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Research Article

Correlation between MRI and Biomodelling Analysis in Masseter Muscle Following Orthognathic Surgery

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Abstract

Purpose: This pilot investigation was designed to apply several and innovative methods of measuring muscle area, volume, structure, function and fibre orientation to a situation where adaptation of muscle is pivotal to the success of a therapeutic approach.

Materials and Methods: Patients attending the combined orthodontic/orthognathic surgery clinic at Clitrofa – Centro Médico, Dentário e Cirúrgico, in Trofa - Portugal were screened using a standardized Magnetic Resonance Imaging protocol, with fine overlapping slices of 1 mm thickness and a spacing of 0.8 mm during 7 minutes. The software used was the AnatomicsTM that allows the correction of muscle and bone limits.
The landmarks considered for this study were: a) the anterior angle from the long axis of masseter muscle versus angle between lower border of the zygomatic bone and the mastoid process; and b) the anterior angle from the long axis of the masseter muscle versus the mandibular plane. The angles were measured by two different observers. The values were registered (T0) and the procedure was repeated after 1 hour (T1), and 6 to 12 months after surgery (T2).

Conclusions: Significant statistical differences ($p < 0,05$) have been identified between Time 2 (1-6 months after surgery) and Times 0 and 1 (prior to surgery) in the mean P2 angle measured, both for Examiner F and C. These differences reveal the masseter muscle adaptation following bimaxillary osteotomy involving a combination of maxillary Le Fort I impaction procedure coupled with a sagittal split advancement of the mandible in this study-case. The measurement of “P1 Masseter Muscle/Zygomatic Bone/Process Mastoid Anterior Angle” and “P2 Masseter Muscle/Mandibular Angle” can therefore be a valuable tool for controlling the reworking of masseter muscle upon orthognathic surgery.

Keywords

Orthognathic Surgery; Masseter Muscle; MRI Analysis; Biomodelling Analysis

Declaration of Conflicting Interest

The author[s] declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

INTRODUCTION

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[1].

For harmonious vertical facial growth and development to exist, the growth on the front of the face must be the same as on the back. If this does not occur, there may be a relative growth rotation of the mandible. For example, if the growth in the posterior part of the face exceeds what occurred previously, the net effect will be an anterior rotation of the mandible, producing the typical deformity of the short face and the deep overbite associated with the short face syndrome[2]. At the opposite end, where growth at the back of the face can be severely reduced compared to what occurred earlier, a clockwise opening or rotation of the jaw is evident, with the net effect of being an excessive anterior facial height and often a bitten anterior opening, associated with a deformity of the long face[3].

For generations, both clinicians and scientists have argued as to the respective contribution of genetics and, so called, environmental factors in influencing ultimate facial form and associated malocclusion. Of all the possible environmental influences, it is not surprising that bearing in mind the origins and insertions of the muscles of mastication, and in particular the masseter and medial pterygoid muscle, that the question has arisen as to whether, or not, abnormalities in the structure and function of the muscular pterygo-masseteric sling could, in any way, influence vertical development in the posterior part of the face. Furthermore, if treatment interventions necessitate a change in function of the muscles that support the mandible, do the adaptive capability of these muscles in any way influence the stability of the treatment outcome[4].

MRI AND BIO-MODELLING

Computers are used increasingly as a supportive tool for the diagnosis, operation planning, and treatment in medicine and dentistry. They are used in connection with the modern digital imaging techniques such as computer tomography and magnetic resonance imaging, as well as ultrasound to improve the visualization of anatomical and physiological conditions in keeping with the human imagination[5].

The ability to extract accurate three-dimensional (3D) images from magnetic resonance imaging (MRI), has proven to be a very useful diagnostic tool to extract the muscle from the scan with secure margins identification and also to extract the facial bones with considerable detail[6].

