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Research Article

Masseter Muscle Adaptation Following Orthognathic Surgery - MRI Analysis

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Abstract

Orthodontic and surgical technical advances in recent years have resulted in treatment opportunities for a whole range of craniofacial skeletal disorders either in the adolescent or adult patient. In the growing child these can include myofunctional orthodontic appliance therapy or distraction osteogenesis procedures, whilst in the adult the mainstay approach revolves around orthognathic surgery.

The literature agrees that for a change in craniofacial morphology to remain stable, the muscles acting upon the facial skeleton must be capable of adaptation in their structure and, therefore, their function. Failure of the muscles to adapt to the change in their length or orientation will place undesirable forces on the muscle attachments leading to potential instability of the skeleton. Adaptation can occur through various processes including those within the neuromuscular feedback mechanism, through changes within muscle structure or through altered muscle physiology, and through changes at the muscle/bone interface.

This prospective, case controlled clinical study was designed to provide information in relation to masticatory muscle adaptation following orthognathic surgery. Both for ease of access, and in order to provide data suitable for comparison with previous studies of muscle function, the muscle chosen for investigation was the masseter muscle.

It is now accepted that because there is no single method of assessing masticatory function, several measures should be taken, and whenever possible, simultaneously.

This pilot investigation was designed to apply several, newly developed and more sophisticated methods of measuring muscle structure and function to a situation where adaptation of muscle is pivotal to the success of a therapeutic approach.

Patients attending the combined orthodontic/orthognathic surgery clinic at the Clitrofa - Centro Médico, Dentário e Cirúrgico, in Trofa - Portugal were screen. Ten patients scheduled for a bimaxillary osteotomy involving a combination of maxillary Le Fort I impaction procedure coupled with a sagittal split advancement of the mandible were select to form the study group.

The 10 patients have Magnetic Resonance Imaging (MRI) of the masseter muscle to evaluate the masseter muscle volume and fibre orientation changes. This exam was taken before surgery and 6 to 12 months after surgery according to the protocol jointly developed between the Eastman Dental Institute - University of London and the MRI Centre - Department of Radiology at John Radcliffe Hospital - University of Oxford.

Keywords: Orthognathic Surgery; Masseter Muscle; MRI Analysis

Introduction

Orthognathic surgery is a practical art, the surgeon often uses direct physical intervention in the treatment of patients. To minimize operative morbidity and mortality, and to maximize therapeutic success, surgical strategies are tailored to each patient and must be carefully planned using the best possible anatomical information. The traditional way for a surgeon to gain basic experience without risk to the patient is to dissect cadavers and to examine carefully preserved pathological specimens. This serves to provide a conceptual anato-pathological framework from which operative interventions may be safely made. However, every patient is unique. Thus, there is a need for the surgeon to attain a specific understanding of the individual's anatomy pre-operatively. Thorough physical examination may be all that is needed for conditions in which the anato-pathology is common and the surgeon experienced. With complicated anato-pathology, detailed information relating to the morphology of internal structures is often required by the surgeon to enhance understanding. To obtain this internal anatomical information non-invasively, the surgeon relies on medical imaging [1].

Advances in medical imaging have created ever increasing volumes of complex data obtained from the patient. The interpretation of such information has become a specialty in itself and the surgeon at times may be left bewildered as to how best to apply the available information to the practicalities of physical intervention. The surgeon seeks to understand the exact morphology of the abnormality, its relationships to surrounding anatomy and the best way to access and correct the pathology operatively. Such specific information is not readily available in the radiologist's report and however experienced the surgeon may be at interpreting images such questions often cannot be easily answered [1].

Three-dimensional (3-D) imaging has been developed to narrow the communication gap between radiologist and surgeon. By using 3-D imaging a vast number of complex slice images can be quickly appreciated. The term "three-dimensional" however, is not a truly accurate description of these images as they are still displayed on a radiological film or flat screen in only two dimensions.

The advent of 3-D imaging has not only improved data display but also promoted the development of even more useful technologies to assist the surgeon in diagnosis and planning [1].

