

Unilateral Masseter Muscle Hypertrophy: Morphofunctional Analysis of the Relapse After Treatment with Botulinum Toxin

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ABSTRACT: This is a case of unilateral masseter muscle hypertrophy (MMH) treated with botulinum toxin (NHA) - normalised hemi-facial asymmetry index improvement from 5.48 to 3.04). After 19 months, the treatment was repeated because of hypertrophy relapse (NHA) increase up to 6.82). The volume variations in the masseter area were monitored during 25 months using a laser scanner to compute facial volume. In order to relate the cause of hypertrophy and relapse to the presence of parafunctional activities, a nocturnal electromyography (EMG) study was conducted with positive results (nocturnal parafunctions of patients 4074.99 μ V to be compared with a control group value of 1644.63 μ V). The lack of the left inferior molars and the consequent right occlusal support seemed to justify the hypertrophy of right masseter (MMRight-POC [percent overlapping coefficient] 91.9%). However, the prosthetic rehabilitation did not prevent relapse in the same muscle. The EMG analysis of both the muscular activation (MMRight-POC 66.0% after relapse) and inhibition activity in Maximum Voluntary Clench (MVC) resulted in contradictory conclusions. At present, the available knowledge regarding MMH physiopathology is very limited and does not support a therapeutic rationale for relapse prevention.

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Uni- or bilateral hypertrophy of the masseter muscle is characterized by an increase in the volume of the muscle mass. This condition is benign, asymptomatic, and must be differentiated from parotid gland illnesses, odontogenic problems, and rare neoplasms of muscular tissue.¹ The reasons why patients request a medical consultation are predominantly related to aesthetics, especially if the hypertrophy is unilateral due to a noticeable asymmetry of the lower third of the face.² In nature, hypertrophy is seen as a reactive event and as secondary to a hyperfunction of the tissue.³ For this reason, parafunctions like clenching of the teeth or bruxism form the etiological hypothesis made by most authors.⁴ Despite this fact, the causes for the condition are still unclear. Several studies on the histological and morphometrical characteristics of the masseter muscles have not demonstrated true hypertrophy of muscle fiber but have instead shown the presence of numerous small fibers⁵ that differ in composition from those normally found in healthy patients.⁴ Based on this point of view,

the term hypertrophy should be replaced with muscular hyperplasia. In this article, however, the term hypertrophy is still used. Electromyographic examination of masseter muscle also failed to provide unambiguous information, as it did not prove muscular hyperactivity⁴ during functioning. A metabolic examination performed with ³¹P-RMN showed no significant difference with normal muscle tissue. The reasons for the onset of benign unilateral hypertrophy are even less clear than those for bilateral. An instinctive and plausible explanation might lie in the different support structure of patients' teeth. Occasional observations made on individual patients could lead one to believe that mandatory unilateral mastication is a factor that favors the onset of asymmetry.⁶ However, more in-depth studies on masseter muscle conditions in patients with unilateral partial edentulism failed to detect any significant difference between the sizes of the left and right muscle masses.⁷

Almost without exception, the therapy prescribed by other authors for the treatment of benign uni- or bilateral muscular hypertrophy is the use of botulinum toxin A. This procedure has become the standard the world over, as it is not invasive, has virtually no side effects and is highly effective in decreasing muscle mass volume.⁸ Follow-up studies that have up to now been conducted on small patient groups and only over short time periods have shown cases of the early relapse of hypertrophy that have necessitated re-treatment.^{9,10} Under such circumstances, the first clinical question should concern the correctness of the diagnosis and the therapeutic protocol implemented. We noticed that many papers were focused on research dealing almost exclusively with therapy, rather than on diagnosis.

The aim of this paper is to present and discuss methodology problems in the diagnosis and treatment of MMH. We will present one study of MMH using an experimental protocol that allows problems associated with diagnosis and treatment to be analyzed from the morphological and functional points of view.

Materials and Methods

The subject was a Caucasian male, aged 35, suffering from unilateral masseter muscle hypertrophy on the right side. MMH treatment was requested for esthetic reasons. Other known causes for the increased volume in the area of the mandibular angle were excluded. An x-ray examination showed no excessive growth of bone in the mandibular angle sufficient to require surgical resetting. Two selection criteria were adopted. The first was the presence of partial lower left edentulism with 3.6 and 3.7 missing from the mandibular arch (the third molars were

all absent). This condition, at least theoretically, lends itself to identifying a possible correlation between MMH and asymmetry of the occlusal support. The second criterion involved the patient's willingness to accept the study protocol as described under study design.

The patient was administered an initial MMH treatment with an intramuscular injection of botulinum toxin A (Vistabex; Allergan Inc, Irvine, CA) in the masseter muscle area. A vial of Vistabex containing 50 units of BTX-A was diluted in 1.25 ml of saline solution to obtain a final concentration of 4.0 units per 0.1 ml. This solution was injected using a 3.0-mL syringe and a 25-gauge needle by cutaneous administration to the right masseter muscle. The BTX-A injection was repeated using the same dosage and method of administration 20 months later due to a relapse of the hypertrophy. Six months later, an implant procedure was performed on the lower left quadrant with the replacement of 3.6 and 3.7.

