ORAL & IMPLANTOLOGY

original research article

Ultrasound and analysis of the deformation patterns of the masseter muscle: comparing surgical anatomy, ultrasound and functional anatomy

A. BUSATO[1], G. BALCONI[2], V. VISMARA[1], L. BERTELÈ[3], G. GARO[4], D. DE GREGORIO[5]

[1] *Medica Libra, Milano, Italy*
[2] *Department of Radiology, Hospital San Raffaele Turro, Milano, Italy*
[3] *Fondazione Apostolo, Merate, Italy*
[4] *President and Founder of Siach - The International Society of Surgical Anatomy*
[5] *Director of Siach, Aesthetic Surgeon, Perugia, Italy*

SUMMARY

Purpose. We have tried to demonstrate whether the analysis of the muscle strain allows us to identify the three distinct functional areas of the architecture of the masseter, as one would see them by performing or viewing an anatomical dissection of said muscle, and whether these sections have behave differently in terms of origin and coping of the strain they face (quantitative analysis).

Materials and methods. This work has been elaborated by the use of an ultrasound machine (MicrUs ext-1H Telemed Medical Systems Milano) and a linear probe (L12-5l40S-3 5-12 MHz 40 mm) which allowed us to record a 45 frame per second video (DCM). Videos has been elaborated by use of an ultrasound machine (MicrUs ext-1H Telemed Medical Systems Milano) and a linear probe (L12-5l40S-3 5-12 MHz 40 mm) which allowed us to record a 45 frame per second video (DCM). We applied to the resulting video a software (Mudy 1.7.7.2 AMID Sulmona Italy) for the analysis of muscle deformation patters (contraction, dilatation, cross-plane, vertical strain, horizontal strain, vertical shear, horizontal shear, horizontal displacement, vertical displacement).The number of videos of masseter muscles in contraction at maximum exertion due to dental clenching made during this research is around 12,000. Out of these we chose 1,200 videos which examine 200 patients (100 females, 100 males).

Results. The deformation pattern analysis of the skeletal muscle on ultrasound basis seems to be an adequate instrument to use during the investigation of the functional structure of the masseter muscle given its ability to highlight the distinct activity of each separate part of the muscle.

Conclusions. Moreover the strain does not apply to the muscle uniformly; instead it varies according to the observed area.

Key words: masseter muscle, ultrasound, deformation pattern, strain, masticatory organ, biomechanics.

Introduction

The masseter is a pennate structured muscle, consisting of three distinct sections: the superficial section at the anterior end of the muscle (Figure 1, point 1), the middle section (Figure 1 point 2), and the internal section at the deep end of the muscle (Figure 1 point 3). These can be detected by both a surgical dissection of the area and an ultrasound examination (Figure 2). With this last option one has the advantage of observing the structure of the muscle either contracting due to the clenching of the teeth, with or without biting aids in between the dental arches (such as cotton rolls, occlusal test films, custom made dental devices, etc.), or contracting repeatedly as occurs when one is chewing food or swallows over and over. The superficial masseter consists of two layers of aponeurotic muscle oriented at 60° to the occlusal plane (Figure 2 layer 1 and 2). The two layers are separated by a thin mem-

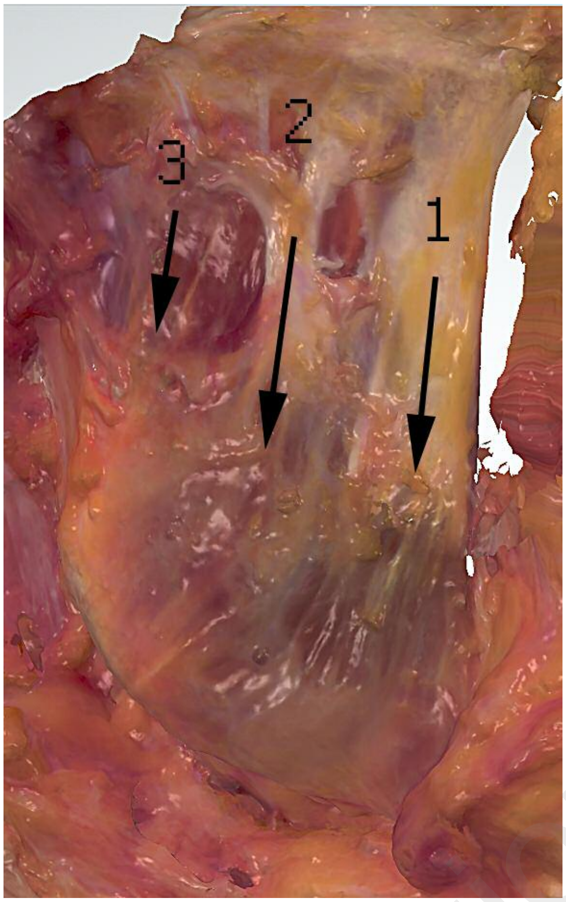

Figure 1
Masseter: (1) superficial section; (2) middle section; (3) internal section.

