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ANALYSIS OF MASSETER DEFORMATION PATTERNS DURING A MAXIMUM EXERTION CLENCHING IN PATIENTS WITH UNILATERAL CHEWING

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SUMMARY
Purpose. The aim of the following study is to examine both masseter muscles (left/right) in a group of patients suffering from unilateral chewing during a maximum exertion isometric contraction using the deformation pattern analysis of ul-trasound videos and compare them with the results obtained by studying patients with alternate bilateral chewing patterns. *Materials and methods*. This study has been conducted by use of an ultrasound machine and a linear probe which al-lowed us to record a video (DCM) comprised of 45 frames per second (MicrUs EXT-1H Telemed UAB, Vilnius, Lithuania) and a linear probe (L12-5L40S-3 5-12 MHz 40 mm). The probe was fixed to a brace and the patients were asked to clench their teeth as hard as possible, obtain the muscle's maximum exertion, for 5 seconds three times, with 30 seconds in-tervals in between. Both right and left masseter muscles were analyzed. We applied to the ultrasound video a dedicated software (Mudy 1.7.7.2 AMID Sulmona Italy) for the analysis of muscle deformation patterns. The total number of patients for this study is 150. Out of this number, 50 belong to Group A, mono lateral chewing on the left side arch, and 50 to Group B, mono lateral chewing on the right side arch. The remains patients belong to Group C, bilateral alternate chewing. The deformation pattern analysis of the skeletal muscles on ultrasound videos allows us to highlight with ease the clear dif-ference in the clenching capabilities and strain management between the dominant masseter and the subordinate mas-seter in a unilaterally chewing patient. *Results*. In the sample investigated both in Group A and Group B the unilateral chewing is associated with a series of pa-rameters (number, shape, volume, position and orientation of the teeth) and is also associated with the extension of the cutting surface really available.

Key words: unilateral chewing, masseter muscle, ultrasound, strains, pattern of deformations.

Introduction

Unilateral chewing is one of the most frequent alterations of the masticatory cycle. This type of masticatory alteration has many different variables in its execution, depending on the number of shifting movements that remain, the use of the tongue, the number of teeth used and the location of the occlusal area used to chew food. Unilateral chewing constitutes a considerable risk that could potentially cause dysfunctional syndromes to the masticatory muscles in the best case scenario, to the muscles of the head and neck and to the temporomandibular joints a whole in the worst.

The aim of the following study is to examine both masseter muscles (left/right) in a group of patients suffering from unilateral chewing during a maximum exertion isometric contraction using the deformation pattern analysis of ultrasound videos and compare them with the results obtained by studying patients with alternate bilateral chewing patterns. Both dissection and ultrasound demonstrate that the structure of the masseter muscle is very complex, composed of three distinct parts (Figure 1) and organized in layers (Figure 2): the superficial masseter is formed by two layers (internal and external), the middle masseter has only one layer and the deep masseter has three separate layers (outward, central and inward) (1).