Morphologic Approach: Collection of 3-Dimensional Facial Features

The four stages of the treatment were named as follows: T0 - the initial condition; T1 - four months after the first injection of botulinum toxin; T2 - after 19 months of follow-up and MMH relapse; T3 - after 25 months; and T4 - after 30 months of follow-up.

Facial volume was measured at each stage of the therapy using laser scanning. A Konica-Minolta VIVID 910 laser scanner was used. A laser scan of the face was performed while the patient was sitting in a special chair fitted to a rotating platform. The back of the chair was fitted with a craniostat to hold the head in position, and the patient was instructed to keep a neutral facial expression during scanning with the teeth together but not clenched. Scans were carried out in the following sequence:

1. Right side at 90°;
2. Right side at 45°;
3. Frontal;
4. Left side at 45°;
5. Left side at 90°;
6. Frontal at 30° below the Frankfurt plane.

When all the scans were united and aligned, they formed a single complete 3-D model of the patient's face. Rapidform 2006 (INUS Technology, Inc., Seoul, Korea) and Rhinoceros 3.0 (Robert McNeel & Associates, Seattle, WA) software was used to process the data obtained from the scans.

Functional Approach: Collection of Muscular Activity

Parafunctional activity measurement: Conjecture about parafunctional origins of MMH called for an instru-

mental examination that could be applied as part of clinical routine.

Parafunctional activity was measured using a nocturnal electromyograph carried out in the patient's home. A ME300 Muscle-Tester electromyograph (Mega Electronics Ltd, Kuopio, Finland) was used. This unit consists of a portable micro-computer (16x7.5x2.5 cm). Disposable bipolar surface electrodes with a diameter of 10 mm and an inter-electrode distance of 21 ± 1 mm (Duo-Trode; Myotronics Inc., Seattle, WA) were positioned on the muscular bellies, whereas monopolar electrodes (Myotrode, Myotronics Inc., Seattle, WA, USA) were used as reference electrodes.

The EMG pre-amplifier had a sensitivity rating of ± 1 μ V. The measurement range covered from 0 to 4095 μ V. A/D (analog-digital) conversion for each channel was performed with an accuracy of 12 bits. The instrument recorded data every 0.1 seconds, but has a limited memory capacity. So to record data overnight, a data registration time of 10 seconds was set and this provided an average of 100 measurement points.¹¹

Occlusal Load Analysis

Electromyographical data recordings from the masseter muscles and the anterior temporal muscles were taken at each stage of the therapy by means of bipolar surface electrodes (Duo-Trode, Myotronics Inc., Seattle, WA) and computerised EMG for dental applications. The signal processing software was used was by Freely, De Götzen Srl; Legnano, Milan, Italy. The analog EMG signal was amplified (gain 150, bandwidth 0-10 KHz, peak-to-peak input range from 0 to 2,000 μ V) using a differential amplifier with a high common mode rejection ratio (CMRR = 105 dB in the range of 0-60 Hz, input impedance 10 G Ω), digitized (12 b resolution, 2230 Hz A/D sampling frequency), and digitally filtered (high-pass filter set at 30 Hz, low-pass filter set at 400 Hz and stop for common 50-60 Hz noise). The signals were averaged over 25ms, with muscle activity assessed as the root mean square (r.m.s.) of the amplitude (unit: μ V).

The reason for recording the data was to gather information concerning the importance of occlusion in the origins of MMH. To achieve this goal, recordings were made regarding activity of the mandibular elevators, the Anterior Temporal (AT) muscles and the Masseter Muscles (MM), when subjected to loading by means of clenching of the teeth. There are, however, several methodological problems. Subsequent recordings of absolute values of Voluntary Maximal Contraction (VMC) displayed wide variations and a very high method error.¹² For this reason, percentage and not absolute measures was used. An index known as the Percent

Overlapping Coefficient (POC)¹³ can quantify muscular behavior caused by contraction of the teeth. A synopsis: A file containing data obtained over five seconds when the patient clenches rolls of cotton placed between the teeth is compared with another file containing data taken later when the patient clenches his/her teeth against each other. While clenching the cotton, the elevator muscles optimise the contraction and achieve the VMC possible. For this reason, the *cotton clench* file is used as a calibration reference.

This file is used for comparisons with occlusion clench files. Clinically, there is a physiological difference between calibration and clench values that prevents 100% overlapping as the characteristics of dental contact introduce a factor of decreased muscle activity. The μ V readings obtained during clenching are expressed as a percentage of the readings taken from cotton clenching. The following indices are calculated on these percentage variations: muscular function, symmetry and torque as described later in *Measurements of Occlusal Load*.