The reconstruction of muscles and bone from the same scan have allowed visualisation of the muscle fibre orientation in relation to the muscle's bony attachments. This could enabled the measurement of potential changes in orientation in relation to a static landmark unaffected by surgery (eg. Frankfort plane) or in relation to functional identifiers (eg. Occlusal plane).

MUSCLES ROLE

Many forms of interceptive treatment, whether they be purely orthodontic in nature or in combination with surgery, bring about changes in the muscles of mastication with regard to one or more of the following changes: a) in muscle fibre orientation; b) changes in the functioning length of fibres; c) changes in muscle structure; and d) changes in muscle phenotype. Successful treatment requires both reorganisation in the connective tissue and regeneration of muscle fibres. Reorganisation of connective tissue is an extremely complex process involving muscle derived stem cells (satellite cells), extra-cellular matrix molecules and receptors for the extra-cellular matrix (for example integrins). Remodeling of the extra-cellular matrix is mediated by a family of enzymes known as matrix metalloproteinases (MMPs)[7,8]. MMP2 is expressed during the regeneration of new myofibres and is a known mechano-responsive gene. A knowledge of how muscles respond to clinical interventions is pivotal to treatment success and can influence the way in which a particular treatment modality is applied[7,8].

With regard to orthognathic surgery the golden rule is that surgery must not stretch the pterygo-masseteric sling, otherwise relapse is likely to occur. This is predominantly through the speed of insult to the muscle in relation to the timing of the muscle adaptive process. The consequence is either an immediate reversion back to the original functioning length of the muscle and return of the bony fragments back to their original pre-surgical position, and/or migration of the muscle attachment along the surface of the bone, thereby leading to an area of bone denuded of muscle force, which ultimately leads to resorption of the bony muscular processes.

One way in which this can be studied more closely is through refinements in protocols for 3-D MRI of the face and jaws. Increasing the resolution of the tomographic cuts has led to a resolution which facilitates the identification of not only the origins and insertions of the muscles of mastication but even the orientation of individual muscle fibre bundles. It is therefore possible to study the changes in muscle fibre orientation in relation to landmarks such as the functional occlusal plane and also those landmarks unaffected by surgery, for example the cranial base.

MATERIALS AND METHODS

Ten patients attending the combined orthodontic/orthognathic surgery clinic at the Clitrofa – Centro Médico, Dentário e Cirúrgico, in Trofa - Portugal were tested according to the following protocol: Accurate extraction of muscles and facial bones using the same scan from MRI three-dimensional (3D), using a standardize scanning process, with fine overlapping slices of 1 mm thickness and a spacing of 0.8 mm during 7 minutes[6]. The software used was the AnatomicsTM that allows the correction of muscle and bone limits at any time[6].