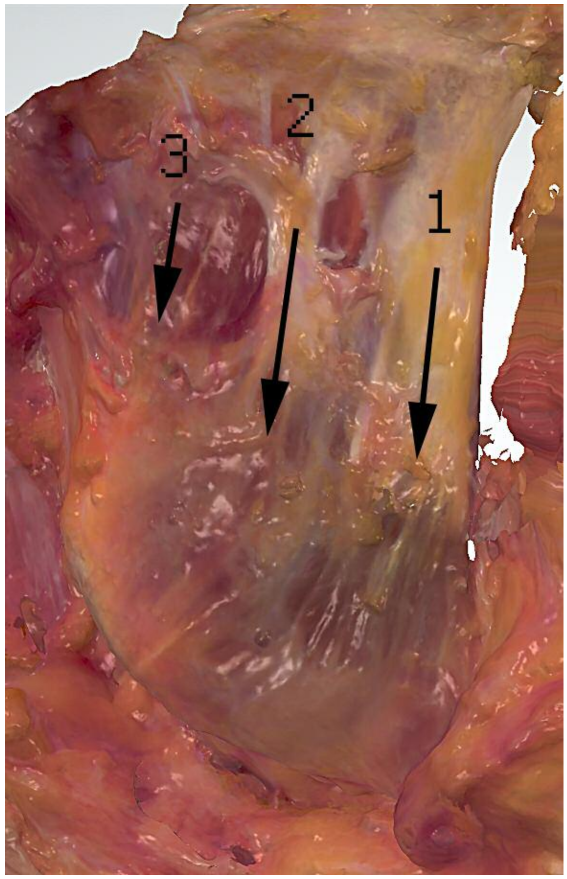

Figure 1
The three parts of the masseter muscle.

Materials and methods

This study has been constructed by data collected with the following methods and instruments:

1. Ultrasound machine for the recording videoclips of masseter muscles contractions, both left and right.
2. Dedicated software for deformation pattern analysis on ultrasound videos.
3. Intra-oral scanner (3Shape Trios) and chromatic markers.
4. Dedicated software for mapped occlusal surfaces analysis (3Shape Convice).

1. Ultrasound machine for the recording on video of masseter muscles contractions, both left and right

This study has been conducted by use of an ultrasound machine and a linear probe which allowed us to record a video (DCM) comprised of 45 frames per second (MicrUs EXT-1H Telemed UAB, Vilnius, Lithuania) and a linear probe (L12-5L40S-3 5-12 MHz 40 mm). The probe was fixed to a brace and the patients were asked to clench their teeth as hard as possible, obtain the muscle's maximum exertion, for 5 seconds three times, with 30 seconds intervals in between. Both right and left masseter muscles were analyzed. During this procedure, the patients were seating down on a dentists' chair with their head leaning on the headrest. The section of the muscle chosen is that in which the greatest possible expansion and the best view of the muscle layers during the contraction were visible. Said section was then marked on the patient's skin using an L shaped ruler that allows us to mark the bottom edge of the mandible. The procedure was then repeated after inserting two cotton rolls in-between the dental arches.

2. Dedicated software for deformation pattern analysis on ultrasound videos

We applied to the ultrasound video a dedicated software (Mudy 1.7.7.2 AMID Sulmona Italy) for the

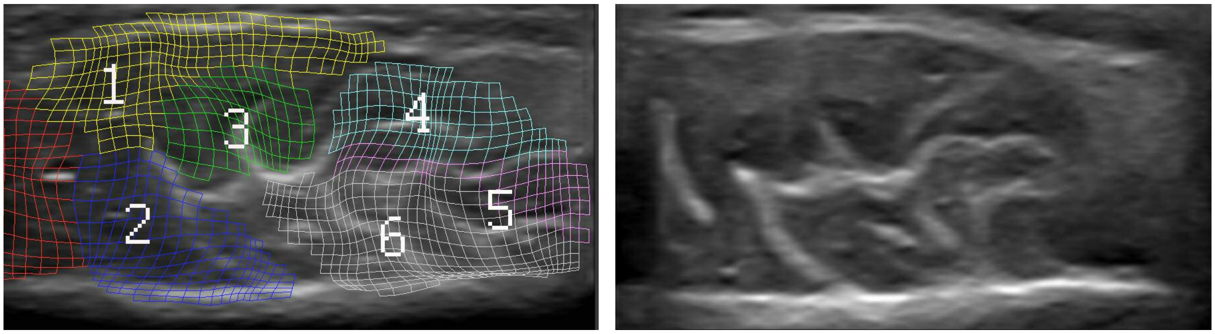

Figure 2
The six layers of the masseter muscle.

analysis of muscle deformation patters (contraction, dilatation, cross-plane, vertical strain, horizontal strain, vertical shear, horizontal shear, horizontal displacement, vertical displacement). During the contraction, some sections of the muscle dilate and others clench. The strain, shear and displacement patterns describe the recorded phenomena analyzing the movement of the points that form the two-dimensional ultrasound image with respect to two axes, horizontal and vertical. The cross-plane pattern adds the third dimension indicating the movement of those same points in cross-section. The compression and dilatation patterns show the global movement of all of points on the two axes. The qualitative analysis of the deformation patterns was done by contouring the resulting chromatic areas and comparing them to the Region Of Interest (ROI) obtained from the underlying anatomical parts. The quantitative analysis was attained by examining the curves that show the strain in relation to the time. For the achievement of this result six ROI were created, one for each muscle layer (2-17).