Data Analysis

Measurements of Facial Volume

The facial mesh was split into two right and left antimeres of a symmetrical plane obtained by semi-automatic extraction.¹⁴ We will call the symmetry plane, *Plane 1*, **Figure 1**. A *Camper Plane* was later created passing through four anthropometric points: R and L tragus, R and L ala of the nose.

The best-fit plane passing through these four points was called *Plane 2* and was made perpendicular to the plane of facial symmetry by being slightly rotated around the axis where the two planes meet. An offset plane of *Plane 2*, called *Plane 3* was moved 80 mm lower to contain the mandibular angle and the soft covering tissue. By construction, this is perpendicular to the symmetry plane and parallel to the horizontal plane. The volume outlined by the three planes described and the facial mesh is closed at the rear by a vertical plane called *Plane 4*. All the others are perpendicular and pass through the points Tragus R and L in line with best-fit approximation logic. The left part of the face was mirrored in the right antimeres, and the volume measured using the same reference planes for the right part, **Figure 2**. This methodology was repeated for all five stages of the study. During the follow-up period, there were no significant alterations in somatic weight. Absolute volumes in mm³ were obtained for two of the lower quadrants of the right and left face. The absolute difference is the percentage difference normalized in relation to the volume of the lower third of the face.

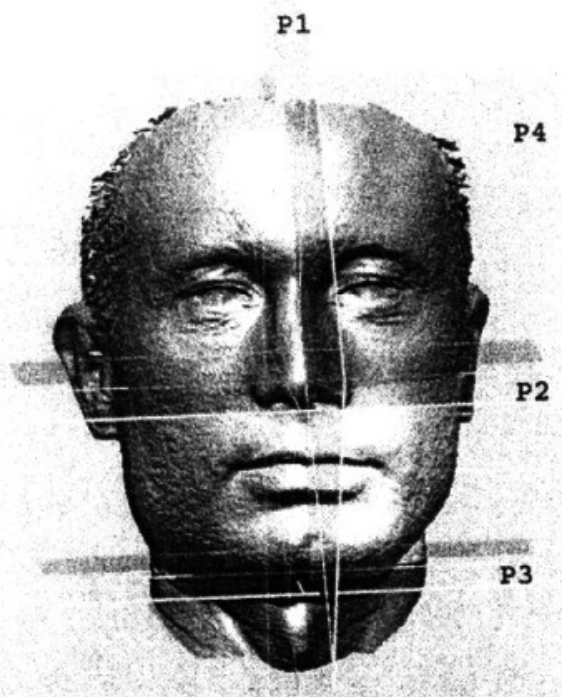


Figure 1
Delimitation of the inferior third of the face by four planes: P1: facial symmetry plane; P2: Camper plane; P3: inferior plane; P4: back plane.

The percentage difference is expressed by an index known as the Normalised Hemi-facial Asymmetry Index (NHAf) using the formula $(VolR - VolL) / [(VolR + VolL) / 2] \%$. This index offers the advantage over the absolute difference of the two hemi-faces in that it takes into account total facial volume.

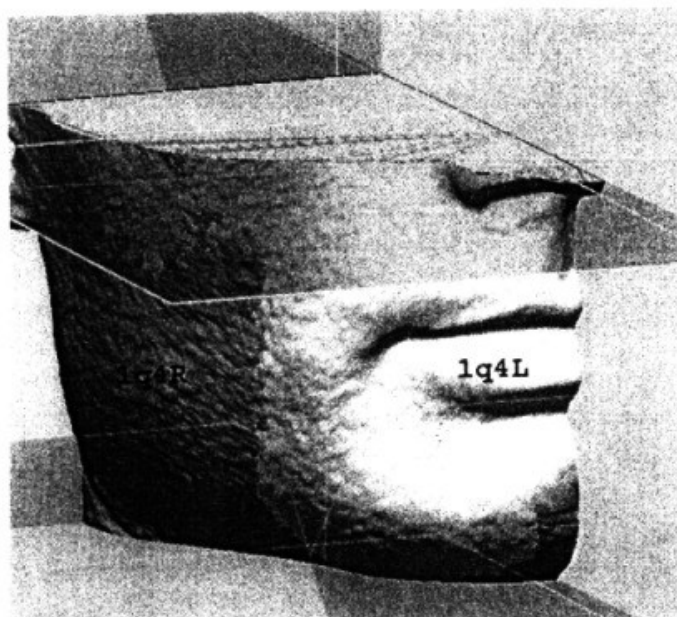


Figure 2
Computation of the volume differences between the right and the left (mirrored) part of the face.

With regard to absolute volumetric difference between right and left hemi-face, the NHAf system provides an index that is related in size to total facial volume.

Measurements of Parafunctional Activity

In assessing the nocturnal activity of the masseter muscles, episodes of parafunctional activity and all episodes of muscular activity in excess of 10 μV were taken into consideration.