brane of connective tissue, which is particularly discernible if observed throughout an isometric contraction of the muscle, during which this membrane can clearly be seen separating the two layers (Figure 3 point 1). The middle masseter (Figure 2 layer 3) is typically described in the books as single stripe of aponeurotic muscle perpendicular to the occlusal plane that inserts itself coronally to the inferior margin of the zygomatic arch, thanks to two tendinous strips that connect them, and caudally on the lateral surface of the blade tendon of the outward layer of the deep masseter (Figure 3 point 3).Once again observation by means of an ultrasound examination allows us to appreciate the volume of the muscle during an isometric contraction (Figure 3 point 2).The weaving of this portion of the muscle is decidedly different than the other two which are defined by the presence of several connective septi (Figure 3 point 4) with the exception for the middle layer of the deep masseter. The deep masseter (Figure 2 layers 4, 5, 6) is organized in three layers as well: outward, middle and inward. The outward layer is extremely complex (Figure 3 point 4) and is composed of numerous thin structures that insert themselves on the inferior margin of the zygomatic arch and on the blade tendon of the middle layer, which in turn is fixed to the zygomatic arch and on the anterior edge of the capsule and of the articular disc of the temporo-mandibular joint. The inward layer enters from the mandibular notch to the zygomatic arch ahead of the articular tubercle of the temporal bone. The isometric contraction highlights the three layers and the gap, more or less deep, that separates the superficial masseter from the internal masseter and the dynamics that establish themselves between these two layers during masticatory activities. The functions that the masseter, in its entirety, is responsible for reported by the literature are the lifting and protrusion of the mandible (Figure 4).

During a voluntary clenching of the jaw the load applied onto the first molar by the contraction of the masseter muscle and the other elevating agents of the mandible can reach 500-900 newton per square centimeter (first molar in male). This type of performance requires the masseter muscle's maximum exertion, which can be documented through a surface electromyography. This exam, though, cannot define neither the separate activity of the three sections of the masseter muscle or the different layers within each, nor can it quantitatively describe the relationship between the architecture of the muscle and its functional activity. An electromyography, in other words, is unable to determine how muscle deformation occurs or how said muscle copes, both as a whole and within the separate parts, with the exhaustion intrinsically associated with muscle deformation.

The objective which the following work has set to achieve is to verify if the analysis of the deformation patterns in ultrasound videos obtained through a dedicated software is a valid instrument for the description of the masseter's structure from a functional (qualitative data) point of view, and if the results can be compared to the visual observations recorded in the literature.

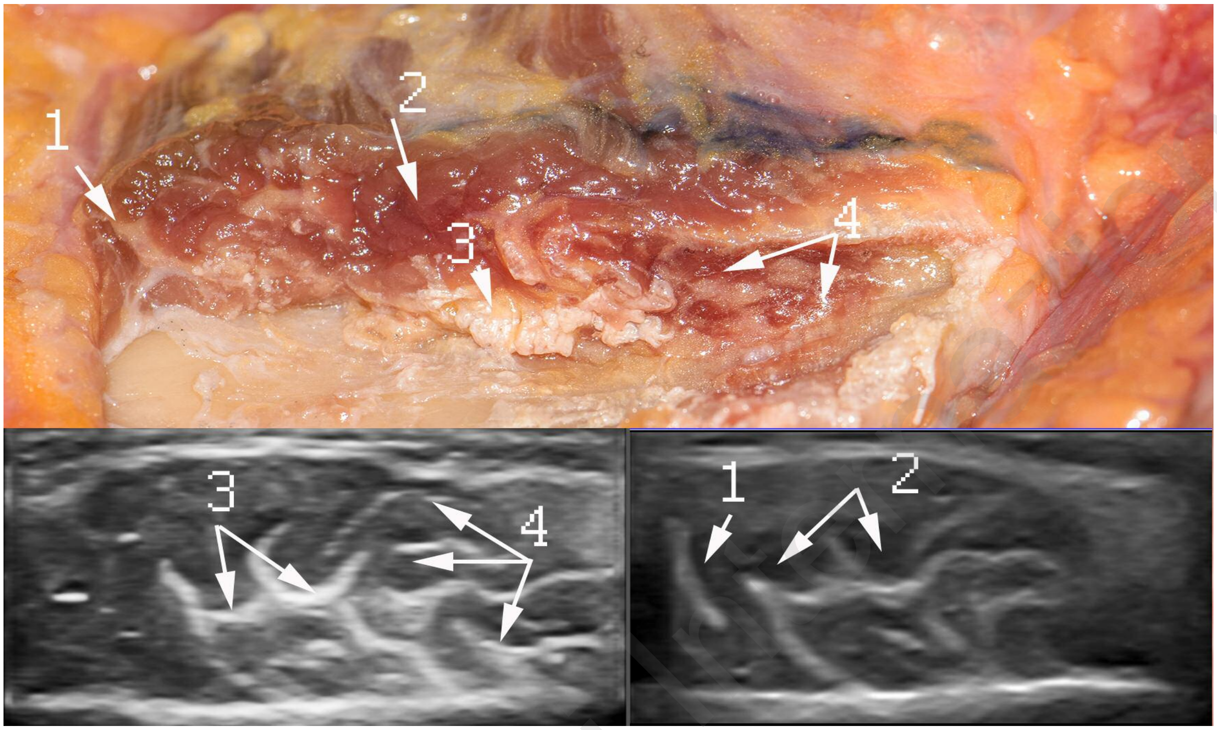

Figure 2
Masseter dissection *vs* ultrasound image: (1) parting of the two layers of the external masseter; (2) intermediate section; (3) blade tendon of the internal masseter; (4) layers of the internal masseter.

