). The loss of dentin volume, in concave areas without enamel, can only result from the action of the chemical components of the diet: fruits and other foods containing citric acid or others. This shows that even a frugivorous diet is able to degrade dentinal surfaces by attack of natural acids. In addition, these 2 gorillas have infectious pathologies similar to humans: several cysts for the first, a fistula chin for the second.

The skull of a baboon cercopithecid, a little further away from the human line, shows moderate to severe attrition in the posterior maxilla and almost total destruction of the occlusal anatomy of the mandibular M_1 and M_2, first by attrition, followed by a very large biocorrosion on exposed dentin. (Figures 4-40 to 4-44).

Figure 4-40: Cercopitecid, Baboon. The maxillary cuspids are in symmetrical support on the root of the P1, partially denuded. See Fig 25, 26

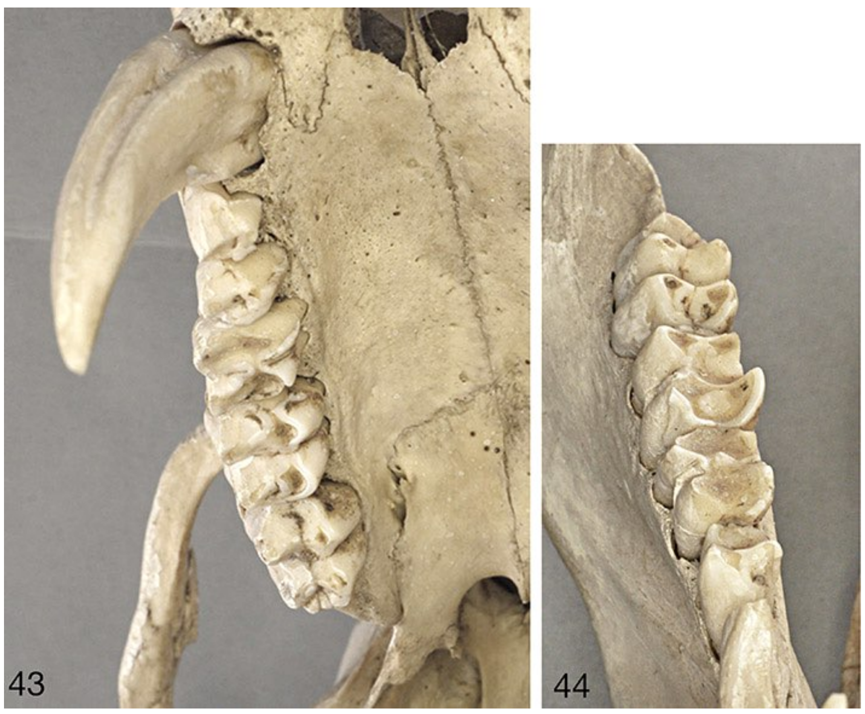
Apart from the domestic rabbit, all the functional models presented above come from animals living in the wild, under much more difficult natural conditions than those reported by Amico, on great park apes, whose diet is much less aggressive than in the wild. (washed and often cooked foods). This is probably why they show much less occlusal damage than in wilderness. The three cases of documented simians clearly show that attrition and significant biocorrosion always occur with the monkeys and current apes, still living in their natural environment. Their frugivorous diet, more or less carnivorous, but certainly partly herbivorous or folivorous, is

Figure 4-41: right maxilla *Figure 4-42: right mandible*

Figure 41, 42: The prior attrition of the enamel was followed by a very significant biocorrosion of the exposed dentin of the mandibular M1 and M2 and the maxillary M1. Only the M3 couples still benefit from balanced functional guidance, which is easily found by manipulation.

responsible for it. (as described in d'Amico's chapter on their nutrition, N°.1, 1958, p.15). They certainly have the omnivorous ability they use depending on the resources of the ecosystem, in nature and in captivity. The observation of the attrition and bio-corrosion of these wild specimens indicates that it is similar to that observed in primitive human lineages and is not so "extraordinary" as Amico's claim for men, but it is the consequence of the complex, non-regenerating morphology of these tribosphenic teeth, associated with an aggressive diet and aging.

Figure 4-43, 4-44: Attrition of M1 M2 P2, followed by a particularly important biocorrosion



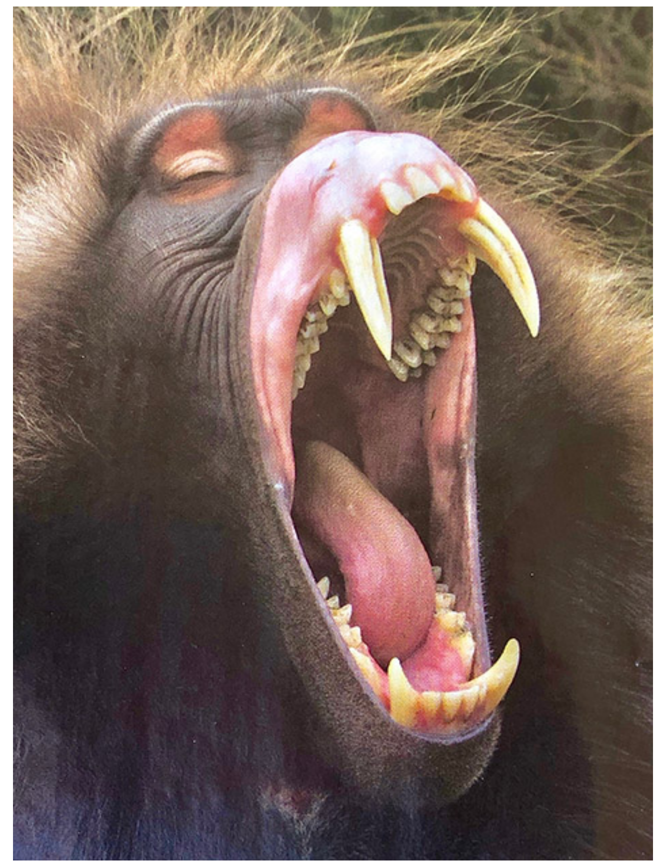


Figure 4-44b:
Young male, Theropithecus gelada, with its dental integrity, Model close to the baboon , with mandibular P1 tilted distally

E- GENERAL ANALYSIS OF THE FUNCTIONING MODELS

All highly specialized mammals benefit from maximum functional efficiency within the limits of their functioning model and their ecosystem, which they generally can't leave.

Their model is perfectly identifiable and most often regenerating. It works in a well-regulated and efficient way, retaining its initial characteristics, but in a limited food register.

Hominids and humans also have a functioning model. It is easily identifiable in young adults, whose occlusal anatomy is intact, and it works in unilateral mastication, usually alternating, without contact on the non-chewing side. This is a very clear point of agreement with d'Amico (D'Amico1958 N°6 P199). But it is a non-regenerating model and it's occlusal anatomy is progressively deteriorated through wear and biocorrosion. It gradually loses its initial characteristics and a significant part of its effectiveness. Under these conditions, there are often contacts on the non-chewing side of elderly patients but this custom adaptive mode of operation has little in common with the initial natural model and its optimal efficiency.

This may be a disadvantage of general omnivorous models with tribosphenic teeth whose occlusal surfaces are too complex and can not regenerate properly in a simple way, and lose, progressively by wear, their characteristics and their functional effectiveness. While specialized models keep it by continuous growth, or replacement of teeth. The question is valid. But the answer is already given by the articles dealing with the resolution of edge-to-edge bites, among Australian aborigines (D'Amico1958 N°4 et N°5). Children raised in their ancestral environment with an extremely abrasive diet, even after cooking, present a very rapid attrition of their occlusal surfaces and put themselves very precocely in edge-to-edge bite. While those raised with western food thoroughly cleaned of external abrasive particles due to improved cooking methods and softer vegetable foods and therefore reduced molar occlusal wear and keep incisal overbite. The edge-to-edge demonstration is also valid for molar chewing guidances that retain their functional anatomy much longer today. The context has further evolved, as the bonding techniques, non-mutilating and reliable, now allow the easy restoration of lost functional volumes.

From the historical characteristics of the natural model of swallowing and chewing of the human line, we will thus make an updated point of these characteristics and the functional kinetics of this model, observed on current young adults. This is an essential prerequisite likely to give precise indications on how to make the diagnosis and on the therapeutic objectives to be attained, according to the situation and the importance of the functional volumes to be rebuilt.

CHARACTERISTICS OF THE CURRENT MAN

Chapter 5

A- INTER-MAXILLARY RELATIONSHIP

Teeth and joints support mandibular relationships, with the craniofacial complex. The growth of the masticatory apparatus is progressively realized by an interaction between the genetic determinants and the main functional stimulations of the swallowing first, then of the mastication.

Where and how to locate, clinically, the Maximum Intercuspation Occlusion (MIO), which is the natural swallowing position, around which chewing will be organized ? This choice must be made in accordance with the physiology of the lower stage of the face and the masticatory apparatus. Which has not always been the case.

After the introduction of the Centric Relation (CR), in the 1930s (Mc Collum 1939), began a mechanistic era with the definition of a joint hinge axis and the design of more and more complex mechanical articulators that followed. These articulators were supposed to be faithful reproducers of occlusal relationships and articular and mandibular kinetics, from Centric Relation.(Figures 3-17 to 3-19). A part of the terminology and the texts of this period now seems obsolete and baroque, as in the case of the Centric Relation:

"*The centric relation reflex*" which would be controlled by muscle receptors and periodontal mechano-receptors, "*the anteroposterior limits of centric relation*". which would be first defined by the temporary incisors (D'Amico 1958 N ° 6 p199), or incomplete demonstrations in their formulation and/or unfounded, such as the following:

"One cannot disagree with Moyer's explanation of neuromuscular reflexes nor can we disagree with his deductions as to how centric relation of the mandible, was first established". (D'Amico 1958 /Moyers,1955.p199)

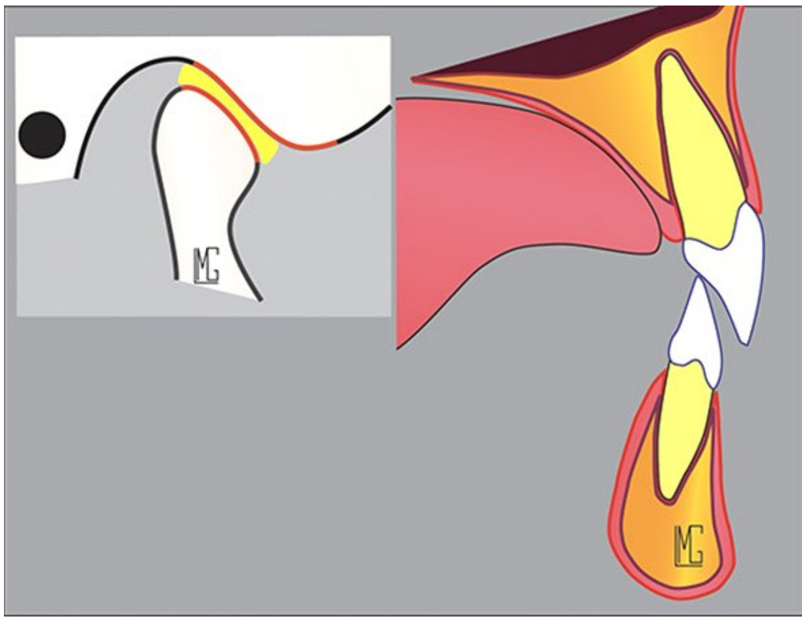


Figure 5-45 *Figure 5-46*

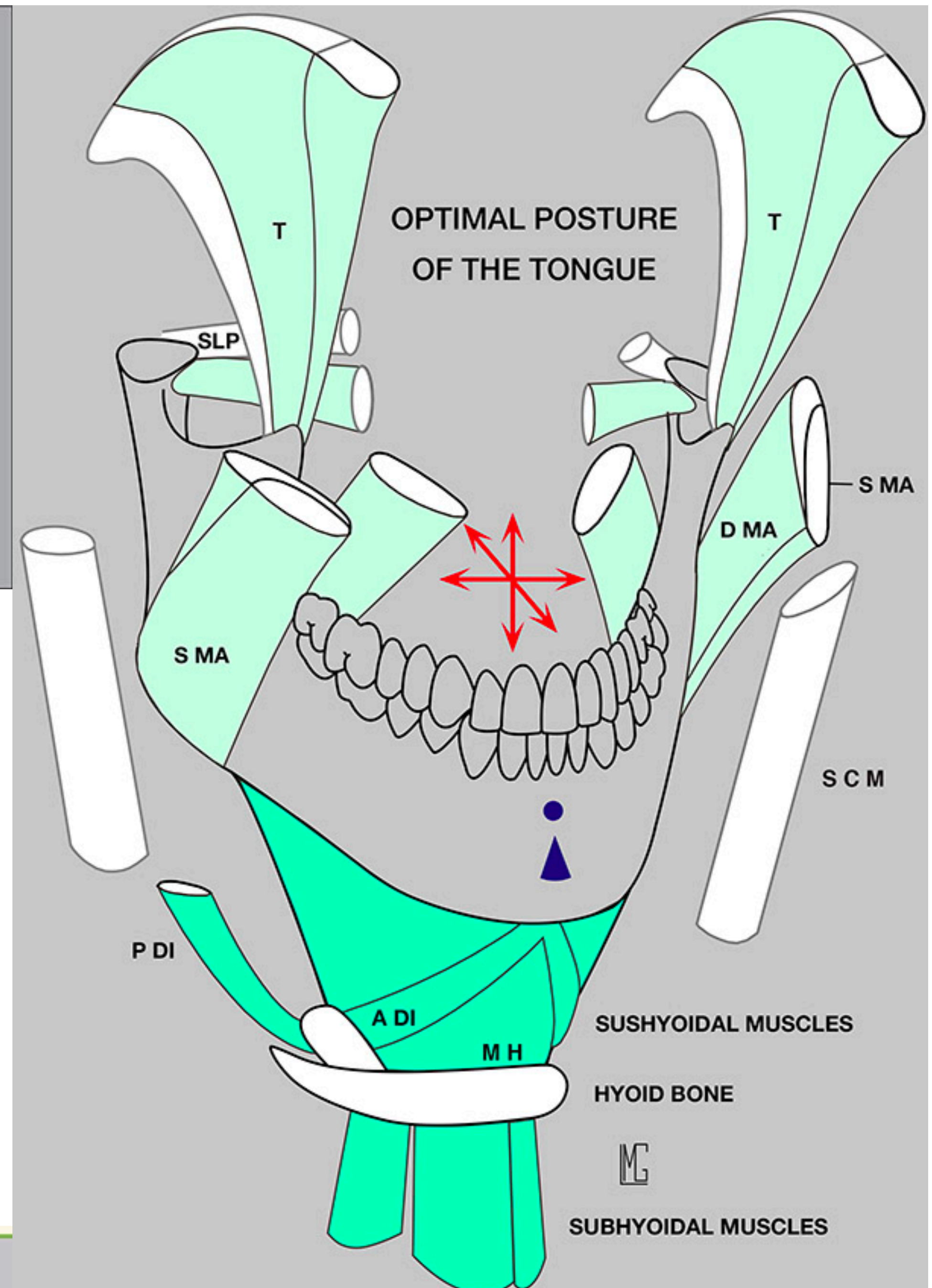


Figure 5-45,5-46 : Lingual posture: Diagrams illustrating the influence of the good lingual posture, (high, centered in anterior support, behind the maxillary medial papilla) on the optimal position of the muscles of the oropharynx, the elevator muscles and then the mandible before swallowing

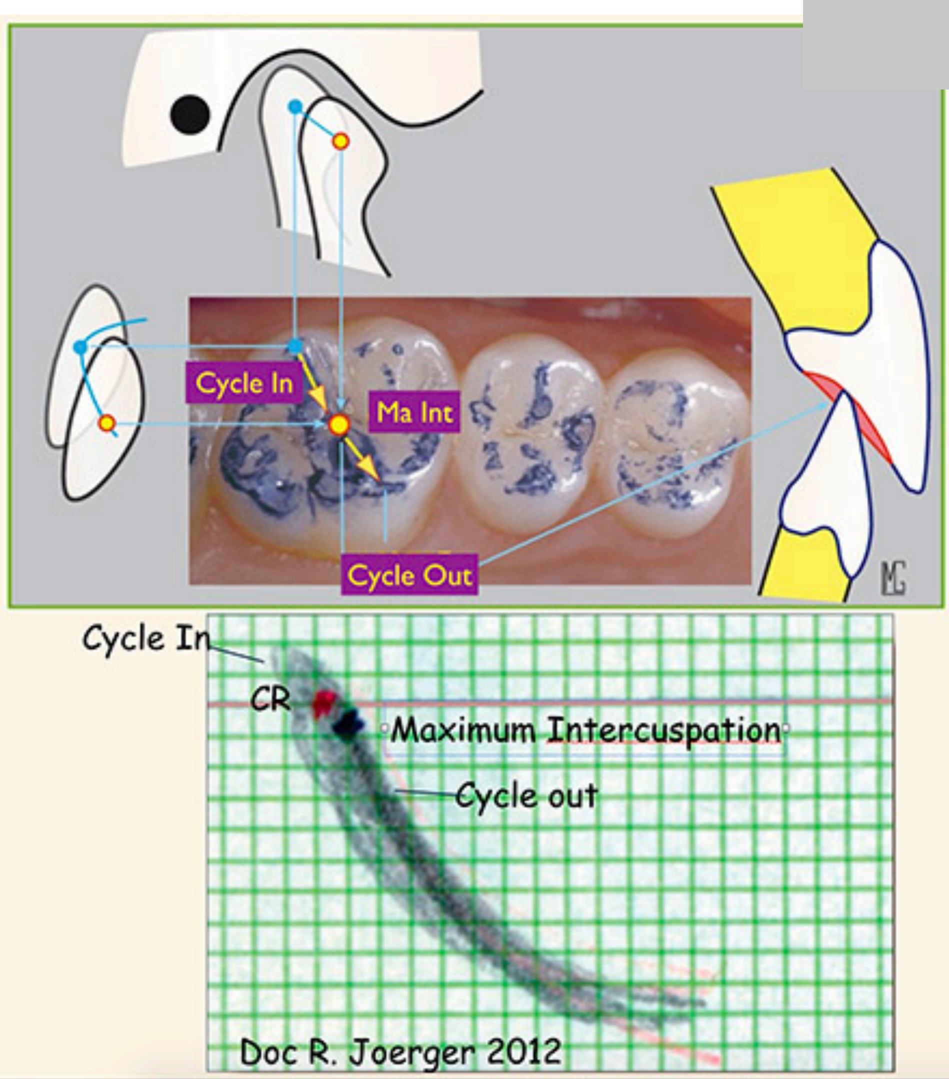


Figure 5-47: Chewing axiography. The recording of the cycles clearly indicates that the cycle input kinetics, needs a functional clearance behind the swallowing MIO. During cycle-in, the mandible comes from a lateral and posterior position. It slides forward and diagonally, towards the MIO, gradually approaching the maxillary posterior occlusal faces. This movement is carried out in a limiting guide envelope, necessary for chewing, which is located behind the MIO and must be respected. This is not the case for the various CR concepts proposed, which are all located within this limit envelope, and reduce it's amplitude, more or less, depending on the manipulation force. While the natural occlusion during swallowing is anterior and respects this posterior functional envelope.

However, the position of the tongue, and swallowing, which are the major initial determinants of mandibular posture and Inter-Maxillary Relationship, are totally absent from this reflection (Figures 5-45, 5-46). While they should have been used as a basis for the definition of the reference position, first associating the role of proprioceptive afferents of the articular region, then the periodontal afferents which will progressively complete them, during the gradual emergence of teeth and the finalization of the TMJ shape. The conformation of the joints results therefore from the complementary influences of the posture of swallowing and the kinetics of mastication, imposed by the teeth, within the framework of the genetic determinants..

Later, in Maximum Intercuspation (M.I.) and during mastication, these same mechanoreceptors will allow the cycles to describe their optimal limit envelope, or will be able to trigger avoidance mechanisms in case of excess or insufficiency of the molar guidance (Anderson et al. 1970,Johnsen and Trulsson. 2003a p1486). In order to:

- protect joint surfaces, which are unable to withstand the stresses,
- and avoid dental fractures in the presence of foreign bodies of the food bolus.

Cervicofacial morphogenesis is complex, and the anatomy of the temporal and mandibular articular surfaces will differentiate until adulthood. The growth of TMJ is influenced from birth by maxillofacial and cervical growth, and particularly by the functional muscle interactions of the oral cavity. The first to settle, depend on breathing and especially swallowing. At birth, deglutition, already established in utero, immediately assumes its role in the nutritional

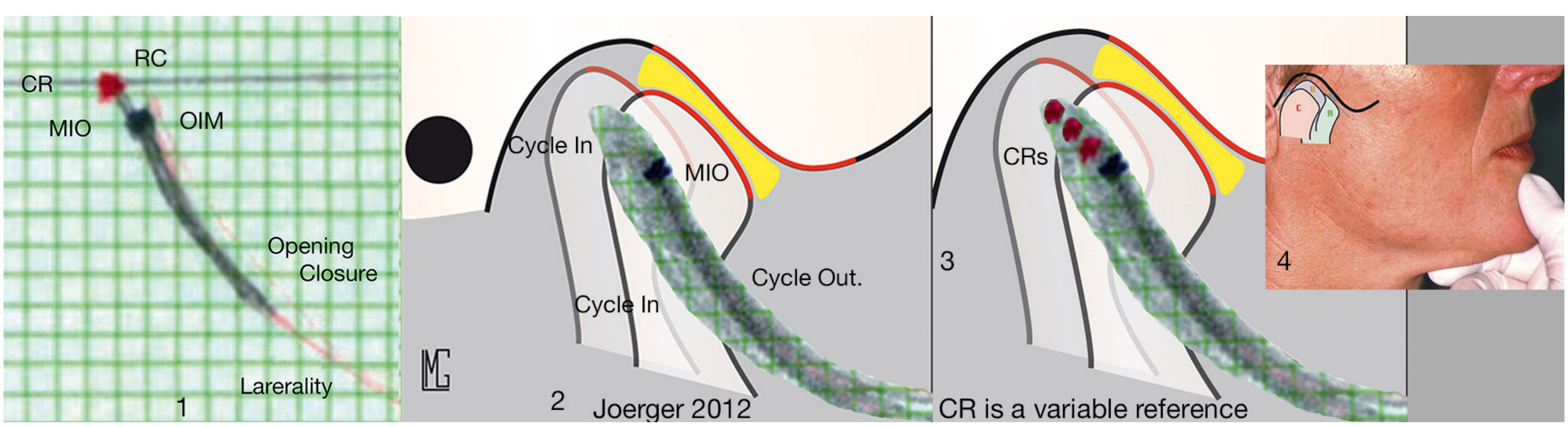


Figure 5-47b 1- Sagittal axiography in opening-closing with a non forced manipulation for CR. The paths are simple and clear. The recording of masticatory cycles of the same patient is superimposed on the opening-closing path. Cycle input transverse guidance informations appear behind the MIO (Swallowing) -2,3- Swallowing is a stable reference already existing at birth. The CRs are located in the posterior functional envelope of cycle input, which it reduces more or less according to the concept and the manipulating force applied. The different Rcs are not a reliable and constant reference.

function, initially limited to sucking. The tongue is then in a low position and interposed between the arcades during swallowing.

As "*Only the postural* (rest) *position is consistently observed prior to the eruption of the teeth"*(Moyers 1955 quoted by D'Amico- 1958 N°6 p198). This position of the tongue allows the mandible to be stabilized during swallowing. "*The postural* (rest) *position is easily recorded in the neonate (newborn), but repeated efforts to locate centric relation met with failure until the âge at which the primary occlusion was established."* (D'Amico- 1958 N°6 p198).

Later, the tip of the tongue will come into contact with the palate and the support of the mandible, during swallowing, will be on the posterior teeth. Its high daily frequency (more than 1000 times a day) and "the constantly repeated functional stimulations that it causes, among others at the joint level, allow the progressive installation, during growth, of a direct anatomical correlation between Maximal Intercuspation and articular position of swallowing "(Le Gall et al., 2010).

"Centric relation is established during the early stages of the primary dentition… At the beginning, centric relation and centric occlusion are identical" (Moyers-1955,D'Amico- 1958 N°6 p198).

In the early years of life CR and Maximum Intercuspation are thus confused with swallowing posture. Later, in about 98% of adults (Posselt 1968, Joerger 2005) the CR will be posterior to the maximum intercuspation .

However, on the axiographic recordings of adult mastication, it appears important information, of cycle input guidances, behind the maximum intercuspation (Fig 5-47-2, Joerger 2012). One can thus reasonably assume that the differentiation between the position of swallowing occlusion, and that of CR would have settled during the progressive establishment of the chewing, first on the lacteal teeth, and later on the permanent ones. In other words, this means that the centric relation(s) would be an invented manipulated position, whose definition and situation have been modified several times, located behind the M.I., somewhere in the boundary envelope of guidance needed for cycle input. The reference position since birth remains the physiological resting posture that leads the mandible to a support position, stable and balanced during swallowing. This is the functional definition of maximum intercuspation.

At first the joints develop in the orientation of the function, which is essentially sagittal and reaches its adult anterior-posterior dimension towards 5 years. At the end of the emergence of the lacteal teeth, the articular eminence reaches more or less 45% of its end-of-growth value (Katsavrias 2002). In a second step, with the installation of primary mastication, and especially adult mastication on the first molars, the transverse dimension of the glenoid fossa will be multiplied by 2.5 between 5-6 years and adulthood (Nickel 1988). The conformation of the glenoid cavity is finalized under these conditions. The role and position of the tongue are essential for a physiological swallowing (Fontenelle et Woda in Chateau 1993; Bonnet 1992, 1993, 2010 ; Fournier in Chauvois et coll.1991).

If the initial cranial growth, lingual posture and swallowing are physiological, first molar couples are usually positioned in class 1 occlusion (Deffez M.J. 2010) **and bear the swallowing in neuromuscular balance.** The articular head is then in a balanced position, around which the anatomy of the temporal fossa will gradually grow and find its adult equilibrium, depending on the functional demands, of which it is the object. **Since birth, the joint relationship and later the occlusal wedging in maximum intercuspation are directly related to the swallowing position** ,and not to mechanistic concepts imagined on the first tomographies of TMJ and mechanical articulators

The axiographic records of chewing cycles (Joerger: 2005, 2012 Figure 5-47) show clearly that chewing is organized around the teeth stalling position, during swallowing. They also show that the cycle input kinetics, on chewing side, is realized behind the maximum intercuspation. The first part of the cycle needs a posterior functional play to express itself. At the first cycle input contact, the mandible comes from a lateral and posterior position and slides forward and diagonally towards Maximum Intercuspation, on the first part of the rail that then passes through the maxillary M_1 enamel bridge. The kinetics of the cycle entry, with interposed food, is realized within this limit guiding envelope, posterior to M.I. which must be respected. This is not the case of the different concepts of C.R. proposed, which have all been located within this envelope and which reduce more or less it's amplitude depending on their position, more or less posterior, which depends on the manipulative force and the operator. Whereas the natural occlusion of swallowing, more anterior, respects this functional envelope. After a slight inflection on the enamel bridge, the diagonal kinetics continues, following the second part of the rail located on the exit tables of cycles, slightly forward from M.I.

The role and position of the tongue are crucial. **Indeed, in children, atypical or inaccurate lingual postures are consistently associated with dysmorphosis** (Deffez et al., 1995). Lingual position and volume disorders, dyskinesias, therefore have a direct impact on growth, and on the shape of the jaws. There is a risk of reduced development (transverse, postero-anterior, vertical…), and the positioning of teeth, and occlusal relationships in situations that will not allow optimal swallowing and chewing, by a bad pairing of occlusal relationship (class 2, Class 3, open-bite, etc ...). These situations, often result in vertical cycles, or a partially truncating of their envelope and optimal efficiency, by incoordination of the guidance of the posterior teeth.

In Orthodontics, Functional Schools, (Bonnet 1992, 1993, 2010, Deshayes 2010 etc.) and techniques of re-education of oral functions (Fournier in Chauvois and Col. 1991, Deffez et al., 1995) insist, during the treatment of atypical deglutition in the child, on methods of early symmetrization (Deshayes 2010) and lingual repositioning, to prevent pathological consequences by a precocious reorientation of growth.

Swallowing in Maximum Intercuspation: protocol and equilibration

The occlusal contacts obtained during swallowing therefore give the natural position of Maximum Intercuspation (Figure 5-45 to 5-47).

How to find this position in clinical practice and be sure of its optimal location?

There are instrumental methods using techniques of bio-feedback, muscular relaxtion, axiogaphy, to assist for example: the current version of Myo-Monitor® (kinesiograph, Jankelson 1972 etc…). However, tedious and unreliable clinical protocols, risks of errors during their implementation, as well as the cost, and rapid ageing of technologies and hardware, still make their use in clinical practice unrealistic.

A simple, fast, reliable and repetitive clinical protocol for checking and/or finding the concordance between the maximum intercuspation, and natural swallowing, has been described. (Le Gall et al. 2010 Figure 5-48). How to find clinically the swallowing posture of the mandible and how to coordinate it with Maximum Intercuspation? A clinical protocol is proposed below. In the absence of general postural interference, the simultaneous combination of two protocols already used separately, puts the mandible in swallowing conditions and gives its optimal posture, which allows to find and balance, Maximum Intercuspation accorded with swallowing, so self-determined and repetitive (Gall et Coll 2010):

It proposes the combination of two techniques already used independently, which allow the patient to find alone and with precision his/her natural position of swallowing and to coordinate it with the Maximum Intercuspation (Figure 5-48):

- ...*“**wearing a few minutes a modified anterior jig,** interposed between maxillary and mandibular incisors, with a single medial contact point, which is already used to search for a balanced intermaxillary relationship“* (Lucia 1964, Le Guern 1987). “*...but whose palatal face has been made neutral, to have no action of anteroposterior and transverse displacement of the mandible“* (Le Gall et Coll 2010).

- *"Associated with the optimal positioning of the tip of the tongue against the anterior part of the palate, as it exists during swallowing and is used for the rehabilitation of the lingual posture"* (Le Gall et Coll 2010, Le Gall and Lauret 2011, Le Gall 2013).