All the episodes relating to both the right and left sides were added together to provide a total reading of nocturnal parafunctional activity. The same methodology was used to study a sample population of 26 patients aged between 20 and 40. This population was split into case and control groups. The case group consisted of 13 patients (seven females and six males) with case histories suggesting parafunctional activities, but neither MMH nor BMH. There were also 13 control subjects (seven female and six male dentistry students). The case control analysis of masseter muscle nocturnal activity was performed so as to provide a reference behavior model for healthy subjects and patients. Nocturnal masseter muscular activity in patients was compared with data from the control group and with data from patients suffering from parafunctional activities but unaffected by hypertrophy.

Measurements of Occlusal Load

Muscular activity can be described in two ways. The first is the *intensity* of a contraction and the second is its *distribution*. Intensity is calculated using the μV value measured during a contraction. The manner of distribution determines the amount of work produced by each individual muscle compared with other muscles and the distribution of occlusal load. Differential muscle activation modes were indicated by means of indices and a *thin-plate spline* graph. The POC algorithm for processing EMG data calculates the total percentage of the overlapping of muscular activity, while clenching the teeth together, compared to while clenching cotton.

There is a physiological difference between calibration values, i.e., clenching cotton and clenching the teeth together. This differing behavior of the muscles means that a 100% overlap of the two performances is not possible as contact between the teeth introduces an inhibiting factor regarding muscular activity that decreases at approximately 85% in the masseter muscles and 87% in the temporal muscles¹³ as shown in **Figure 3**. Differential activation of individual elevator muscles, expressed as a percentage of MVC on cotton, can be expressed by indices that can fairly accurately estimate the placing of dental contacts. The physiological presumption behind this analysis is the positive correlation between posterior

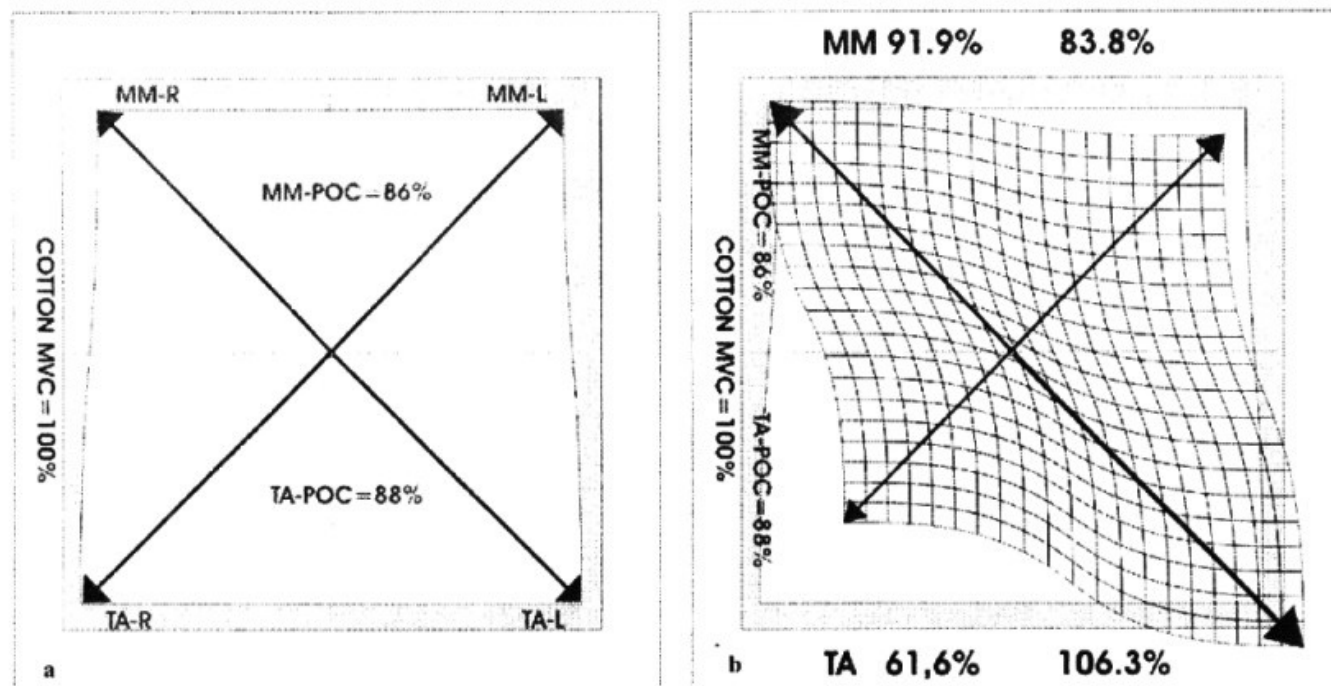


Figure 3

a. Normal reduction of the Maximum Voluntary Clench (MVC) on teeth (white area) compared to the MVC on cotton (grey area) in normal population. **b.** The deformation of the grid shows the excess or shortage in muscular activity on teeth in clench.