Magnetic resonance imaging-MRI

Magnetic resonance imaging has become accepted as a powerful imaging tool. A customised software programme has been developed at John Radcliffe Hospital - Oxford University which enables the reconstruction of 3D images allowing measurement of muscle volume and area with a high level of accuracy.

To date this technology had only been applied to tongue muscles, when applied to the muscles of mastication the resolution and results were disappointing.

The goal was to develop the system and software to produce accurate and reproducible data for masticatory muscles which not only provided data for muscle area and volume, but also was of sufficient detail to enable analysis of muscle fibre orientation in particular of masseter muscle.

The masseter muscle displays a penniform structure typically characterized by the presence of alternating muscular/aponeurotic layers. The anatomical sections and the MRI section in the same plane allowed the appearance of the intra-muscular aponeurotic layers on the MRI to be defined [2].

The architecture of the masseter muscle has been studied for a long time but the lack of clinical applications led to descriptions which were often global or contradictory, giving the muscle sometimes two bundles sometimes three [2]. The successive studies of Gaspard [3-5], Yoshikawa [6,7] and Gaudy [8] allowed the definition of the arrangement of the muscular aponeurotic layers making up the human masseter muscle. Unger [9] affirmed the value of magnetic resonance imaging in the oro-facial field for the study of the musculature of the tongue and the walls of the oral cavity, but gave only very general information on the masticatory muscles [10].

Anatomics™ software

The Anatomics™ Rx software is a 3D DICOM viewer and allows to view CT and MRI scan data in both slice format and fully interactive 3D. Anatomics™ can convert 3D images to the STL format for rapid prototyping, or as a bridge from medical imaging to Computer Aided Design (CAD). A good quality 3D scan is required to create an accurate biomodel or implant.

To standardise the scanning process, a scanning protocol was developed and applied that describe the preferred imaging parameters and provide the imaging technician with an area to note specifics.

The patient must remain completely still during the scan, if the patient moves during the scan, it will need to be repeated. Only the original fine slice data must be used in the software, reformats will not be accepted.

Fine overlapping slices must be used, the thickness of 1 mm (or nearest to) and a spacing of 0.8 mm.

The objective was to extract the muscle from the image (margins identification, extract the muscle considering the 3 planes of space, calculation of area and volume). The software allows the correction of limits at any time what gives the observer the capacity of double-check all the process.

During this study the MRI machine used was a Sigma MR/I Twinspeed from GE Medical Systems, after several attempts the software was further developed to produce slices through the muscle at 1mm intervals rather than 2 mm; the scanning time was about seven minutes.

The first masseter muscle 3D images reconstruction were acceptable in terms of definition, area and volume but with a lack of

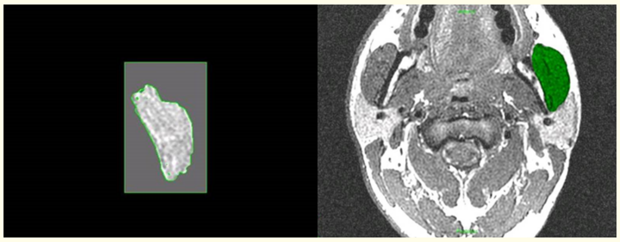

Figure 1: Identification of masseter muscle limits in a sagittal plane.

detail in terms of muscle fibres visualisation and orientation. Increasing the scanning time from five to seven minutes and changing the muscle slices to 1mm intervals was possible the acquisition of more muscle details. As a consequence, the resolution of the muscles was greatly enhanced and the final masseter muscle 3D images reconstruction permits a good visualisation of muscle fibres and their orientation. This type of reconstruction have also allowed visualisation of the muscle's bony attachments and enabled the measurement of potential changes in orientation in relation to a static landmark unaffected by surgery (e.g. Frankfort plane) or in relation to functional identifiers (e.g. Occlusal plane).