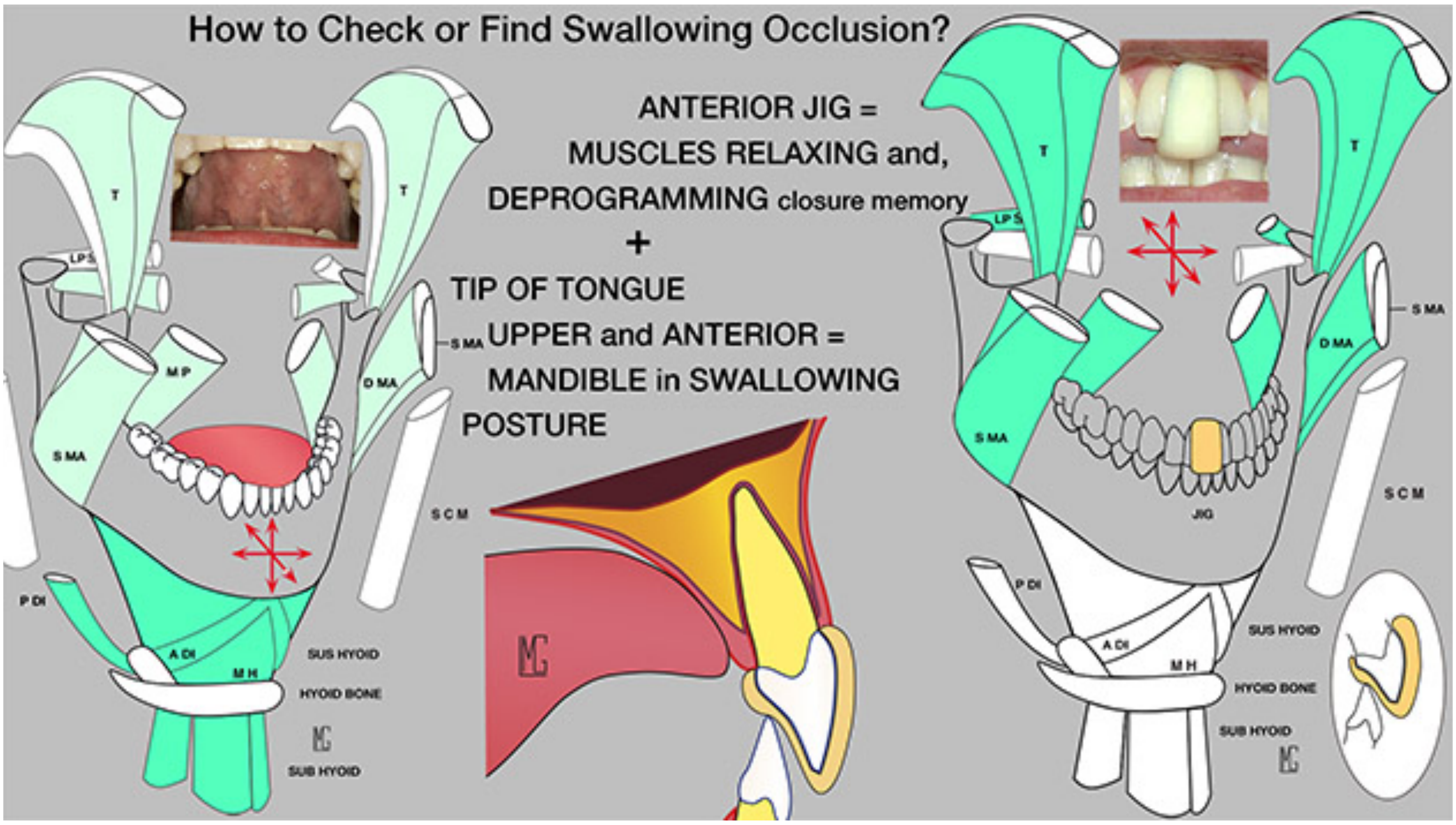


Figure 5-48: How to find clinically the swallowing posture of the mandible and how to coordinate it with Maximum Intercuspation? A clinical protocol is proposed above. In the absence of general postural interference, the simultaneous combination of two protocols already used separately, puts the mandible in swallowing conditions and gives its optimal posture, which allows to find and balance, Maximum Intercuspation accorded with swallowing, so self-determined by the patient and repetitive (Le Gall et Coll 2010):
- the wearing of an anterior jig, which allows the relaxation of the elevator muscles and the deprogammation of the closure memory of the mandible (Le Guern 1987),
- maintaining the tip of the tongue in a upper and anterior position which puts the mandible in the swallowing position (used in tongue and swallowing rehabilitation).

The jig has a relaxing action on the elevator muscles, and deprograms, in a few minutes, the adaptative engrams that may exist in the presence of malocclusions, while at the same time the posture of the tongue puts the mandible in a swallowing position. **Under these conditions the closure gives the balanced position of swallowing, repetitively.**

Clinical protocols are available in the referred articles and/or from the website: *www.mastication-ppp.net* or directly on the following YouTube clinical videos: *https://youtu.be/E6e5sFx_GGc* *https://youtu.be/85slx25-mCw*

B- MORPHOLOGY AND KINETICS OF TEETH AND TMJ

The work of Lundeen and Gibbs on the Replicator (1982) constitutes a breakthrough and a fundamental contribution allowing the observation and the recording of the mandible during functional movements of chewing and incision. They were followed by the introduction of electrognathography by Lewin in 1985 which made it possible to objectify, in a simpler way, the functional movements of mastication and allowed complimentary studies. Like those of Mongini et al 1985, Pröschel 1987 on classification and interprétation of cycles, Nishio et al 1988, Lauret and Le Gall from1994 to 2016. Le Gall and Lauret have shown the clinical difference between a laterality movement and a centripetal chewing cycle (Figure 5C-1 to 5, 5D-2, 5D-3 Le Gall and Lauret 1994) and the impact of dental guidance on the shape of a cycle, which can be modified by optimizing, by addition, the occlusal anatomy and guidance of the posterior teeth (Figure 7-1)

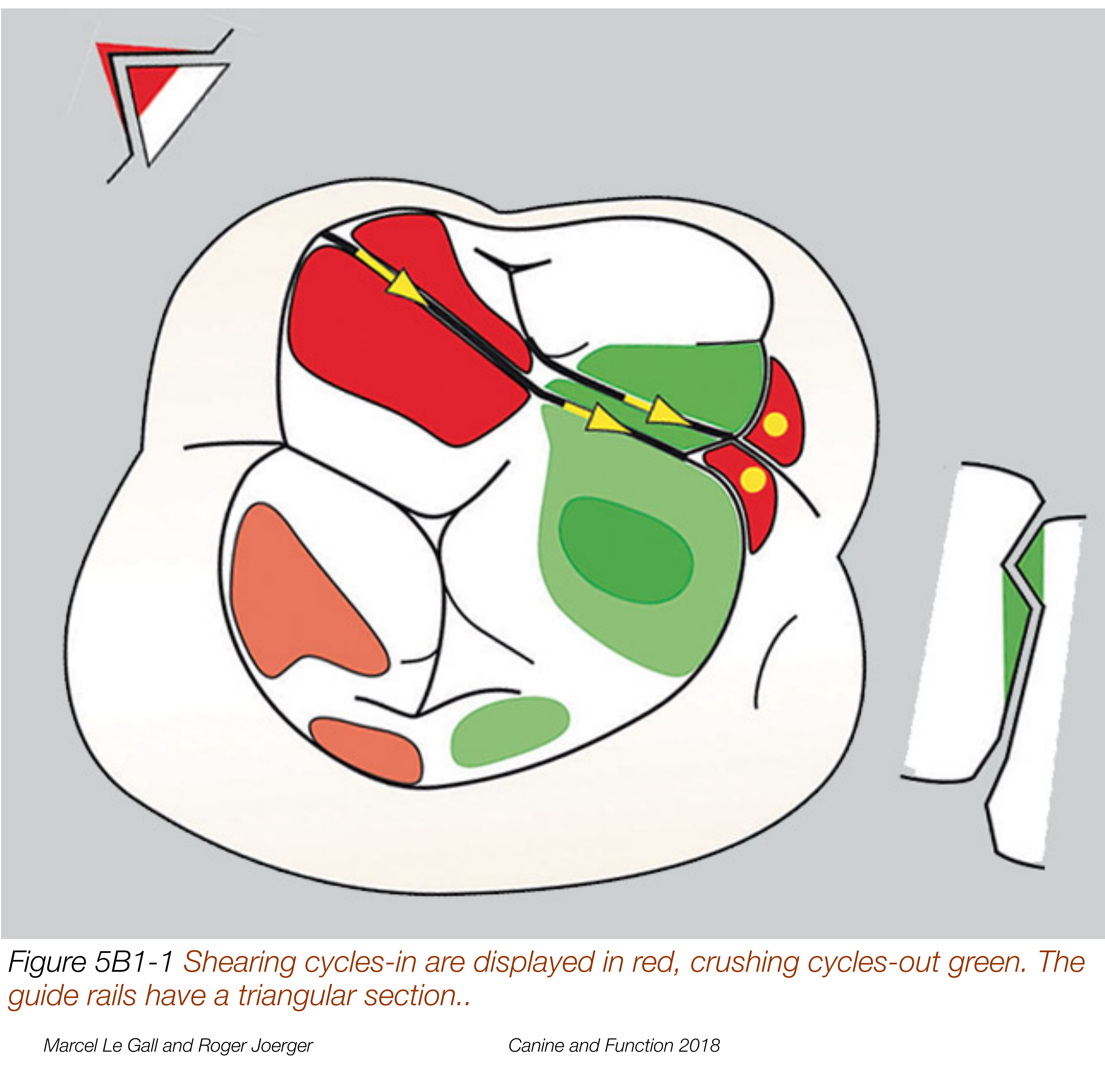


Figure 5B1-1 Shearing cycles-in are displayed in red, crushing cycles-out green. The guide rails have a triangular section..

(Le Gall and Lauret 1998). They also described chewing guide rails on the occlusal faces of couples of M_1 (Le Gall and Lauret 2011 and their anatomical kinship with those observed in the human lineage, since more than 32 My. (Figures: 5B3-3A, 5E-1 to 5F-4 or see website www.mastication-ppp.net).

The tooth-joint apparatus of the man has 3 degrees of freedom, allowing opening, closing, anteroposterior and transverse movements. The arcades of the current man are rounded with complex cuspidary molars, and therefore, to adapt to the chewing of all types of foods, under the management of a cerebral center that determines the muscular action. The good coadaptations of the articular surfaces, during the multiple movements realized in human kinematics, is ensured by the interposition of a complex capsulo-discal apparatus.

1. Set Up of Adult Occlusal Scheme

Figure 5B1-2A: *The occlusal relationship couple 1st molar in Class I, allows a balanced occlusal wedging capable of supporting alone the vertical dimension and balanced chewing function.* Fig. 2B: *Progressively bicuspids are integrated at the first molars functional envelope, Followed by second molar* Fig. 2C: *Lately cuspid is incorporated at the functional envelope still in place. It had Not any role in the set-up of occlusion.*

The occlusal anatomy of the first molars, their optimal class 1 relationships and the fact that the dento-alveolar axis of inertia passes through the first pair of molars in the frontal plane (Treil and Casteigt 2000), help to understand why these teeth play a fundamental role in the development of the occlusion pattern in adults and in the ability of the child to bear alone for several years, swallowing contact in the MIO and balanced chewing, without any pathology.

The emergence, and occlusal relationship of couple first molar , at six years, marks the set up of adult occlusal pattern and chewing function. (Lundeen et Gibbs, 1982). Adjacent teeth progressively emerge on the arcades during several years and then integrate gradually, the functional scheme of the first molars, including canines whose appearance is often later than the second molars. The adult functional diagram is already fully developed and balanced when cuspids integrate with the existing chewing envelope. These finding strongly suggest that they

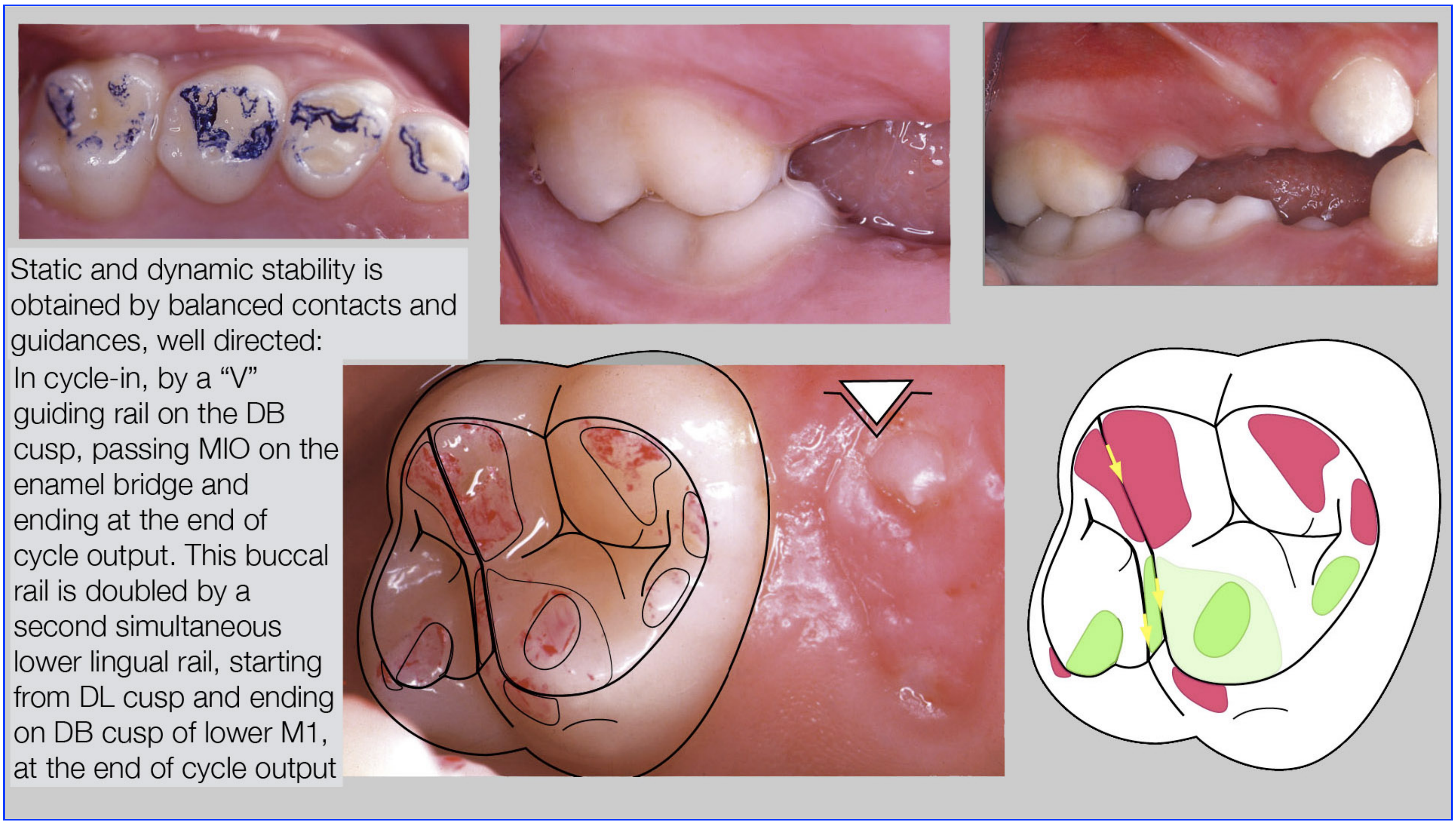


Figure 5B1-3: *In the input cycle, there is a main rail running from the maxillary cusp DB that works optimally in class I. It is balanced by a mandibular rail that starts from the mandibular cusp DL. After passing through the enamel bridge, the cycle exit tables, constitute a 3-slope accordion rail, more directive and efficient.*

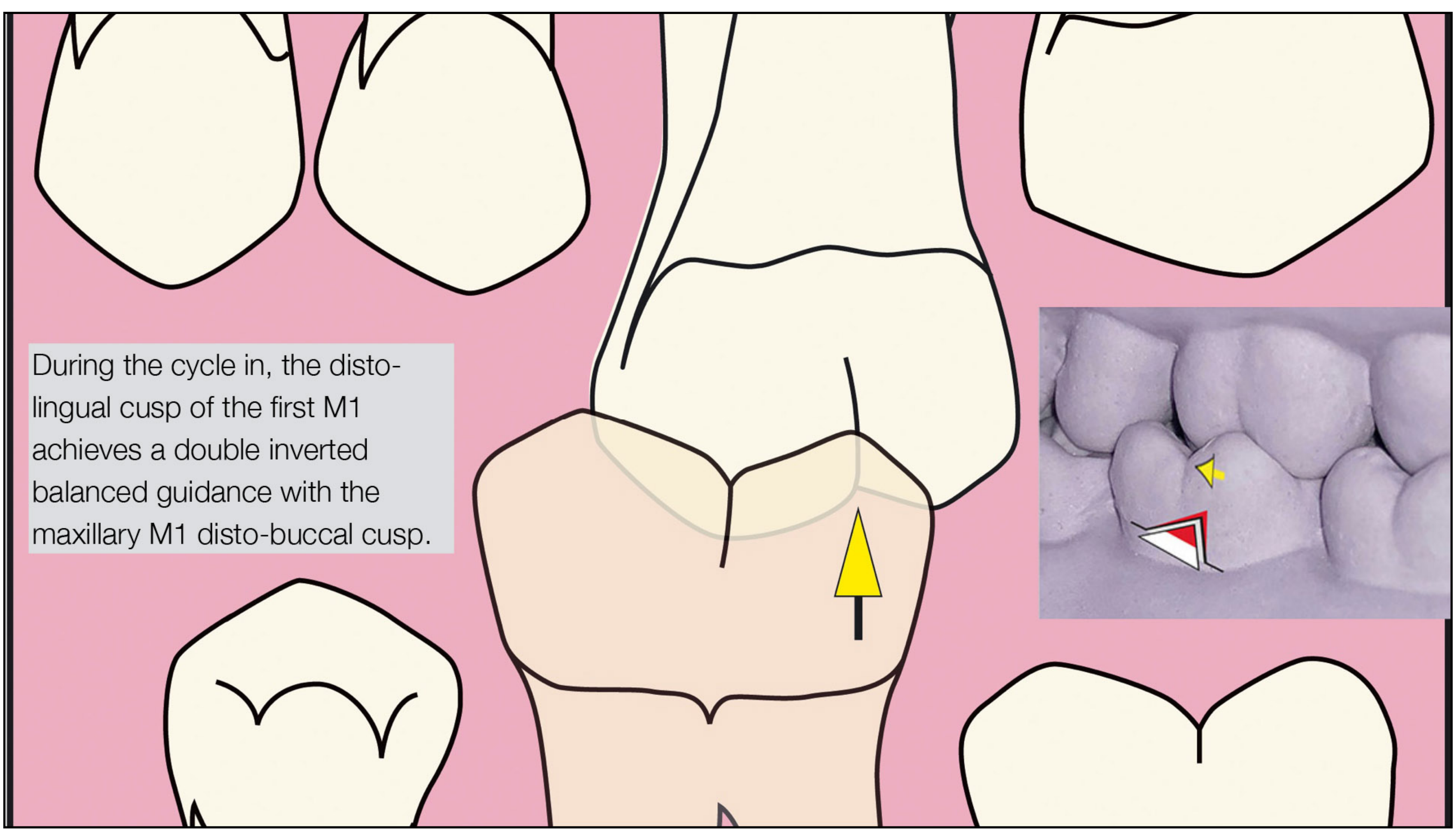


Figure 5B1-4: *On the lingual side, the cusp DL, which provides the same guiding role as the DB, makes it possible to balance and stabilize the couples M1, particularly when the couples M1 are still alone on the arches, when the adult occlusal scheme is put in place.*

do not have the so significant role as it has been assigned them.

The couple of first molars have enough wedging and guiding potential, allowing it to channel alone, without any slippage, the diagonal and transverse kinetics of the chewing cycles and to impose this scheme to the next emerging teeth. Thanks to the presence on their occlusal surfaces, of transverse guiding rails (Le Gall et al 2010, Le Gall and Lauret, 2011, Le Gall 2013), that are essential anatomical, features, for auto-stabilizing MIO and chewing dynamic guiding. (Le Gall et al 2010, Le Gall and Lauret, 2011)

As soon as they come in occlusion, the first molars become the leading teeth for the posterior guidance when they are in optimal relationship.

In addition, early establishment of stable staging and wide class 1 mastication, where they are perfectly matched, will promote transverse and postero-anterior growth.

Moreover, obtaining a stable occlusal wedging and optimal chewing, will promote the rise of the tongue to the palate. These two interdependent factors will stimulate transverse growth and fronto-maxillary advancement.

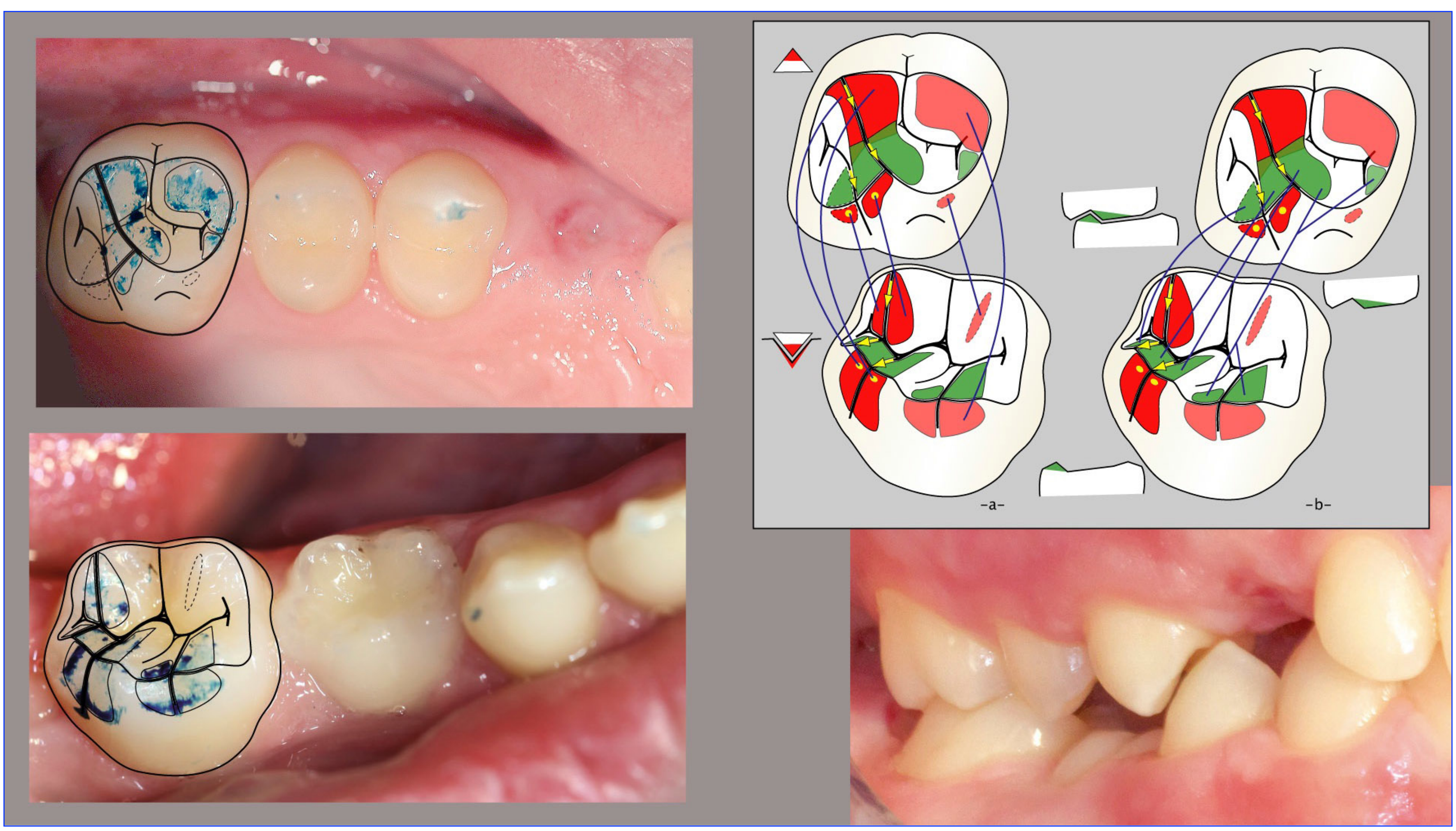


Figure 5B1-5: *This figure shows the occlusal guidelines on first molars of cases* 5B1-2a,b
Occlusal rails of triangular section are paired with their receiving opposite, V-shaped.
The occlusal surfaces of the rails are incorporated into the occlusal anatomy. These are functional guideways responsible for occlusal stability and efficiency of shearing and crushing.
Shearing cycle-in are in red (carnivorous component), crushing cycle-out are in green (herbivorous component).

It's in well established class 1 relationship that form and function find the best clinical fitting. In class1 occlusion, the occlusal anatomy of the first maxillary molar is an exact reversed volume of the mandibular one. During closure in MIO, a small functional interplay, between cycle out tables, and escaping grooves, is only remaining between .

Video in slow motion and simulation of mastication on thin colored paper, show that all along of the dental kinetics of a cycle, occlusal guidings, and rails are continuously and finely matched together, with a very reduced but sufficient interplay, to avoid any occlusal blocking,

A small necessary and sufficient transverse functional clearance is observable at the beginning of the cycle exit (Functional ISS). It allows the kinetics of cycles to pass the MIO without occlusal blockage. It is the occlusal anatomy and functional guidance which delimit the guiding boundary envelope and give the shape of the apical ant general pattern of the cycles.

The other types of occlusion have not a so optimal occlusal fitting than type 1 (class 1. They show often, significant underguidances, resulting in cycles incompleted or deformed, and even reduced to a mere shearing.

In child, these occlusal relations are very often associated to abnormalities of tongue position (Deffez 1995) and can be jointly responsible for vertical, transverse or anterior, anomalous

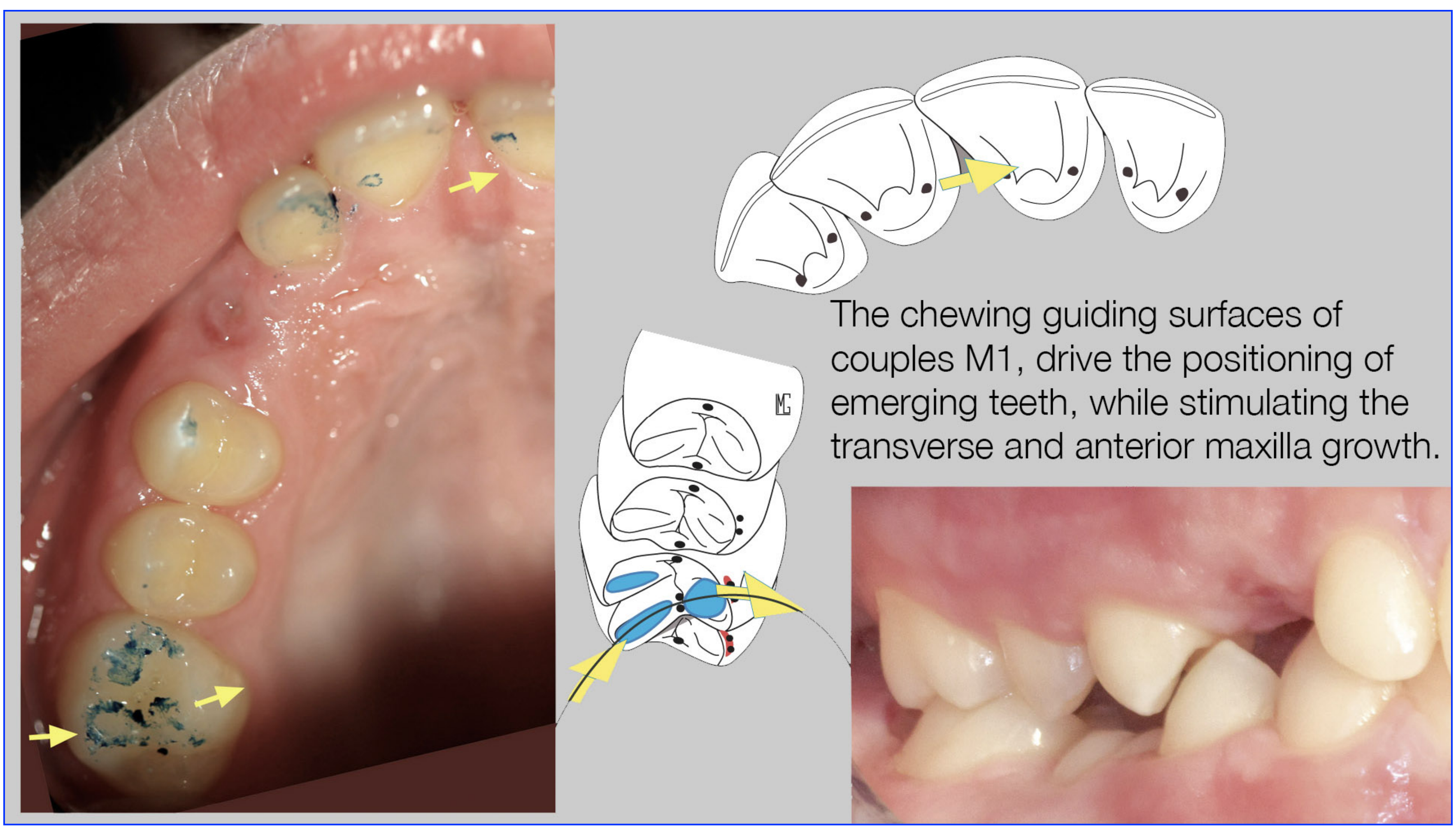


Figure 5B1-6: *A wide cycle (resulting from balanced guidance) is stimulating for maxillary expansion. The free edges of the mandibular incisors crossing the palatal concavity of the maxillary incisors at the time of cycles ouputs, position the maxillary incisors while stimulating the fronto-maxillary advance.*

growth, resulting in hypo or hyper-facial developments, more or less, progressive and asymmetrical, as well as mandible mis-positioning

In children, the treatment of facial asymmetries before 6 years of age (Deshayes 2010), the early lingual reeducation and the rapid optimal occlusion of the first right and left molars, will allow a more natural, full and alternating chewing, capable of reorienting the growth and thus avoid potential secondary treatments sometimes heavy (Bonnet 1992, 93, 99, 2010).

In adult, the build-up of an occlusal anatomy, that is functional and working like class 1 occlusion , with cycle-in and cycle-out well balanced, in a swallowing occlusion relationship and matched with the present articular kinetics, allows to re-establish instantly, without any training, an optimal cycle, fitted with the own patient. Showing that form and function are mutually dependent. (See the second Ebook: "Occlusal Balancing", available in French and soon in English).

2. Incisors

Fig 5B2-1

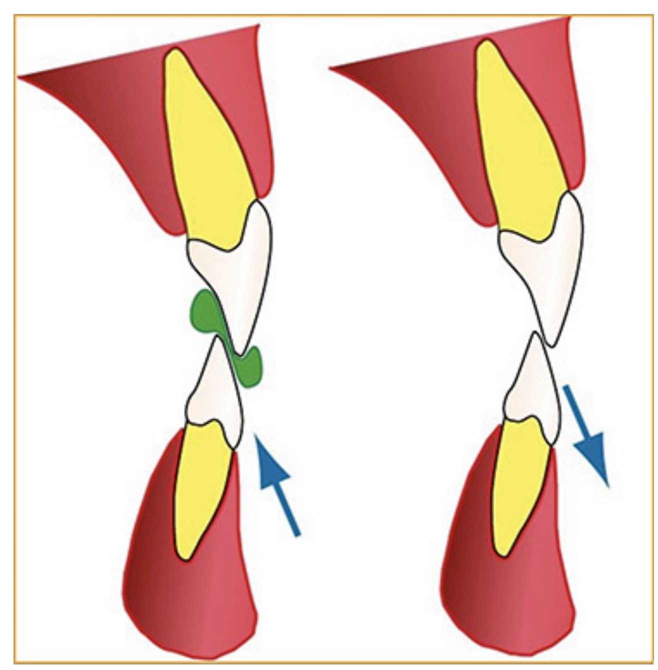


Fig 5B2-2

Figure 5B2-1,2: The incision is performed under the symmetrical recruitment of elevators muscles, and retropulsors. While the protrusion is realized under the symmetrical action of the two lower lateral Pterygoids, which are depressors and propulsors.

The incisors guide the protrusive movement, sometimes with the canines, but without posterior contacts, except in anterior open bites. The incisors grip the bolus and usually guide the incision, through an upward posterior movement of the mandibular incisors, which allows the selection and introduction of the bolus into the oral cavity (Figure *5B2-1 to, 5B2-3*). They are then very often associated with the canines, and accompanying guidance by the posterior teeth. In addition, the dynamic incision relationship gives the anterior teeth a gnawing ability, but limited by the risk of wear.