support and masseter muscle activity and anterior support of the temporal muscles.¹⁵⁻¹⁷ The following symmetry $(MMR+ATR-MML-ATL)/(MMR+ATR+MML+ATL)$ and torque indices were calculated $(ATR+MML-MMR-ATL)/(ATR+MML+MMR+ATL)$. The numerical value to be attributed to each muscle comes from the percentage of overlap between teeth clenching and cotton clenching activities: $\mu V/\mu V \times 100$. The analysis methodology used is detailed by Ferrario, et al.¹³

Another interesting factor related to muscular activity concerns the inhibitory effect that dental contact has on MVC. This concept is illustrated by a graph similar to that known as *thin-plate spline*,²⁴ **Figure 3**. The grey square in **Figure 3** represents 100% MVC on cotton while the white square represents the POC (Percent Overlapping Coefficient), i.e., the average physiological decrease of muscular contractions of the teeth measured from a sample population with normal occlusion and with no symptoms of dysfunction.¹³ The values reported in the literature can be overlapped exactly with the data from our sample group. The vectors that create the axes are the POC of the individual AT and masseter muscles in any measurement.

In **Figure 3(b)**, a grid that shows the POC of individual muscles at T0 has been superimposed over **Figure 3(a)**. The percentage variation of the activity of the masseter and temporal muscles while clenching the teeth is repre-

sented by the deformation of the grid. This grid is deformed or *warped* by four vectors to express the POC of individual muscles. When the grid crosses the white square, it means that the teeth clenching has a higher value than the characteristic average POC for that muscle.

Under such circumstances, we can say that the inhibitory effect of occlusion on the muscles is lessened or suppressed. **Figure 3(b)** shows teeth clenching at T0. It is possible to see how the right MM and left AT muscles do not inhibit teeth from clenching.

Method Error

Morphological analysis of changes to the face during treatment involves evaluating the volumes calculated using facial laser scanning. The same methodology was applied to five plaster cast masks, and the realignment of various scansion shells showed a potential realignment error of 0.187 mm. This degree of error has no relevance to the aims of this study. The error method in measuring muscular activity is linked to variations in recording data at different times. The decision to express teeth clenching activities in percentages for cotton clench calibrations eliminates the problem of variations in the absolute value of clench intensity recorded in subsequent sessions conducted much later. EMG recordings performed using the same protocol have been tested recently and found to be good.¹³

Discussion

By its very nature, a case report is not an appropriate means of providing answers but serves better to question issues that are still unclear. This article presents a case of MMH with 20-month relapse that is suited to raising questions concerning the clinical methods used for diagnosis and choice of therapy when dealing with benign hypertrophy of the masseter muscles. Problems associated with methods will be discussed and a rational approach to studying these problems will be presented.

Variations in Facial Volume

The method used to record variations in facial volume is based on laser scanning the facial surface and calculating the volume taken up by an arbitrary portion of surfaces that definitely contain masseter muscles. **Table 1** summarizes the measured volumes at T0-T4, which are shown in **Figure 4**.

It is clear that the absolute reduction of muscle volume cannot be calculated, as allowed by other methods like CAT¹⁸ or ultrasound scans.¹⁹ However, calculating the volume of the two facial quadrants, bordered by the planes described previously, allows facial volumes to be described fairly accurately. The lower right quadrant of the face affected by hypertrophy passes from 448633.01 mm³ to 437835.25 mm³ four months after a local injection of botulinum. At T2, right volume reduces to its minimum to then increase again due to relapse until reaching a final volume of 458970.53 mm³ that is in fact larger than the original measurement. A second injection of botulinum between T2 and T3, although reducing the

EMG activity of clench, did not decrease facial volume. An analysis of absolute variation of volume leads to two considerations. The first consideration concerns the fact that if the cause of the problem is not known and is not eliminated, the final outcome of therapy cannot be predicted. The second is that using the toxin does not always provide an appreciable reduction in muscle mass volume.

Volume measurements other than absolute readings were also performed. The difference between the lower right and lower left quadrants of the face certainly offers a means of measuring facial asymmetry. From a methodological point of view, however, this is not an index and does not take overall facial volume into account. To overcome this problem, the percentage difference was expressed by an index known as the Normalised Hemi-facial Asymmetry Index (NHAI) using the formula $(VolR - VolL) / [(VolR + VolL) / 2] \%$. As regards absolute volumetric difference between right and left hemi-face, the NHAI system provides an index that is related in size to total facial volume. In cases of 3-dimensional facial reconstruction studied up to now, it was observed that the request for facial modification was sustained by an NHAI greater than three. Patients, on the other hand, were satisfied with their treatment when the facial index was less than three. From the methodological point of view, the availability of an index is frequently fundamental in order to establish what degree of asymmetry affects the request for therapy, when it is reasonable for public institutions to provide such service, and when treatment can be considered successful, et cetera.