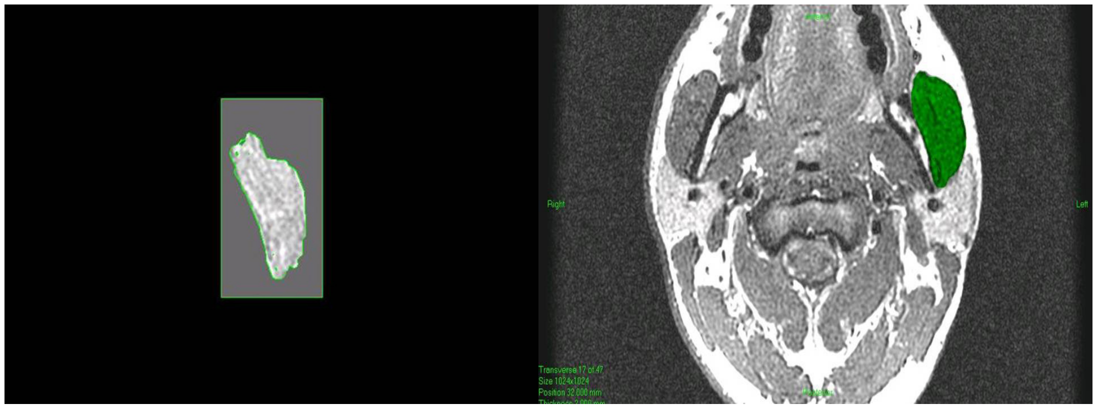
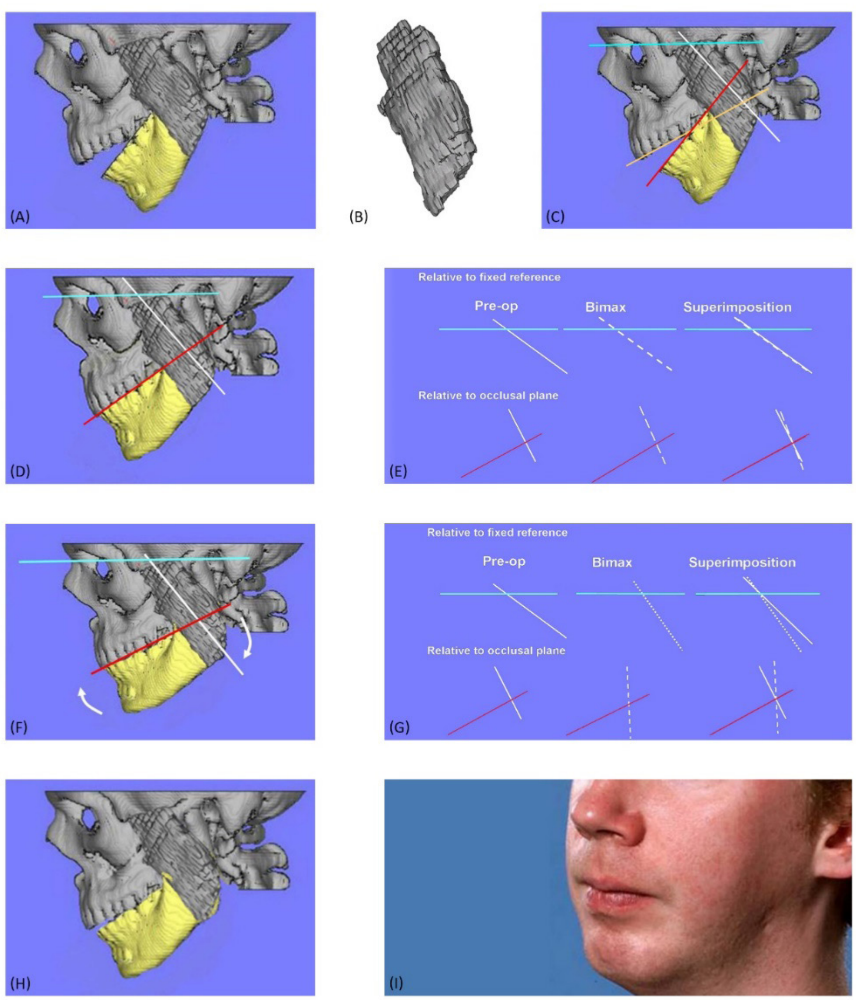


Figure 1 Identification of masseter muscle limits in a sagital plane

The landmarks considered for this study were: (a) the anterior angle from the long axis of masseter muscle versus angle between lower border of the zygomatic bone and the mastoid process, (b) the anterior angle from the long axis of the masseter muscle versus the mandibular plane[9].