3. Intra-oral scanner (3Shape Trios) and chromatic markers

Patients were asked to chew 13 micron blue occlusion test films for 25 seconds as naturally and comfortably as possible after having cleaned all dental surfaces with a weak acid solution. Subsequently the patient underwent a color scan of the dental arches in order to document which parts of the dental surface were stained with color, and therefore were effectively used during the masticatory process. The test was repeated after a month in order to rule out patients that did not meet the necessary criteria.
An interview on the patient medical history confirmed their belonging to one of the following three groups: right side unilateral chewer (group A), left side unilateral chewer (Group B), bilateral alternate chewer (Group C) (Figure 3).

4. Dedicated software for mapped occlusal surfaces analysis (3Shape Convince)

The occlusal surface used by the patient was measured using a dedicated software (3Shape Convice). Only unilateral chewing patients who used no less than 70% of the total occlusal surface and bilateral chewing patients who used no less than 60% of the total occlusal surface were taken into consideration (Figure 4).

Sample investigated

The total number of patients for this study is 150. Out of this number, 50 belong to Group A, mono lateral chewing on the left side arch, and 50 to Group B, mono lateral chewing on the right side arch. The remains patients belong to Group C, bilateral alternate chewing.

Figure 3
The functional mapping of the dental arches with color markers.

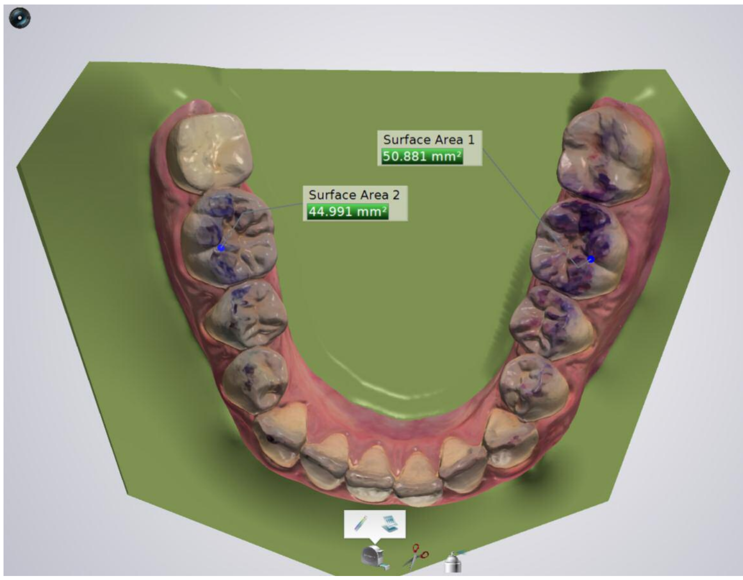

Figure 4
The measurements of the areas used by the patient to chew.

Results

In unilateral chewing patients the deformation pattern analysis allows us to view the radical difference between the "dominant" masseter muscle and the "subordinate" masseter muscle. By "dominant" masseter we refer to the masseter on which the masticatory process take place whereas by "subordinate" we refer to the masseter on the opposite side which does not perform said activity. In the case of Group C patients, we refer to the masseter muscle as "alternating".