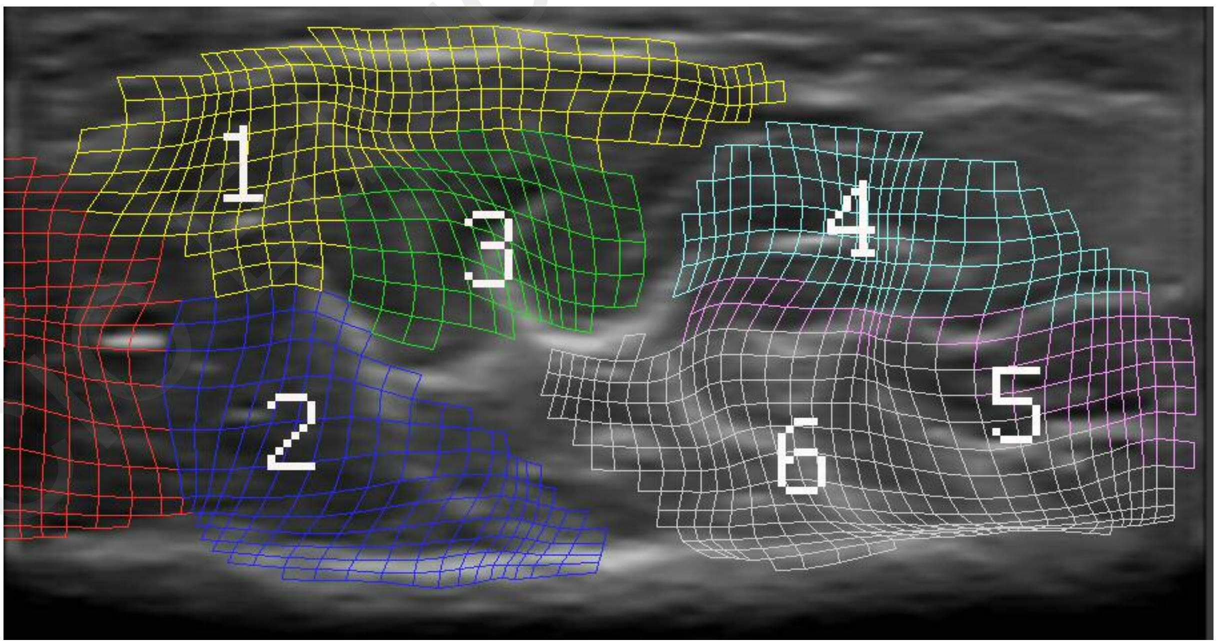

Figure 3
Ultrasound of the master during maximum exertion. External section: (1) external layer; (2) internal layer. (3) Intermediate section. Internal section: (4) outward layer; (5) central layer; (6) inward layer.

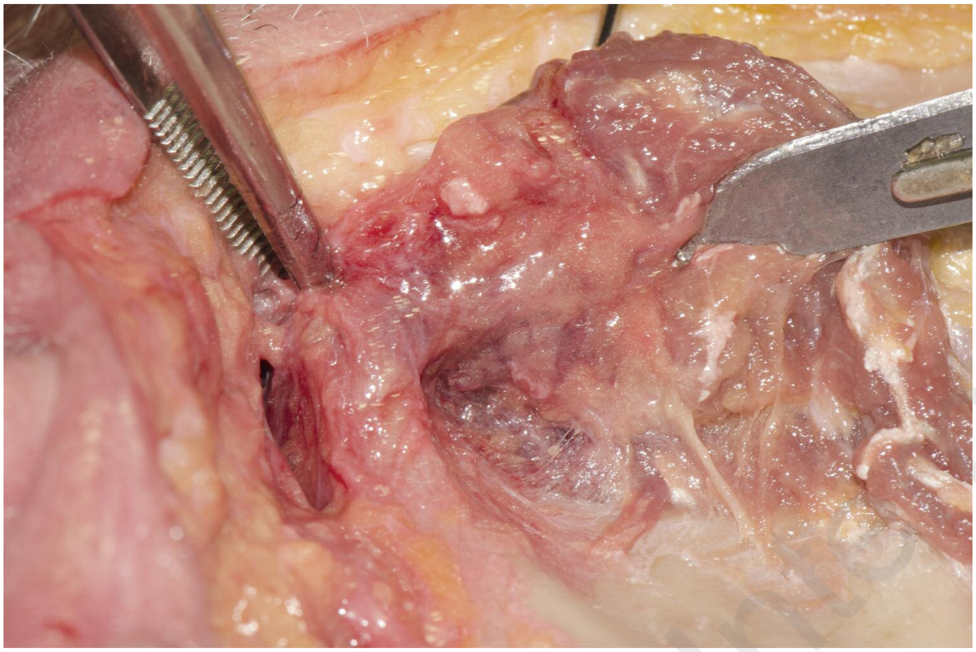

Figure 4
Deep masseter and temporo-mandibular joint: (1) deep masseter; (2) mandibular condyle.

That is to say, we have tried to demonstrate whether the analysis of the muscle strain allows us to identify the three distinct functional areas of the architecture of the masseter, as one would see them by performing or viewing an anatomical dissection of said muscle, and whether these sections have behave differently in terms of origin and coping of the strain they face (quantitative analysis). During the contraction, the masseter suffers a notable deformation and is subject to potentially wearing activities which can lead to repeated deformations that do not follow the natural physiological process. The possibility of precociously discovering a pattern of damaging deformations is certainly an auspicious goal (1).

Materials and methods

This work has been elaborated by use of an ultrasound machine (MicrUs ext-1H Telemed Medical Systems Milano) and a linear probe (L12-5l40S-3 5-12 MHz 40 mm) which allowed us to record a 45 frame per second video (DCM). The probe was fixed to a brace and the patient was 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.

Then we applied to the resulting video a software (Mudy 1.7.7.2 AMID Sulmona Italy) for the analysis of muscle deformation patters (contraction, dilatation, cross-plane, vertical strain, horizontal strain, vertical shear, horizontal shear, horizontal displacement, vertical displacement) (2). 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 (3-18).

In this work the pattern used for the analysis is the cross-plane pattern. The aim of the study of the ultrasound videos has been to determine whether the software for the analysis of deformation patterns has the ability to show and highlight three distinct areas and if said areas matched the sections that form the masseter muscle.