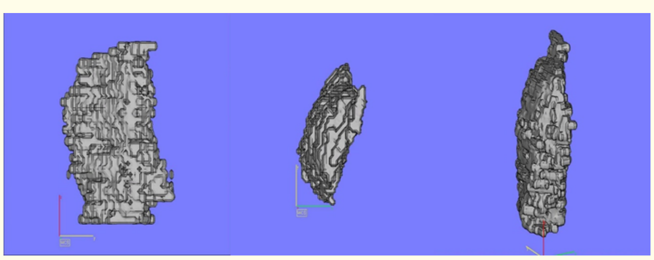

Figure 2: Final images from the left masseter muscle reconstruction using AnatomicsTM Software.

Facial deformity

To ascertain whether identifiable and measurable changes occur in parameters in conditions which simulate those occurring during the correction of both horizontal and vertical facial deformities a repeatability test was performed.

To build the occlusal splints, a subject was chosen to take dental impressions in silicone from upper and lower dental arches. The cast models were digitalized using the Anatomics™ software and placed in occlusion.

Using Stereolithography "surgical wafers" were built in photosensitive resin designed to mimic skeletal discrepancies. These were extremely accurate occlusal splints which hold the lower jaw of a Class I (normal) patient in a position which mimics an increasingly Class III deformity or alternatively with an increasingly severe vertical skeletal deformity with associated anterior open bite.

The horizontal simulation deformities starts with a Class I and progress to a 3 mm overject, 6 mm overject and a 9 mm overject. In terms of vertical simulation deformities starts with a Class I and progress to 5 mm anterior open bite and 10 mm anterior open bite.

The occlusal splint was placed between the upper and lower dental arch, and the subject was instructed to bite for about 7 minutes. The values were registered (T0) and the procedure was repeated after 30 minutes (T1). The process was repeated twice for each surgical wafer after rest period. In the proposed repeatability test the area and volume were measured using the same developed MRI protocol for the right and left masseter muscles.

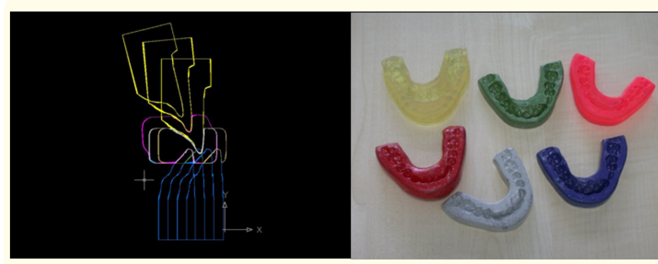

Figure 3: Demonstration of all the skeletal discrepancies simulated and the occlusal splints colour code

Materials and Methods

Patients attending the combined orthodontic/orthognathic surgery clinic at the Clitrofa - Centro Médico, Dentário e Cirúrgico, in Trofa - Portugal were screen. Ten patients scheduled for a bimaxillary osteotomy involving a combination of maxillary Le Fort I impaction procedure coupled with a sagittal split advancement of the mandible were select to form the study group.

The 10 patients have Magnetic Resonance Imaging (MRI) of the masseter muscle to evaluate the masseter muscle volume and fibre orientation changes. This exam was taken before surgery and 6 to 12 months after surgery according to the protocol jointly developed between the Eastman Dental Institute - University of London and the MRI Centre - Department of Radiology at John Radcliffe Hospital - University of Oxford.

A combination of different parametric tests has been used to compare the different experimental variables. The experimental design devised for this study is depicted in figure 4, comprising a combination of different examiners, patients, MRI analysis parameters and occlusal deformities.

Comparison A - Testing the differences between examiners (F *versus* C) → Study A

The statistical comparison between examiners F and C regarding the measurement of mean left masseter area (mm^2) and mean left masseter volume (mm^3) of ten patients by MRI was performed using a Paired Student's *t*-test.