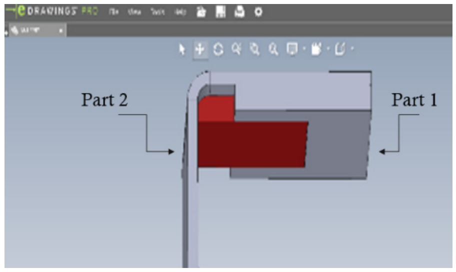


Figure-1 The design of the st.st mold and guiding part of the preparation

4.3. Effect of combination between two variables on blending

By combination of the two variables, the BvM had the least color difference (ΔE= 3.36) which is within the clinically acceptance range and this is confirmed by the highest percentage of the visual scoring which was (28%), this could be as mentioned before, bevel allows for a gradual transition and provides bulk across the cavosurface angle (J.Bagheri and G.E.Denehy,2015; Y.K.Lee,2005) , and microhybrid has low translucency than nanofill as nanofill composite has filler particle size range from 0.005 to 0.01μm

Figure-2 Skirt preparation through the guide

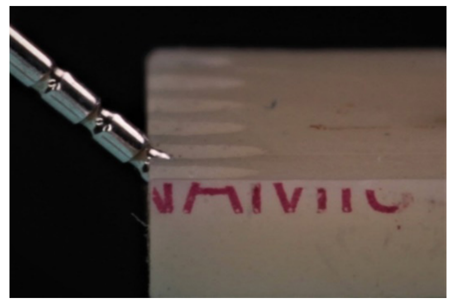


Figure-3 Depth of the skirt 1mm

Figure-4 Bevel preparation through the guide

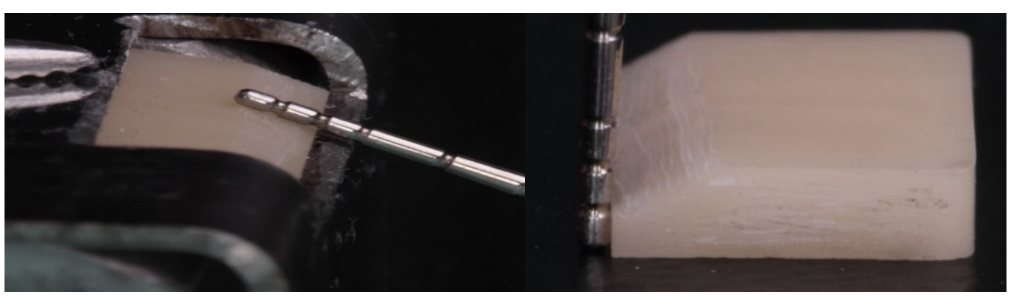


Figure-5 2mm bevel length with depth 1mm, leaving 1mm unprepared from the thickness of the block.

while microhybrid has the smallest particle size is 0.04μm and the organic fillers in the nanofill has high transparency, and as we said before the microhybrid resin composite may have BE more than the nanofill resin composite due to microhybrid composite has higher filler weight 86% than the nanofill 78% (I.L.Vegting, et al.,2011; B.J.Kim and Y.K.Lee,2009; B.H.Cho, et al.,2007), not only this but also the color A2 from the VITA classic color scale and may appear a little darker and shows low translucency values (D.Awad, et al.,2015) So by combination microhybrid resin composite with bevel preparation on VITA enamic, this permits blending of color and gives more color depth at the repair site. The rest groups had color difference above the acceptable range statistically (ΔE=3.7). Values of ΔE might have been smaller if the diameter of the circle reflecting the light in the spectrophotometer was smaller which might have affected the chameleon effect and hence blending of the color and color match [34] (Alghazali N., et al.,2011). With the aforementioned results, it is clear that color blending at repair site is a multifactorial process depending on type of substrate material, design of preparation as well as the type of repairing composites; and the null hypothesis for the study was rejected. Further studies are highly needed to have an accurate recommendation of the ideal repair material and design for such ceramic material.

5.Conclusion

Within the limitation of this study, it could be concluded that:

Preparation designs and composite material type (microhybrid and nanofill) had an effect on the color match and blending effect. Combining the bevel preparation with microhybrid composite provided the best color matching instrumentally as well as visual color blending.