Another quantitative analysis of the muscle's contraction was done, dividing the muscle in three sections (superficial, middle and deep) in order to measure the deformation pattern inside each separate section and compare it to that of the adjacent sections (Figure 5).

Each video includes the recording of three contractions at maximum exertion in order to confirm both the repeatability of the data and to obtain average data of the muscle's behavior (Figure 6).

The number of videos of masseter muscles in contraction at maximum exertion due to dental clenching made during this research is around 12,000. Out of these we chose 1,200 videos which examine 200 patients (100 females, 100 males). The criteria for the choice of which videos to include in this case studies are:

a) the patients do not have any conditions or pathologies that affect the masticatory muscles or the temporo-mandibular joints. No evident symptoms of DCM;
b) at palpation the contractions were ranked 0-5 based on the following criteria, which take in consideration the stiffness of the muscle at the moment of maximum exertion, the speed of the contraction, the ability to keep the muscle contract for 5 seconds and to repeat it for three times. The ranking was done by a single operator. (0) contraction absent; (1) weak contraction; (2) satisfactory contraction; (3) good contraction; (4) excellent contraction; (5) outstanding contraction;
c) both masseters (left and right) show the same amount of force during contraction;
d) alternate bilateral chewing.

The aim of this selection is to have a group based entirely on clinical criteria such as those that are normally considered satisfactory in order to consider the masticatory muscles in good health and in full functional efficiency. Only videos that ranked at 4 were taken into consideration.

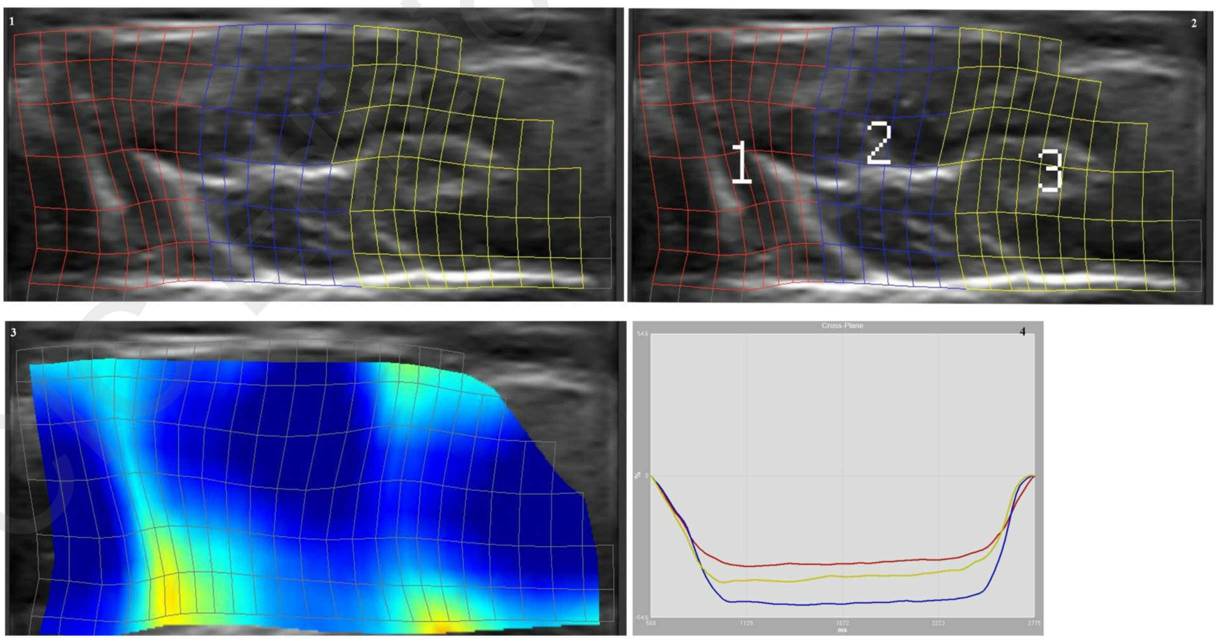

Figure 5
(1) Masseter in maximum exertion contraction with grid for the study of patterns; (2) masseter in maximum exertion contraction with grid for the study of patterns divided in three areas; (3) masseter in maximum exertion contraction and cross-plane; (4) curves time/strain of the three parts of the muscle.