The incision movement has a centripetal orientation. The protrusion movement usually requested of the patient to check the anterior occlusal balance, has a reverse orientation, with a totally different muscle recruitment (Figure 5B2-3). During the simulation of the protrusion movement, only anterior guidances are observed, whereas during incision, the anterior guidance is dominant and, almost always, accompanied by balanced and non-dominant bilateral

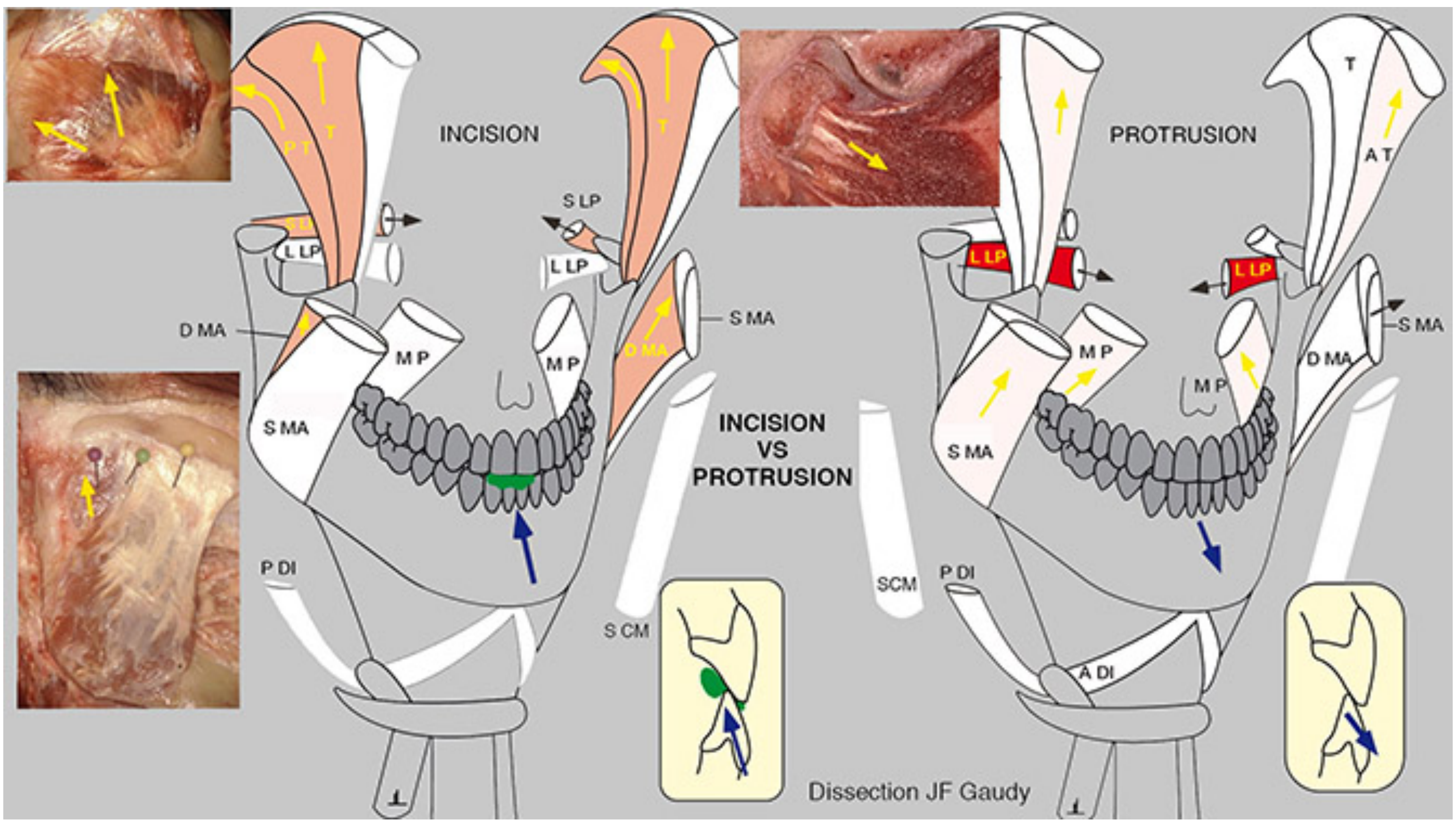


Figure 5B2-3 Comparison between incision and protrusion
The protrusion and incision movements are of opposite orientation. The muscles in action are symmetrical but totally different and of opposite action: The lowers lateral pterygoids which are depressors and propulsors, during the protrusion movement, with a light action of the elevators to maintain the anterior contacts. The elevator and retropulsive beams, deep masseter muscle, posterior and middle temporalis muscle, to make the incision.

posterior guidances.

Moreover, during the outputs of the chewing cycles, in slight anteposition of the jaw, the transverse kinematics of the free edges of the incisors find their functional equilibrium in their good coordination with the shape of the palatal concavity of the maxillary incisors (Figure 5F-5) *YouTube* : https://youtu.be/UUad0HgjvKo .

In d'Amico's descriptions, the functional role naturally devolved to the incisors is attributed to the canines, always in the same theoretical concept of canine protection (D'Amico1958 N°6 P200, N°7 P240). *YouTube* https://youtu.be/0inlZj9HvRM

3. Bicuspids, molars and canines

The description that follows is that of a typical chewing cycle, in centripetal orientation, in a young adult , in class 1 occlusion, with all his guiding capital and concerns one of the last cycles prior to swallowing. (Lauret and Le Gall, 1994, 1996). It describes the limit envelope defined by the functional dental guidances. Most cycles that preceded it, with interposed foods, are within this boundary envelope.

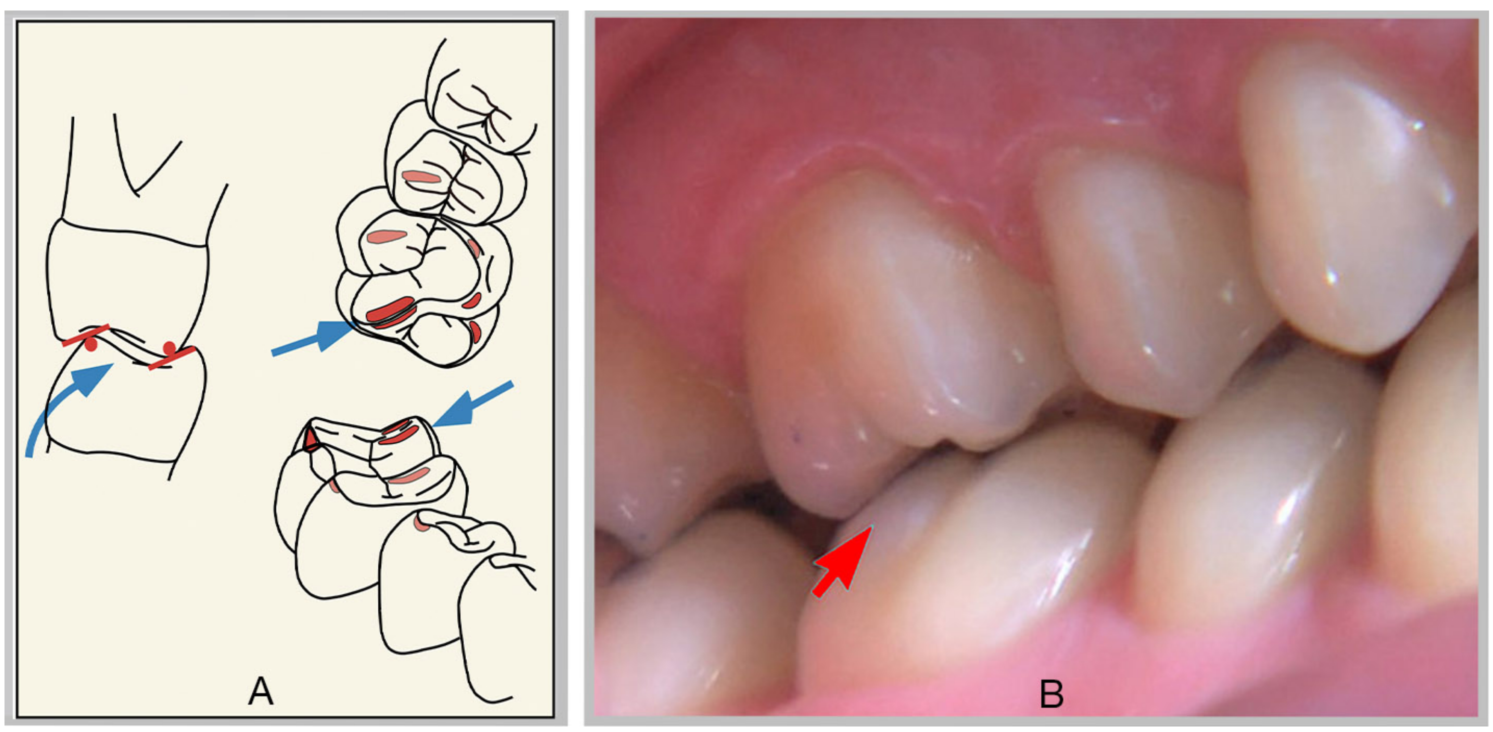


Figure 5B3-1A,B: Cycle-in, see video at the following Youtube address: https://youtu.be/jiZD7JppW3w

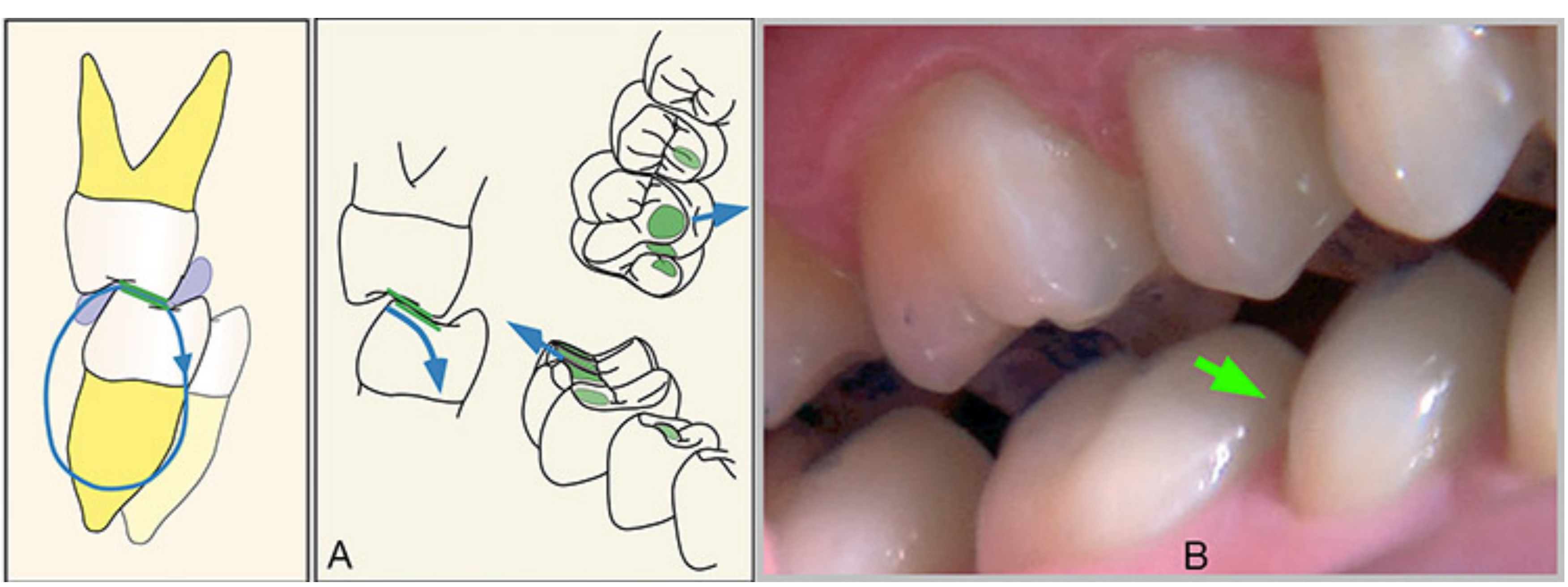


Figure. 5B3-2 A,B : Cycle-out: see the previous video and the following at the Youtube address: https://youtu.be/UUad0HgjvKo

Figure 5B3-3A,B Tracing of guidelines, occlusal guidance of chewing cycles. On superior M1 the main guide rail starts from the tip of the disto-buccal cusp and ends on the palatal side on the tip of the mesio-palatal cusp

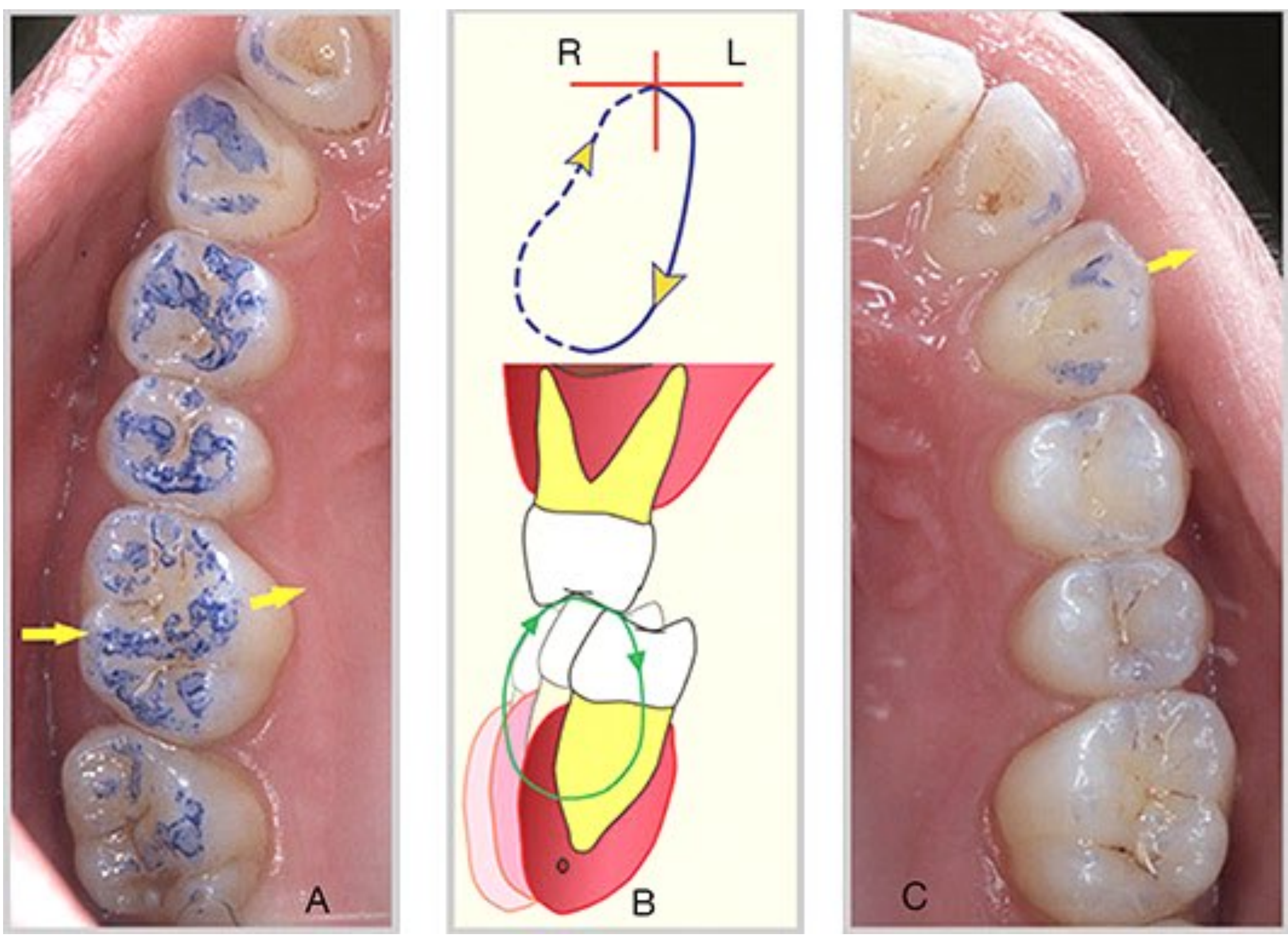


Figure 5B3-4 A,B: Occlusal view of maxillary guidance, for chewing on the right side, in a 28-year-old woman. The limiting mastication envelope is determined by the occlusal anatomy of the teeth and their dynamic occlusion relationship. In this case, the chewing functional equilibrium is optimal and the group function of coordinated guides concerns all the extent of the occlusal faces, the chewing side.

Figure 5B3-4 C: During the cycle ouput, after the passage of Maximum Intercuspation, the mesial inflection of the orientation of the enamel bridge, situates the mandible in slight anteposition, that is why there exists one or more contacts at the level canine on the non-chewing side. This contact is physiological. It plays a mechanical and particularly proprioceptive role in controlling the amplitude of the cycle output and the initiation of the opening, which begins the next cycle.

On the chewing side, during the cycle input (Figures 5B3-1 A,B, 5B3-2 A,B) the internal slopes of the maxillary buccal cusps slide against opposite external supports. Simultaneously the internal slopes of the mandibular disto-lingual cusps slide against external palatal supports. This simultaneous and stabilizing double sliding, directs the mandible towards the Maximum Intercuspation. Following the M.I. passage, during the cycle outflow, the internal slopes of the mandibular buccal cusps, slip against the inner slopes of the maxillary palatal cusps (Figures 5B3-2 A,B, 5B3-3 A,B).

The mandible performs a centripetal displacement. However the relative movement of two teeth, sliding against each other, indicates that the guide facets are in the opposite direction:

- In the fixed maxilla, the reading of the guiding facets is done from the buccal side, towards the inside, in the same orientation as the movement of the mandible.
- whereas the reading of the mandibular guiding facets is done from the lingual side, towards the outside, in the opposite direction of the displacement of the mandible. Watch the following YouTube video: https://youtu.be/jiZD7JppW3w

However, it is not a simple slip between two congruent surfaces. Indeed, on the occlusal surfaces of the first molars, **there are transverse guide rails in more or less diagonal orientation and triangular section** (Le Gall and Lauret, 2011), which channel the movements of the teeth during chewing. The most significant, easily identifiable rail is located on the first maxillary molar (Figures 5B3-1 to 5B3-3A). During the cycle input, this rail starts from the tip of the disto-buccal cusp of maxillary M_1, passing through the enamel bridge that guides the passage the Maximum Intercuspation. and ends, during the cycle output, on the distal part of the mesio-palatal cusp, at the edge of the occlusal table (Figures 5B3-3B, 5F-1a, b, 5F-3a 5F-3b).

The triangular section of this guide rail is finely matched with its V-shaped antagonistic receiving structure, located between the mandibular second and third buccal cusps of M_1, on their outer and inner sides (Fig.5E-5). This rail channels the movement:

During the cycle input, by 2 external supports between which slides the rail of the internal slope of the maxillary disto-buccal cusp. This buccal rail is balanced, lingual side, by a simultaneous but inverted rail, because located on the inner side of the mandibular disto-lingual cusp and sliding in the V located between the external slopes of the two palatal cusps of M1 (Figures 5F-1a,1b, 5F-2a,b, 5F-3a, b).

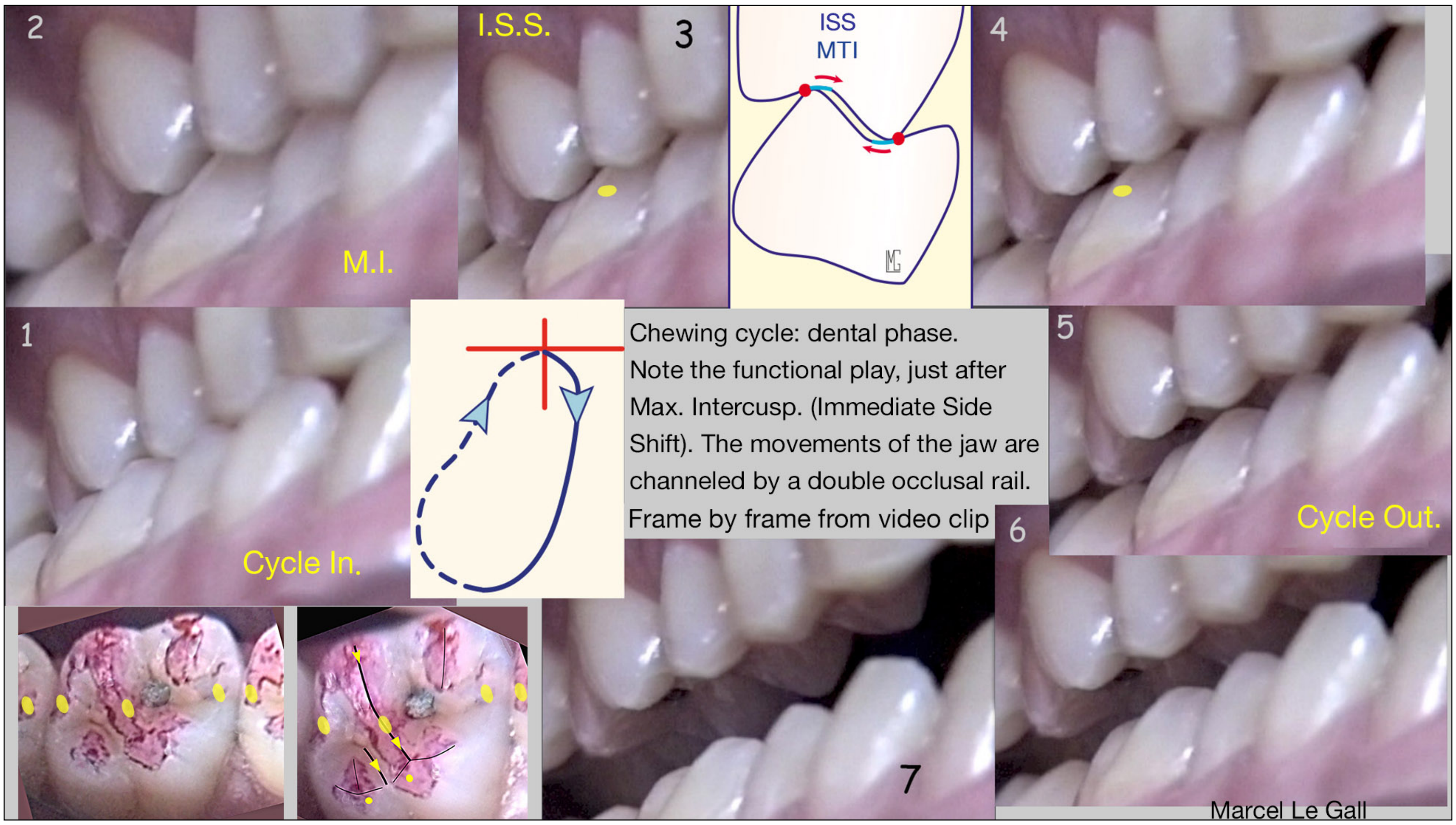


Figure 5B3-5 (1-7):Snapshots of different times of the dental phase of a right chewing cycle. (images taken from a video of a young man, 25 years old)..

- 1: Cycle input, shear phase of the bolus -2: Maximum Intercuspation

- 3,4 : When passing through M.I., note the small transverse displacement of the mandible. This functional game between CO allows chewing to pass the MI without any blockage. 5,6,7:The cycle output phase crushes food. The existence of this crushing slip between the internal slopes of the palatal cusps, and the buccal jaw is determinant of the very existence of chewing.

- The constant clinical existence of this small displacement called Immediate side shift, the amplitude of which is peculiar to each patient, shows that the blocking tripodism of the gnathological school exists only in textbooks. Bottom right the the diagrams represent the situation of this ISS on the marginal ridges. Vidéo YouTube, click on the following link: https://youtu.be/5i9cUZRwNns

Then during the passage through Maximum Intercuspation, it marks a mesial inflection on the enamel bridge which, at this moment, is the only active guiding structure between the cusps 3 and 5 of M1.

To complete it's directional guidance, during the cycle-out, between the internal slopes of the upper mesio-palatal and lower disto-buccal cusps.

The maxillary main rail is doubled at the mandible, by a second inverted V rail, adjoined to the first. It starts from the tip of the disto-lingual cusp of M_1. This second rail is parallel to the maxillary rail, but without enamel bridge. It is sometimes not very visible at the beginning, but it is gradually reinforced, with the wear of the occlusal faces (Figures 5F-1a, 5F-1b).

These rails benefit from an optimal coordination in class 1 occlusion. This double twin rail gives the cycle exit a highly directive in counter-point configuration, a bit similar to that of herbivores, but more complex, because in the form of a comma , non-linear. (Figure 5F-2a,b).

Dental guidance may also exist on the mesial cusps of the first molars. They are less constant and depend on the relative size of the maxillary / mandibular M1, and are rarely channeling..

The guidance of the posterior teeth is accompanied during the cycle entry by sliding on the inner side of the ipsilateral maxillary canine.

During the cycle input, there are no contacts on the non-chewing side, but at the cycle output, there is one on the inner side of the contralateral maxillary canine or its neighbours. This contact is due to the slight ante position of the mandible at this moment. It ensures the physical and proprioceptive transversal limitation of the cycle and causes its opening (Figure 5B3-4 b).

The mesial orientation of the axis of the maxillary first molar, as well as the constant prominence of its disto-buccal cusp (much more than in dental anatomy textbooks!) Certainly contribute to the early and privileged interception of the mastication, and constitute one of the keys to functional occlusion,.going beyond the static description of Andrews (1972), and introducing the specificities of masticatory dynamics.

The dynamics of the cycle pass the maximum intercuspation unimpeded, because at the MIO's passage, there is a small transverse play, the functional Immediate Side Shift, which allows this passage to be smooth. The presence of this custom play is verifiable on mastication films, frame by frame (Figure 5B3-5 5-55b). Its constant presence shows that the tripodic relationship, cusp/ fossa, described in the gnathological publications, does not exist naturally in the mouth of the patients, because it would block the chewing at the passage of MIO.

The limit guide envelope of the cycles is reached when interdental or/and marginal ridge contacts occur through the bolus, in the last cycles, and are a strong signal of triggering swallowing.

We observe an anatomical correlation between the shape of the mastication cycles and its articular and dental determinants, ie:

- the occlusal morphology of the posterior teeth,
- coordinated, during cycle input, with joint kinetics
- coordinated, during cycle output with the articular kinetics and the shape of the palatal concavity of the maxillary anterior teeth.

During the cycle-out, the mandible is slightly anteposed to the M.I.O and the free edges of the mandibular incisors transversely cross the upper palatal concavity of the incisors. The presence and shape of this concavity is directly related to the dynamics of mastication cycles, whereas during the incision, they have no particular role. This functional kinetics, coordinated in 3D, is realized under the control of the only center of mastication.

Sufficient functional play must therefore be provided at the level of the palatal concavity of each maxillary anterior tooth, in order to allow the transversal dynamics of chewing, at the cycle input and especially at the cycle output (Figure 5F-5, 5-73).

When posterior cycle-out guides are under-evaluated, or worn with missing guide rails and possibly loss of DVO, the jaw slides forward. The free edges of the mandibular incisors then come in contact, sliding transversely in the palatal concavity of the maxillary incisors, first during the cycle exit, then during the whole cycle, as the wear increases on the posterior and anterior teeth. It is this process that leads progressively to anterior edge-to-edge bite. Today the correction can and must be performed early by adding on the cycles output of the posterior teeth and not by subtraction in the palatal concavities of the maxillary incisors. On the other hand, if an anterior restoration has a too straight palatal face, there is overguiding of the restoration during cycle output. The correction consists in correcting the maxillary palatal concavity by subtraction, and not in retouching its lower antagonist, which would not solve the problem related to transverse chewing.

3-Joint kinetics

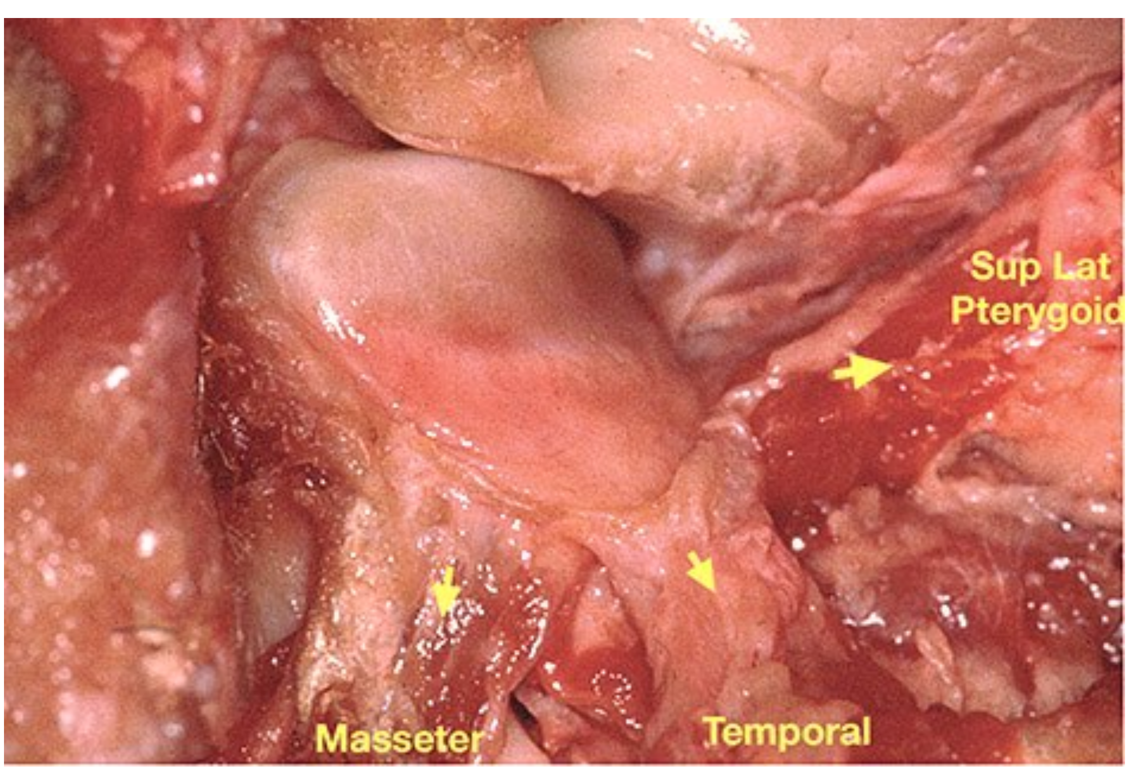


Figure 5B4-1 On the chewing side, the insertions of the elevator muscles on the capsule and the viscoelastic properties of the disc, which bring together the articular surfaces during mastication and allow the molars, on chewing side, to reach the dynamic contact with opposites, during the last cycles before the swallowing.. (dissection JF Gaudy).

On the chewing side, the viscoelastic properties (Tanaka and van Eijden 2003) and the intra-articular kinetics of the disc (fibro-cartilage interposed between temporal and condyle), associated with the recruitment of the capsular muscles allow the vertical approximation of the articular surfaces and that of the occlusal surfaces of the molars, in synergy with the action of masticatory elevator muscles. The preparation of the alimentary bolus interposed between the posterior occlusal surfaces can thus be performed before swallowing.

At the end of chewing, the guide boundary envelope is reached, interdental contacts occur through the bolus, in the last cycles, and are a strong signal of triggering of swallowing.

Three muscular bundles are inserted on the joint (Gaudy et al. 1992): the superior fibres of the lateral Pterygoid is inserted within the disc and the capsule, fibres emanating from the middle layer of the deep posterior Masseter and another from the deep part of the posterior Temporal are inserted on the capsule. They are fan-shaped and their contraction is synergistic with that of the elevator muscles, which ensures articular kinetics are connected to dental guidance (Figure 5B4-1). The disc is fact a portion of the Sup LP tendon, with additional functional capabilities.

The vertical approximation of the articular surfaces, thanks to the adaptive plasticity of the disk (Jaisson et coll. 2011)) and all capsulo-discal apparatus, is not reproducible on conventional articulators, (Figure 5B3-1 à 5B4-1) which does not allow them to simulate the mastication (Figure 5-52 to 5-56). Verification and final equilibration of chewing should be done in the mouth.