Comparison B - Testing the differences between masseters (Left masseter *versus* right masseter) → Study B

The statistical comparison between left and right masseters of a selected patient subjected to different levels of occlusal deformity

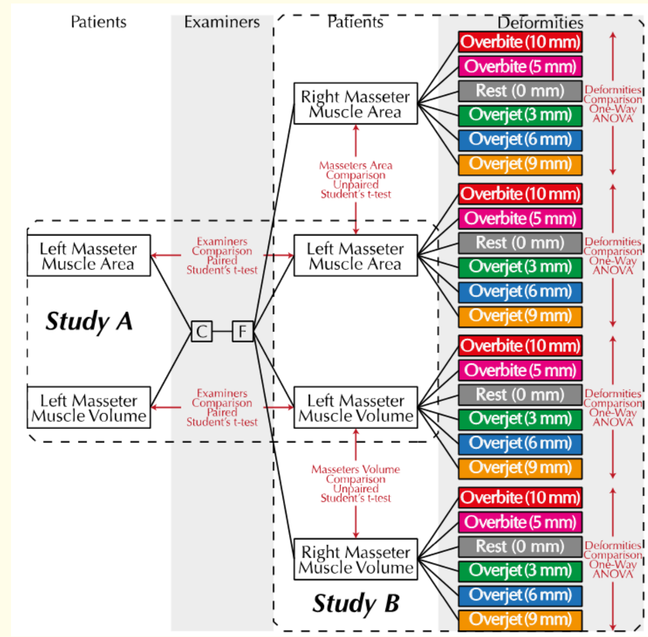

Figure 4: Experimental design used for the analysis of magnetic resonance imaging. Study A involved the contribution of two independent examiners (F and C), that measured the left masseter muscle area (mm^2) and left masseter muscle volume (mm^3) of ten patients. Study B investigated the left/right masseter muscle area (mm^2) and left/right masseter muscle volume (mm^3) of one selected patient (two replicas per experimental condition) subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm).

MRI Analysis Parameter	Examiner F	Examiner C
Left Masseter Area (mm^2) (Average ± SD)	12493 ± 904	12531 ± 871
Left Masseter Volume (mm^3) (Average ± SD)	31066 ± 2936	31164 ± 2922

Table 1: Mean left masseter area (mm^2) and mean left masseter volume (mm^3) of ten patients analysed by independent examiners F and C. Data was obtained by MRI.

MRI Analysis Parameter	Overbite (10 mm)	Overbite (5 mm)	Rest (0 mm)	Overjet (3 mm)	Overjet (6 mm)	Overjet (9 mm)
Left Masseter Area (mm^2) (Average ± SD)	10356 ± 145	9433 ± 132	11963 ± 86	12398 ± 88	13059 ± 93	9992 ± 209
Right Masseter Area (mm^2) (Average ± SD)	9884 ± 69	8270 ± 173	12617 ± 88	12164 ± 170	11719 ± 82	9422 ± 197
Left Masseter Volume (mm^3) (Average ± SD)	27934 ± 196	28412 ± 199	26842 ± 190	25105 ± 351	26398 ± 185	36488 ± 257
Right Masseter Volume (mm^3) (Average ± SD)	25927 ± 182	25821 ± 181	29212 ± 205	25855 ± 182	28704 ± 202	32003 ± 225

Table 2: Mean left/right masseter area (mm^2) and mean left/right masseter volume (mm^3) of one patient subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm). Data was obtained by MRI.

Examiners Comparison	Mean Diference	Standard Deviation of Differences	Degrees of Freedom (df)	Test statistic from Paired t-test	P-value from Paired t-test
Examiner F versus Examiner C, Left Masseter Muscle Area (mm^2)	-38,200	41,016	9	-0,931	0,376
Examiner F versus Examiner C, Left Masseter Muscle Volume (mm^3)	-97,300	39,518	9	-2,462	0,036

Table 3: Statistical parameters obtained in the Paired Student's t-test for the comparison of examiners F and C regarding the measurement of mean left masseter area (mm^2) and mean left masseter volume (mm^3) of ten patients by MRI.

(*): The mean difference is significant at the 0,05 level.