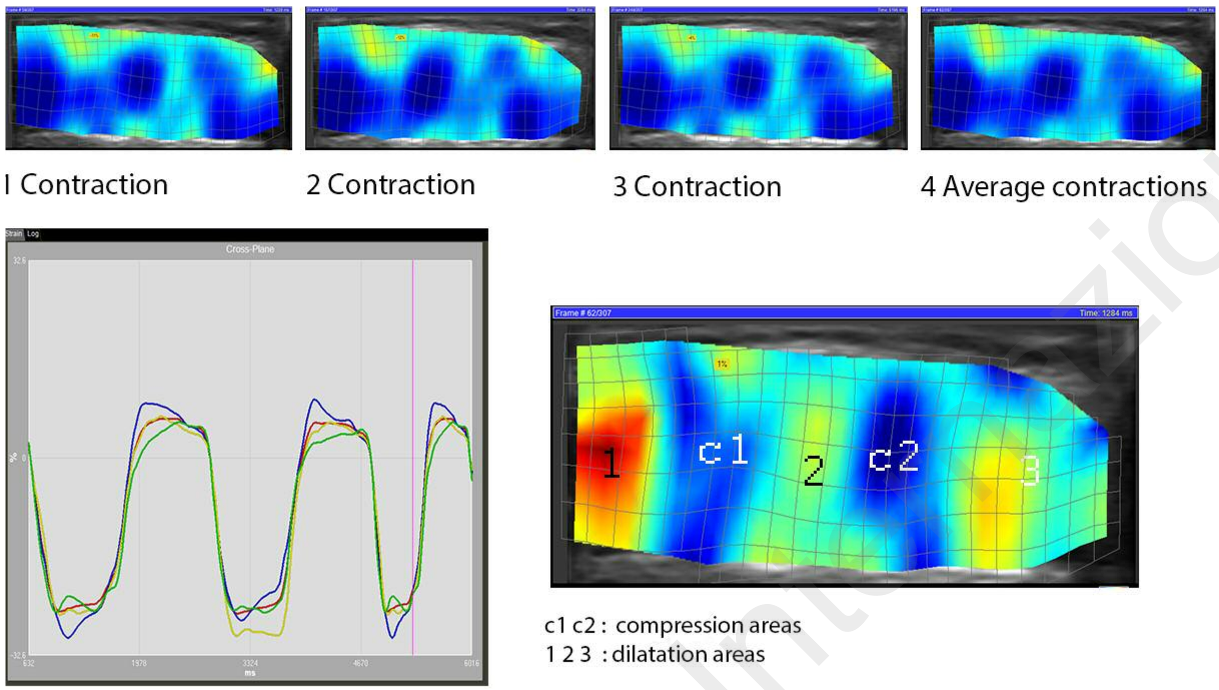

Figure 6
The cross-plane id measured on three single cycles of contraction repeated at 30 seconds intervals and an average is calculated based on that data. C1 and C2 represent the compression areas obtained with another pattern that highlight the parting of the muscle in three functional areas.

Results

During a maximum exertion contraction of patients belonging to group 4, we can observe on the cross-plane pattern the highlighting of three sections (superficial, middle and deep) with variable degrees of extension that present a higher value in the central area. The superficial section can comprehend one area (40%) or two areas (60%). In 30% of cases the middle section is divided in two areas, whereas in the other 70% it appears as one single area. The deep section presents itself as an area with a single spot (60%), two spots (30%) or three spots (10%). The qualitative analysis of the videos allows us to observe the constant presence of three distinct functional areas (100% of cases) seemingly corresponding to the three sections of the masseter muscle (superficial, middle and deep). The images suggest that there is a match between the surgical anatomy of the masseter as described in the literature and the functional anatomy on ultrasound base as described by the analysis of the deformation patterns. The strain does not apply to the muscle uniformly, instead it applies to separate areas. Said strain differs greatly in the three sections with predominance in the middle section in 75% of cases followed by the superficial section (15%) and the deep section (10%). In the investigated sample, the clenching of the masseter (right and/or left) had been able to produce a cross-plane pattern of the muscle movement equal to or greater than 30% of its potential and negative in 98% of cases.

Discussion

The deformation pattern analysis of the skeletal muscle on ultrasound basis seems to be an adequate instrument to use during the investigation of the functional structure of the masseter muscle given its ability to highlight the distinct activity of each separate part of the muscle. Unlike the surface electromyography the deformation pattern analysis on ultrasound basis allows to compare the study of the structure of the muscle (form, size, weaving, etc.) with its clenching capabilities, both as a whole and as separate parts. This is of paramount importance also in orthodontics and implantology (19-84). Moreover the strain does not apply to the muscle uniformly; instead it varies according to the observed area. The deformation pattern analysis of the skeletal muscle on ultrasound basis apparently offers new, fertile soil for the development of applications useful for the diagnosis and treatment of various dysfunctions of the masticatory organ because we believe that it can be used not only for the study of its functional structure but also to identify and distinguish with clarity patterns of physiological deformations from pathological ones and/or dysfunctions both during the clenching test and during real activities such as food chewing, swallowing and phonation.