Dilatation Pattern Analysis (Figure 5)

The dominant masseter presents a constant dilatation pattern that is, on average, almost double that of the

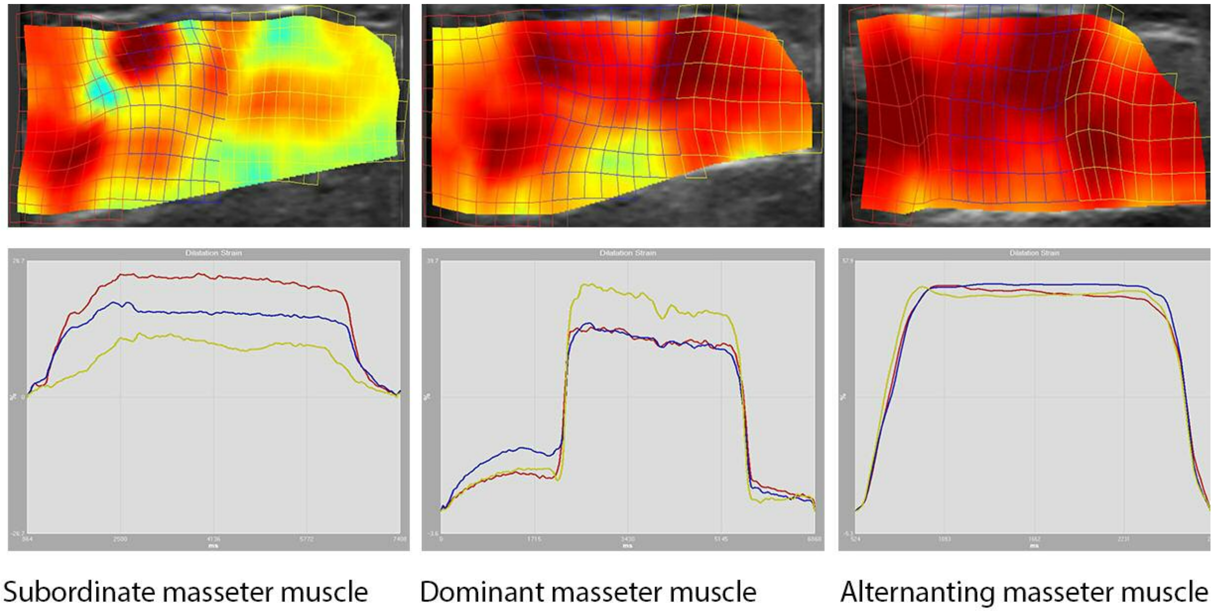

Figure 5
Isotonic contraction: analysis of the strain (dilation pattern).

subordinate. In the dominant muscle the dilatation value is around 35% whereas in the subordinate it is less than half that number. The patient feels the greater force of the clenching on the dominant side almost constantly. The subordinate frequently presents an irregular dilatation pattern, making it impossible to recognize and define the three functional areas typical of the masseter muscle discernible in the dominant and alternating masseters. The strain/time curves of the subordinate are clearly the most irregular of the three.

Cross-plane Deformation Pattern (Figure 6)

This pattern is one amongst those that appears to be most changed in the subordinate muscle. It features a fragmentation of the concentrated spots in the three sections that constitute the muscle, which sometimes disappear altogether and the image come back as white, and the contemporary disappearance of cross-plane areas with opposite signs. As for the previous pattern, the observed values of the subordinate are almost cut by half. Also noteworthy are the increasing irregularities of the strain/time curves.

Horizontal Shear Pattern (Figure 7)

The management of the twist on the horizontal plane is a control mechanism that is activated regardless the amount of pressure applied when clenching the muscle and in the subordinate masseter's case appears to be steadily compromised, especially in the deep section of the muscle. The loss of the typical horizontal shear cross pattern is a constant recurrence for the subordinate masseter.

Horizontal Displacement Pattern (Figure 8)

During an isometric contraction, the anterior part of the muscle (superficial masseter) and the posterior part (deep masseter) suffer a movement of opposite degree in a dorsal-ventral direction. The middle masseter appears scarcely active in this pattern. As for the subordinate masseter we can observe that also in this pattern a part of the muscle suffers from a loss of mobility, normally in the deep area (posterior).