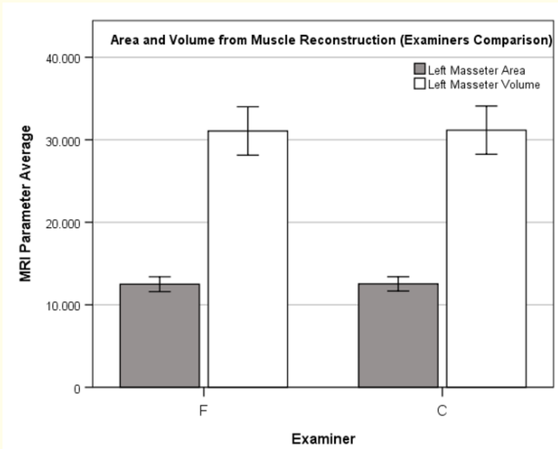

Figure 5: Mean left masseter area (grey, mm²) and mean left masseter volume (white, mm³) of ten patients analysed by two independent examiners (F and C) through the technique of MRI.

was performed using an Unpaired Student's *t*-test, regarding the measurement of mean masseter muscle area (mm²) and mean masseter muscle volume (mm³) by MRI.

Comparison C - Testing the differences between occlusal splints

(Overbite versus rest versus overjet)

The statistical comparison between the different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm) to which a selected patient was subjected, was performed using an One-Way ANOVA test, regarding the measurement of mean left/right masseter area (mm²) and mean left/right masseter volume (mm³).

Examiners Comparison	Mean Diference	Standard Deviation of Differences	Degrees of Freedom (df)	Test statistic from Unpaired t-test	P-value from Unpaired t-test
Left Masseter versus Right Masseter, Masseter Muscle Area (mm²)	520,583	628,854	22	0,830	0,415
Left Masseter versus Right Masseter, Masseter Muscle Volume (mm³)	609,417	1318,328	22	0,462	0,648

Table 4: Statistical parameters obtained in the Unpaired Student's t-test for the comparison of left and right masseter muscle area (mm²) and masseter muscle volume (mm³) of the selected patient analysed by MRI and subjected to different levels of occlusal deformity.

(*): The mean difference is significant at the 0,05 level.

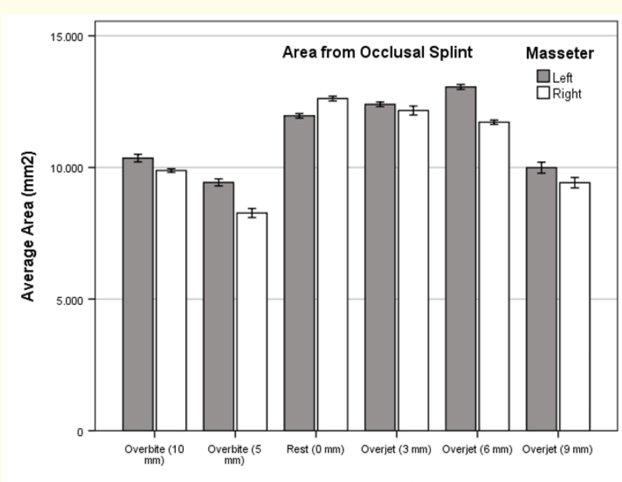

Figure 6: Mean left masseter area (grey, mm²) and mean right masseter area (white, mm²) of one patient analysed by the technique of MRI, and subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm).

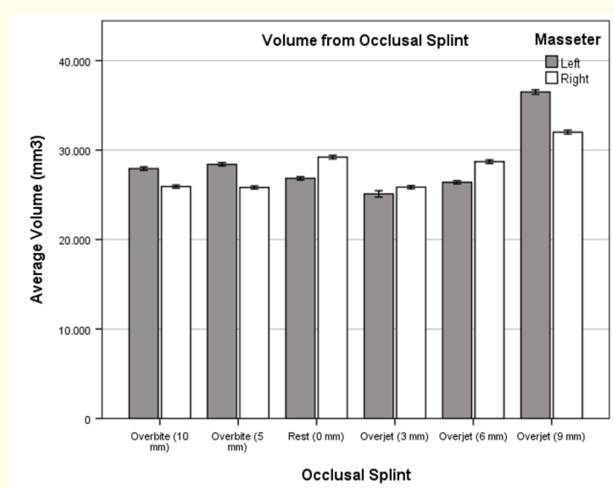

Figure 7: Mean left masseter volume (grey, mm3) and mean right masseter volume (white, mm3) of one patient analysed by the technique of MRI, and subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm).