References

1. Hylander WL, Ravosa MJ, Ross CF, Wall CE, Johnson KR. Symphyseal fusion and jaw-adductor muscle force: an EMG study. Am J Phys Anthropol. 2000; 112:469-92.
2. Busato A, Balconi G, Vismara V, Bertele L, Tonti G, Pedrizzetti G. Strain Analysis of Masseter Muscle by Ultrasound. J Biol Regul Homeost Agents. 2015;29:74-81.
3. Rocha CP, Croci CS, Caria PH. Is there relationship between temporomandibular disorders and head and cervical posture? A systematic review. J Oral Rehabil. 2013;40:875-81.
4. Singh A. Optic Flow Computation: A Unified Perspective. Place: IEEE Comput. Soc.,1992.
5. Barron JL, Fleet DJ, Beauchemin SS. Performance of optical flow techniques. International Journal of Computer Vision. 1994;12:43-77.
6. Bohs LN, Geiman BJ, Anderson ME, Gebhart SC, Trahey GE. Speckle tracking for multi-dimensional flow estimation. Ultrasonics. 2000;38:369-75.
7. Malpica N, Santos A, Zuluaga MA, Ledesma MJ, Perez E, Garcia-Fernandez MA, Desco M. Tracking of regions-of-interest in myocardial contrast echocardiography. Ultrasound Med Biol. 2004;30:303-9.
8. Leitman M, Lysyansky P, Sidenko S, et al. Two-dimensional strain-a novel software for realtime quantitative echocardiographic assessment of myocardial function. J Am Soc Echocardiogr. 2004;17:1021-29.
9. Vannan MA, Pedrizzetti G, Li P, et al. Effect of cardiac resynchronization therapy on longitudinal and circumferential left ventricular mechanics by velocity vector imaging: description and initial clinical application of a novel method using high-frame rate B-mode echocardiographic images. Echocardiography. 2005;22:826-30.
10. Pedrizzetti G, Sengupta S, Caracciolo G, et al. Three-dimensional principal strain analysis for characterizing subclinical changes in left ventricular function. J Am Soc Echocardiogr. 2014;27:1041-50 e1.
11. Loram ID, Maganaris CN, Lakie M. Use of ultrasound to make noninvasive in vivo measurement of continuous changes in human muscle contractile length. J Appl Physiol (1985). 2006;100:1311-23.
12. Yoshii Y, Villarraga HR, Henderson J, Zhao C, An KN, Amadio PC. Speckle tracking ultrasound for assessment of the relative motion of flexor tendon and subsynovial connective tissue in the human carpal tunnel. Ultrasound Med Biol. 2009;35:1973-81.
13. Peolsson M, Lofstedt T, Vogt S, Stenlund H, Arndt A, Trygg J. Modelling human musculoskeletal functional movements using ultrasound imaging. BMC Med Imaging. 2010;10:9.
14. Korstanje JW, Schreuders TR, van der Sijde J, Hovius SE, Bosch JG, Selles RW. Ultrasonographic assessment of long finger tendon excursion in zone v during passive and active tendon gliding exercises. J Hand Surg Am. 2010;35:559-65.
15. Darby J, Hodson-Tole EF, Costen N, Loram ID. Automated regional analysis of B-mode ultrasound images of skeletal muscle movement. J Appl Physiol (1985). 2012;112:313-27.
16. Mor-Avi V, Lang RM, Badano LP, et al. Current and evolving echocardiographic techniques for the quantitative evaluation of cardiac mechanics: ASE/EAE consensus statement on methodology and indications endorsed by the Japanese Society of Echocardiography. Eur J Echocardiogr. 2011;12:167-205.
17. Pedrizzetti G, Kraigher-Krainer, E, De Luca, A, et al. Functional strain-line pattern in the human left ventricle. Phys Rev Lett. 2012;109:048103.
18. Lopata RG, van Dijk JP, Pillen S, et al. Dynamic imaging of skeletal muscle contraction in three orthogonal directions. J Appl Physiol (1985). 2010;109:906-15.
19. Lucchese A, Carinci F, Saggese V, Lauritano D. Orthodontic tooth movement and distraction osteogenesis. European Journal of Inflammation. 2012;10:49-54.
20. Lucchese A, Carinci F, Brunelli G. Skeletal effects induced by twin block in therapy of class II malocclusion. European Journal of Inflammation. 2012;10:83-87.
21. Mancini GE, Carinci F, Zollino I, Avantaggiato A, Lucchese A, Puglisi P, Brunelli G. Lingual orthodontic technique: A case series analysis. European Journal of Inflammation. 2011;9:47-51.
22. Mancini GE, Carinci F, Zollino I, Avantaggiato A, Puglisi P, Caccianiga G, Brunelli G. Effectiveness of self-ligating orthodontic treatment. European Journal of Inflammation. 2011;9:53-58.