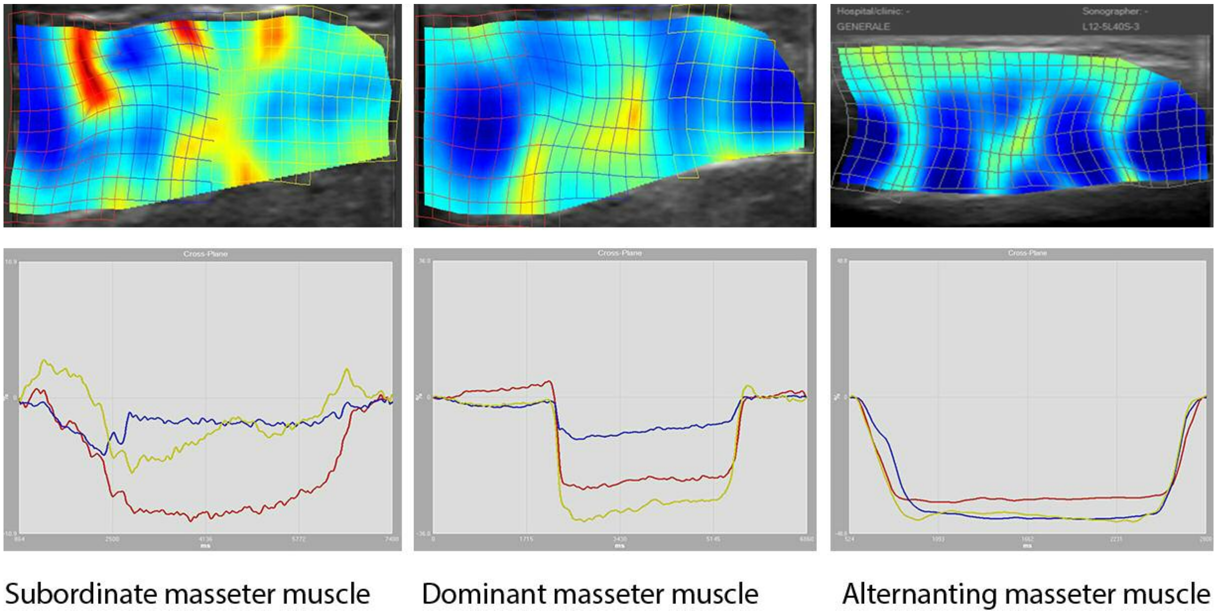

Figure 6
Isotonic contraction: analysis of the strain (cross-plane pattern).