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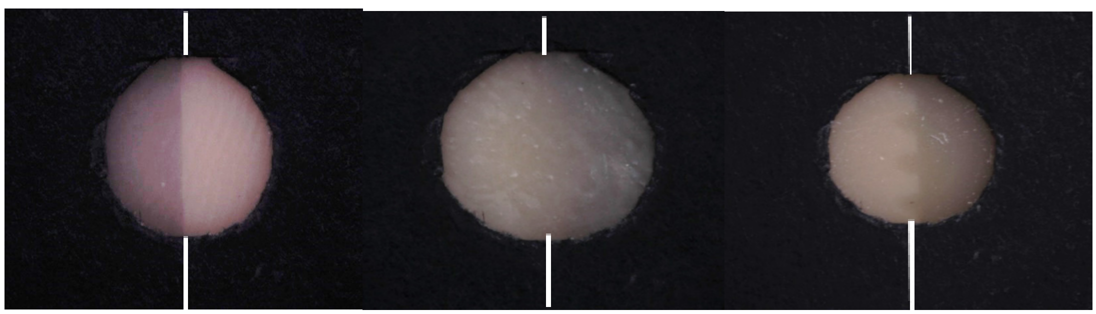

Figure-6 The center of the paper coincides with the center of the prepared part of the specimen.

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Composite	Preparation extension (mean±SD)			p-value
	Butt joint	2 mm bevel	Skirt	
Nano-filled	5.25±0.09B	6.01±0.12A	5.77±0.17B	<0.001*
Micro-hybrid	6.41±0.15A	3.36±0.13B	6.74±0.06A	<0.001*
p-value	<0.001*	<0.001*	<0.001*	

Table-3 Mean ± standard deviation (SD) of color difference (ΔE) for different composite types and preparation extension designs.

Different superscript letters indicate a statistically significant difference within the same horizontal row; significant (p ≤ 0.05) ns; non-significant (p>0.05)*

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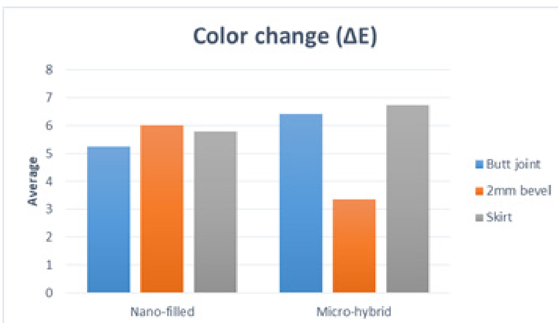

Figure-7 Bar chart showing average color difference (ΔE) for different composite types and preparation extension designs (A)

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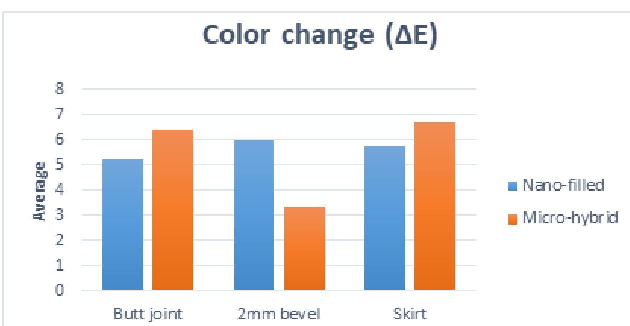

Figure-8 Bar chart showing average color difference (ΔE) for different composite types and preparation extension designs (B)

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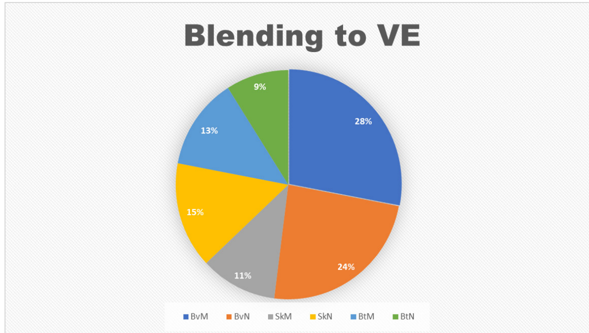

Figure-9 Pie Chart of the visual scoring for exact match

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