23. Mancini GE, Carinci F, Avantaggiato IZ, Puglisi P, Caccianiga G, Brunelli G. Simplicity and reliability of invisalign® system. European Journal of Inflammation. 2011;9:43-52.
24. Avantaggiato A, Zollino I, Carinci F. Impact of orthodontic treatment on crestal bone resorption in periodontally compromised patients: A case series. Acta Stomatologica Croatica. 2010;44:188-94.
25. Busato A, Vismara V, Bertele L, Zollino I, Carinci F. Relation between disk/condyle incoordination and joint morphological changes: A retrospective study on 268 TMJs. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology. 2010;110.
26. El Haddad E, Lauritano D, Carinci F. Interradicular septum as guide for pilot drill in postextractive implantology: a technical note. J Contemp Dent Pract. 2015;16:81-4.
27. Andreasi Bassi M, Lopez MA, Confalone L, Carinci F. Hydraulic sinus lift technique in future site development: clinical and histomorphometric analysis of human biopsies. Implant Dent. 2015;24:117-24.
28. Lopez MA, Andreasi Bassi M, Confalone L, Carinci F. Maxillary sinus floor elevation via crestal approach: the evolution of the hydraulic pressure technique. J Craniofac Surg. 2014;25:e127-32.
29. Lucchese A, Carinci F, Saggese V, Lauritano D. Immediate loading versus traditional approach in functional implantology. European Journal of Inflammation. 2012;10:55-58.
30. Danza M, Paracchini L, Carinci F. Tridimensional finite element analysis to detect stress distribution in implants. Dental Cadmos. 2012;80:598-602.
31. Fanali S, Carinci F, Zollino I, Brugnati C, Lauritano D. One-piece implants installed in restored mandible: a retrospective study. European Journal of Inflammation. 2012;10:19-23.
32. Scarano A, Murmura G, Carinci F, Lauritano D. Immediately loaded small-diameter dental implants: evaluation of retention, stability and comfort for the edentulous patient. European Journal of Inflammation. 2012;10:19-23.
33. Fanali S, Carinci F, Zollino I, Brugnati C, Lauritano D. A retrospective study on 83 one-piece implants installed in resorbed maxillae. European Journal of Inflammation. 2012;10:55-58.
34. Scarano A, Perrotti V, Carinci F, Shibli JA. Removal of a migrated dental implant from the maxillary sinus after 7 years: A case report. Oral and Maxillofacial Surgery. 2011;15:239-43.
35. Scarano A, Piattelli A, Assenza B, Carinci F, Donato LD, Romani GL, Merla A. Infrared thermographic evaluation of temperature modifications induced during implant site preparation with cylindrical versus conical drills. Clinical Implant Dentistry and Related Research. 2011;13:319-23.
36. Gargari M, Ottria L, Morelli V, Benli M, & Ceruso, FM. Conservative zirconia-ceramic bridge in front teeth. Case report. Oral Implantol (Rome). 2015;7:93-98.
37. Andreasi Bassi M, Andrisani C, Lopez MA, Gaudio RM, Lombardo L, Carinci F. Guided bone regeneration by means of a preformed titanium foil: A case of severe atrophy of edentulous posterior mandible. J Biol Regul Homeost Agents. 2016;30(S2):35-41.
38. Milillo L, Fiandaca C, Giannoulis F, Ottria L, Lucchese A, Silvestre F, Petruzzi M. Immediate vs non-immediate loading post-extractive implants: A comparative study of Implant Stability Quotient (ISQ). Oral Implantol (Rome). 2016;9:123-31.
39. Bartuli FN, Luciani F, Caddeo F, et al. Piezosurgery vs High Speed Rotary Handpiece: a comparison between the two techniques in the impacted third molar surgery. Oral Implantol (Rome). 2013;6:5-10.
40. Clementini M, Ottria L, Pandolfi C, Agrestini C, Barlattani A. Four impacted fourth molars in a young patient: a case report. Oral Implantol (Rome). 2012;5:100-3.
41. Gargari M, Comuzzi L, Bazzato MF, Sivolella S, Di Fiore A, Ceruso F. Treatment of peri-implantitis: Description of a technique of surgical 2 detoxification of the implant. A prospective clinical case series with 3-year follow-up. Oral Implantol (Rome). 2015;8:1-11.
42. Inchingolo F, Marrelli M, Annibali S, et al. Influence of endodontic treatment on systemic oxidative stress. Int J Med Sci. 2014;11:1-6.
43. Scarano A, Piattelli A, Assenza B, Sollazzo V, Lucchese A, Carinci F. Assessment of pain associated with insertion torque of dental implants. A prospective, randomized-controlled study. International Journal of Immunopathology and Pharmacology. 2011;24:65-69.
44. Traini T, Danza M, Altavilla R, et al. Histomorphicmetric evaluation of an implant retrieved from human maxilla after 13 years. International Journal of Immunopathology and Pharmacology. 2011;24:25-30.
45. Danza M, Grecchi F, Zollino I, Casadio C, Carinci F. Spiral implants bearing full-arch rehabilitation: Analysis of clinical outcome. Journal of Oral Implantology. 2011;37:447-55.
46. Danza M, Zollino I, Avantaggiato A, Lucchese A, Carinci F. Distance between implants has a potential impact of crestal bone resorption. Saudi Dental Journal. 2011;23:129-33.
47. Scarano A, Murmura G, Sinjiari B, Sollazzo V, Spinelli G, Carinci F. Analysis and structural examination of screw loosening in oral implants. International Journal of Immunopathology and Pharmacology. 2011;24:77-81.
48. Scarano A, Murmura G, Sinjiari B, Assenza B, Sollazzo V, Spinelli G, Carinci F. Expansion of the alveolar bone crest with ultrasonic surgery device: Clinical study in mandible. International Journal of Immunopathology and Pharmacology. 2011;24:71-75.
49. Traini T, Danza M, Zollino I, et al. Histomorphic-metric evaluation of an immediately loaded implant re-