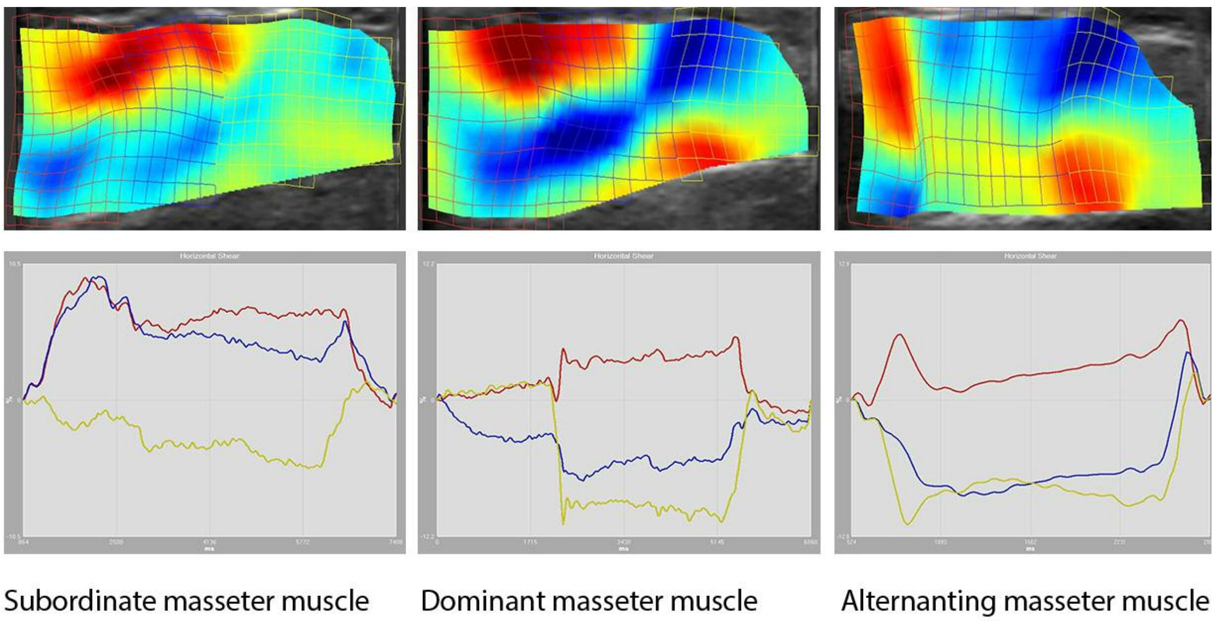

Figure 7
Isotonic contraction: analysis of the strain (horizontal-shear pattern).

Vertical Displacement Pattern (Figure 9)

Shows the relative movement in the mediolateral direction, to be interpreted as opposite in relation to the observations from the ultrasound video of the previous case. The subordinate masseter once again suffers from a constant alteration in terms of relative and absolute mobility.

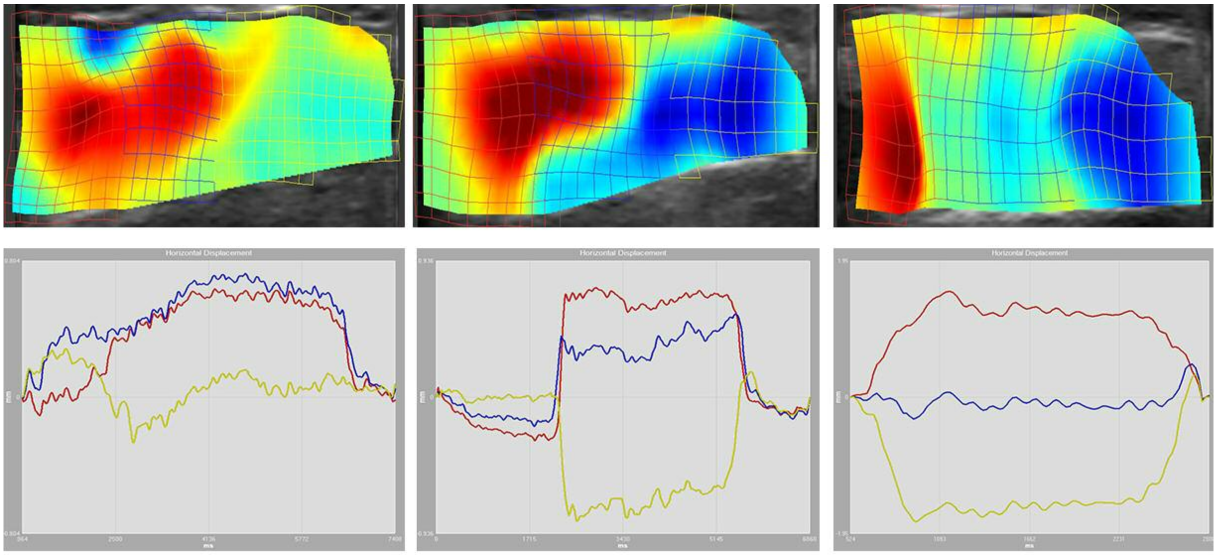

Figure 8
Isotonic contraction: analysis of the strain (horizontal displacement pattern).