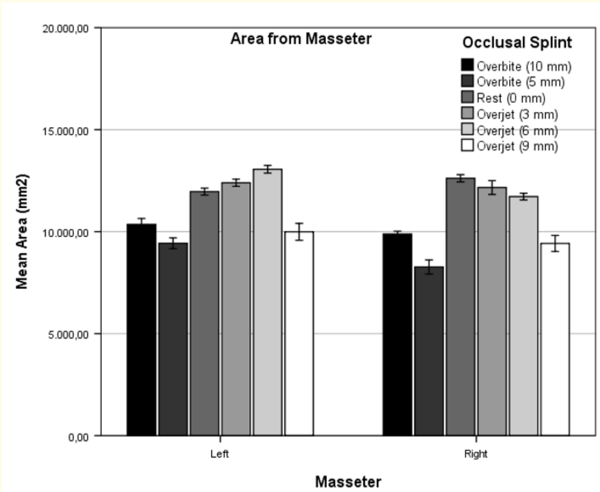

Figure 8: Mean left and right masseter area (mm^2) of one patient analysed by the technique of MRI, and subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm).

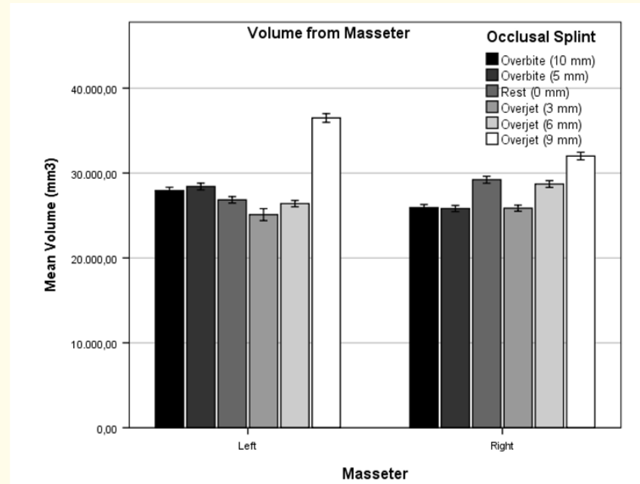

Figure 9: Mean left and right masseter volume (mm3) of one patient analysed by the technique of MRI, and subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm).

Occlusal Deformities Comparison		Sum of Squares	Degrees of Freedom (df)	Mean Square	Test statistic (F)	P-value (Sig)
OB10mm vs OB5mm vs Rest-0mm vs OJ3mm vs OJ6mm vs OJ9mm, Masseter Muscle Area	Between Groups	49095633,708	5	9819126,742	40,176	0,000
	Within Groups	4399270,250	18	244403,903		
	Total	53494903,958	23	-		
OB10mm vs OB5mm vs Rest0mm vs OJ3mm vs OJ6mm vs OJ9mm, Masseter Muscle Volume	Between Groups	188723573,708	5	37744714,742	15,830	0,000
	Within Groups	42919230,250	18	2384401,681		
	Total	231642803,958	23	-		

Table 5: Statistical paramete Mean left and right masseter volume (mm3) of one patient analysed by the technique of MRI, and subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm). rs obtained in the One-Way ANOVA test for the comparison of the different levels of occlusal deformity to which a selected patient was subjected, regarding the measurement of mean left/right masseter area (mm^2) and mean left/right masseter volume (mm^3).

Results and Discussion

Comparison A - Testing the differences between examiners - Study A

Research question: Are there any differences between Examiners F and C regarding the measurement of mean left masseter area (mm^2) and left masseter volume (mm^3) of ten patients by MRI?

H0: There are no differences between Examiners F and C regarding the measurement of mean left masseter area (mm^2) and left masseter volume (mm^3) of ten patients by MRI.

H1: There are differences between Examiners F and C regarding the measurement of mean left masseter area (mm^2) and left masseter volume (mm^3) of ten patients by MRI.

Comparison B - Testing the differences between masseters - Study B

Research question(s): Are there any differences between the left and right masseter muscle area (mm^2) and masseter muscle volume (mm^3) of the selected patient analysed by MRI, and subjected to different levels of occlusal deformity?