To summarize, it is the first molar couples that have ensured, alone, the guidance of adult mastication, which is why the definitive chewing pattern first settled on these molars, then on the bicuspids well before emergence and occlusion of the canines.

Intype 1 occlusion (class 1 of Angle), the occlusal surfaces of the first molars are the inverted relief image of each other, with a small functional play and some secondary exhaust grooves for the bolus. The enamel bridge rail and its counterparts are directly operational in Type 1 (Class I). They allow the channeling of the first molar couples in the three planes of the space, which gives them a great stability during the installation of the occlusion. They remain active in adults, at least as long as the occlusal surfaces retain their original anatomy.

The slopes of the molars that perform the preparation of the bolus present very early small facets of wear. The latter increase more or less with aging, depending on the level of abrasiveness of the diet and masticatory power (Figure 5E-6).

The general evolution of this model, by wear, and biocorrosion of the dental determinant, makes it lose progressively its occlusal characteristics, even going as far as to destroy it completely, in some cases, frequent and precocious formerly, but more rare and late, today.
The complexity of these omnivorous occlusal surfaces did not allow a satisfactory adaptive response to compensate for this wear, by regeneration, as in herbivores. Considering the high abrasivity of the plants, due to the presence of phytoliths and external abrasives in the bolus (Figures 3-6, 3-7), they are the internal slopes of the palatal cusps, opposite to the internal slopes of the jaw buccal cusps which present the fastest abrasion, because they are the ones which carry out the fine crushing of the bolus, therefore of the plants, and of all the consistent foods, during the phase of exit of the mastication cycles.
However, there have been some adaptive response attempts that will be developed later.
Apart from functional abrasions, parafunctions such as bruxism can affect the human species and amplify dental wear to a greater or lesser extent. Their existence in the animal world, is an unanswered question, for the moment.

C- MASTICATORY CYCLES OF MAN

Different phases of a chewing cycle

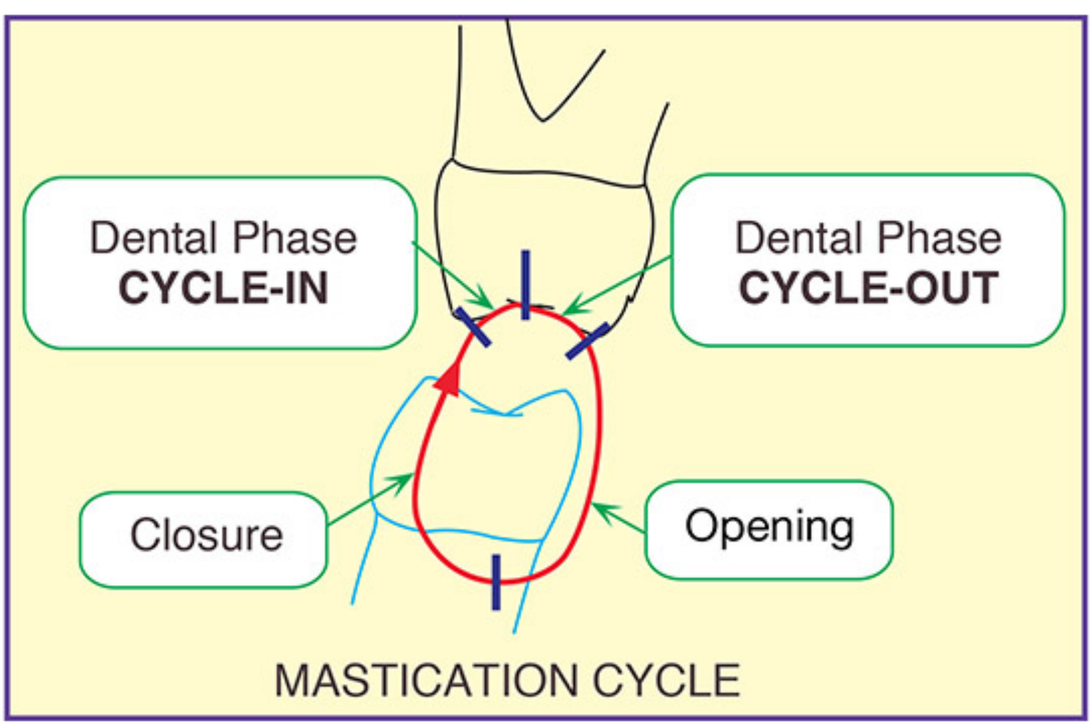


Fig. 5C-1 Different phases of a chewing cycle.
A mastication cycle consists of a dental phase and an open-close phase, which carries out the end of the previous cycle, followed by the preparation of the next. Dental phase is subdivided in a dental input of the chewing cycle (cycle-in) and a dental output of the chewing cycle (cycle-out), prior and after Maximum Intercuspation

The records show that mastication results in a series of successive cycles of the mandible that result in the fragmentation and progressive grinding of the bolus before swallowing. (Yeager1978, Lundeen and Gibbs 1982, Pröschel 1987, Lauret and Le Gall 1994,1996 Le Gall and Lauret (†) book ed., 2008, 2011).
A chewing cycle, in centripetal orientation, can be divided into two phases:

- A preparation phase, at a distance from the teeth, which begins with an opening following the dental exit of the previous cycle, then with a closure that leads to the dental input of the next cycle. This phase has the appearance of a loop, shifted laterally to the chewing side.
- A dental phase located at the apex of the cycle, itself subdivided into a dental cycle input and a dental cycle output, before and after passing through the Maximum Intercuspation. The recordings reveal that the occlusal phase of the cycles is guided before the M.I. on the so-called "working" slopes and after the passage of the M.I. on slopes traditionally referred to as "non-working". As this term is unsuitable, all these slopes will be called, "chewing" for more coherence (Figures 5C-1 to 5C-5).

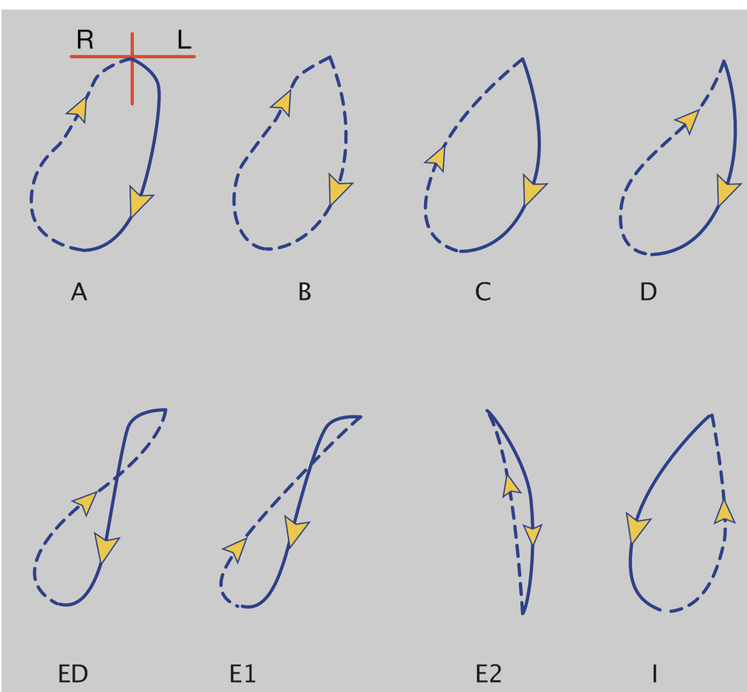


Figure 5C-2 Mastication cycles according to Pröschel (1987): the shape and amplitude of cycle A represents 50% of the cases. Cycle A represents the optimal and the most efficient shape, generally observed in class 1 of Angle.The meaning of cycles B, C and D was not yet known. Some are pathological and others not, without being able to specify the reason.

A large variety of cycle forms have been recorded. The ample and regular shape (Figure 5C-2 A 5C-3C1) is considered optimal by Pröschel (1987) and represents 50% of the cases. But without he will be able to give the meaning of the majority of the other forms, some being accompanied, or not, of various pathologies (Figure 5C-2 B,C,D).

The description of the shape of the mastication cycles by Jones and d'Amico was incomplete and corresponds only partially to the descriptions of the kinetics and the muscular actions, that were made later. (Figures *5D-1 to 5D-4*). Moreover, it has already been written that the absence or deficit of sensory inputs, resulting from inappropriate occlusal surfaces, reduces the chewing forces and has a direct impact on the shape and the reduction of the amplitude of the masticatory cycles. (Johnsen SE and Trulsson M. 2003a p1486).

The shape of a cycle is not fixed data, it is determined by the balance of the posterior and anterior dental guidance with that of TMJ, thus to the equilibrium of the dental and articular sensory inputs.

It is clear today, that a chewing cycle shape, which is shearing or truncated in part of its functional envelope, **can be modified by addition of composite test and easily restored in its optimal envelope.** (Le Gall M. G, Lauret J.F 1998 French and English).

Videos of correction of masticatory cycles forms, are available on line on the site: www.mastication-ppp.net *or accessible directly on YouTube* https://youtu.be/-QBFdJZcWKc https://youtu.be/OB9t3sYEazw

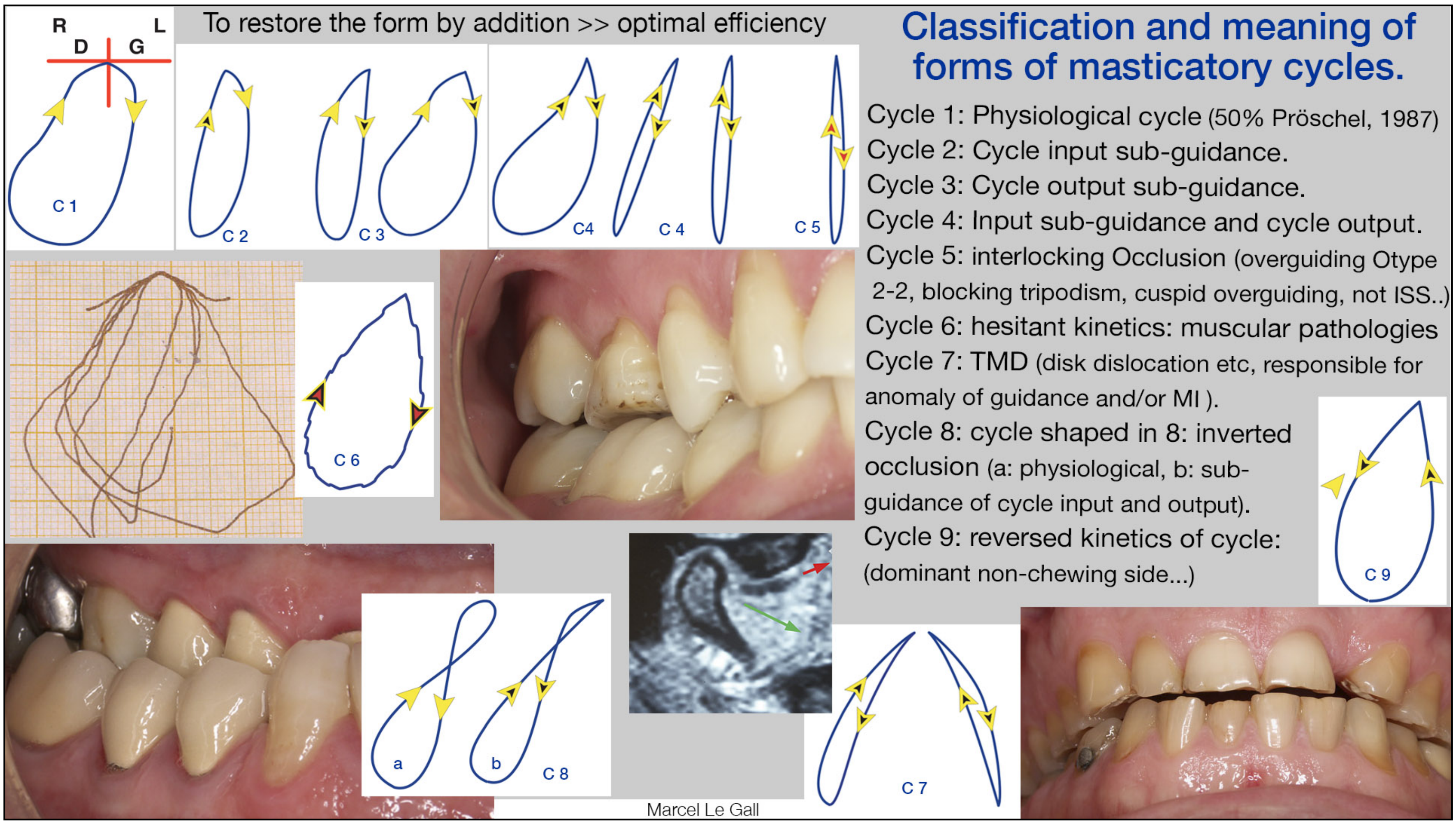


Figure 5C-3 Proposition of a new classification of mastication cycles, by the authors, in the frontal plane. (Replicator®, Sirognathograph®, Zebris®.)The C1 cycles, recorded are physiological. The C2, 3, 4 result from occlusal sub-guidance, responsible for the deficiency of underlying proprioceptive information and the deformation of the cycles (Johnsen SE and Trulsson M. 2003a p1486). Their shape is modifiable by addition in order to restore and balance the information transmitted to the periodontal mechano-receptors, which allows the cancellation of the protective mechanisms and immediate restoration of the shape and the optimal efficiency of the cycles. For C5 cycles in over-guidance, the shape can be restored by orthodontics or subtraction. C7 cycles require complete occlusal rehabilitation of the two arches by addition. C9 cycles result from various mechanical joint interference. They can be partially, totally or not at all improved by addition. But the reversible addition test must be done to find out.Youtube:https://youtu.be/Heo8c8KM4WY

During growth it is the occlusal anatomy and the dynamic occlusal relationships of the first molar couples, which shape the mastication cycles and guide the adult conformation of the TMJ. Later when the occlusal morphology is lost, it is the memory of the joint form, which will allow reconstruction by addition the lost functional anatomy . Firstly couples M_1, then P_2 and P_1 and canines. If necessary the I_1, I_2 and M_2 can also be rebuilt afterwards, in order to

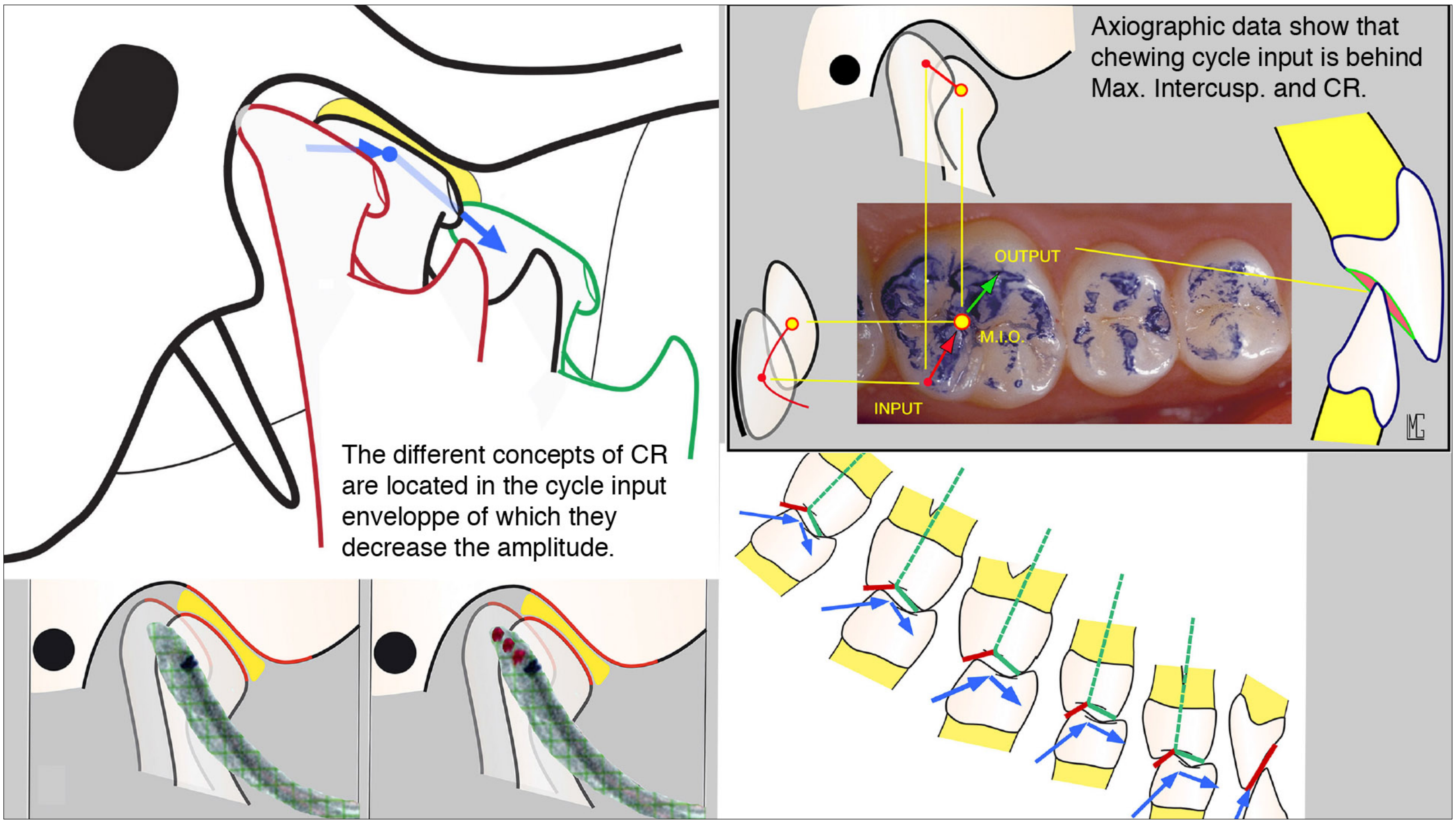


Figure 5C-4 The different concept of CR have been located in the posterior cycle input functional enveloppe, of which they decrease more or less the amplitude. Axiographic data show that the limiting envelope of chewing cycle input is located behind MIO and CR.

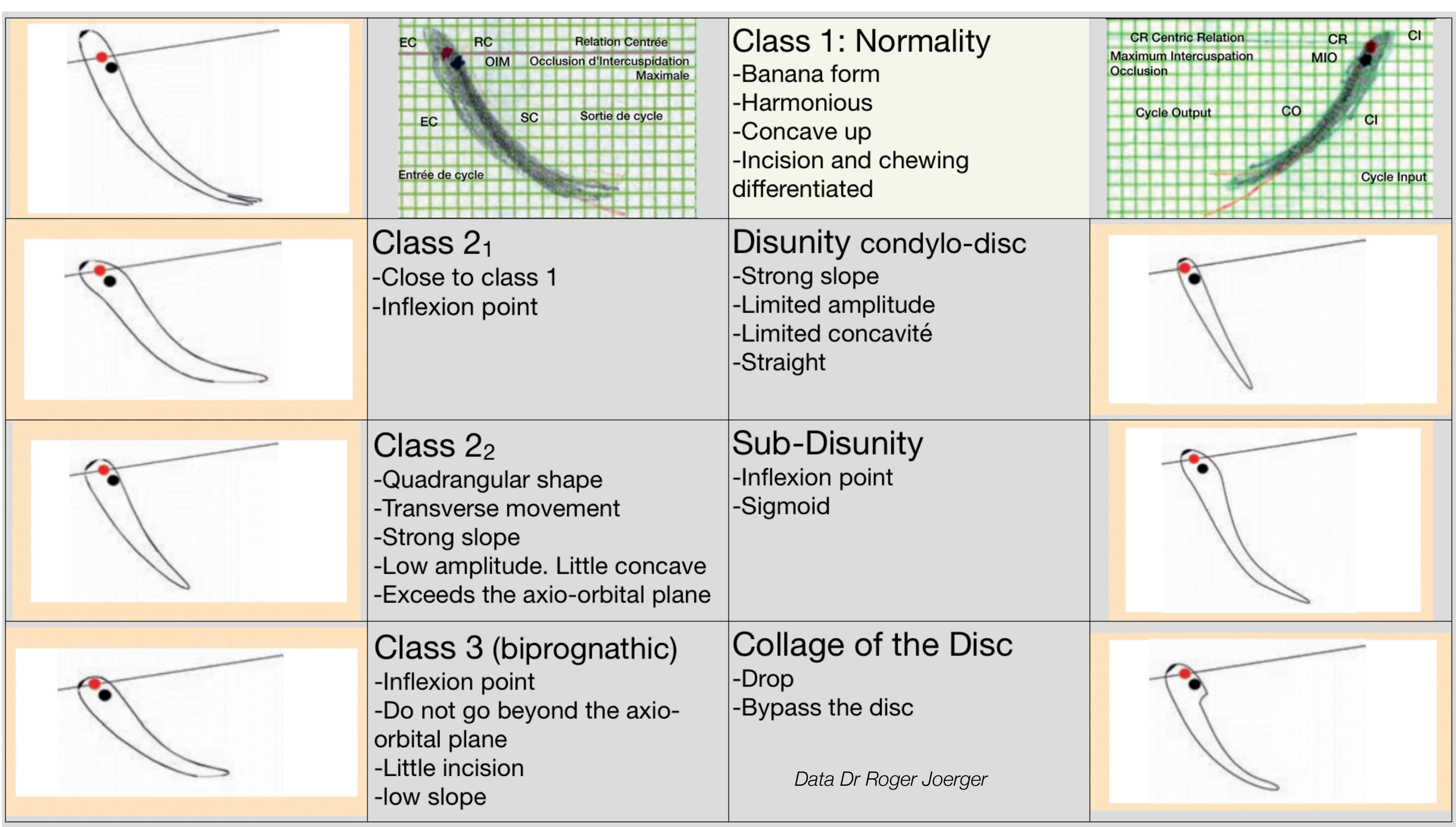


Figure 5C-5 Proposition of a new evolutive classification of chewing cycles, in the sagittal plane, by the authors. The cycles are recorded by axiograhy.

restore maximum efficiency of the whole.

When the inner slope of the upper canines (and/or the volume of the lower ones) have been restored by addition in coordination with the posterior cycle entry guides, it is noteworthy that these cuspids, then ensure alone the guiding of the laterality movement, if they are asked (contralateral ILP muscle, lateralizer and depressor). This movement is then realized with the natural value of disclusion. This functional coherence indirectly confirms that it is the M1 couples who guided the emergence and imposed the position of the canines, during their late arrival on the arcades.

In type 1 occlusion, the human jaw M_1 which have alone retained the ancestral morphology, with 5 cusps, are the inverted image of their opposite, guided in their dynamic relations by the presence of paired rails, whose principal relates the enamel bridge and a part of the Y5 pattern (Fig. 5E-5, 5E-6, 5F-1,5F-2). In order to restore their functional capacity, when they are worn out, it suffices in class 1, to rebuild the cusps in the same location, by composite-up test, respecting the curves and to pair them finely by simulating chewing. On the other hand, when they are in class 2 or 3, resulting from growth dysmorphosis or others, and that the position of the teeth is not modifiable, it is generally possible and necessary to modify their occlusal morphology, by "composite-up ". By moving the cusps, to make them work in a coordinated way as in type 1.

This allows to restore their role of guiding / crushing and their optimal functioning. (*see video YouTube*: https://youtu.be/2GAsyxStD0Q).

Under these conditions, it is common to observe that a triturating area, previously unused, can after composite-up equilibration, instantly support chewing and become the dominant functional side.

When the addition technique is mastered it is successfully achieved in usual practice.

D- MUSCLES AND CHEWING CYCLES

Masticatory muscles are muscles with a penniform or semi-penniform structure, composed of thin alternate musculo-aponeurotic layers. This organisation result from a functional specialization that allows short muscles to develop considerable power, virtually without movement.(Gaudy et col.1992).

In his articles, d'Amico did not write anything about the muscular actions compared between the laterality movement and the kinetics of centripetal chewing. However, the contraction of the bundles of the elevator muscles (Wood 1986, 1987) and their joint insertions (Gaudy 1992) are determining, the elevation of the posterior teeth during the mastication (Figures, 5B4-1, 5D-1 to 5D-4). This is not the case during the laterality movement, caused by the recruitment of the Inferior lateral Pterygoid, contro-lateral, which is a depressor and lateralizer.

Under these conditions, the disclusion of the posterior teeth is carried out by the canine, on the same side (so called "working" side).

Functions and vectors of action of different bundles of masticatory muscles, as well as their consequences on jaw posture and occlusion relationship, were still imprecise, at the time of d'Amico. They have since been supplemented by numerous publications concerning the anatomy of the various muscle bundles (Gaudy J.F 2007), their recruitment in synergy or opposition, and their respective roles, during the different phases of chewing. (Figures 5B3-1 to 5B3-4, 5B4-1 to 5C5 5-57 to 5-62).

Detailed works have associated electromyographic studies with chewing movements (Sessle 1976, Steiner 1974, Horio and Kawamura 1989, Wood 1986, 1987) Scenarios necessarily simplified, resulting from these works, are proposed figures *5D-1 to 5D-4*, or available online

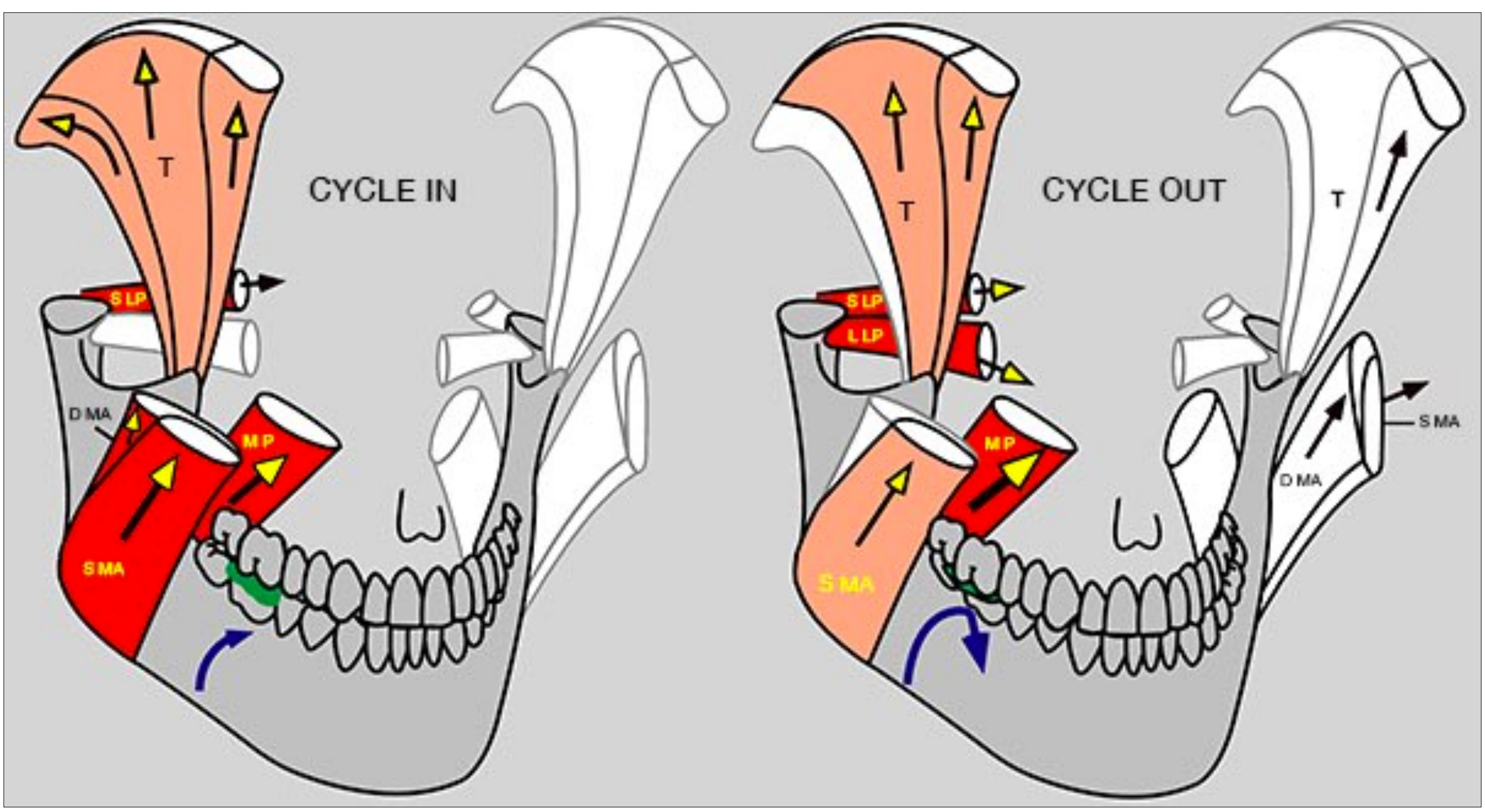


Figure 5D-1 The muscles recruited during the dental phase of chewing are almost exclusively elevator muscles (Wood 1986, 1987). They allow the approximation of the molars that crush the food on the chewing side. This kinetics is very different from the laterality movement.

(www.mastication-ppp.net) or on publications and works (Le Gall M. and Lauret J.F. book ed., 2008, 2011).

Chewing is unilateral and alternated. It is composed of a series of successive cycles of the mandible that carry out the comminution of the bolus, between the teeth, before swallowing. The preparatory phase of opening begins after the dental exit of the previous cycle. It is caused by the coordinated contraction of the two Lower Lateral Pterygoids and two Anterior Diagastrics that manage the vertical and transverse amplitude of the opening cycle. In the following return phase, the external offset and the amplitude of the closure are first caused by MP recruitment, non-chewing, then coordinated to the chewing PM. They are quickly accompanied, by the increasing action, of all the elevator muscles of the chewing side, and the posterior diagastric, which places the mandible in a lateral and retracted position, before the first cycle input contact, in centripetal orientation toward MI. The coordinated powerful contraction of the temporal, masseter, medial pterygoid, on the same side, is responsible for the gradually moving closer of the posterior occlusal surfaces, together with the kinetics of coordinated confrontation of the teeth, which allows the bolus to be prepared before swallowing (Figure 3-13 to 3-16).