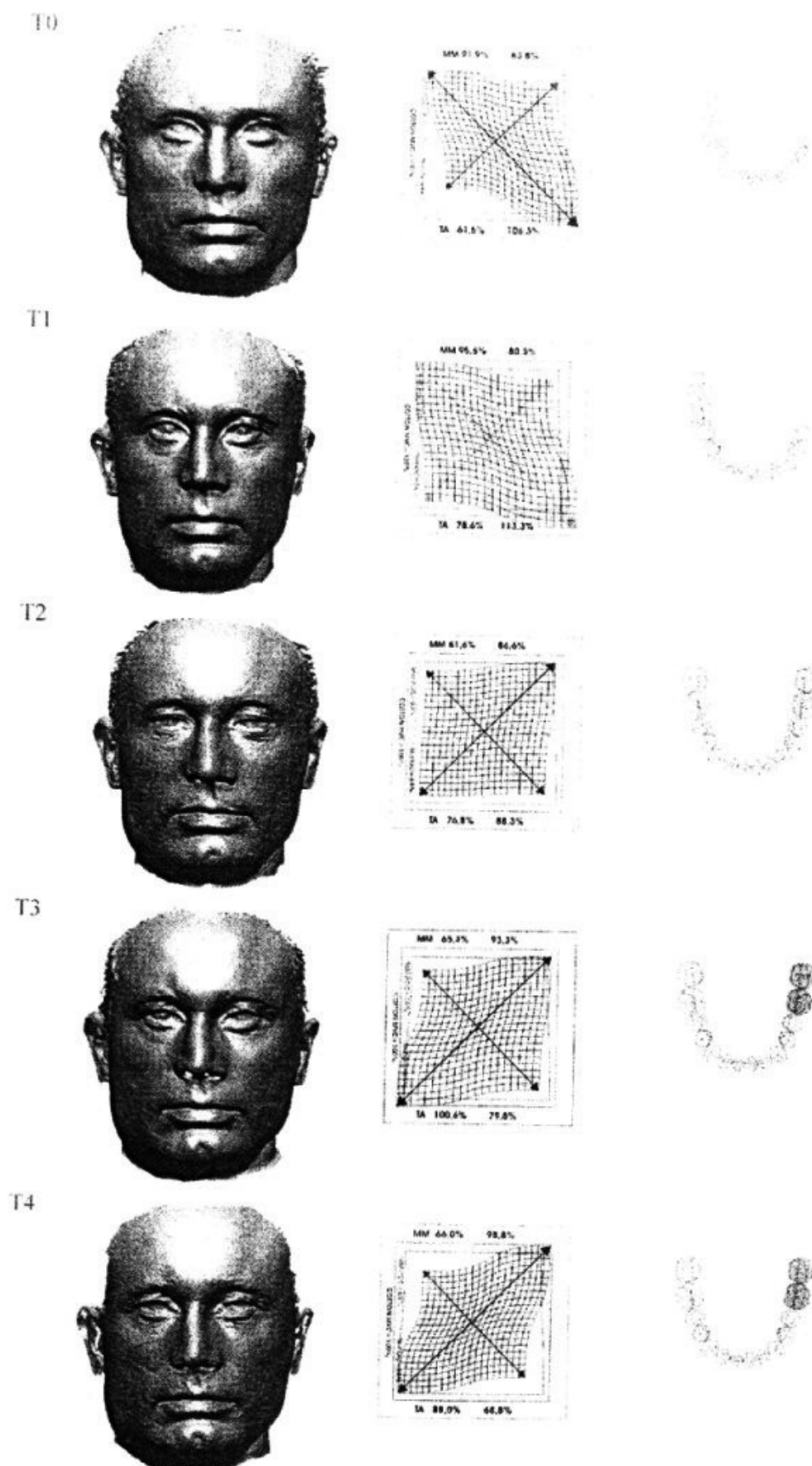
One particularly interesting issue concerns requests for facial modification when the NHAI is very low. In such

Table 1
Variations in Volume of the Lower Right Hemi-Face (1q4face R) as an Absolute Value and Relative to the Lower Left Mirrored Value (1q4mirror L)

Month	T0 0	T1 4	T2 19	T3 25	T4 30
1q4face R	448633.01	437835.25	430320.07	450593.83	458970.53
1q4mirror L°	424726.64	420330.44	417424.72	427436.58	428717.79
Δ(R-L)	23906.37	17504.81	12895.35	23157.25	30252.73
NHAI	5.48	4.08	3.04	5.28	6.82
Botulinum	(*)		(**)	(**)	

°Absolute values: mm³; NHAI: Normalized Hemi-Facial Asymmetry Index.

Note: Injections of botulinum toxin were administered as follows: the first (*) at T0 and the second (**) at a time between T2 and T3 at the first sign of relapse.

**Figure 4**

Variation sequence of facial volume, muscular activity, and dental arch restoration from time T0 to T4.

cases, there should be an in-depth psychological diagnosis so as to avoid raising hopes of unrealistic changes in patients with over-anxious personalities.