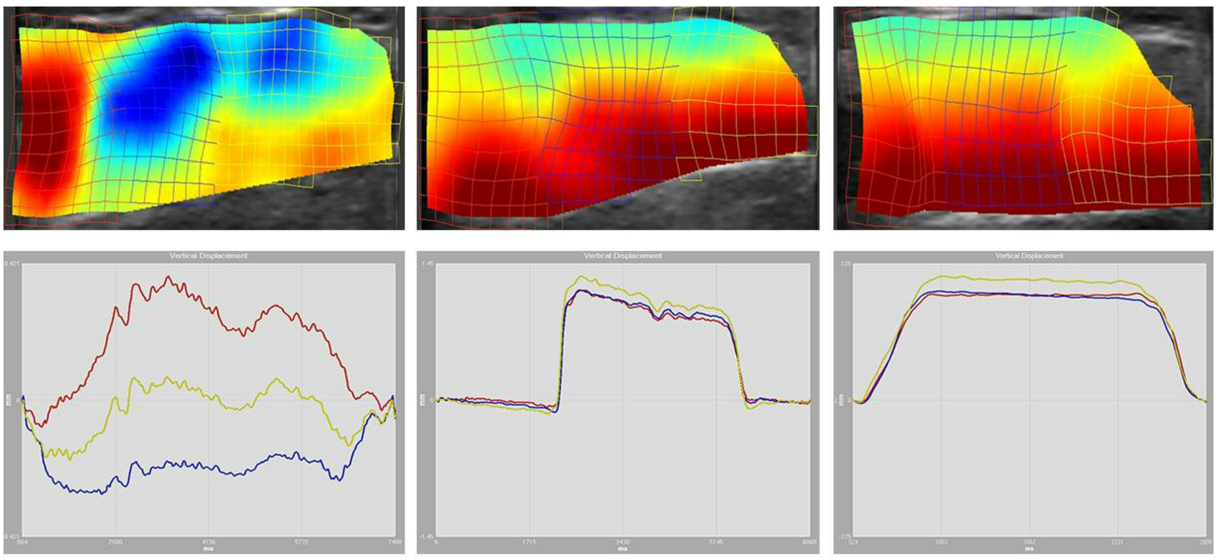

Figure 9
Isotonic contraction: analysis of the strain (vertical displacement pattern).

Discussion

The dominant masseter normally displays three defined functional areas as described by the literature and as observed during the anatomical dissection. The dilatation pattern is, on average, equal to or higher than 30% of the overall capabilities of the muscle. The curves appear to be fairly continuous and regular with a predominance of the middle masseter and of the central layer of the deep masseter. The dilatation capabilities of the muscle are incremented by about 10% in 65% of cases by the addition of the cotton rolls. The cross-pattern of the dominant masseter is generally negative with three prominent areas visible. The deformation patterns of the dominant masseter are rather similar to those of the alternating masseters.

On the other hand, the subordinate masseter usually presents a lack of functional areas (64% of cases) and, when present, the three are poorly defined. The dilatation pattern is often under 15% (75% of cases) and the cross-plane pattern is positive or both positive and negative at the same time. The curves appear as discontinuous and irregular. The patterns of the subordinate masseter are very different both qualitatively and quantitatively from the twisting control mechanisms of bilateral chewers. The addition of cotton rolls follows a modest improvement in less than 40% of cases. In the other 60% the cotton rolls either worsen the performance of the muscle or leave it unvaried.

In patients from Group C both masseters, left and right, display similar characteristics to the dominant masseter of the other groups allowing us to dismiss the need to classify one of them as subordinate.

The deformation pattern analysis of the skeletal muscles on ultrasound videos allows us to highlight with ease the clear difference in the clenching capabilities and strain management between the dominant masseter and the subordinate masseter in a unilaterally chewing patient. This is of paramount importance also in orthodontics and implantology (18-68,69 Scarano, 2007 #1896,70). In the sample investigated both in Group A and Group B the unilateral chewing is associated with a series of parameters (number, shape, volume, position and orientation of the teeth) and is also associated with the extension of the cutting surface really available. Dental fillings, prosthetic crowns, seals and usury derived from fatigue of the occlusal surface can sensibly reduce the cutting surface available. Moreover, the performance of the subordinate masseter in a considerable amount of cases (60%) does not experiment any improvement after the insertion of cotton rolls, thus indicating the predictable uselessness or even harmfulness of custom made devices, such as dental guards (for night and/or day use), used for the treatment of dysfunctions and pathologies presumably caused by unilateral chewing, which would then have nothing to do with parafunctional issues or postural anomalies of the mandible.

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