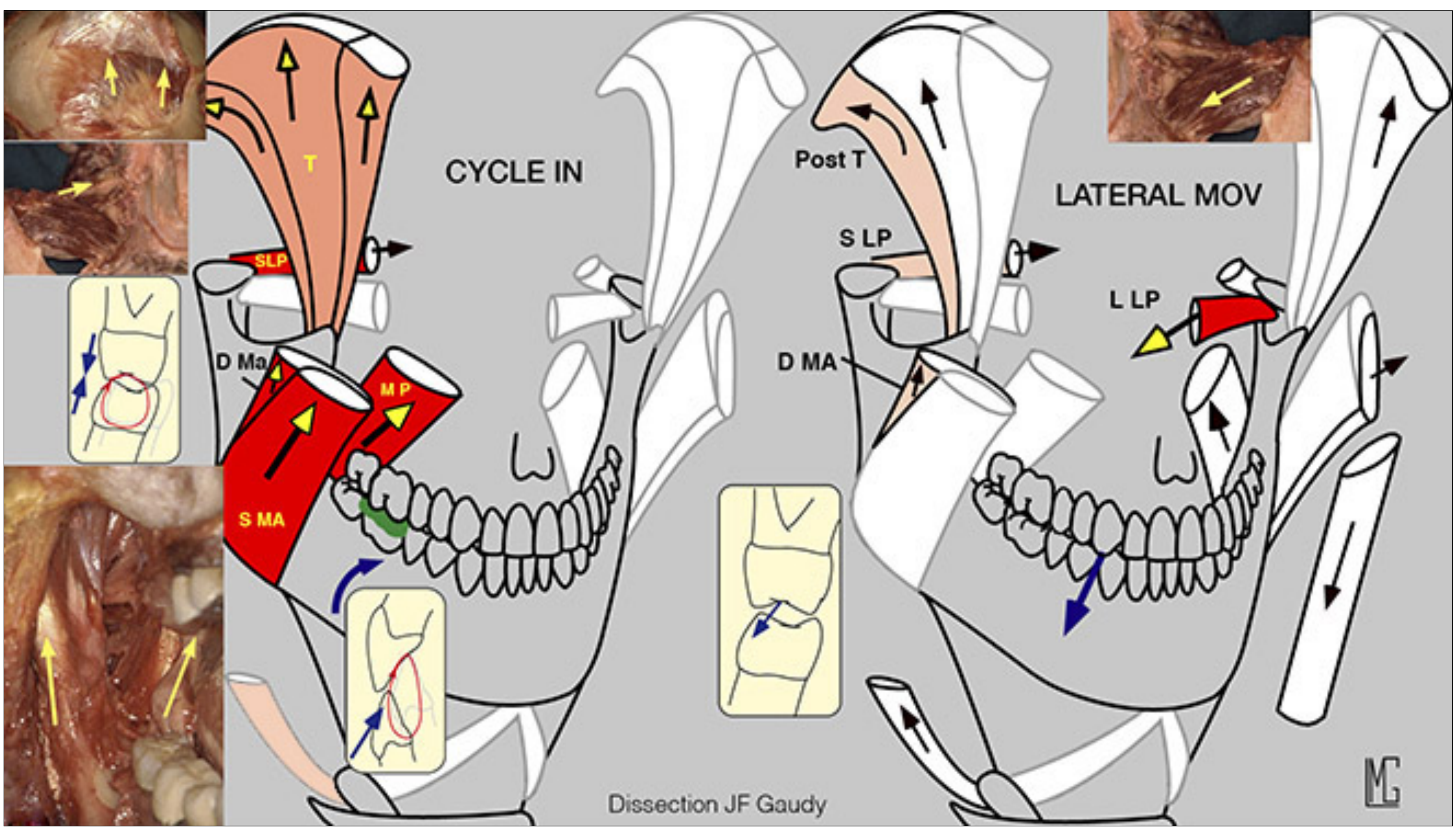


Fig. 5D-2 Comparison between a right chewing cycle-in and a right lateral movement. The muscles in action are totally different and of opposite orientation: -Elevator muscles (Ma, M., T, S.L.P) during the right cycle-in centripetal orientation, with dental cycle-in contacts.
- During the right laterality movement. the non-chewing, Lower Lateral Pterygoid which is a depressor and lateralizer, is recruited. The movement is in reverse orientation, with a disclusion by the right canine and without posterior contact.

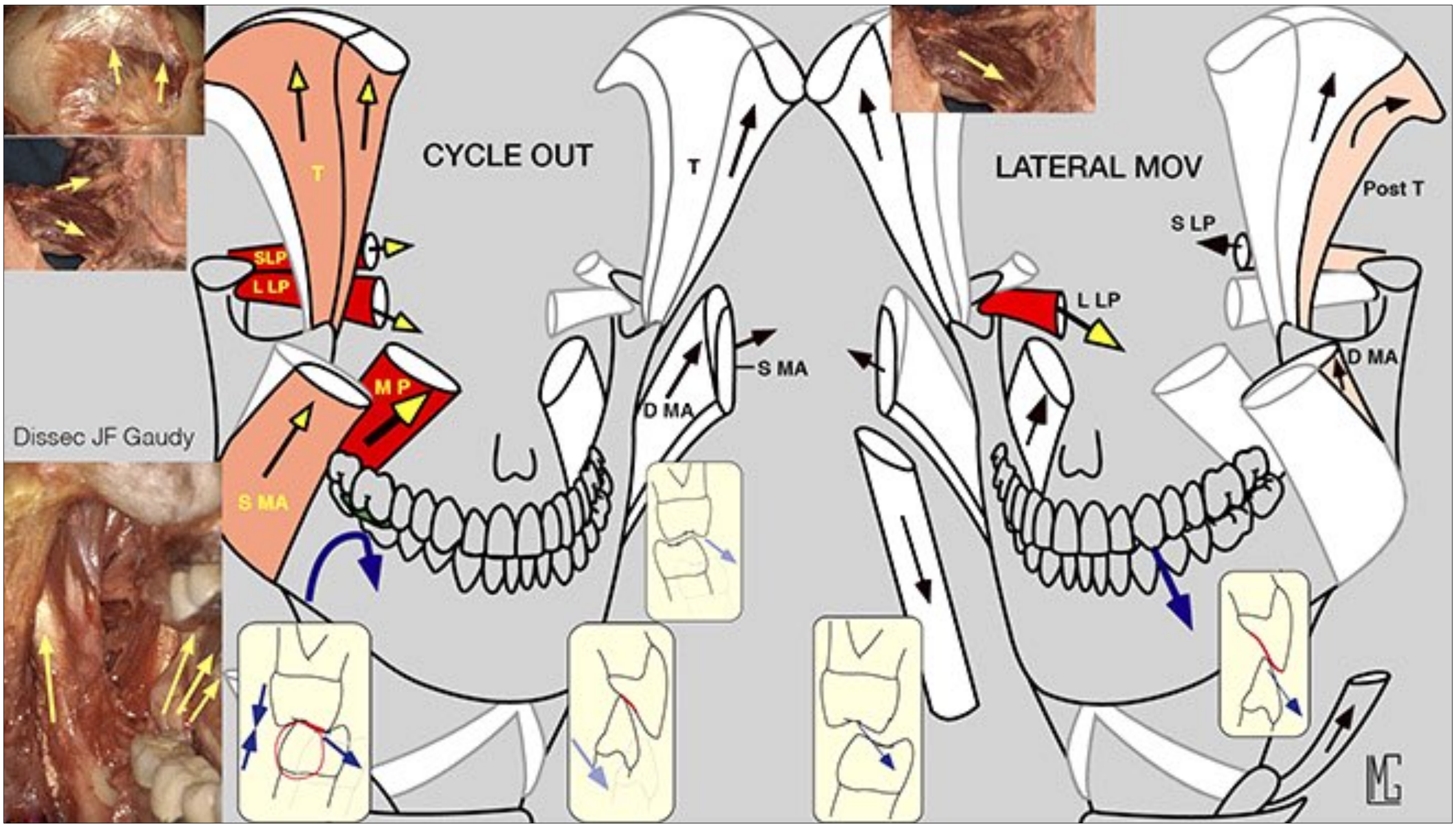


Fig. 5D-3 During a right cycle output and a left laterality movement, of the same orientation, the recruited muscles are the following:

- During the centripetal cycle-out, the elevators on the same side are in action (MP, Ma, T., SLP and the LLP, diduct and lower.) There are posterior interdental contacts of cycle-out on the chewing side and on the canine non-chewing side.

-During the left laterality movement, of the same orientation, only the inferior lateral. pterygoid is recruited. With disclusion by the left canine and no posterior contact.

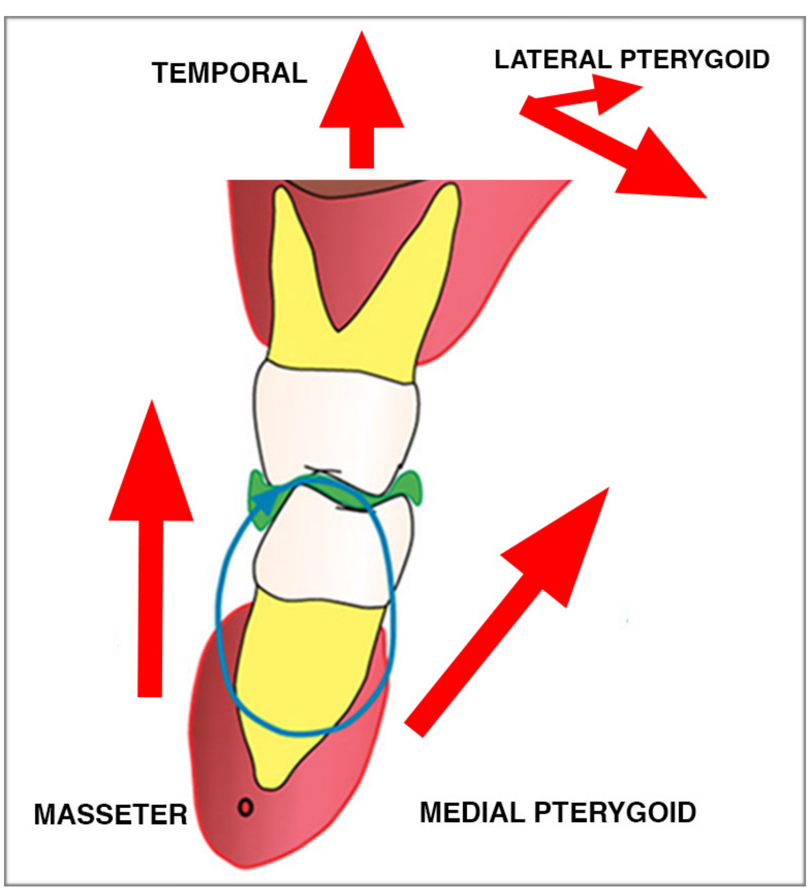


Figure 5D-4: MP-ILP Cycle output: in front view:

- addition of horizontal latero-medial components

- opposition of the vertical components. Instant adaptation of the crushing power to the bolus texture and the orientation of the cycle output tables (proprioceptives efferences / muscle recruitment).

Powerful transverse crush-slip forces between cycle output tables

The masseter and pterygoid medial muscles are powerful elevators that develop their action in a partially symmetrical way of the distal and angular part of the horizontal branch of the mandible:

- one on the outer side
- the other on the inner side.

They are capped by the temporal muscle whose point of application of forces is located on the coronoid process, above the occlusal plane, with an elevator action alone, or partially propulsive or retropulsive. In addition to its elevator action of crushing, it has a positioning role of the mandible in the sagittal plane.

The resultant of the forces applied, during the recruitment of the masseter, starts from the external gonion angle, with a vertical or diagonal postero-anterior elevator action. This muscle is very active during cycle input in association with medial pterygoid and temporal.

The resultant of the forces applied during the recruitment of the medial pterygoid starts from the internal gonion angle with an elevator and diagonal orientation, that is postero-anterior and latero-medial. This is the muscle of the crushing power of the dental cycle output, in diagono-transverse orientation.(Figure 5D-3, 5D-4).

It's action coordinated with that of the homolateral PLI, a lowerer and diductor, carries out a crushing sliding movement, guided by the occlusal rails of the M1, towards the contralateral canine. Apart from the rails, the exit tables are relatively flat and congruent with small grooves exhaust, which facilitate the fine fragmentation of the bolus.

During cycle-in, on M_1 couples, muscle kinetics generate vertical and diagonal forces. They are supported, in the sagittal plane by 2 buccal and slightly divergent roots. The cycle-out, forces have a diagonal and transverse orientation. There is an anatomical correlation between the cycle-out occlusal table and the axis of the palatal root of massive maxillary M_1, whose orientation is substantially parallel to the PM and orthogonal to the exit table.

It is this tripod architecture that helps to dissipate the cycle-out chewing forces in a bone of mediocre quality, while its mandibular antagonist only needs two roots, implanted in a bone with thick cortical walls. and with a much lower radicular bearing surface, to dissipate the same forces (Johnsen and Trulsson 2003).

The position and association of the masseter, temporal, medial pterygoid, and lateral pterygoid of the articular area, gives a remarkable efficiency to chewing.

Provided the dental and articular sensory inputs are balanced, which implies a functional anatomy balanced with joint kinetics. If this equilibrium exists, it can be maintained over time with coordinated wear of the tooth and joint surfaces (Mongini). On the other hand, if the occlusal anatomy is modified suddenly or too rapidly, with the installation of sub-contacts or sub-guidages, the articular structures, which can not withstand constraints, do not have time to adapt to this situation. The consequence is a deformation of the cycles, which can even be totally verticalized, with a significant reduction of muscular strength and functional efficiency. (Johnsen and Trulsson 2003). It is surprising that this natural model and its anatomo-functional convergences are still ignored today, whereas they have been observed in numerous anatomical works published since Jones and d'Amico.

E- D'AMICO AND CHEWING

D'Amico deals with mastication by quoting almost in extenso an article by H. Jones from 1947. The latter describes mastication: *"… Briefly, the mandible is thrust laterally so that the buccal cusps of the lower posterior teeth occlude with the lateral border of the buccal cusps of the maxillary teeth on that side. The temporal, masseter and internal pterygoid muscles then crush the occluding teeth together, and at the same time the mandible moves medially and slightly upward to the position of centric occlusion."*(Jones p 256 ,quoted by D'Amico 1958 N°2 point: 15) Jones's description, though succinct, is already in keeping with our current knowledge of chewing cycle entry (Figure 5B3-1, 5B3-2). **D'Amico's subsequent proposals will be contrary to these descriptions because the preeminence of the guidance of chewing will be left to the canine, like on the articulators** ... Jones continues: *"Mastication is from lateral to medial, and is unilateral, the teeth of the opposite side* (not chewing) *being definitely not in contact: The food bolus is, by means of the tongue and teeth kept on that side only where the shearing stresses are taking place."*(Jones p 256 ,quoted by D'Amico 1958 N°2 point:15) .

The description, by Jones, stops just at the passage in maximum intercuspation. The second dental part of the cycle (the dental cycle-out) is not described, whereas it is the crushing part of the cycle (Figure 5B3-2, 5B3-3). Does Jones consider that it should not exist and that the first part of the cycle should be followed by a vertical opening? This is perhaps not surprising since among Australian aborigines living in primitive conditions, with an abrasive diet, the molar cycle exits were already totally worn out when they observed them. In these circumstances, it is not surprising that he did not describe them because they no longer existed and/or that he considered this wear to be abnormal.

However, there is some inconsistency in ignoring the internal slopes of the upper palatal cusps and their opposites, whereas it is these cycle-out sides, which are the crushing component, that serve the most and therefore wear-out more quickly, especially on an abrasive vegetable diet, until the frontal occlusal plane normally oriented in a curve described by Wilson is inverted (Monson first described this curve and that of Spee as being integrated into a same sphere of 8', which has not been validated). Ackerman described these wear curves as being helicoidal. It is the wear of the cycle-out of molar (the internal slopes of the mandibular buccal cusps against the internal slopes of the maxillary palatal cusps) which gives this helicoidal shape to the occlusal plane. This phenomenon is regularly observed in all ancient anthropoid populations with a very abrasive food repertoire (hard, raw, vegetable or other) and given their constancy in situation, on the cycle-out, they can not be confused with parafunctions, like bruxism (Figure 5E-6, 5F-4).

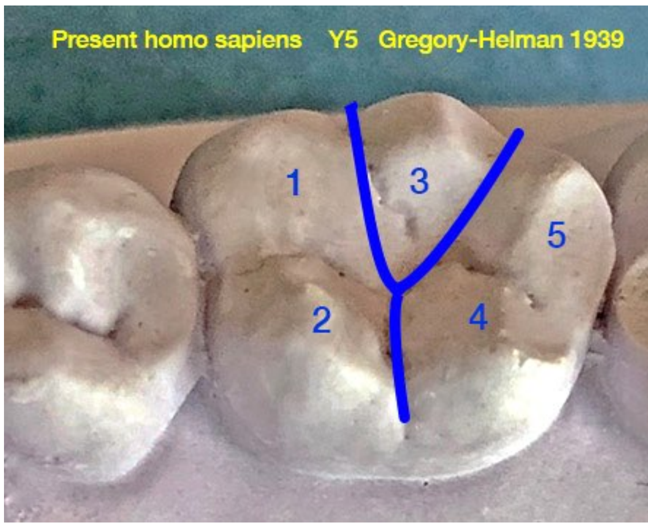
Jones' conclusions about the non-hereditary nature of edge-to-dge bite could have been usefully complemented if, he had observed young aborigines chewing on a western style diet which is minimally abrasive.

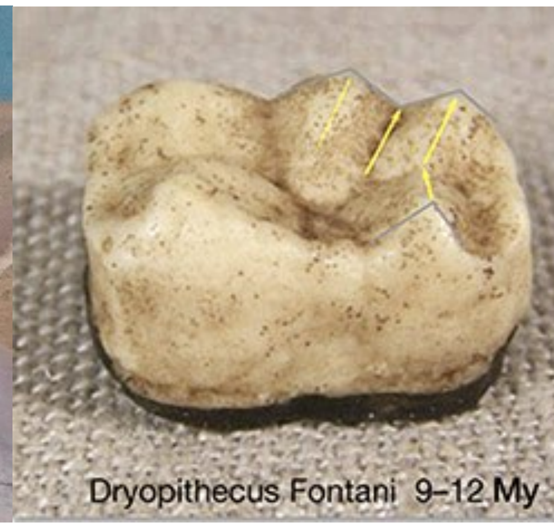
About the occlusal anatomy of molars, D'Amico (No.1 1958) also quotes Gregory and Hellman who wrote in 1939:

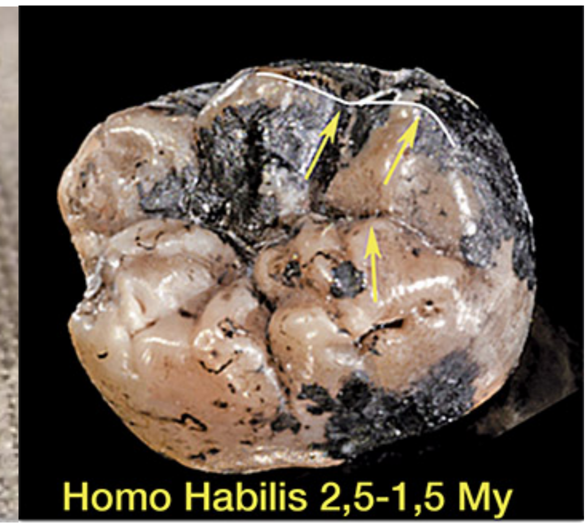
> *"The lower molars of apes and primitive men show various modifications of what we have called the Dryopithecus pattern, because this pattern is seen in its primitive form in the fossil ape of that name. On the outer side of each lower molar, there are three main cusps, numbered in our system 1, 3, 5. Number 3 is bounded on its inner slope by two grooves that form a V and the tip of the V is continued to the inner side of the crown, forming a Y."* (Gregory and Hellman1926; Gregory and Hellman,1939, quoted by D'Amico 1958 N°1 p19) (Figure 5E-1 to 5E-3).

This configuration (Figure 5E-5) is often described as a Y5 motif by paleo-anthropologists (Granat 2001). The static description is good, but we can regret:

- on the one hand, that Gregory and Hellman did not observe the guiding facets of chewing on the occlusal surfaces of these molars where, they are very present.
- on the other hand, in his reflections D'Amico did not take account of these descriptions, of teeth with anatomy integration.
- It is not possible to determine the functional model of anthropoids from totally abraded and flattened teeth, whose occlusal morphology is totally destroyed. It should be done on young adults still having occlusal faces slightly abraded and enjoying all their guiding potential. It is on such occlusal surfaces that Gregory and Hellman described the dryopithecus Y5 model without occluding it because they probably did not have the antagonists.







5E-1 5E-2 5E-3

Figure,5E-1: View of Y5 pattern dryopithecus (Gregory and Hellman 1926, 1939) on a current human model. The numbering of the cusps is that adopted by Gregory and Hellman.

5E-2 View of a mandibular M1 of dryopithecus fontani (St Gaudens France) 12-9My. The configuration of the guide rails is similar to the current man.

5E-3 View of a mandibular M1 of homo abilis (2.5-1.5My), with a similar pattern

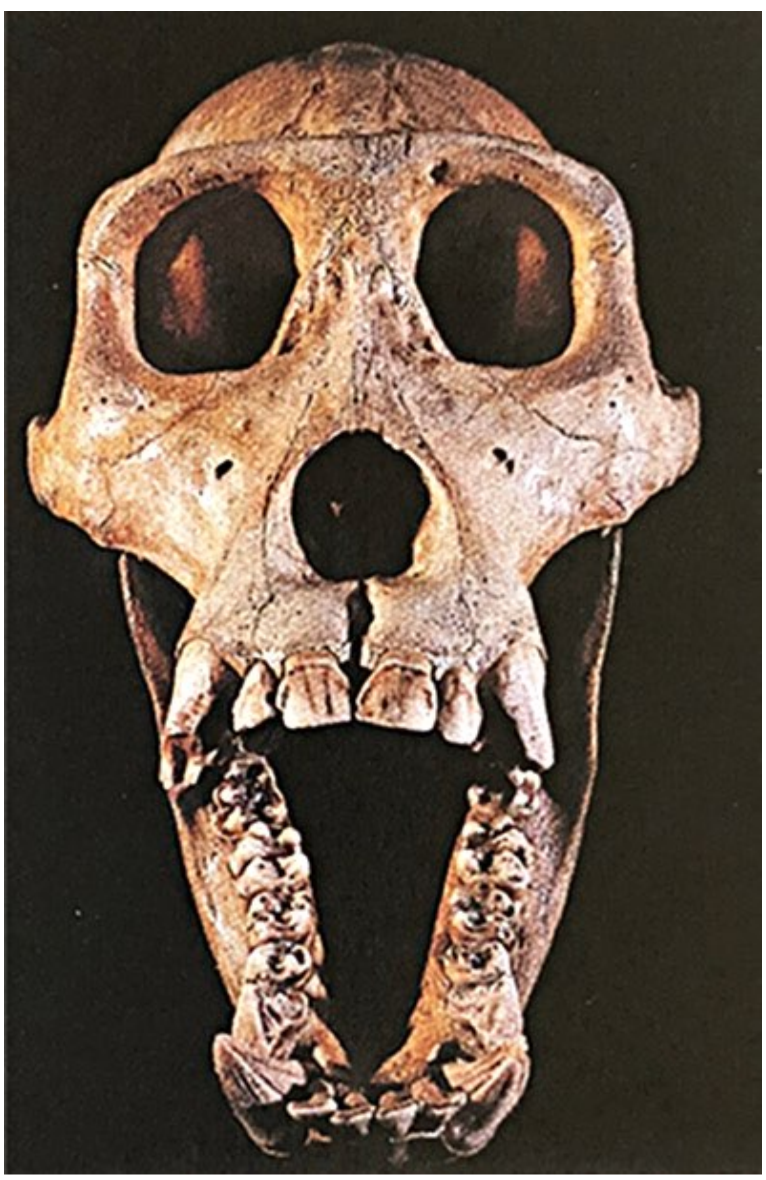
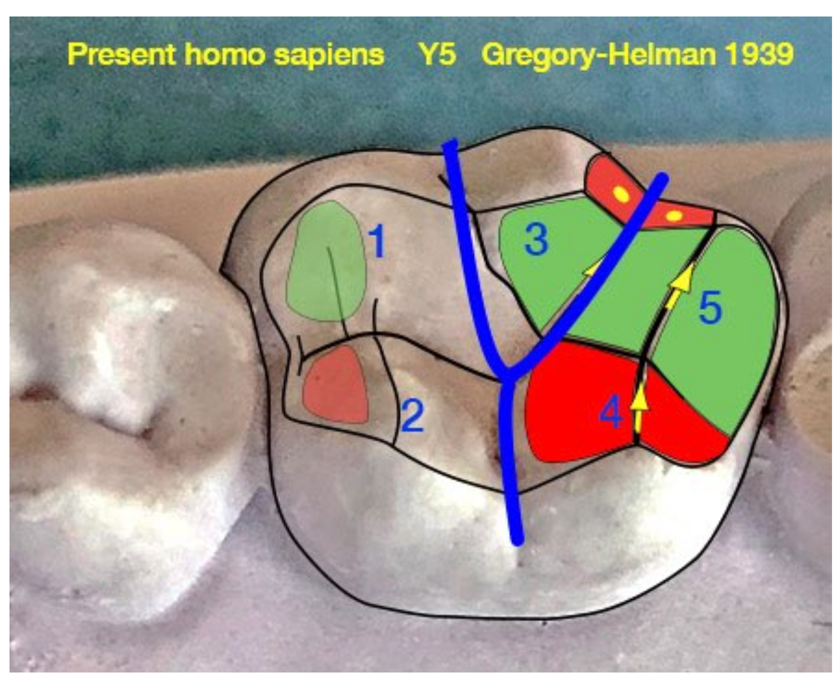


Figure 5E-4: (Coppens-Picq) View of an anthropoid (32My) The pattern Y5 dryopithecus is already present on M1 (small), M2 and M3 (much larger)

5E-5: The integration of mastication guidances ,of a current man, in the Y5 ancestral pattern, shows that it is the same functioning model for more than 32 My.

<<Fig 5E-4 Fig 5E-5



This dynamic pairing, between the enamel bridge of maxillary molars and the V receptacle of the opposite Y5 configuration, has existed on all three molars for more than 32 million years (Figure 5E-4). It is observable with its transverse functional facets, when the occlusal faces still have their integrity. Initially the volume of M_1 was significantly lower than that of M_2 which themselves had a volume lower than M3. This configuration was maintained very long. The cooking of the foods (first occasional fires towards 1,5 My and certain control of the fire towards 465ka - Menez Dregan 29780 Plouhinec Fr) modified the previous balances. M_1 has grown and keeps the Y5 configuration, M_2 has decreased in volume and M_3 even more. M_2 often loses the Y5 configuration to keep only 4 cross cusps, as well as M_3 whose anatomy is inconsistent. But overall the model remains the same. It's still, that of current men.

We can even propose the hypothesis that, on individuals whose average life expectancy was a little more than 20 years, the presence of the Y5 configuration, on the three mandibular molars, is an adaptive response to the rapid wear of occlusal tables by plants. The early loss of the

Figure 5E-6: Homo Naledi (photo Lee Berger) between 1 and 2 My
All molars still have the Y5 Dryopithecus configuration, which gives the best guiding ability. The molar volume is still slightly increasing from M1 to M3, but much less than the ancestral configuration. It can be noted that M1 has lost all its guiding capacity, that M2 will soon lose it and that only M3 still retains cusps and their guide rails

dynamic guidance of M_1 is compensated by the occlusion of the rails, and guidance of M_2, then after the wear of M_2, by those of M_3. The increasing volumes of M_2 and M_3, with a thick enamel, result from an adaptation to the mastication of hard food. This presumed adaptive response would have allowed them to retain guidance and masticatory efficiency in their short lives (Figure 5E-6).

F- GENERAL EVOLUTION OF THE MODEL

The functioning model of Man and more generally that of simians and anthropoids is an omnivorous generalist model that has no capacity for self-regeneration, unlike other highly specialized animal models. It's initial characteristics (Figures 5F-1, 5F-2, 5F-3), such as its alternating unilateral mastication and occlusal morphology, are highly versatile and efficient, and are progressively damaged, according to the longevity, the abrasiveness of the available food repertoire, its preparation and the environment.

When the occlusal surfaces are degraded, while flattening, and the vertical dimension collapses, the chewing gradually passes to a different functioning, in Balanced Occlusion, by losing a big part of its functional efficiency.

This adaptation to wear, personalized and multiform, has often been confused with a model to imitate, while it is only the consequence of the degradation of the system, and ageing.

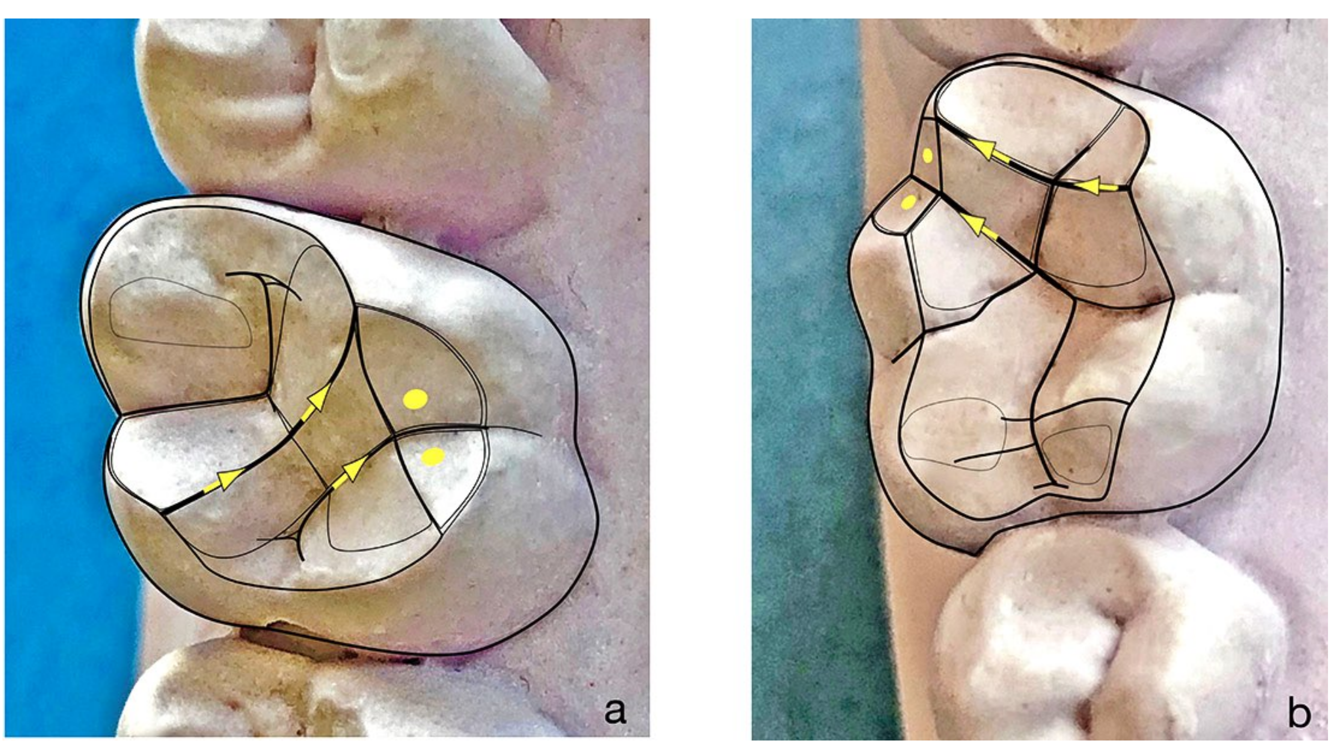


Figure 5F-1a, Occlusal views of a patient's models, centered on maxillary and mandibular M1. The guidelines of the chewing guides, delimited by the wear facets were plotted. The arrows indicate the sliding direction of the facets. -69a- The maxillary M1 main guidance passes through the enamel bridge. In the maxilla, the sliding of the facets is centripetal.
5F-1,b-The mandibular M1 guide rails fit into the Y5 model. The sliding of the facets is centrifugal at the mandible, whereas the displacement of the mandible is centripetal.