Parafunctional Activity

The etiology of masseter muscle hypertrophy is still unknown. The most widely held belief is that parafunctions are caused by an increase in muscle volume.⁴ If this opinion is to be considered, there are three pertinent questions that from the methodological point of view have to be answered. The first deals with the type of parafunction, the second concerns how to measure the parafunction, and the third concerns threshold values. In this article, muscular parafunctions were measured while the patient was asleep at home with no distinction made between clenching and grinding, **Table 2**. Parafunctional activities can be measured during sleep since the main oral functions of chewing and phonation are absent. The domestic setting meets all the requirements for confirming the presence of parafunction, as it provides all the patient's normal rhythms, locations, and interpersonal relationships that characterise his or her life.^{20,21} One limit to this methodology is that it is impossible to distinguish between clenching and grinding. This distinction has a practical value associated with load. Clenching is fundamentally an isometric activity that creates a much greater force than grinding which is virtually an isotonic activity. As reported in **Table 3**, we assessed parafunctional activ-

ity in a control group consisting of young, healthy subjects with no symptoms of dysfunction. The average reading for nocturnal muscular activity was 1644.63 μ V with an SD of 365.11. Measurements of parafunctional activity were also taken for a similar number of patients with TMD with mainly muscular disturbances and the mean figure was 2493.96 μ V with an SD of 614.85. Parafunctional activity in this case was studied before the administration of botulinum was 4074.99 μ V, and thus significantly greater than in the two reference groups. At T1, the activity decreased drastically to 500.35 μ V. At T4, the problem of hypertrophy relapsed, and the parafunction measured was greater than the original reading. This observation does not allow simple conclusions to be reached, but raises two issues: The importance of parafunctions as a pathogenetical factor of MMH and BMH and the methodological necessity of assessing and measuring their presence and intensity. Indeed, the patient under study showed a parafunction that was significantly greater than that measured in patients with TMD with no hypertrophy. This raises the question as to whether there is a threshold value of parafunction with a hypertrophic risk. This question concerns the capacity of botulinum toxin to control the parafunction by chemodenervation.²² In the case under study, the control of parafunction was only temporary. One factor that is in line with other studies concerns the period of time for relapse to appear, which is usually about 25 months.²³

Table 2

Variations in Muscular Activity of the Elevator Muscles in MVC (Maximum Voluntary Clench) in Absolute Value on Cotton Clench (μ V) and Percentage MVC on Teeth Relating to Cotton

	T0		T1		T2		T3		T4	
	[μ V] Cot	% Cle	[μ V] Cot	% Cle	[μ V] Cot	% Cle	[μ V] Cot	% Cle	[μ V] Cot	% Cle
MMR	330.0	91.9	81.09	95.6	300.7	81.6	101.2	65.3	215.4	66.0
MML	248.5	83.8	343.70	80.3	253.4	86.6	196.2	93.3	247.0	98.8
ATR	248.8	61.6	178.10	78.6	181.5	76.8	186.2	100.6	130.2	88.0
ATL	229.4	106.3	229.30	113.9	206.1	88.3	196.0	79.8	276.9	68.8
Torque index	-15.35%		-13.76%		-1.95%		+14.38%		+16.18%	
Symmetry index	-10.64%		-5.43%		-4.95%		-2.13%		-4.23%	
Prosthesis	-		-		Temporary		Definitive		Definitive	

MMR: masseter muscle right; MML: masseter muscle left; ATR: anterior temporal right; ATL: anterior temporal left

Table 3

Measurement in μV of Nocturnal Parafunction in a Patient with MMH (Masseter Muscle Hypertrophy) from the Control Group and of Patients with Parafunctions But Not Suffering from MMH or BMH (Bilateral Muscle Hypertrophy)

	T0 [μV]	T1 [μV]	T2 [μV]	T3 [μV]	T4 [μV]
Case report	4074.99	500.35	*	*	4755.45

*Nocturnal parafunctions were not measured during these times

	Average MM (R+L) [μV]	SD [μV]
Control group	1644.63	365.11
Dysfunctional patient w/o MMH or BMH	2493.96	614.85

Occlusal Load Analysis.

The intensity and distribution of muscular activity was analyzed. In terms of common wisdom, the intensity of muscular contraction in MVC is used frequently to indirectly express the intensity of parafunctional activities that a patient experiences. Again, common wisdom would have it that more parafunctional activities correspond to more hypertrophy.

This supposition would call for a thorough methodological examination given the complexity of muscular physiology. As has already been noted, confirmation of the existence of parafunctional activities and the identification of a threshold risk value are essential factors. Now, a look at the notion of MVC intensity as an indirect index of parafunction and therefore the risk of hypertrophy. At T0, the intensity of MVC on cotton of the right masseter has a value of 330 μV , **Table 2**. This value drops drastically to 81.09 μV after an injection of botulinum. This decrease is accompanied by a reduction in volume of the lower right hemi-face. During follow-up, EMG analysis showed that the right masseter never reached a value similar to the original reading. With a second injection of botulinum, the reduction went from 300.7 μV at T2 to 101.2 μV at T3 and finally settled at 215.4 μV at T4. Notwithstanding this significant, stable reduction in MVC intensity, the hypertrophy relapsed to an even greater volume than the original reading. Numbers alone, therefore go against practical knowledge (at least in this case).