Dependent Variable	(I) Occlusal_Splint	(J) Occlusal_Splint	Mean Difference (I-J)	Std, Error	Sig.
Masseter Muscle Area (mm^2)	Overbite (10 mm)	Overbite (5 mm)	1268,250*	349,574	0,026
		Rest (0 mm)	-2169,750*	349,574	0,000
		Overjet (3 mm)	-2161,000*	349,574	0,000
		Overjet (6 mm)	-2269,250*	349,574	0,000
		Overjet (9 mm)	413,000	349,574	0,970
	Overbite (5 mm)	Overbite (10 mm)	-1268,250*	349,574	0,026
		Rest (0 mm)	-3438,000*	349,574	0,000
		Overjet (3 mm)	-3429,250*	349,574	0,000
		Overjet (6 mm)	-3537,500*	349,574	0,000
		Overjet (9 mm)	-855,250	349,574	0,273
	Rest (0 mm)	Overbite (10 mm)	2169,750*	349,574	0,000
		Overbite (5 mm)	3438,000*	349,574	0,000
		Overjet (3 mm)	8,750	349,574	1,000
		Overjet (6 mm)	-99,500	349,574	1,000
		Overjet (9 mm)	2582,750*	349,574	0,000
	Overjet (3 mm)	Overbite (10 mm)	2161,000*	349,574	0,000
		Overbite (5 mm)	3429,250*	349,574	0,000
		Rest (0 mm)	-8,750	349,574	1,000
		Overjet (6 mm)	-108,250	349,574	1,000
		Overjet (9 mm)	2574,000*	349,574	0,000
	Overjet (6 mm)	Overbite (10 mm)	2269,250*	349,574	0,000
		Overbite (5 mm)	3537,500*	349,574	0,000
		Rest (0 mm)	99,500	349,574	1,000
		Overjet (3 mm)	108,250	349,574	1,000
		Overjet (9 mm)	2682,250*	349,574	0,000
	Overjet (9 mm)	Overbite (10 mm)	-413,000	349,574	0,970
		Overbite (5 mm)	855,250	349,574	0,273
		Rest (0 mm)	-2582,750*	349,574	0,000
		Overjet (3 mm)	-2574,000*	349,574	0,000
		Overjet (6 mm)	-2682,250*	349,574	0,000
Masseter Muscle Volume (mm^3)	Overbite (10 mm)	Overbite (5 mm)	-186,500	1091,879	1,000
		Rest (0 mm)	-1096,750	1091,879	0,992
		Overjet (3 mm)	1450,500	1091,879	0,931
		Overjet (6 mm)	-620,750	1091,879	1,000
		Overjet (9 mm)	-7315,250*	1091,879	0,000
	Overbite (5 mm)	Overbite (10 mm)	186,500	1091,879	1,000
		Rest (0 mm)	-910,250	1091,879	0,999
		Overjet (3 mm)	1637,000	1091,879	0,859
		Overjet (6 mm)	-434,250	1091,879	1,000
		Overjet (9 mm)	-7128,750*	1091,879	0,000
	Rest (0 mm)	Overbite (10 mm)	1096,750	1091,879	0,992
		Overbite (5 mm)	910,250	1091,879	0,999
		Overjet (3 mm)	2547,250	1091,879	0,329
		Overjet (6 mm)	476,000	1091,879	1,000
		Overjet (9 mm)	-6218,500*	1091,879	0,000
	Overjet (3 mm)	Overbite (10 mm)	-1450,500	1091,879	0,931
		Overbite (5 mm)	-1637,000	1091,879	0,859
		Rest (0 mm)	-2547,250	1091,879	0,329
		Overjet (6 mm)	-2071,250	1091,879	0,606
		Overjet (9 mm)	-8765,750*	1091,879	0,000
	Overjet (6 mm)	Overbite (10 mm)	620,750	1091,879	1,000
		Overbite (5 mm)	434,250	1091,879	1,000
		Rest (0 mm)	-476,000	1091,879	1,000
		Overjet (3 mm)	2071,250	1091,879	0,606
		Overjet (9 mm)	-6694,500*	1091,879	0,000
	Overjet (9 mm)	Overbite (10 mm)	7315,250*	1091,879	0,000
		Overbite (5 mm)	7128,750*	1091,879	0,000
		Rest (0 mm)	6218,500*	1091,879	0,000
		Overjet (3 mm)	8765,750*	1091,879	0,000
		Overjet (6 mm)	6694,500*	1091,879	0,000