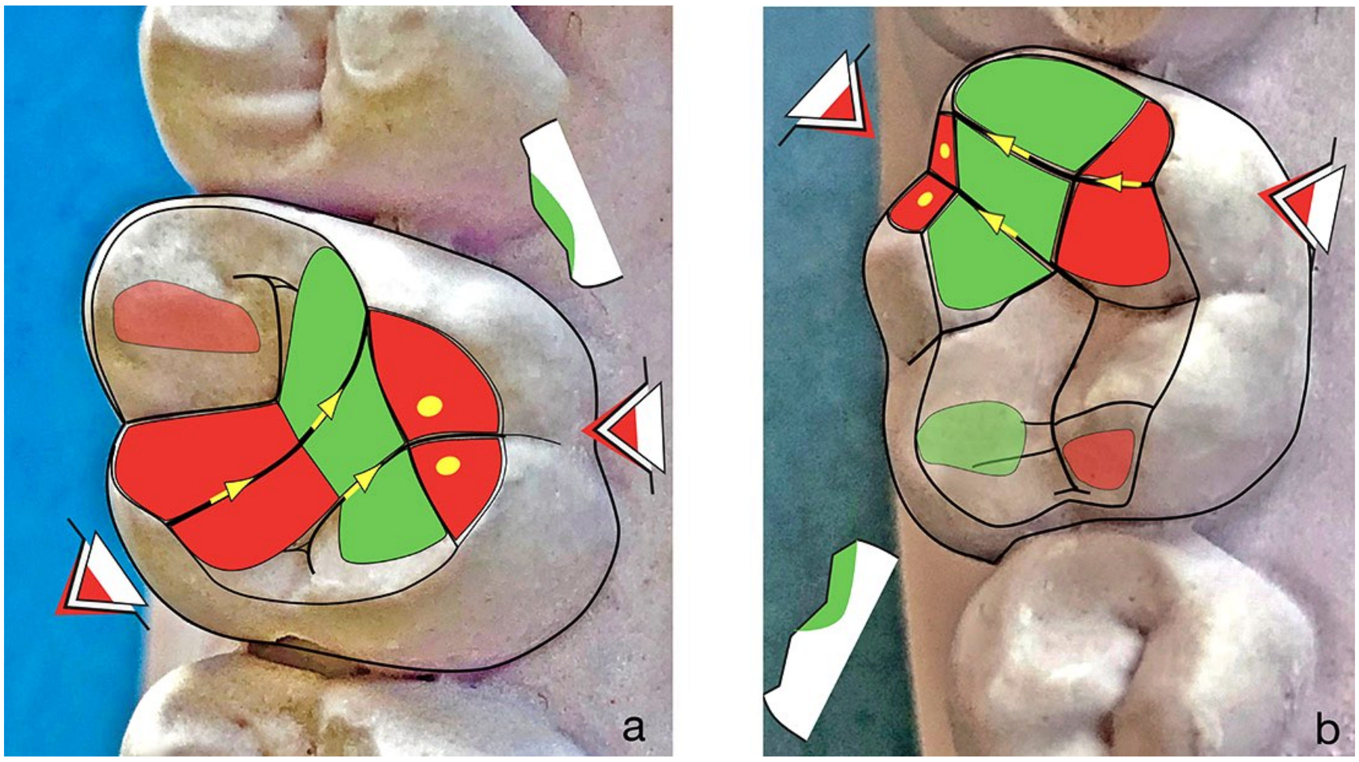


Figure 5F-2a,b: Occlusal views of models of the same patient, centered on maxillary and mandibular M1. The guidelines of the chewing guidances, delimited by the wear facets were plotted. The arrows indicate the direction of sliding of the facets. The guide surfaces and supports of the double guidance of cycle-in are in red color. The tables of cycle-out, in reciprocal gliding contact, are identified in green

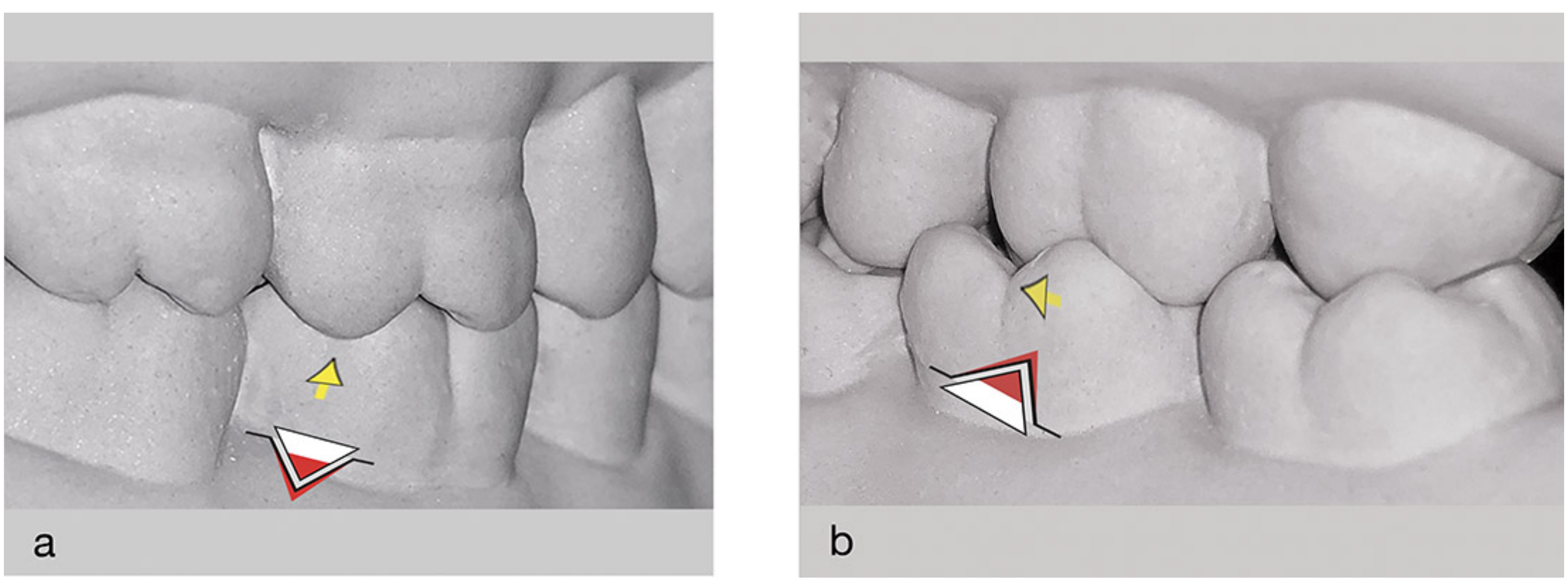


Figure 5F-3a Buccal view of the M1 maxillary disto-buccal cusp that supports the maxillary main rail on its internal slope, which then passes through the enamel bridge.
Figure 5F-3b Lingual view of the M1 mandibular disto-lingual cusp that supports the beginning of the inverted rail supporting the second cycle in guide on its inner side. This double guide is self-stabilizing for the teeth during cycle in.

The ambition of every practitioner must be to restore the harmonious functioning of the masticatory apparatus and to do so, a thorough knowledge of the initial functioning model is required. (As an example: when studying the physiology of walking, we do not take a lame model).

Wear by attrition is very widely discussed by d'Amico, but incompletely, because pre-existing occlusal relationships are not well described. For example, in d'Amico's model, protrusion and

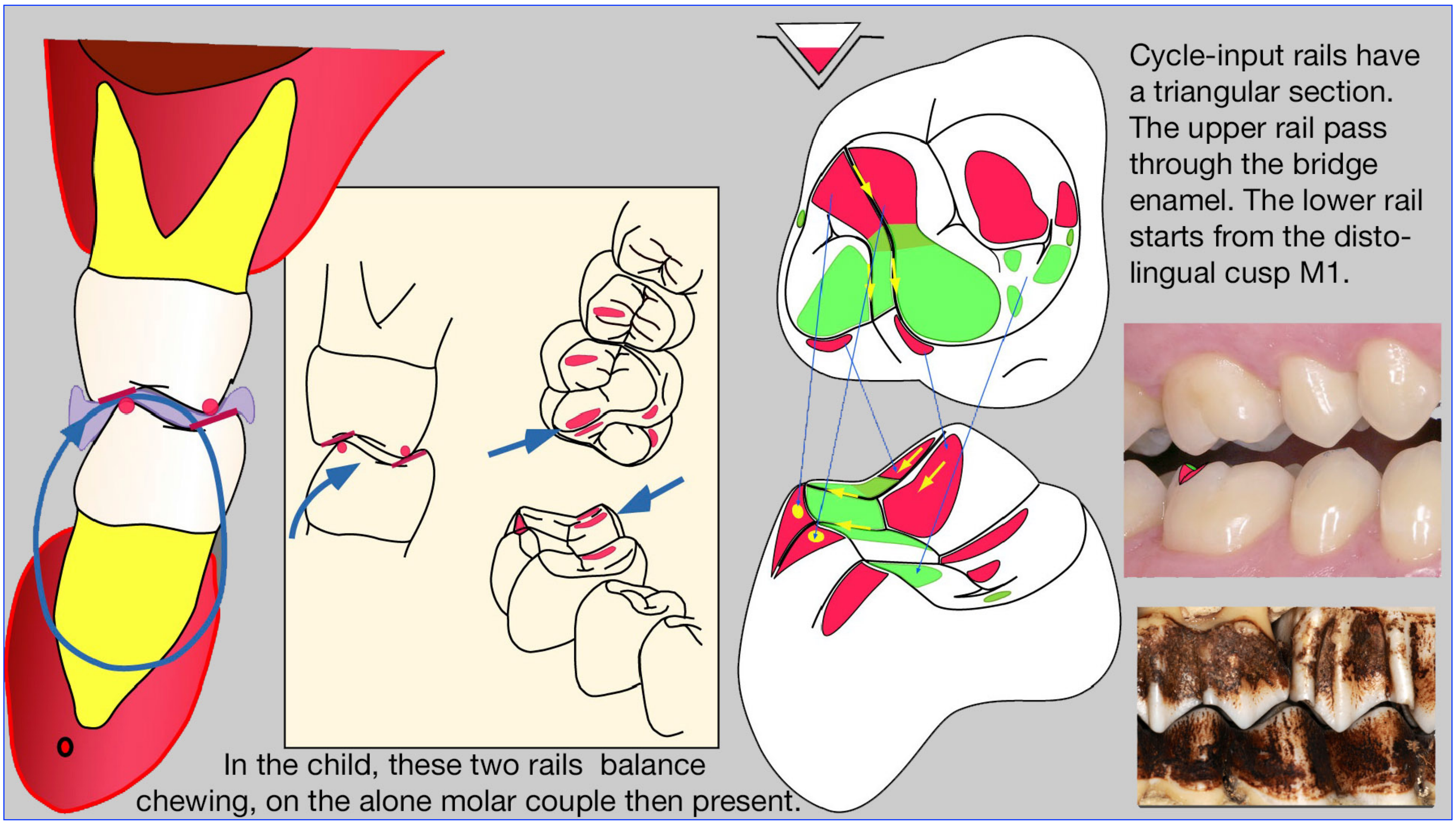


Figure 5F-4: *At the passage of the MIO, the continuity of the cycle in rails is first ensured by the enamel bridge and, with progressive wear, also by the mandibular rail. Such rails exist in manv mammals.*

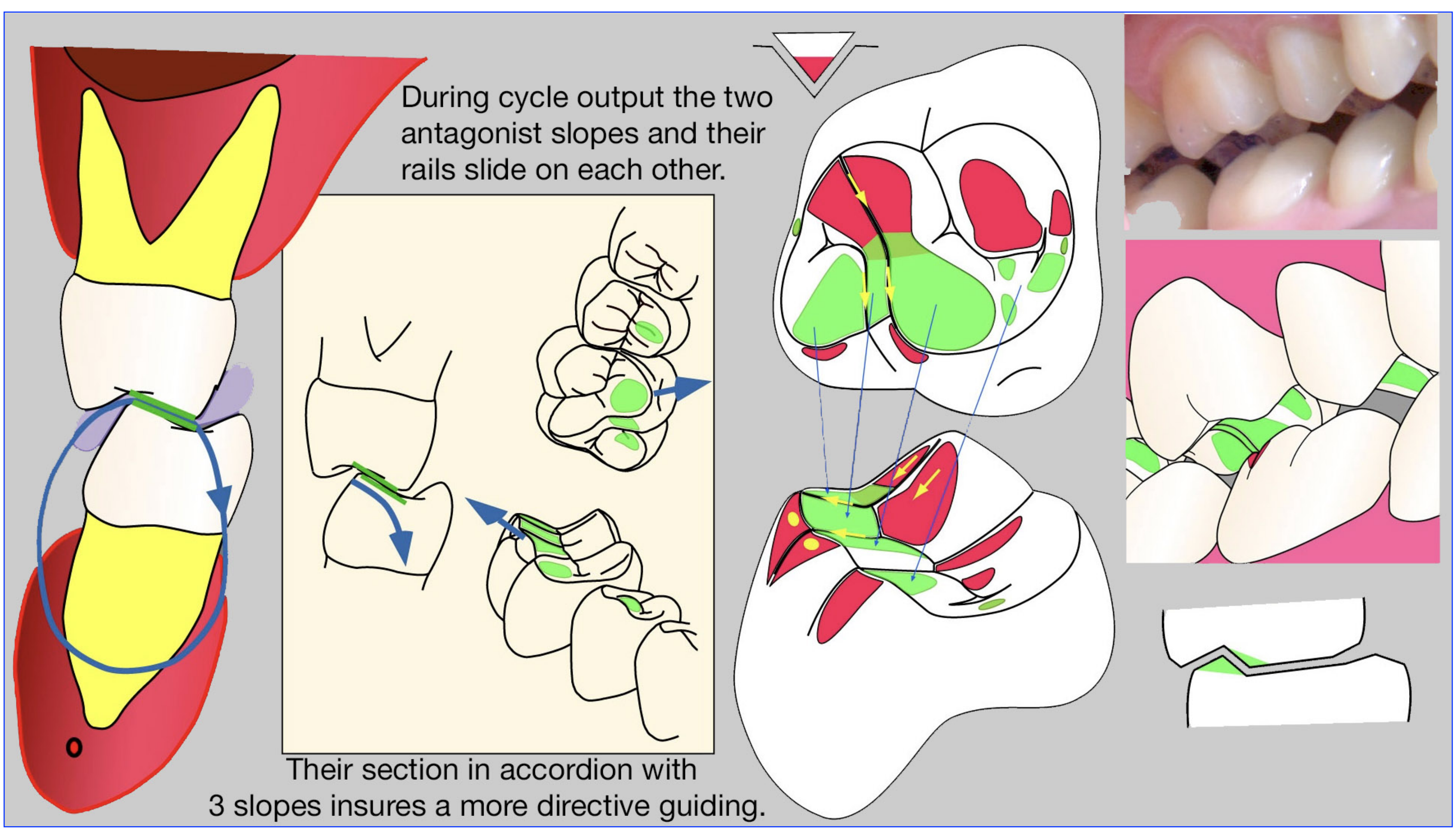


Figure 5F-5: *The cycle in rails extend at the cycle out by a double rail with three slopes flanked accordion. This guiding structure is well identifiable on the driopithecus (5E-2) and habilis (5E-3) models. This is the same operating model. This model of 5 cusp molar (Y5) allows the operation of the guide rail of the enamel bridge. The enamel bridge and the Y5 configuration are identifiable on models of over 32 Ma (aegyptopithecus zeuxis).*

incision are also supported by the canines, which is not the natural model of man (D'Amico N ° 6 1958 p 200). In addition there is no reference to bio-corrosion, the consequences of which on the degradation of the model are also very important.

While the cycle output tables are the most used, and therefore the most worn, d'Amico systematically criticizes *"An extra-ordinary or excessive use of teeth."* during cycle-out, to justify canine protection as: N°4 1958 p.127: *"To increase the leverage of the mandible in order to eat and crush hard foods more readily, the primitive instinctively learned to exercise the internal pterygoïd so as to move the mandible medially while the temporal and masseter muscles moved it vertically. This produces a glancing* (transverse) *shearing action of the buccal cusps, increasing their efficiency in function. However,* ***as the lingual cusps of the upper teeth glide laterally on the transverse ridges of the buccal cusps of the lowers, the abrasive nature of the food hastens the wear of those cusps."*** (D'Amico N°4 1958 p.127)*"*.

He deals with the transversal displacement caused by the action of the Pterygoid Medial as an adaptive mode acquired. The understanding of the PM's role is incomplete. Now the masticatory apparatus obeys a central programming, of which all the components work in synergy: *"the receiver field of periodontal afferents of the posterior teeth is very well adapted to the signalling of information coming from the bolus and ensures the regulation of the vertical and horizontal forces developed by muscles during mastication"* (Johnsen and Trulsson, 2005 p1889), ie the muscles, temporalis, masseters, medial and lateral pterygoids. Chewing is a primary function of our physiology, which is not receptive to learning. It has to be receptive to learning but that is neurological). Johnsen and Trulsson's neuro-physiology work discredits many of d'Amico's predecessor and subsequent statements.

The functional dynamic relation of human molars is not random, nor under the control of the will. It is organized and channeled during, the dental entry and exit of the cycle, and has just been described.

The environmental conditions and nutritional repertoire that prevailed among anthropoids and primitive human societies, before and since the control of fire and cooking, have not been discussed either and have evolved considerably, since the publications of Gregory, Hellman, Jones and d'Amico.

Figures 5F-6 and 5F-7 illustrate the helical wear of the cycle output tables.

In primitive societies, the progressive diagonal mesialization of the mandible, due to the rapid wear of the cycle exit tables, led to the early onset of strong contact on the non-chewing side, on the internal slopes of the maxillary buccal cusps of P and C and in the palatal concavity of

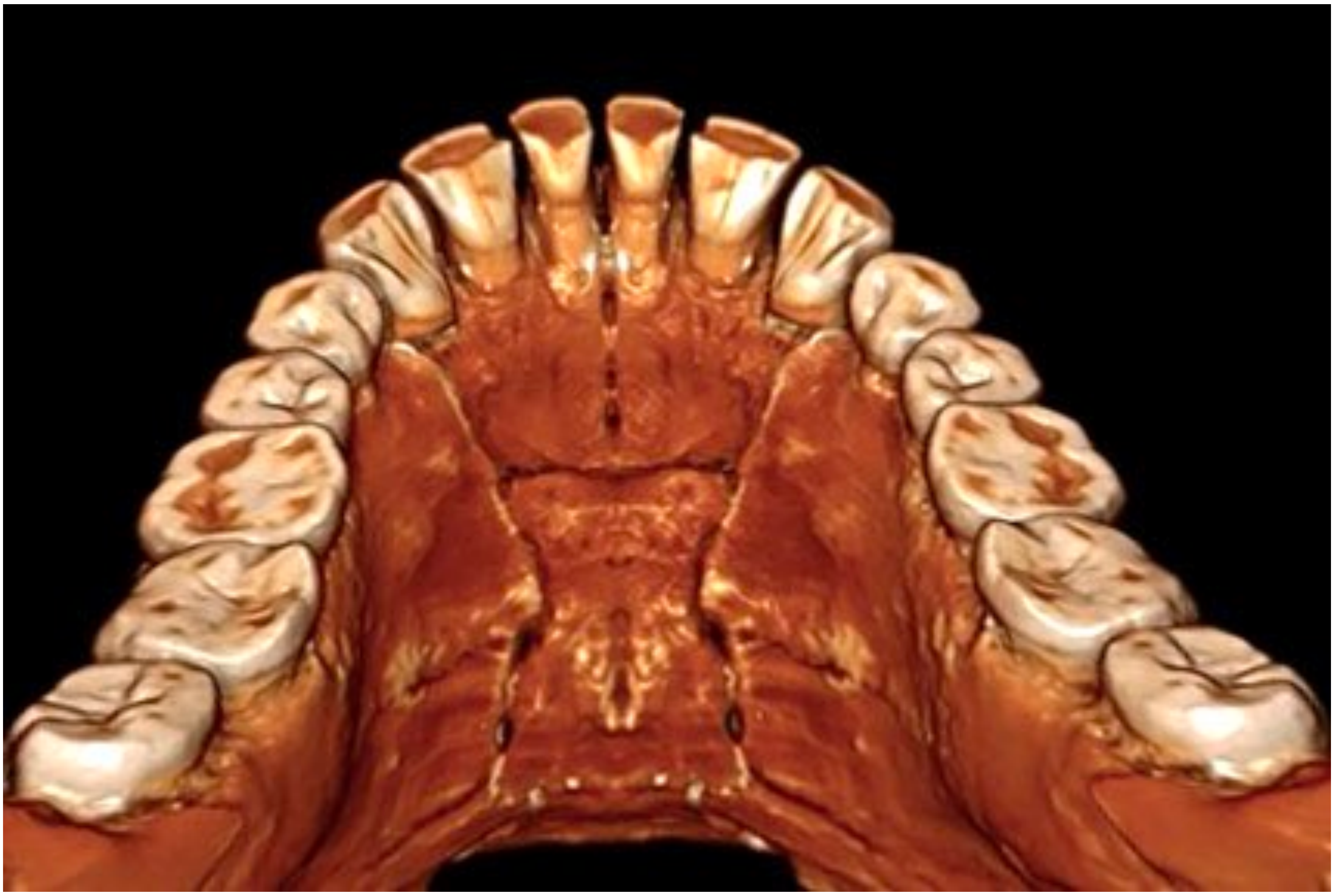


Figure 5F-6: Homo sapiens 315Ky Jebel Irhoud Morocco (2017) photo J. Hublin.
In primitive populations, the early onset of edge-to-edge bite, finds a consistent explanation in the rapid loss of occlusal wedging and the volume of molar cycle output tables (helical wear), with or without loss of VDO. Indeed, in similar situations on current patients, the simple test of restoration of the lost volume of the cycle outputs of posterior teeth, by addition of composite, makes it possible to stabilize the former drift (and even to reduce it slightly) and to find again instantly patient comfort.

the maxillary incisors. This drift accompanied a gradual decrease in the vertical dimension that ultimately led to the loss of all occlusal morphology, with edge-to-edge incisors, even in adolescents. The initial natural functional model was destroyed and replaced by custom adaptive modes, not subject to any normative classification. This resulted in deformed or vertical cycles, a loss of functional efficacy, with or without DAM, depending on the type of relationship with joint kinetics.

Figure 5F-7 provides a consistent explanation for the progressive mesialization of teeth described in the manuals. Depending on the typology of the patient and the stability of the dental units, the anterior drift of the mandible can result in:

- either by a mesial and transversal displacement of the maxillary teeth,
- either if they are very stable by their wear and an edge-to-edge occlusion,

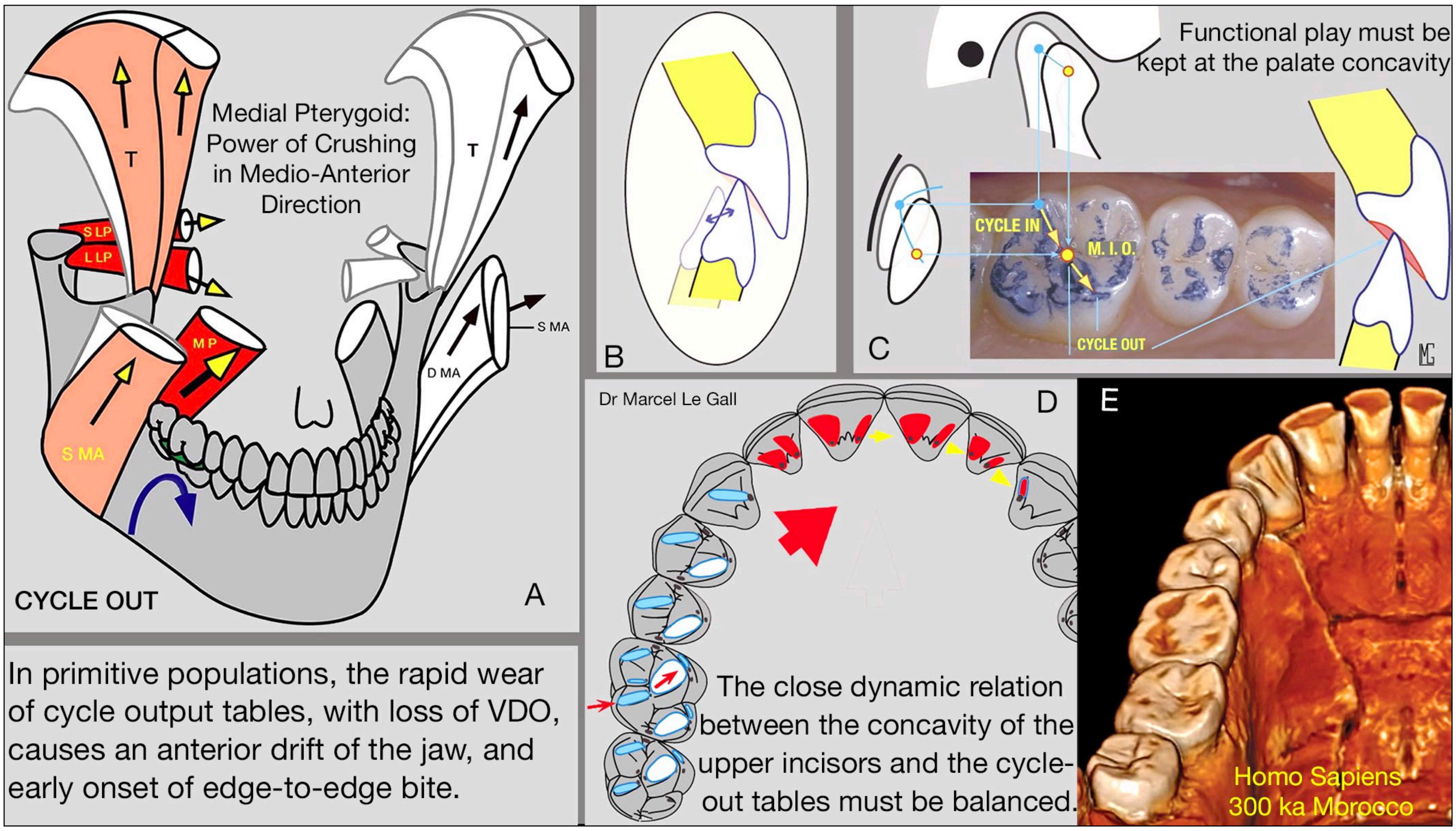


Figure 5F-7: In the human line, the constant wear of the cycle exit tables has led Amico to propose the concept of canine protection, reducing the muscular power and the masticatory efficiency of the posterior teeth. As a result, even today the palatal exit tables of maxillary molars, in particular, are too often reduced on restorations. For example, in implantology, where the concept of premolarization of molars has been proposed. Under these conditions, decreasing the outputs of cycles of the molars, there are constant remarks from patients indicating that, during chewing, their mandibular incisors are in permanent contact with the concavity of the maxillary one's and that they feel "too low". These concepts of minimization are unphysiological, in relation to the real capacities of the man's masticatory apparatus.

- either, depending on the level of loss of DVO and on the behaviour of the tongue in a reduced functional volume. It's protrusion and/or interposition may be responsible for mesialization and secondary displacement of all teeth.

In today's developed societies it is generally only observed in older individuals, except for biocorrosion. This wear therefore depends directly on the composition of the diet and especially its preparation.

She does not have such an "extra-ordinary" character as d'Amico's writings claim to justify cuspid protection. Indeed, in today's societies, although the preparation and abrasiveness of the food repertoire are well controlled, the same is not true of the acidity of certain foods and drinks and sodas containing citric or phosphoric acid. (Ph 2.7) which are still responsible for uncontrolled bio-corrosion. These habits, although globalized, are modifiable. They can be corrected, but with difficulty.

The problem of the preventive control of the bio-corrosion remains whole. The techniques of addition and bonding should nevertheless allow the functional and sustainable restoration of the losses of substances for which it is responsible. Indeed, the main ceramic and composite restoration materials are not attacked by bio-corrosion. Moreover, the current composites, micro or nano charged, have a wear modulus similar to natural teeth (Lambrechts P et al 2006). An independent comparative test of some recent machining blocks made of composite or ceramic, used in CADCAM, shows an identical wear of some composites and their opposing tooth, which is not the case for ceramics whose opposing teeth all exhibit more wear (Stawarczyk et al., 2016). The solution of this problem has never been so close.

G- CANINE PROTECTION: TMD AND IMPLANTS

1- CPO and Temporomandibular Disorders (chapter from www.mastication-ppp;net)

In the seventies, TM Disorders have been very often imputed to occlusion. Two currents of thought were then opposed: An occlusal approach (Rosenthal 1980) and a psycho-physiologic approach (Laskin 1969,1977).

The attempts at occlusal treatment of TMD, based on the gnathologic model (CR+CPO) , gave very poor results with very high failure rates (Moloney and Howard 1986 64%, Palla 1996 45%, Le Bell and Kirkeskari 1990 59%, Molhin and al 2004 75%)..

Today a multifactorial aetiology is admitted for TMD, and occlusal aetiology is not regarded as the only primary factor (Rinchuse et al 2007). Its rate of involvement would be situated between 10 and 20% (Mac Namara et al 1995).

Otherwise the evidence-based view on occlusion and TMD does not argue or conclude that occlusion has no relevance to TMD (Rinchuse 2007)..

A literature review on the topic by Rinchuse (2006) concluded “that occlusion and orthodontic treatment do not cause TMD, and occlusal adjustments are not recommended for the initial treatment of TMD”.

How credible are these contradictory data? While applying them, the success rate of Tmd treatment has not been significantly improved.

It’s essential to question on the reason for such high failure rates reported above:

- Have all of the clinical parameters been well assessed?

- Is the treatment appropriate?
- Are there other alternative therapies?

The various possible aetiologies, of TMD have been assessed, but regarding occlusion, the numerous studies have been linked to the **classical CPO model** (canine protected occlusion) which *"is equivocal and unsupported by the evidence-based literature"* (Rinchuse 2007), because it doesn't takes into account chewing function and swallowing, the two originator functions of the masticatory apparatus. **In fact we have shown that it takes into account, only a very reduced part of the real functional envelope and in reverse orientation.**

We can not draw definitive conclusions on such fragile bases and the peremptory judgments made about the non-involvement of occlusion in TMD.

For in the context of the human body, the restoration of physiology of the anatomical structures of an injured organ, is a necessary and often sufficient end goal objective. In the TMD context, one can then well understand why, pain resolution and healing, could not be obtained, if the functional physiology of the masticatory apparatus is not restored.

The relationship between occlusion and TMD must not be, a priori, questioned, but rather the functioning model and the occlusal procedures used.
To find relevant data on the real percentage of TMD resulting from occlusal origin, it's essential to take into account the natural model of man, founded on deglutition and mastication.
There is a kinetic and anatomic close relation between the shape of occlusal faces and TMJ, that has been established during growth.
Furthermore, in a child, we have seen that anomalous occlusal relations (class 2, Class 3…) are related to abnormalities of tongue posture (Deffez et al 1995, Bonnet 1992, 93,99) and are co-responsible for disorders in facial growth and progressive dysmorphoses, like defects in vertical, transversal and anterior growth, possibly resulting in anomalies of mandible posture. If the growth is not reoriented early (Bonnet 2010, Deshaies 2010), these dysmorphoses will worsen and there secondary treatment possibly requiring orthognathic surgery.

In the adult, articular anatomy and occlusal guidances will maintain their coordination by a progressive adaptation (Mongini, 1972, 75, 77). The functional coordination of articular surfaces is maintained by the constant postural tone of the elevator muscles.

But the occlusal anatomy of the teeth can be quite quickly destroyed by wear, biocorrosion (with TMD or not) or more brutally by the loss of the teeth. In this case, if the system does not have time to adapt, it goes into protection.

The objective of the occlusal reconstruction (from a restored VDO and an MIO granted with the swallowing position) is to put the contacts and dental guides in functional coordination within the envelope of the articular movements, in the state of adaptation-wear where the joints are, at the time of the restoration, because the TMJ are then the only memory of the preexisting functional occlusal kinetics of lost occlusal surfaces.

When the harmonious coordination of the guides, between occlusal surfaces and joints, is reestablished, the dento-articular system resumes its physiological functioning, the optimal envelope of the cycles is recovered spontaneously and without learning and the pains and clicks disappear (provided there is no disc lesions, and the tension factors are controlled).

Vidéo YouTube, click on the following link: https://youtu.be/-QBFdJZcWKc

Clinical case of a Young woman, dental practitioner, with a past of orthodontist treatment. The right side is the dominant chewing side (optimal guidances and breadth cycle).The left side is a rarely used (misguidance, vertical cycle and TMJ noise). When the choice is possible, it's alway the side with the best coordinated guidances that becomes the preferred chewing side. Left side is balanced in CPO. Either centrifugal or centripetal movement have a Canine Protected Occlusion (it's ideal for a gnathologist, but in reality the human model does not work that way).