Another widely held belief regards the etiology of asymmetry in hypertrophy (MMH). Common wisdom

would dictate that a muscle like the masseter over-functions to the extent that it undergoes hypertrophy when ipsilateral dental support is the only one used. Conditions of unilateral edentulism or mandatory unilateral mastication are conditions that favor hypertrophy. As noted previously, such statements are not heavily supported by research, and episodic observations do not explain how this occurs from a physiopathological point of view. In each case, the physiopathological principle that can be called upon in a case of MMH is that of differential activation of the masseter muscles. The concept of differential activation of the masseter (and also temporal) muscles has been studied in this article in two ways, i.e., the facilitating and inhibiting effects that the teeth have in relation to muscular contractions of the mandibular elevators.

The facilitating effect has already been studied¹⁵⁻¹⁷ and is based on the positive correlation between posterior supports, masseter and muscle activity, and anterior supports and temporal muscle activity. Analysis of the torque index would seem to confirm this supposition. In fact, we see that the initial torque is -15.35%. The absolute value is high. The reading indicates a tendency to left rotation of the mandible sustained by the dominant activation of the right masseter and the left temporal, and then by an occlusal right posterior and left anterior support. This is precisely the occlusal condition of the patient and coincides perfectly with muscular hypertrophy of the right masseter and left temporal muscles. After an injection of botulinum toxin, although the MVC absolute value changed, the torque index remained the same, thus con-

firming that torque depends upon occlusal support and that this support has the same effect of muscular activation distribution. At T3, the patient received prosthetic rehabilitation to the third quadrant designed to optimise contact on the occlusal surfaces. The effect upon the distribution of muscular activity was immediate and the torque inverted. This indicates a tendency to right rotation of the mandible sustained by the dominant activation of the left masseter and the right temporal muscles. Under these conditions, it was expected that relapse of the MMH of the right would not be possible. Instead, the relapse involved the muscle affected by hypertrophy right from the start. Muscle activation indices were unable to supply a clear physiopathological explanation for the relapse.

The second method for studying muscle function in this article relates to the inhibiting effect of the teeth on clenching. If it is true that contact between the teeth is necessary to adequately activate the corresponding muscles, the inhibiting effect produced by contact between the teeth at the moment of MVC has also been demonstrated and quantified by Ferrario, et al.¹³ This effect can be seen in the graph in **Figure 3**. The mean percentage value of this inhibition measured on healthy patients can be used to describe behavior in both qualitative and quantitative terms in pathological cases. In the case under study, the grid representing muscular inhibition during clenching the teeth together compared with clenching on cotton was selected as a parameter of calibration. It can be seen that at T0, the grid is warped towards the outside of the normal area corresponding with the right masseter and left temporal muscles. This means that while clenching the teeth, the muscles are not subjected to physiological inhibition. This is particularly interesting, if it is considered that the patient suffers from parafunctional activities. Since the parafunctional activity involves contact with the teeth, the fact that the muscles are not inhibited in that situation may well be a very important factor in the onset of relapse. This, however, does not explain why the hypertrophy affected the right masseter, given that after prosthetic rehabilitation, the same muscle demonstrated much more inhibition than its counterpart on the left. It was expected to see hypertrophy of the left masseter caused by the decreased inhibition of dental contact. This did not take place and leads to the conclusion that there are other much more complex mechanisms involved that cannot be explained with the model described. It seems reasonable to suggest that this theory, regarding the hyperactivity of missing inhibition and present particularly in parafunctional activity, may be a significant physiopathological factor in the onset of hypertrophy and may explain the

fact that it is not possible to record, in all cases of MMH, an absolute increase in masseter muscle activity.⁴

Conclusions

Analysis of the problems presented in this case of MMH with relapse has raised many questions about methodology. This applies to both diagnosis and choice of therapy.

The fact of facial deformation is a critical component as regards indications for symptomatic therapy with botulinum toxin. The morphological difference between the right and left should not be assessed in absolute terms but in terms relative to facial volume.

A diagnosis of MMH or BMH cannot ignore the presence of a parafunction since this disregard can expose the patient to the risk of relapse.

Conditions of occlusion must also be carefully assessed: It would seem that asymmetry of the occlusal support is involved in the appearance of morphological facial asymmetry.

The physiopathology of muscular hypertrophy is unknown. Assuming that a parafunction is in fact a decisive etiological factor, it needs to be decided which parafunction is most involved and if a risk threshold exists.

Given that parafunction control by means of chemodenervation has only a temporary effect, it is reasonable to administer botulinum toxin as symptomatic therapy at the same time as other complementary treatments in order to control clenching and grinding of the teeth.

The inherent mechanism of the appearance of hypertrophy may be associated not only with the intensity of the voluntary muscular activation during clenching, but also with the lack of inhibition of muscular activity when clenching the teeth. This would also explain the importance of parafunctions at the heart of the problem.

These questions all remain unanswered and underline the need for further research to find the solutions.

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