Table 6: Statistical parameters obtained in the Post-Hoc Gabriel test for the comparison of the different levels of occlusal deformity to which a selected patient was subjected, regarding the measurement of mean left/right masseter area (mm^2) and mean left/right masseter volume (mm^3).

H0: There are no differences between the left and right masseter muscle area (mm^2) and masseter muscle volume (mm^3) of the selected patient analysed by MRI and subjected to different levels of occlusal deformity.

H1: There are differences between the left and right masseter muscle area (mm^2) and masseter muscle volume (mm^3) of the selected patient analysed by MRI and subjected to different levels of occlusal deformity.

Comparison C - Testing the differences between occlusal splints (Overbite versus rest versus overjet)

Research question(s): Are there any differences between the occlusal deformities (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm) to which the selected patient was subjected, regarding the left/right masseter muscle area (mm^2) and left/right masseter muscle volume (mm^3)?

H0: There are no differences between the occlusal deformities to which the selected patient was subjected, regarding the left/right masseter muscle area (mm^2) and left/right masseter muscle volume (mm^3) analysed by MRI.

H1: There are differences between the occlusal deformities to which the selected patient was subjected, regarding the left/right masseter muscle area (mm^2) and left/right masseter muscle volume (mm^3) analysed by MRI.

Conclusion

Comparison A - Testing the differences between examiners - Study A

The results show no significant difference between Examiner F and Examiner C regarding the measurement of left masseter area (mm^2) of ten patients through MRI, when the measurement is made in the same experimental conditions ($p > 0,05$). Regarding the mean left masseter volume (mm^3), statistical differences have been identified between Examiners F and C ($p < 0,05$), probably due to small discrepancies in the experimental methodology used by both examiners.

In view of these results, it is recommended the standardization/homogenisation of the experimental methodology used, in order to avoid the differences detected in this study.

Comparison B - Testing the differences between masseters - Study B

The results show no significant difference between the left and right masseter muscle area (mm^2) and masseter muscle volume (mm^3) of the selected patient, despite having been subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm). This means that the patient presents a rather left/right symmetrical bite in the frontal plane, even when he is using different occlusal splints.

Comparison C - Testing the differences between occlusal splints (Overbite versus rest versus overjet)

There are significant differences in the masseter muscle area (mm^2) and masseter muscle volume (mm^3) of the selected patient, when he is subjected to different levels of occlusal deformity (overbite 10 mm, overbite 5 mm, rest 0 mm, overjet 3 mm, overjet 6 mm and overjet 9 mm). All experiments reveal *p-values* below the cut-off value of 0,05 ($p < 0,05$), which means that H0 proposition is invalid. Thus, it is concluded that the MRI analysis is capable of detecting differences in the masseter muscle area (mm^2) and masseter muscle volumes (mm^3) of patients presenting different levels of occlusal deformities.

Because One-Way ANOVA only gives information about the presence of differences, not specifying where these differences are located, a Post-Hoc Gabriel test was used to perform pairwise comparisons between the occlusal deformities, and these results are represented in table 6.

Significant differences ($p < 0,05$) have been identified between certain pairs of occlusal deformities (Table 6), particularly when one of the elements of the comparison is an overbite pattern (10 or 5 mm) or an overjet pattern (9 mm).

This contrasts with the near absence of significant differences ($p > 0,05$) in pairs of occlusal deformities where all the included bite patterns are rest pattern (0 mm) and overjet pattern (3 or 6 mm).

MRI therefore seems to be a valid tool for measuring differences in the masseter muscle area (mm^2) and masseter muscle volume (mm^3) associated with high-severity occlusal deformities, although showing not to be as efficient in detecting the same differences in cases of low-severity occlusal deformities.

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