Similar results are constantly observed. The restoration of the functional guidances on the first molars is generally sufficient to find again the cycle breadth. Occasionally it's necessary to add to the second bicuspids. The next teeth, are then progressively integrated to the restored functional scheme. If first molars are missing, coordinated guidances between second molar and bicuspids are generally sufficient. To only reestablish the bicuspids does not allow the maximum breadth of a cycle, because their guiding potential is small-scaled.

These are not conceptual statements, but observation of results obtained regularly and progressively improved for nearly 20 years, in clinical practice and during workshops on occlusion. If in private practice the results could not be easily quantified, it is not the same in clinical occlusion training, where the vast majority of cases were filmed or documented.

Over a period of more than 16 years (the exact figures are missing beyond this date), more than 80 occlusion training sessions, of two days, were organized with an average of 10 participants (updated July 2019). Following the analysis of the models, the closing path of all the participants was checked and balanced, if necessary, using the protocol of the anterior jig, already described.

Vidéo YouTube, click on the following link: https://youtu.be/PQ3Y0arluWs

The patient is a man, a dental practitioner. Antecedent of orthodontics treatment. The closure path and the MIO have already been verified. There is incoordination of guidance on both sides, with adaptive cycles. The patient does not have the opportunity to choose the best chewing side, but only the one that works the least badly!

Two to five patients, with various subguidings, were then selected for composite addition tests, a low average of 3 per training, representing a total of at least 207 patients. In this context, positive results were obtained in more than 90% of cases. These results include immediate improvements in cycles, allowing restoration of chewing and occlusal comfort, increases in mandibular range of motion (opening, laterality), sedation of muscle pain and headache, reduction and/or immediate disappearance of articular noises. These tests also make it possible to detect almost immediately the patients who do not belong to an occlusal treatment and to reorient them quickly, ***without any occlusal mutilation*** because the tests were carried out by reversible addition of composite.

All these results have **gradually turned our doubts into certainties about the functional inadequacy of the gnathological model and the lack of relevance of the studies that have been conducted with reference only to it.**

New Modified Protocol

In the multi-factorial etiology of TMD, the restoration of occlusal physiology has been considered, as may be the aetiological treatment of dysfunctions, of dental origin.

The standard treatment protocol is to wear an orthosis to temporarily change occlusion relationship and then apply the CR and CPO concepts to balance the occlusion. Given the importance of failures, this protocol has been modified.

During the initial occlusal analysis, if a functional malocclusion is observed, reversible etiological tests are made immediately after the verification of the closing path and prior to any other treatment. They consist in, composite addition, aiming to restore balanced chewing guidances.

If symptoms improve immediately after the restoration of physiological cycles, the share of occlusal aetiology is considered decisive. If these tests are not followed by any improvement, the patient can be rapidly redirected to assess other possible aetiologies of dysfunction.

This etiological approach has led to numerous clinical successes, in comparison with the very high failure rates observed with the conventional occlusal model. In addition, this procedure has made it possible to considerably speed up the treatment of patients whose aetiology was occlusal.

It has become our clinical protocol for more than 20 years and in these conditions the recourse to the conventional treatment by therapeutic relaxing bite planes, has been reduced by approximately 90%.

Considering the important clinical successes (improvement in kinetics, decrease/disappearance of pain and joint noises) and immediate recurrences, when composite additions are coming off as a block, it became apparent that the restoration of functional occlusal physiology was the etiological treatment of TM Disorders with dento-articular origin. These results could not be quantified in private practice because it was difficult and they were unexpected. But they are similar to those obtained during the Practical Works that were estimated in the previous chapter. It remains to more accurately account for their results in prospective studies, and to determine their actual share in the multifactorial context of the aetiology of the TMD.

The patient who consults for temporomandibular disorders is a patient worried because he is suffering. When the restoration of functional dental balance allows the instantaneous disappearance of muscle contracture, responsible for pain, it has an immediate positive impact on confidence, stress level and its behavioural consequences. That's why it's important to relieve him quickly.

This is one of the reasons that led us to practice reversible aetiological tests as soon as possible, even if it means delaying additional examinations, which may then lose their indication, if the "composite-up" tests are positive (often). In fact we have never had to remove these additions of composites because they have always improved the comfort of the patient, even if sometimes the presence of structural lesions of TMJ. (confirmed by secondary MRI) did not allow the disappearance of the articular clinical signs.

2- CPO or Real Function: impact on peri-implant bone

A recent study: "Impact of the Occlusal Scheme on the Peri-Implant Crestal Bone Level" (The Gall and The Gall 2016) sought to evaluate the incidence of occlusal load level on the peri-implant bone. It was necessary to first select implant-abutment complexes, to better eliminate the risk of infection around the implants. This took time, but finally allowed to compare the ability of the main occlusal concepts to balance the occlusal surfaces and make them atraumatic for the implants they support.

From two implant lines, of the same concept, two groups were compared. The former has been balanced in canine protection and the second by simulating actual chewing.

The study is interesting because the immobility of implants amplifies the consequences of malocclusions and the absence of mechanoreceptors reduces the ability to avoid malocclusions. *For more details, the pdf of this work is available online at the following* ***Dropbox*** *address:*

https://www.dropbox.com/sh/s5djul5pa4y38np/AAB_Pid6iRrarg2lWXkOsN2qa?dl=0

Study and results: Implants Straumann Sin Octa ©

A clinical study of 2 years (Akça and Çerheli, 2008) compare the evolution of the bone level on 15 fixed restorations of 3 units on 2 implants with 34 fixed restorations of 3 units supported by one tooth and one implant, rigidly connected. Against all expectations they measured a significant bone level augmentation around the implants connected to natural teeth (+ 0,189mm in average), and a decreasing bone level around the implants connected together (-0,285mm in average).

Study and results: Implants Zimmer Swiss-Plus©

This is a retrospective study of a randomized group of 30 patients and 40 single or two connected implants. Only one implant was connected to a natural tooth. The prostheses were all sealed and the cement was thoroughly cleaned. These implants were all placed and the prostheses balanced by both authors.

The follow-up period ranges from 1 to 8 years. All the clinical cases illustrated above show an increase in the bone level and an improvement in its density, unexpected at the time of implant placement. The average bone gain is 1.33 mm with an average follow-up of 43.7 months. The general standard deviation ∂ is =1.51, indicating homogeneous, non-dispersed data. The average bone gain is high and significant (Fig 5G-1).

In the posterior areas, where the occlusal forces are much higher than in the anterior sector, the average vertical gain is 1.45 mm with a follow-up of 48 months, against 1.15 mm in the anterior. These figures are amazing and compare with those of Akça and Çehreli, who are negative for implants connected together, but for a more limited period of 2 years (Akça and Çehreli, 2008).

These figures clearly indicate that thorough occlusal adjustment during chewing makes the occlusal surfaces atraumatic, with well distributed forces and maintained within the bone

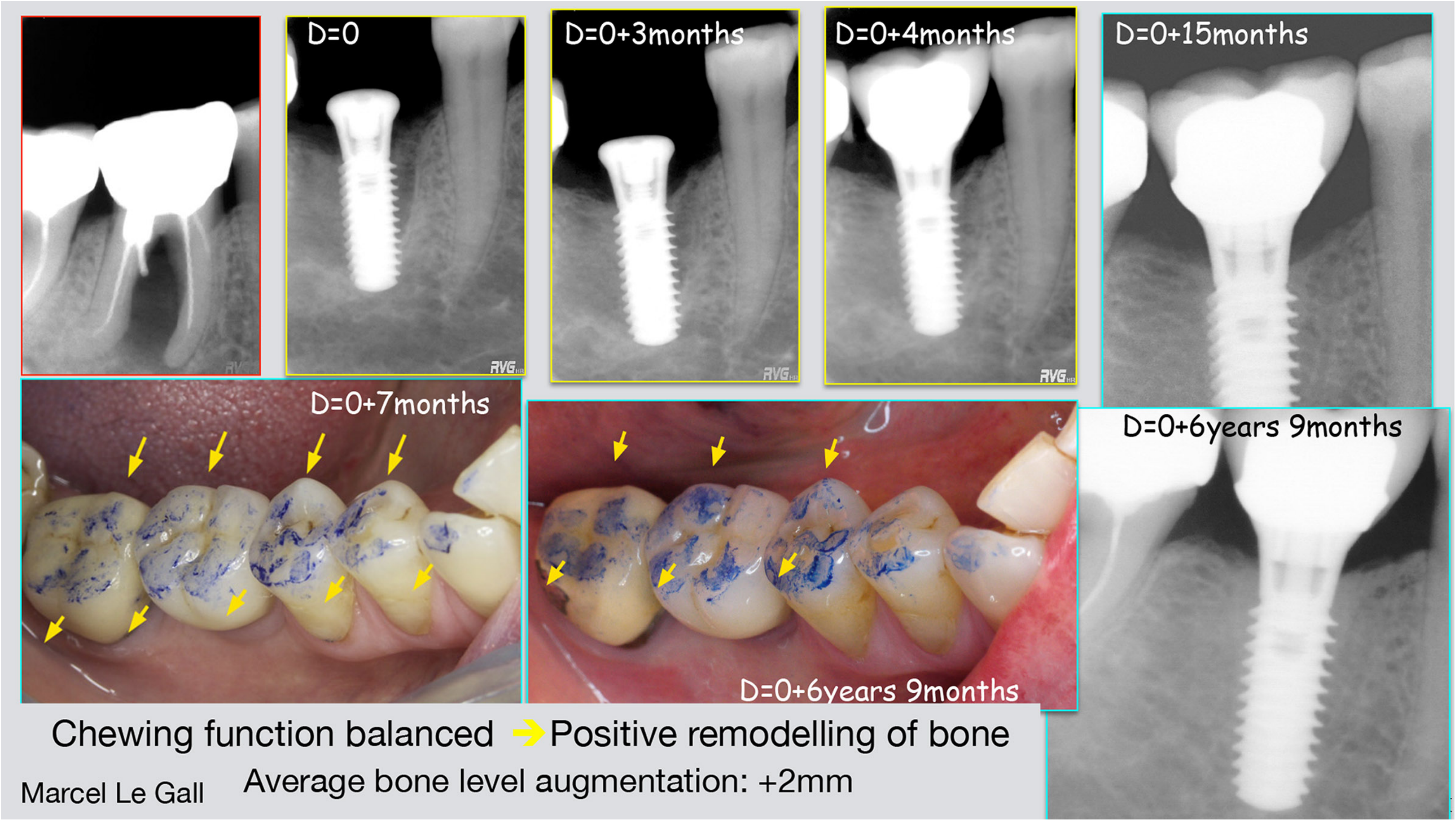


Figure 5G-1: The implant was placed 10 days after avulsion of the molar. The final restoration was placed and balanced 4 months after implant placement. The first picture was taken 3 months later. The second almost 7 years later. Between these two photos, no occlusal retouching was done. Only M3 was extracted. Chewing guides, initially non-dominant, have become progressively more marked, until they are similar to those of neighboring teeth, whose physiological functional wear is of the order of 40 µm per year. (Lambrechts et coll., 2006). The average bone gain between 4 and 15 months is 0.45 mm, between 24 and 81 months it is 1.55 mm. The average total gain is 2mm. With bone remodeling that continues throughout the observation period, particularly beyond 2 years. The new bone structure is reconstructed at the neck and its density is visually optimal.

stimulation range. The consequence is the achievement of unexpected bone gains and the radiological improvement of bone density (which is visible but has not been evaluated). This phenomenon is not limited to a single year but continues in time.

The consequences are interesting. They show that bone remodeling is not limited to a short period but probably continues as long as the stimulation exists (up to 8 years old in one case of this study and 12 years for another late case not included), it is the same for the bone density.

In addition, these results were obtained on implants whose machined titanium necks are simply flared, without microspires, nor switching platform, without complex shape or rough surface treatment at the level of the microgap. It is legitimate to question the real utility of these features, which were introduced with the aim of reducing bone loss around the neck of the implants and which most often lead to opposite results.

The results also show that, even if occlusal overload, interference or overguiding may be responsible for bone loss, conversely controlled and well-balanced loading conveys weak and stimulating forces to the peri-implant bone. which allow an increase in the bone level and an improvement in its density. The occlusal surfaces must be carefully balanced to maintain occlusal forces within the bone stimulation range.

The application of the concept of canine protection alone, which does not make it possible to balance the occlusal surfaces of the posterior sectors, shows negative results.
Only the respect of the natural model of mastication and swallowing allows the occlusal equilibration to reach the level of sufficient fineness, which is the decisive condition for maintaining and increasing the level of the peri-implant bone.
Conversely, it is clear that the gnathological concepts of occlusion must be abandoned in implantology because their to limited possibilities of equilibration make them dangerous for the durability of the implants.

SYNTHESIS

Chapter 6

The Essential

The masticatory function is a primary function of human physiology which must be respected and whatever the field of care, its preservation and restoration must be imposed as therapeutic objectives.

As long as the morphological and nutritional characteristics of the human species are preserved, they give it a great capacity of adaptation to varied environments. They represent a compromise that has enabled man to adapt to the different environments of our planet and has paved the way for his development and expansion on virtually the entire surface of the globe. Whatever the type of food available, the man was able to cook it, prepare it with his teeth, digest it and assimilate it. Under these conditions, the presence of continuously growing teeth could have been a disadvantage, because in areas with a dominant meat diet, the low abrasiveness of the meat would probably have been insufficient to compensate for the continuous growth of the teeth, by their wear.

In first analysis, a number of contradictions appear:

- between the reducing functional characteristics proposed by D'Amico and Jones as a model of human functioning, and our current knowledge of the actual functional capacity of the masticatory apparatus.
- D'Amico wrote that humans do not work in balanced occlusion, like herbivores, which is true for young adults with all their dental potential. But in the example he gives on the morphology of the dentition of herbivores, there is an inaccuracy. Indeed the horse (D'Amico 1958 No. 1 p 8) does not masticate balanced occlusion, (as previously described Chapter 4 B Figures

23-26). It has a chewing side and a non-chewing side in disclusion, like many other herbivores (Figures 4-27).

- Moreover, the observation of two hominids and a cercopitecid having lived in their natural environment with a diet defined by Amico as frugivorous, insectivore-carnivore, clearly shows for the first of them an extremely important attrition of all the occlusal surfaces (Fig 4-34-4-38), for the second a moderate/important occlusal attrition, but a significant biocorrosion of the exit tables of cycles (Fig 4-39). As for the third, it shows a mandibular occlusal anatomy largely destroyed by chemical erosion. These biocorrosion phenomena, totally ignored by Amico, are most likely to be related to the acidity of the frugivorous diet.

These findings clearly show the incomplete nature of d'Amico's thinking about the human diet and the rather dogmatic conclusions he draws from the "extra-ordinary" wear of the teeth during the mastication of herbaceous food and the little relevance of this reasoning, leading to the definition of a restrictive model of human functioning, in relation to its real possibilities and its optimal efficiency.

All these elements developed above lead us to consider, in agreement with G. V. Black, that the man is an omnivore, by his functional occlusal morphology and his ability to digest and assimilate an extremely varied diet. Its nutritional characteristics have been a decisive condition for its global expansion.

Agree or Disagree with d'Amico

In agreement with Amico and Jones, we will keep in mind that:

- the canine guides the eccentric laterality movement, on the same side
- the contralateral canine (non-chewing side) limits the amplitude of the guidance of the chewing cycle output table.
- The edge to edge bite of the anterior teeth result from the early occlusal wearing of the posterior teeth, especially the cycle out tables.

In disagreement with d'Amico and Jones, we will keep in mind that:

- the different definitions of the Inter-Maxillary Relationship in CR does not take into account lingual posture and swallowing,
- the functioning model of the man is generalist, omnivorous,
- the size of the canine is correlated with criteria of sexual selection, the incisors guide protrusion, sometimes with the canines. The incisors grip the bolus and usually guide the incision, often accompanied by the canines and posterior teeth.
- the occlusal anatomy of molars drive and give shape to the centripetal chewing cycles,
- The position of the canines, chewing and non-chewing side, was imposed, by the pre-existing chewing kinetics of M_1 couples,
- the canine, on chewing side, accompanies the centripetal cycle inputs,
- mechanical articulators can not reproduce the kinetics and rapprochement of posterior teeth during chewing,
- Incision and chewing guides, on natural and prosthetic teeth, must be checked and balanced in the mouth, for optimal functional efficiency.
- if they are not balanced in real function, malocclusions persist on the occlusal surfaces, which can be dangerous for the teeth, their periodontium and even more for the implants and responsible for peripheral bone loss, or malfunctions of the masticatory apparatus and TMJ disorders.
- if an equilibration is necessary, it must be realized and finalized in the mouth, by favouring the addition procedures.

CONCLUSION

Chapitre 7

Remaining in the scope of the princeps function of the natural teeth, it is clear for d'Amico and the publications he quotes, that the teeth are used first to chew. It seems useful to remember it, because many current authors on occlusion, which refer to d'Amico, seem to have totally forgotten. We can now add that they also serve to stall the mandible during swallowing.

The functioning model of the human masticatory apparatus is very old. D'Amico writes about it: *“Man has not specialized to the extent that herbivores have, and basically the morphology of his teeth remains the same as seen in Dryopithecus”* (D’Amico N°2 1958 P 51). The current human dental formula still has a first mandibular molar Dryopithecus type (9-12million years Gregory and Hellman 1926,1939). We have described the dynamic functioning of this configuration, in pairing with the guidance of the enamel bridge of the antagonist molar (Lauret and Le Gall 1994,1996). Well beyond the restrictive hypothesis of D'Amico on canine guidance, the morphology and especially the function of the Dryopithecus model remained the same. This functioning model is even older. It’s origins place it beyond 32million years (Coppens Y and Picq P: 2000) and it still exists today.

It is quite unlikely that we can say as much about cuspid protection in the near future ...

A remarkable quote by Georges Monson in 1932, taken by d’Amico is worth recalling: *“Instead of studying the movements of the condyles independently to détermine the relation of the two occluding surfaces of the teeth, we can, with check bites, go directly to the problem of occlusion.* ***The movements of the condyles can be considered a result and not a guide. The guiding element in the mastication of food is the cusps of the teeth when the first contact is made with the opposing teeth. While the condyles guide the mandible to the first contact of the teeth, the major guidance is the teeth”.*** (d’Amico, n ° 1, 1958, pp. 9-10)

We totally subscribe to this quote. Because when Monson writes that: *"The guiding element in the mastication…is the cusps of the teeth"* et *"the major guidance is the teeth"* It obviously refers to the posterior teeth. His observations correspond to what we regularly observe by rehabilitating the lost volumes of the molars in subguidage, mainly by addition of composite material (Figure 7-1). These addition tests, usually start on first molar pairs and are statically balanced, during swallowing and dynamically by chewing. When the functional balance between occlusal guidance and joint kinetics is restored, the protective mechanisms are instantly lifted, the muscle power is released and the cycles resume their amplitude and find their maximum efficiency, without any learning. These clinical protocols began to be described in 1998 (Le Gall and Lauret Mastication: implication for occlusal therapy 1998 PPAD) and were gradually developed and generalized. (Le Gall et Lauret 2002 2007,2011).

The understanding of the natural functioning of the masticatory apparatus, has been made by the observation of young adults having all their potential of dental guidance. These investigations gradually led to a better knowledge of its characteristics and the conditions of its better functional efficiency. (Lauret et Le Gall 1994, 1996; Le Gall et col 1994… Le Gall et Lauret 2004, 2007, 2011).

These advances invalidate a number of statements by D'Amico that appear incomplete and sometimes unfounded.

The second determining element is a definition of Dr. Forrest Orton to which we adhere completely:

Dr Forrest H. Orton déclares: *"Just what do we mean by the term "dental restoration?" Here is his definition: "A dental restoration" may be described to be any artificial substitute which restores the lost part of a tooth, an entire tooth, or any number of teeth. The substitute, however, must accurately restore the lost part or parts, and also must restore normal function of the same."*

"This definition is comprehensive and to the point, i.e., that we cannot call an artificial substitute a restoration, unless it restores normal function. The term normal means natural. pertaining to nature." (*Orton quoted by D'Amico N°7 July 1958 p 237*).

We simply have to agree on the definition of a natural function, without contesting and misinterpreting natural selection. As, for example, when D'Amico invents a simplified functioning model, which is not in agreement with the natural model of man. Or when he speaks of the intention of nature as to how the masticatory apparatus of man should work, and by suggesting that small canines in man *"seem to be evolutionary accidents"* (N ° 2 1958 p127), or, as below, by reserving the additions to the canines only (d'Amico N°6 1958 p 206-207):

"Restoring the abraded areas of the cuspids to their original dimension, so as to eliminate the possibility of developing horizontal vectors will not only be of great aid in periodontal therapy, but it will also prevent further fatigue of the entire periodontium. This procedure is far more desirable than the spot grinding of cusps and transverse ridges as advocated by the supporters of the "balanced" occlusion theory practising the equilibration method." Even if he fights against the supporters of balanced occlusion, it is regrettable that D'Amico, reserves the additions to the canines only, because the fact of not controlling and balancing the chewing directly in the mouth, will leave malocclusions on the occlusal surfaces, of posterior teeth, whose consequences may be detrimental to the teeth and their supporting tissues and contrary to the stated objectives.

All of these statements by D'Amico indicate an incomplete knowledge of the causal links that exist between form and function. The current concept of Causal Anatomy, that arose from these links, aims at designing prostheses to replace deficient organs and their function, which requires a thorough knowledge of functional anatomy. What was not the case of d'Amico, at the time or his reference articles were published.

D'Amico had there, more than 60 years ago, all the elements to describe the functional model of the man? Through these lines, it appears that no (Fig. 7-1).

Let us recall an additional paradox of d'Amico's thought:

-He quotes Orton as a reference whose vision, complete and coherent, concerns the restoration of lost functional volumes of all teeth.

-But unlike him, d'Amico proposes a model of functioning, copied on the disclusion of the articulator in laterality, which tries to prevent the functional contacts between the posterior teeth by advocating the rehabilitation of the lost functional volumes of only the canines. By not considering the simultaneous restoration of abraded posterior teeth, it may drastically reduce their functional effectiveness.

That's why in light of our current knowledge of mastication, swallowing and the functioning of the masticatory apparatus, we proposed to evolve the model in canine protective occlusion, proposed by D'Amico, towards a model of natural functioning, in line with our current knowledge. A better consideration of the physiology of mastication should allow to correct the errors that prevent the validation of d'Amico's proposals. This is the foundation of the **Organo-**

Functional Theory of Occlusion (Le Gall M 2013), which is probably, to date, the most serious candidate to replace the Gnathological concepts:

-Because, unlike the d'Amico model, it aims to balance mastication, in a more natural way, and integrate swallowing.

-Because, like Orton, he proposes to restore all lost functional volumes, during incision, chewing, and swallowing. Only the realization of these decisive stages will allow the restoration of the functional equilibrium of the masticatory apparatus.

-Because its objectives of respect or restoration of chewing and swallowing, and more generally oral functions with dental contacts, are sufficiently extended to allow it to integrate future potential advances in our knowledge, in CAD/CAM or future innovations, which would allow for an improvement and simplification of procedures to achieve this.

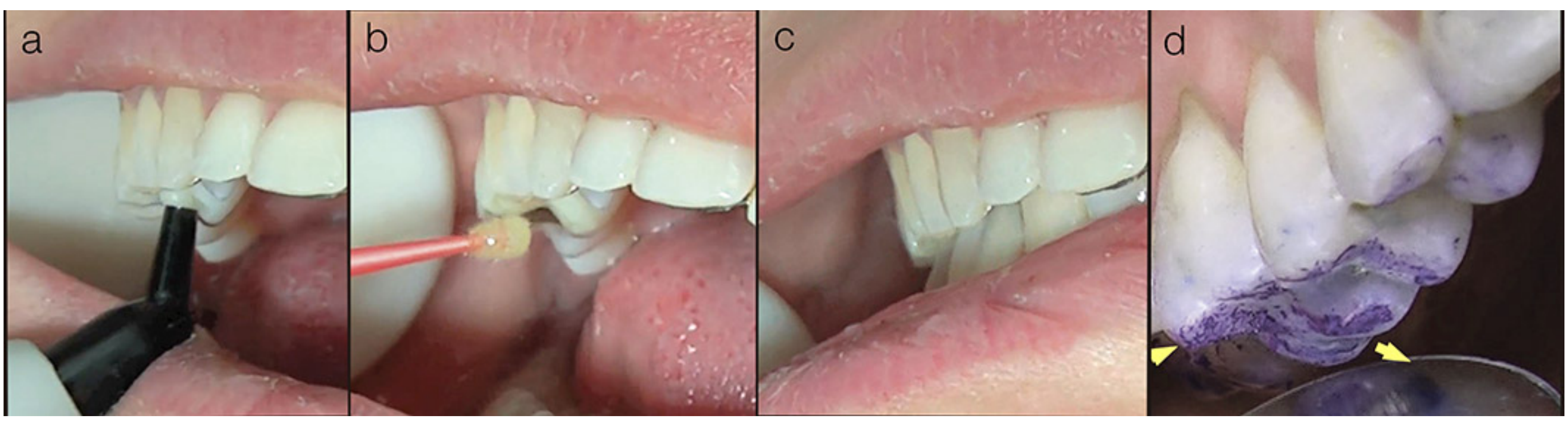


Figure 7-1 A,B,C,D The techniques of addition of composite, ceramic chip bonding or other, can restore lost or unsuitable dental volumes and restore their function in a meaningful and non-mutilating manner.

Note

Additive restoration techniques, of lost dental volumes, have been the subject of a thorough reflection on how to implement them with current composite materials. They follow a precise protocol that will be developed in a second part.

For more information on this topic, please refer to:

- Either at work in French: “La Fonction occlusale: implications cliniques“ (Occlusal function: clinical implications). Le Gall Marcel G. and Lauret Jean-François (†): 3rd edition augmented Editions CDP 2011 Paris www.editionscdp.fr/ (French, Italian, Portuguese edition)

- Either the website in French and English: www.mastication-ppp.net www.mastication-ppp.fr

- Either the many articles in French and English, whose pdf are available for free from the website above, in the "publications" section from a ***Dropbox*** *link.*

- Either to clinical videos, in French and English, available on the site or directly online: https://youtu.be/UUad0HgjvKo

https://youtu.be/5i9cUZRwNns

- *Some links work by clicking directly on it. Others must be copied on the internet browser*
- *The PDFs, of the majority of author’s articles, are directly accessible by clicking the following* dropbox *link:*

https://www.dropbox.com/sh/s5djul5pa4y38np/AAB_Pid6iRrarg2lWXkOsN2qa?dl=0

A B R E V I A T I O N S - C L A S S I F I C A T I O N

Annexe 8

Abreviations

AD: Anterior Digastric

AI: Artificial Intelligence: One of its objectives is the search for resolution methods of problems with high complexity.

AT: Anterior Temporal

Big Data: massive volumes of data. New ways to analyze big data, which conventional ways do not know how to handle

C: Canine, Cuspid

CADCAM: Computer Aided Design Computer Aided Machining

CGP: Chewing Generated Path

CGS: Chewing Generated Surface

CPO: Canine Protected Occlusion

CR: Centric Relation

DM: Deep Masseter

DAD: Dento-Articular Dyskinesia

Dento-Maxillary Dyshamonia DMD: Dento-Maxilla Dyshamonia

EMG: Electromyography

FD: Full Denture

FGP: Functional Generated Path ; Old term improper. In fact it is the recording of the voluntary movement of laterality, which is not a functional movement.

Hypo-D: Hypo-Development

Hyper-D: Hyper-Development

I: Incisive I_1, I_2

IR: Intermaxilla Relationship

Ky: thousands of years

LLP: Lower Lateral Pterygoid muscle

LP: Lateral Pterygoid muscle

M: Masseter

MI: Maximum Intercuspation

MIO: Maximum Intercuspation Occlusion

MRI: Magnetic Resonance Imaging

My: millions of years

P: Premolar, Bicuspid

PD: Posterior Digastric

PT: Posterior Temporal

PM: Ptérygoïdien Médial Pterygoid (MP)

SLP: Superior Lateral Pterygoid muscle

SM: Superficial Masseter

T: Temporal

MT: Middle Temporal

TMD: Temporo-Mandibular Disorder

TMJ: Temporo-Mandibular Joint

Tribosphenic: Tribosphenic teeth (Granat and Peyre 2011): refers to the teeth with cusps of some primitive mammals and primates. These are the first occlusal teeth. Their specific morphology gives them a dominant role in occlusal wedging and /or chewing.

VD: Vertical Dimension VDO: Vertical Dimension of Occlusion

Proposition of a static and dynamic classification of occlusion

Why a new classification?

The classification introduced by Edward Angle in 1899 proposed to take as a mesiodistal reference to class1 occlusion, the articulation of the mesio-buccal cusp tip of the maxillary M1 with the vertical groove separating the mesio and centro-buccal cusps of the antagonistic M_1. His classification is still used today, although at the time, he considered class 1 a frank malocclusion that affected 69.2% of his patients. However, he considered that the occlusion of the first molar pair was the basis of the morphogenesis of the face, without saying why and how (Riaud 2008). His objectives were to classify the malocclusions and to find the harmonious balance of the face (with Apollon in reference), aligning the teeth. Without specifying, however, what were the characteristics of the M1 couples that led to the optimal morphogenesis and without balancing them.

At this time, the role of muscles, proprioception, lingual posture and especially the physiology of mastication, were still completely unknown and no direct relationship could be established later, between its buccal reference of class 1 and the occlusal kinematics of chewing.

The various occlusal concepts developed in the first half of the twentieth century have paid little attention to posterior occlusal anatomy, advocating balanced, highly mutilating occlusion concepts inspired by complete dentures. D'Amico introduced in 1958 the concept of canine protection, which was the antithesis of balanced occlusion on natural teeth and recommended exclusive canine guidance in laterality, to avoid any dynamic contact between the posterior teeth during mastication, except in MIO.

The various occlusal concepts developed in the first half of the twentieth century have paid little attention to the occlusal anatomy of posterior teeth, advocating highly mutilated balancing occlusion concepts, inspired by complete dentures. D'Amico introduced in 1958 the concept of canine protection on natural teeth, which was the antithesis of the balanced occlusion applied to the teeth and advocated an exclusive guidance of the canine in laterality, to avoid any dynamic contact between the posterior teeth during chewing, except in MIO.

The introduction of Replicator® by Lundeen and Gibbs (1981-82) provided the first records of chewing cycles. Subsequently additional work has been published on this theme (Mongini et al., 1985, Pröschel 1987, Nishio et al., 1988). Other work began to show that there was no canine protection during chewing (Le Gall et al 1994). They described the functional occlusal anatomy of the M1 which delimits the maximum boundary envelope of the cycles, on the chewing side (Lauret and Le Gall 1994). They noticed that the shape of the cycles depended on the occlusal morphology of the posterior teeth and that it could be changed by modifying their occlusal anatomy by addition (Le Gall and Lauret 1998). They also described chewing guide rails on the occlusal surfaces of first molar pairs in type 1 occlusion, corresponding to the former class 1 of Angle (The Gall and Lauret (†) 2011 and above Chapter 5F). They have been able to observe on the fossil teeth that this model of functioning existed since at least 32 My, in anthropoids ancestors of the human line (Chapter 5-E).

In Occlusotype 1 (class1) the pairs of first molars are the 3D image inverted from each other in maximum intercuspation and are matched together in dynamic relation by the presence of self-stabilizing occlusal rails which channel their movements during the occlusal phase of mastication, while ensuring their efficiency. This canalization exists as soon as they are in occlusion, whereas they still are the only guide structures actually present in the mouth. All the following teeth will progressively be included in their chewing functional scheme as they progressively emerge on the arches, including the canines.