trieved from human mandible after 2 years. International Journal of Immunopathology and Pharmacology. 2011;24:31-36.
50. Carinci F, Danza M. Clinical outcome of implants inserted in piezo split alveolar ridges: A pilot study. In: Perspectives on Clinical Dentistry. 2011:29-30.
51. Danza M, Zollino I, Guidi R, Carinci F. Computer planned implantology: Analysis of a case series. In: Perspectives on Clinical Dentistry. 2011;287-300.
52. Grecchi F, Pagliani L, Mancini GE, Zollino I, Carinci F. Implant treatment in grafted and native bone in patients affected by ectodermal dysplasia. Journal of Craniofacial Surgery. 2010;21:1776-80.
53. Danza M, Carinci F. Flapless surgery and immediately loaded implants: a retrospective comparison between implantation with and without computer-assisted planned surgical stent. Stomatologija. 2010;12:35-41.
54. Grecchi F, Zingari F, Bianco R, Zollino I, Casadio C, Carinci F. Implant rehabilitation in grafted and native bone in patients affected by ectodermal dysplasia: evaluation of 78 implants inserted in 8 patients. Implant Dent. 2010;19:400-8.
55. Grecchi F, Mancini G, Parafioriti A, Mineo G, Zollino I, Pricolo A, Carinci F. Ectodermal dysplasia treated with one-step surgical rehabilitation: a case report. Singapore Dent J. 2010;31:9-14.
56. Danza M, Quaranta A, Carinci F, Paracchini L, Pompa G, Vozza I. Biomechanical evaluation of dental implants in D1 and D4 bone by Finite Element Analysis. Minerva stomatologica. 2010;59:305-13.
57. Carinci F, Brunelli G, Franco M, Viscioni A, Rigo L, Guidi R, Strohmenger L. A retrospective study on 287 implants installed in resorbed maxillae grafted with fresh frozen allogenous bone. Clin Implant Dent Relat Res. 2010;12:91-8.
58. Viscioni A, Rigo L, Franco M, Brunelli G, Avantaggiato A, Sollazzo V, Carinci F. Reconstruction of severely atrophic jaws using homografts and simultaneous implant placement: a retrospective study. J Oral Implantol. 2010;36:131-9.
59. Danza M, Riccardo G, Carinci F. Bone platform switching: a retrospective study on the slope of reverse conical neck. Quintessence Int. 2010;41:35-40.
60. Degidi M, Piatelli A, Iezzi G, Carinci F. Wide-diameter implants: Analysis of clinical outcome of 304 fixtures. Journal of Periodontology. 2007;78:52-58.
61. Degidi M, Piattelli A, Gehrke P, Felice P, Carinci F. Five-year outcome of 111 immediate nonfunctional single restorations. J Oral Implantol. 2006;32:277-85.
62. Degidi M, Piattelli A, Gehrke P, Carinci F. Clinical outcome of 802 immediately loaded 2-stage submerged implants with a new grit-blasted and acid-etched surface: 12-month follow-up. Int J Oral Maxillofac Implants. 2006;21:763-8.
63. Danza M, Fromovich O, Guidi R, Carinci F. The clinical outcomes of 234 spiral family implants. J Contemp Dent Pract. 2009;10:E049-56.
64. Scarano A, Piattelli M, Carinci F, Perrotti V. Removal, after 7 years, of an implant displaced into the maxillary sinus. A clinical and histologic case report. Journal of Osseointegration. 2009;1:35-40.
65. Carinci F, Brunelli G, Danza M. Platform switching and bone platform switching. J Oral Implantol. 2009;35: 245-50.
66. Grecchi F, Danza M, Bianco R, Parafioriti A, Carinci F. Computer planned implant-orthognathic rehabilitation: a case of one step surgical procedure with implants insertion, Le Fort I advancement, grafting and immediate loading. J Osseointegration. 2009;3.
67. Franco M, Rigo L, Viscione A, et al. CaPO4 blasted implants inserted into iliac crest homologue frozen grafts. The Journal of oral implantology. 2009;35:176-80.
68. Danza M, Guidi R, Carinci F. Comparison Between Implants Inserted Into Piezo Split and Unsplit Alveolar Crests. Journal of Oral and Maxillofacial Surgery. 2009;67:2460-65.
69. Grecchi F, Zollino I, Parafioriti A, Mineo G, Pricolo A, Carinci F. One-step oral rehabilitation by means of implants' insertion, Le Fort I, grafts, and immediate loading. J Craniofac Surg. 2009;20:2205-10.
70. Viscioni A, Franco M, Rigo L, Guidi R, Brunelli G, Carinci F. Implants inserted into homografts bearing fixed restorations. Int J Prosthodont. 2009;22:148-54.
71. Degidi M, Piattelli A, Felice P, Carinci F. Immediate functional loading of edentulous maxilla: a 5-year retrospective study of 388 titanium implants. J Periodontol. 2005;76:1016-24.
72. Franco M, Viscioni A, Rigo L, Guidi R, Zollino I, Avantaggiato A, Carinci F. Clinical outcome of narrow diameter implants inserted into allografts. J Appl Oral Sci. 2009;17:301-6.
73. Danza M, Guidi R, Carinci F. Spiral family implants inserted in postextraction bone sites. Implant Dent. 2009;18:270-8.
74. Viscioni A, Franco M, Rigo L, Guidi R, Spinelli G, Carinci F. Retrospective study of standard-diameter implants inserted into allografts. J Oral Maxillofac Surg. 2009;67:387-93.
75. Carinci F, Brunelli G, Zollino H, et al. Mandibles grafted with fresh-frozen bone: An evaluation of implant outcome. Implant Dentistry. 2009;18:86-95.
76. Carinci F, Guidi R, Franco M, Viscioni A, Rigo L, De Santis B, Tropina E. Implants inserted in fresh-frozen bone: a retrospective analysis of 88 implants loaded 4 months after insertion. Quintessence Int. 2009;40:413-9.
77. Franco M, Tropina E, De Santis B, Viscioni A, Rigo L, Guidi R, Carinci F. A 2-year follow-up study on standard length implants inserted into alveolar bone sites augmented with homografts. Stomatologija. 2008;10: 127-32.
78. Scarano A, Carinci F, Quaranta A, Di Iorio D, Assenza B, Piattelli A. Effects of bur wear during implant site preparation: an in vitro study. International journal of

immunopathology and pharmacology. 2007;20:23-26.
79. Scarano A, Carinci F, Quaranta A, Iezzi G, Piattelli M, Piattelli A. Correlation between implant stability quotient (ISQ) with clinical and histological aspects of dental implants removed for mobility. International journal of immunopathology and pharmacology. 2007;20:33-36.
80. Concolino P, Cecchetti F, D'Autilia C, et al. Association of periodontitis with GSTM1/GSTT1-null variants-A pilot study. Clinical Biochemistry. 2007;40:939-45.
81. Giannitelli SM, Basoli F, Mozetic P, et al. Graded porous polyurethane foam: A potential scaffold for oro-maxillary bone regeneration. Materials Science and Engineering C. 2015;51:329-35.
82. Giancotti A, Romanini G, Di Girolamo R, Arcuri C. A less-invasive approach with orthodontic treatment in beckwith-wiedeman patients. Orthodontics and Craniofacial Research. 2002;5:59-63.
83. Germano F, Bramanti E, Arcuri C, Cecchetti F, Cicciù M. Atomic force microscopy of bacteria from periodontal subgingival biofilm: Preliminary study results. European Journal of Dentistry. 2013;7:152-58.
84. Bramanti E, Matacena G, Cecchetti F, Arcuri C, Cicciù M. Oral health-related quality of life in partially edentulous patients before and after implant therapy: A 2-year longitudinal study. ORAL and Implantology. 2013;6:37-42.

Correspondence to:
Antonio Busato, DMD
Medica Libra
Via Gian Girolamo Savoldo 3
Milano, Italy
Phone/fax: +39.02.6437937
E-mail: info@medica-libra.it