In Occlusotype 1, the main entrance guide of the cycle, of upper M_1, starts from the tip of it's disto-buccal cusp, lower on the arcade, continues on the enamel bridge and then on the distal part of its mesio-palatal table, at the end of cycle output. It is balanced simultaneously by a second rail starting from the the tip of it's disto-lingual cusp of the mandibular M_1, which ends in cycle output on the internal slopes of its centro and disto-buccal cusps.

These opposing rails, of triangular section, slide reciprocally into paired V-shaped receptacles, on the antagonistic lower M_1 with 5 cusps (Y5 dryopithecus):

- for the buccal cycle input, respectively between the outer slopes of the centro and disto-buccal cusps of the mandibular M_1 with 5 cusps (Y5 dryopithecus).
- for lingual cycle input, between the outer slopes of mesio and disto-palatal cusps of upper M_1.
- The cycle output tables slide against each other by engaging their rails reciprocally.

It is not the reference cusp used by Angle that is directly involved in this guidance, but the disto-buccal cusp of maxillary M_1. It is this disto-buccal cusp that was retained, in orthodontics, by Andrew (1972) as the sixth buccal key of the static occlusion. The dynamic occlusal analysis shows that the maxillary cycle entry guide rail starts well from this disto-buccal cusp, but it also shows that this rail is doubled by a second rail starting from the mandibular disto-lingual cusp. The pairing of this double cycle entry guidance appears today as the first dynamic key to the implementation of the adult occlusal schema and balanced mastication. The second key is the continuity of these rails on the cycle output tables. This ensures a permanent channeling of the dental phase:

- **This makes it possible to associate the MIO type1 relationships, in buccal and lingual view, with the kinematics of mastication in occlusal view,**
- by integrating the occlusal guide rails, around which the adult occlusal scheme has been organized and that functions optimally and coordinated in type 1 occlusion.
- In type 1 relationships, the maxillary and mandibular first molars are inverted volume representations of each other. It is in type 1 occlusion that they have the best static coordination during swallowing, the best dynamic coordination during chewing and the best form and efficiency of chewing cycles.(Johnsen et Trulsson 2005). This Y5 configuration and the enamel bridge was already present on the 3 molars of anthropoids of the human line, there are more than 32My. Only the current M_1 have retained this configuration, gradually becoming the most important molars. It is thus around the fundamental relationship of these teeth located at the frontal center of gravity of the arch (Treil et Casteigt, 2000).
- **It is therefore from their fundamental relation in Type 1 that the optimal occlusal pattern of the adult is constructed, and that a new classification must be arranged.**

In the static mesiodistal classification of class 1 occlusion reports, any reference to Angle should be abandoned as he considered it as a malocclusion. The static key of Andrew, only well situated on the buccal side, but absent on the lingual side and without any occlusal and dynamic reference, can not be preserved either.

We therefore propose the introduction of a new classification of occlusal relations based on the optimal static and dynamic characteristics of the pair of first molars in Type 1 occlusion (or Occlusotype 1), defined as functional normality:

- **Serving as a reference for the classification of malocclusions,**
- **And serving as a model for their rehabilitation.**

Other occlusion relationships staggered mesially or distally from a cusp or cusp fraction, in Type 2 (Class 2) or Type 3 (Class3), do not have the same functional consistency, do not allow operation occlusal rails and often show deformed chewing cycles, which can disrupt physiological growth in children. However, the shape of these cycles can be restored by addition of composite, sometimes moving the location of the cusps. In close Type1 (class1), it is often possible to restore the rails when they are mismatched. (They have important during the establishment of occlusion and facial growth). While in other occlusion relationships, it will usually be sufficient to establish a good coordination of the antagonistic surfaces, which will restore the shape and amplitude of the cycles, their efficiency and therefore the functional balance of the masticatory apparatus.

In summary, we propose to replace the usual incomplete classification, taking into account deglutition and chewing, as well as the different occlusotypes and their subtypes in relation to their level of functional efficiency and their relevance in the treatment of DADs.

- Occlusotype 1.

Fig.8-1

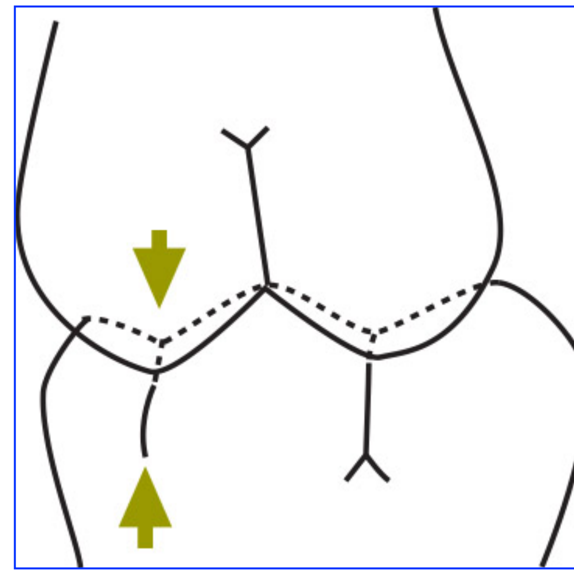


Fig.8-2

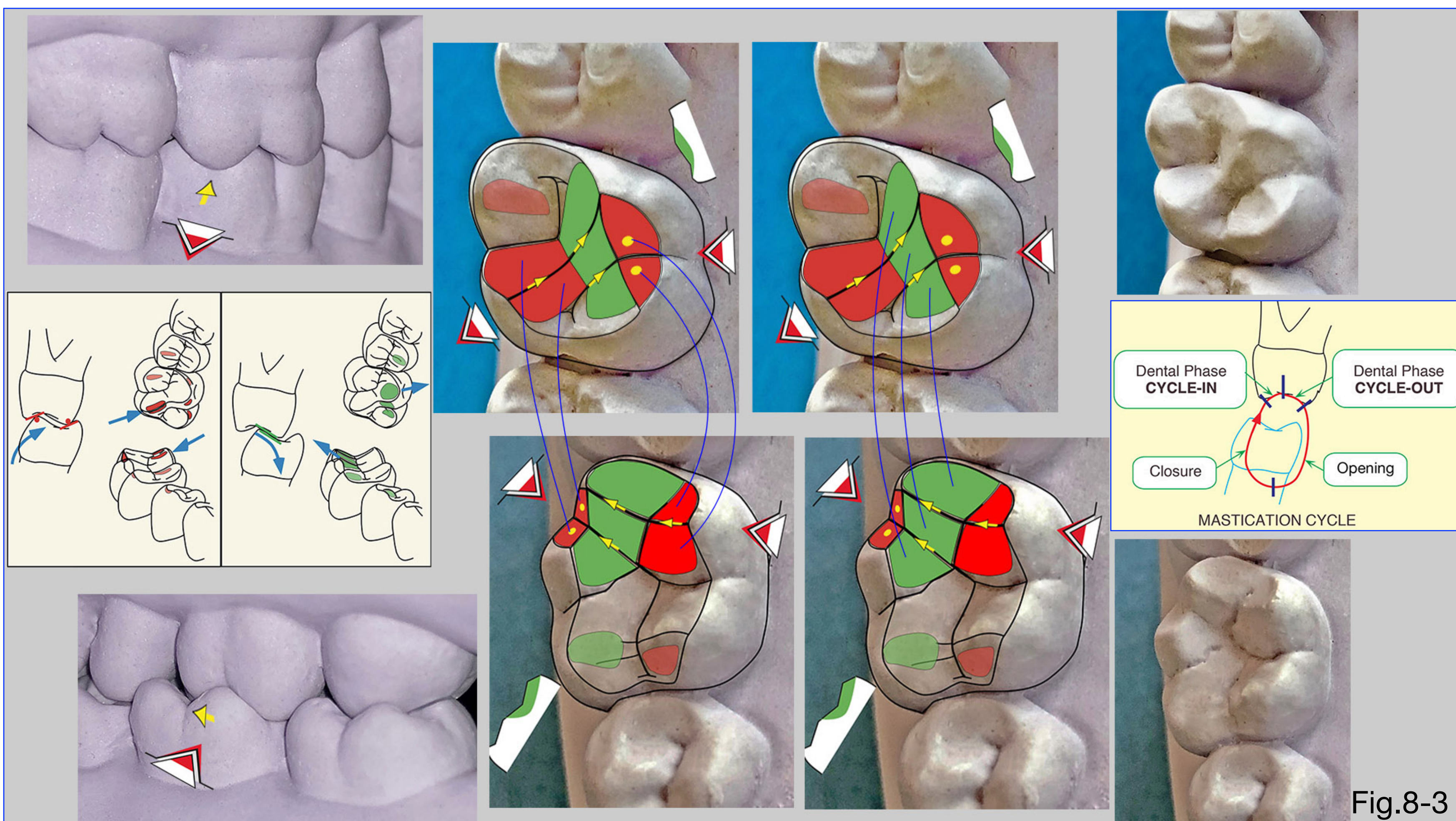


Fig.8-3

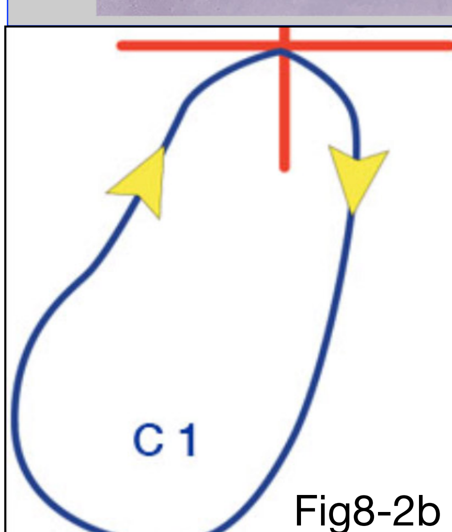


Fig8-2b

This is the new reference of the functional, static and dynamic relationship of the pair of first permanent human molars (Fig. 8-1 à 8-3, Fig. 5F-1 à 5F-5).

In normal occlusion type 1, the natural swallowing contacts are located in MIO. What can be verified by the protocol associating -the wearing of a modified anterior jig -to the posture of swallowing of the tip of the tongue. The position obtained is self-determined by the patient, without any guiding manipulation).

The concept of canine protection guides eccentric laterality, but does not protect the posterior areas during chewing. That's why we've abandoned it for almost 30 years, in favor of f the real simulation of chewing and its adjustment by addition in the mouth.

It is in occlusotype1 that the optimal cycle pattern is most commonly observed. Its amplitude depends on the patient's natural occlusal morphology and articular kinetics. It's in type 1 that the masticatory apparatus has the best static and dynamic anatomical-functional balance, the best masticatory power and efficiency, with a total absence of dental DAD. When dyskinesias between teeth and joints are observed in other O-types, establishing a type 1 model is the best way to treat them. Type 1 is generally associated with facial and musculoskeletal growth naturally balanced with that of the arches, which is also why it represents the model to be established during early treatments in child. All other occlusal features of this chewing pattern are recalled in the illustrations of figure 8-3 and are an integral part of the Type 1 specifics.

The bilateral type 1 with alternating and ample chewing (C1) is optimal.

Type 1 can be unilateral and associated with type 2 or contro-lateral type 3: O-type 1-2 and O-type 1-3. See the general table.

The other occlusotypes present varying levels of Dento-Maxillary Dyshamonia (DMD) and Dento-Articular Dyskinesia (DAD), with more or less deformed cycles, which can depend on:

- genetic factors such as the relative size of the teeth and arches, the presence of cleft palate, trisomy 21 etc,
- abnormal facial growth due to atypical lingual postures, whether or not related to swallowing alone, and later, to imbalance of dental swallowing contacts,
- the impact on facial and skeletal growth and TMD, of changes in the occlusal pattern of chewing and vice versa,
- accidental trauma,
- of various pathologies.

Some of these DADs and DMDs can be easily treated by prior ODF treatment and / or by using the same balancing techniques of additional equilibration, which restore the functional equilibrium and the shape of the cycles, as they are observed in type 1, but by adapting them to the actual occlusion relationships of the patient. These protocols will be developed in Part 2.

For others, presenting hypo-development **(hypoD)** or hyper-development **(hyperD)** skeletal and/or facial*, the use of orthognathic surgery may be necessary, prior to or jointly with the occlusal rehabilitation.

*During growth, abnormal orientations of facial and skeletal growth can affect the volume of the middle and lower floors of the face. These changes can be localized or generalized, vertical, asymmetrical, transverse, lateral, anterior or posterior and concern the maxillary, the mandible or both. Their diagnosis and their early treatment make it possible to reorient growth and to avoid the subsequent use of sometimes heavy orthognathic surgeries.

- **Occlusotype 2:**

In Type 2 occlusion, mandibular M1 is shifted distally, with a fraction of a cusp, a cusp or more (mandibular hypo-development (ramus, corpus…). The MIO contacts are no longer balanced and the occlusal surfaces of the M1 couples are no longer coordinated during chewing cycles. The MIO contacts between cycle output tables are often absent , with an often total under-guiding of the cycle outputs. The lack of proprioceptive information often reduces the cycles to a simple vertical shear, especially on partial types 2. These deformed and vertical cycles are frequently associated with DAD (painful muscle contractures, joint sounds, etc.).

Even when the displacement of the teeth is impossible, the modification of the occlusal anatomy by addition, either to the maxillary or the mandibles, according to the curves, makes it possible to restore balanced dental outputs, therefore of the amplitude and the efficiency of the cycles observed in Type1. In type 2, restoration of the guide rails is rarely possible in clinical practice. When the reproduction of chewing will be well mastered on the virtual articulators, it will probably be possible to reproduce them in CAD/CAM, during the realization of the virtual therapeutic model.

Fig.8-3

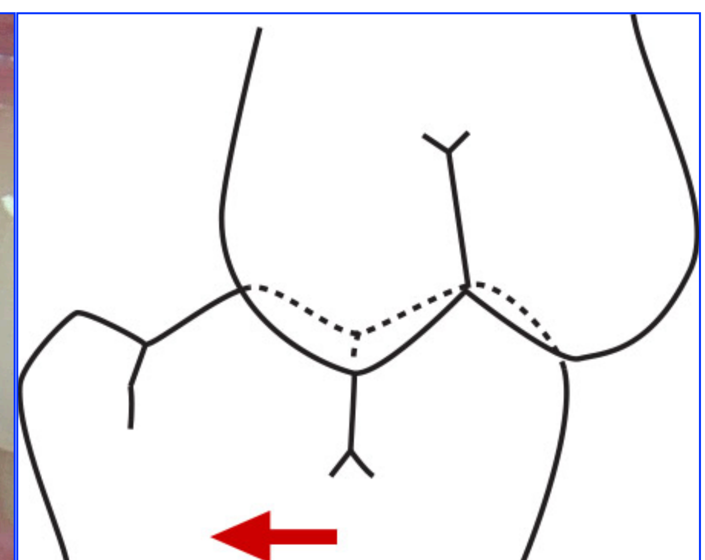


Fig.8-4

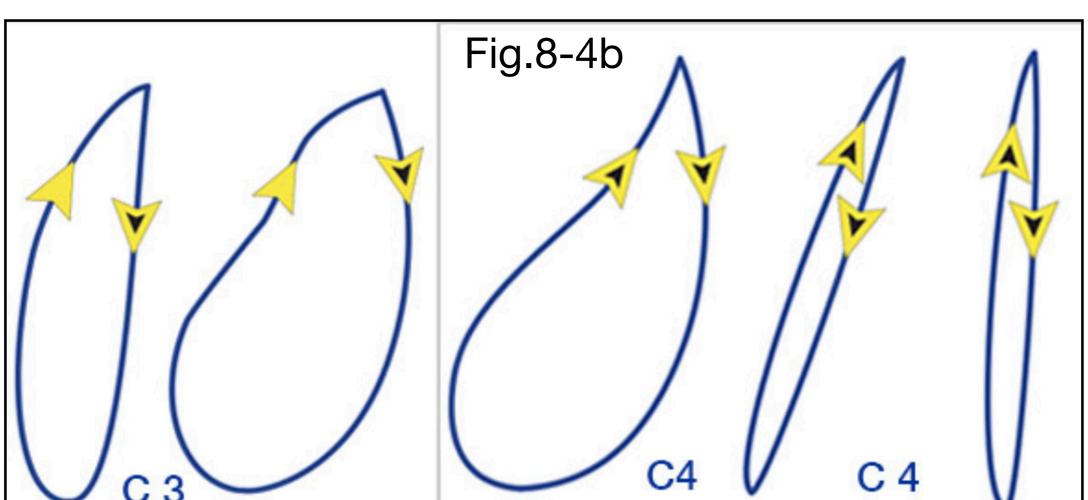


Fig.8-4b

Occlusotype 2: Two Subtypes:

Type 2 Subtype 1 (S1): distal offset of mandibular M1 with postero-anterior horizontal open bite and a relay function with the posterior teeth during the incision**.** (Figures 8-5 to 8-7)
VideoYoutube of this case (F): https://youtu.be/gnpabYTa2mU

Fig.8-5

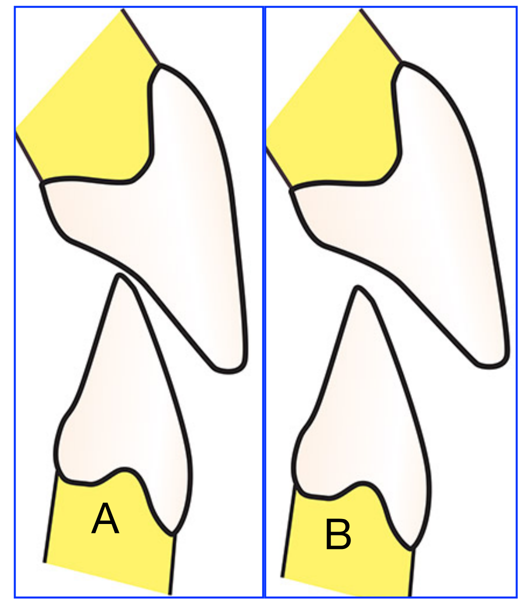


Fig.8-6

Fig.8-7

Figures 8-5 to 8-7: Type 2 Subtype1
Figures 8-8 and 8-9: Type 2 Subtype 2.
The cycles of subtypes 1 and 2 have variable forms that can be not very efficient or not efficient(Figure 8-4b)

Fig.8-8

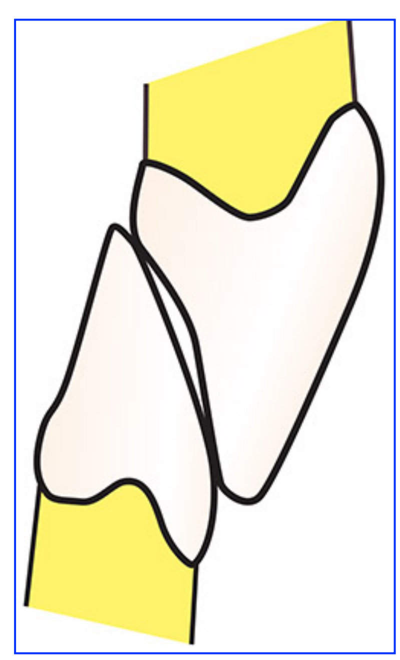


Fig. 8-9

Type2 Subtype 2 (S2): distal offset of M1 mandibular, with a large vertical overbite, locking mandibular incisors by the maxillary one's. (Figures 8-8, 8-9)

- **Occlusotype 3:** mesial shift of mandibular M1, ranging from a cusp fraction to a cusp or more (fig.8-10, 8-11). (Anterior and/or transverse mandibular hyper-development. Quite a few pathologies observed).

Fig.8-10

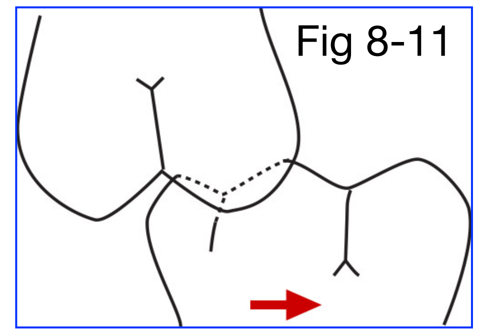
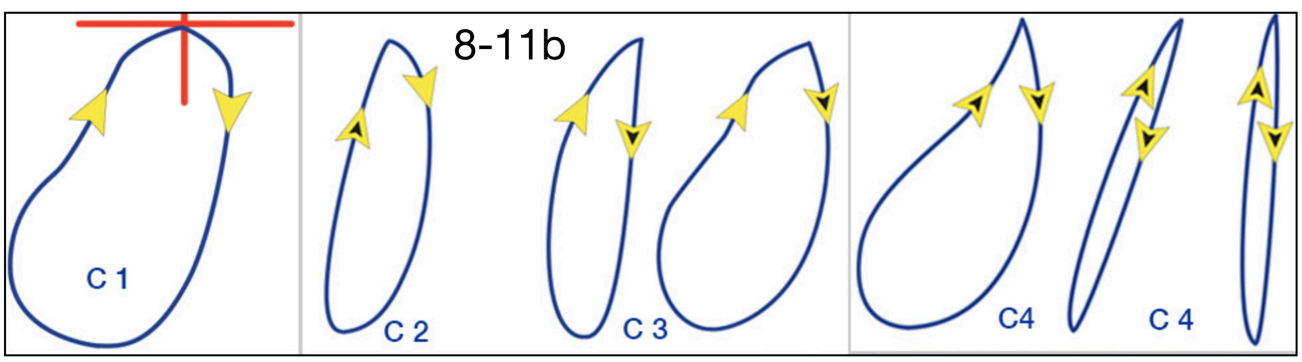
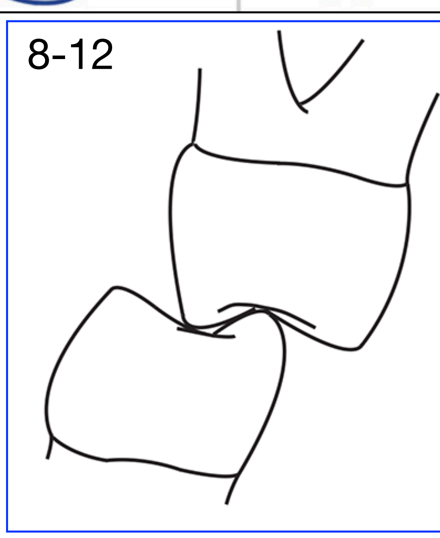


Fig 8-11



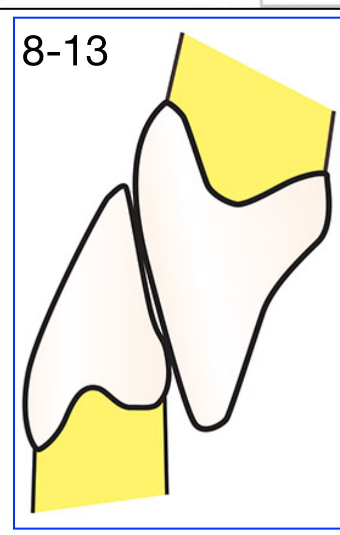
8-11b

Fig.8-11b Great variability of the cycles. They are often frontally coordinated by wear. DAD are less common than in Otype-2



8-12

Occlusion inversée



8-13

Occlusion croisée

Figure 8-14 is divided into two parts. a-The right posterior reversed occlusion is stable sector. Mastication can be made efficient even with cycles in 8. b-The anterior sector is in evolutionary cross-bite, because without occlusal locking in MIO. Figure 8-15 shows a posterior left crossbite, in evolution, because without vertical wedging.

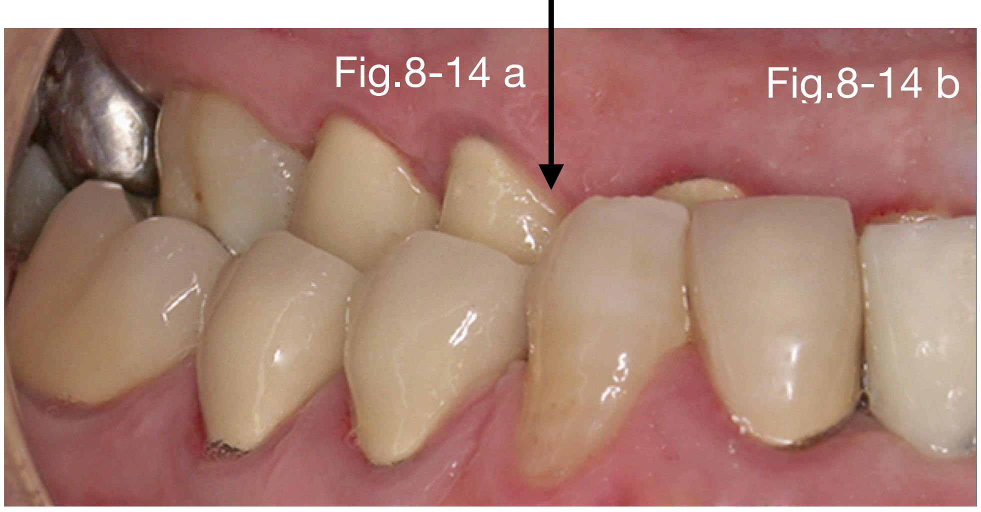


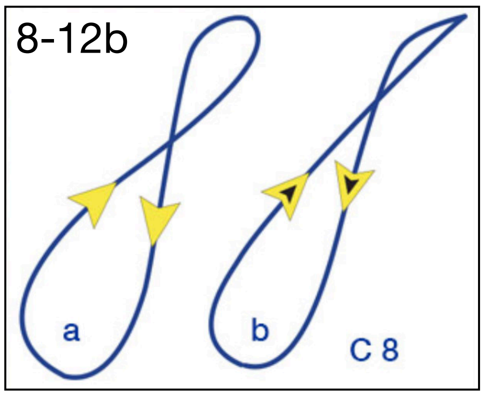
Fig.8-14 a

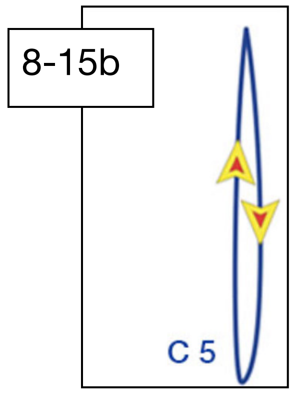
Fig.8-14 b

Fig.8-15

As in type 2, the coordination of the occlusal faces is not good. However fewer pathologies, than type 2, are generally observed.

Type 3: Three Subtypes





Type3 Subtype1 (S1): Posterior inverted occlusion with 8 shaped cycle, or not (fig. 8-12 and 14a).

Type3 Subtype2 (S2): Fig.8-15: Evolutionary posterior cross-bite, without oposite occlusal wedging. Vertical overguiding cycle.

Type3 S3: Fig.8-13 and14b: Cross anterior occlusion evolutionary, without vertical wedging. Frontal chewing without recoil. Cycles that can be wide Fig. 8-11

Type3 S3: Fig.8-16: Cross anterior occlusion consecutive to maxillary hypo-development associated with a double cleft palate.

Type3 S3: Fig.8-17: cross anterior occlusion consecutive to a traumatic fracture of the maxillary (frontal collision on the highway taken in the opposite direction, followed by more than 3 months of coma).

- Occlusotype 4: The open bites:

There is no static and dynamic contact between certain groups of maxillary and mandibular teeth. The open bite usually results from lingual apraxia. In this case they may affect the anterior teeth and a portion of the posterior teeth, sometimes leaving only one pair of molars in occlusion on each side. In this context they can also affect only one posterior sector. But they can result from other etiologies (Fig. 8-21).

Figure 8-18, open bite in lactated dentition

Figures 8-19: open bite in a young adult.

Figure 8-20: open bite in a young adult.

Figure 8-21:open bite in a 45-year-old adult secondary to biocorrosion due to excessive consumption of soda containing phosphoric acid (PH 2.7) for 25 years.

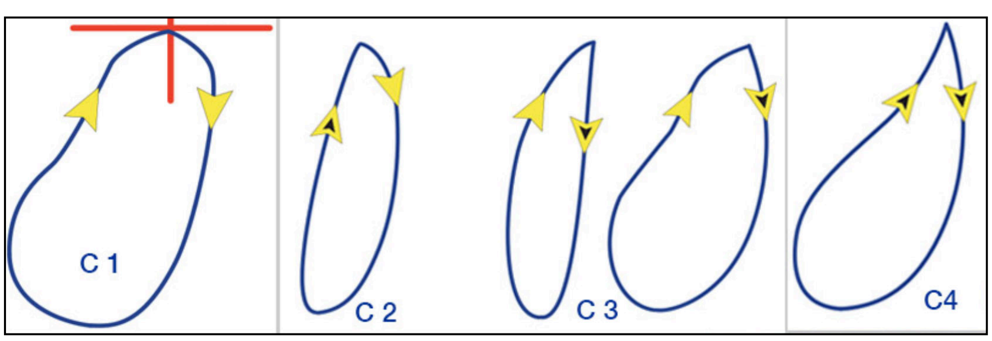


Figure 8-22: Open bites: Cycles of various forms. Front chewing, guidance sometime coordinated by wear.

Two Subtypes

Type 4 S1: Vertical open bite: anterior, lateral, total (Fig. 8-18).

Type 4 S2: Anterior horizontal open bite (Fig. 8-19 et 20

- **Occlusotype 5: Grouping of complex and atypical cases: cross-bite on one side** (Fig. 8-15) **or reversed on one side** (Fig. 8-22, 8-23)**, or type 2 on one side and type 3 on the other side** etc.

Figure 8-22, 8-23. Right lateral inverted occlusion, asymptomatic, in a patient over 65 years of age, in comfort. The solution proposed was surgical and prosthetic. It was dismissed by the patient, himself a surgeon. Only conservative care and periodontal treatment were performed.

Synthesis

We restricted the occlusal classification to static and dynamic interdental relationships during swallowing and chewing. The maxillomandibular relationship is not included in the classification because it is still controversial. We explained why in chapter 5. Although still subject to controversies over the many definitions of CR, it is clear today that MIO is the natural position of swallowing wedge and that it is the natural reference of the Relationship between Mandible and Maxilla. We explained why in chapter 5.

In any occlusal analysis, the closing path must be verified before any therapeutic decision. MIO is the natural position of swallowing wedging. This is the natural reference of the Mandibulo-Maxillary Relationship. The modified jig protocol, associated with the posture of the tip of the tongue, which allows to verify it, is developed in chapter 3 of volume 2 "Clinic of occlusal equilibration". Joint pathologies and their classification are also discussed in Chapter 5.

In general, all non-mutilating occlusal equilibrium techniques and protocols that make it possible to verify and restore the equilibrium of the dental functions of the masticatory apparatus are developed in Volume 2. It is these procedures that make it possible to treat the pathological consequences of the Dento-Articular Dyskinesias, which represent the important part of the dysfunctions of the Masticatory apparatus, that dental practitioners are able to assume alone or in collaboration with the interveners of the oro-facial sphere and its morphogenesis, mainly Orthodontics specialists and Maxillofacial surgeons.

Volume 2 of this ebook: "Clinic of Occlusal Balancing" is available in French.
Download link: https://univoak.eu/islandora/object/islandora:79189
The English edition will be available soon.

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FOURTH COVER

Summary

The analysis of the founding articles of the concept of canine protection, by Angelo d'Amico in 1958 and 1961, indicates that important new works have been published since that time. They concern the physiology of chewing and swallowing, the proprioception, the role of sexual selection in the size of the canines and the possibilities and limits of the reproduction of function on classical articulators. These advances in knowledge, still poorly known or ignored, between 1958 and 1961, would not allow today the publication of much of D'Amico's work on Canine Protected Occlusion. Although this principle is still widely used clinically, these new data still encourage us to question the need for a new approach to oral functions, which would be more physiological. This would remove the discredit that exists on the occlusion, following the disappointments resulting from the application of complex mechanistic concepts, far removed from chewing and swallowing, which are the natural functions of the masticatory apparatus.

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