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1. Introduction

Facial expression, such as the smile, is expressed by the zygomaticus muscle (ZM). In case of facial paralysis, toxin injections are performed inside this muscle on the non-paralyzed side to restore the patient's expression. The anatomic composition of the facial muscle, and more specifically for the zygomaticus, has been determined through muscle dissection (Pessa et al. 1998). A non invasive way allows to record the anatomical properties of the facial muscle is to use ultrasound (US). Alfen et al. (2003) performed US test for the main facial group of muscles and it has been demonstrated the feasibility and the reproducibility to measure the muscle thickness and the echo intensity with ultrasound technique.

The knowledge of the morphological properties (diameter of the fascicle, presence of collageneous tissue, etc…) will allow a better understanding of the facial muscle structure (McComas et al. 1998) with the possibility to correlate this information to mechanical properties. The novelty of this study is to discriminate the characteristics of bifid, fibrous and fine zygomaticus muscles with US elastography.

2. Methods

2.1 Participants

31 healthy volunteers (16 women, 15 men, age range: 20 to 29, mean age: 24.8 ± 3.2 years) with no facial muscle damage underwent an ultrasound test. This study was approved by the CPP SUD-EST IV.

2.2 Ultrasound acquisition

The zygomaticus muscle is a cheek muscle starting from the malar bone and moving downwards to be inserted in the corner of the lips (McComas et al. 1998). The subjects laid on their sides in a relaxed, reclined position with pillows under their heads. B-mode images were recorded with the Aixplorer Multiwave[TM] System (Supersonic Imagine, Aix-en-Provence, France) with the same protocol and setting parameters as previously published (Ternifi et al. 2019). Briefly, the SuperLinear[TM] SLH20-6 transducer was used to visualize the ZM. The spatial resolution is 38 μm, the bandwidth 6-20 MHz, the footprint 2.38 cm with 192 elements in phased array. The average (SD) muscle thickness (MT) was manually measured in the belly part of ZM (Figure 1A).

2.3 Shear Wave Elastography (SWE)

In parallel to morphological analysis, ZM elasticity (Figure 1B) was visualized with SWE acquisition. A circular region of interest (ROI) was manually placed in the same belly area where the thickness measurement was made. The diameter of the ROI (from 1 to 3 mm) was adjusted in function of the thickness of the ZM. The mean, minimum, maximum, and standard deviation of ZM elasticity were automatically calculated and displayed from the ROI.

3. Results and discussion

The use of high frequency SLH 20-6 probe provide a clear B-mode representation of surperficial and thin muscle (Kammoun et al. 2019). Among the healthy cohort, an anatomical classification of the ZM has been performed based on the morphology and the echo intensity of the ZM. The results of the classification revealed four ZM groups defined as :

1) a *normal structure* (Figure 1A) represented by hypoechoic zones compared to those of subcutaneous fat tissue. This anatomic structure represents 50% of the cohort.

The following ZM structures are less present in healthy subjects compared to patients. Thus, a limitation of the study is the small sample size of the cohort for these categories.

2) a *bifid structure* (Figure 1B) showing a collagenous

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separation inside the ZM muscle. This shape was was in agreement with the litterature (Hu et al. 2008).

3) *a fibrous structure* (Figure 1C) composed of hyperechoic regions which corresponds to fibrous or fatty tissues.

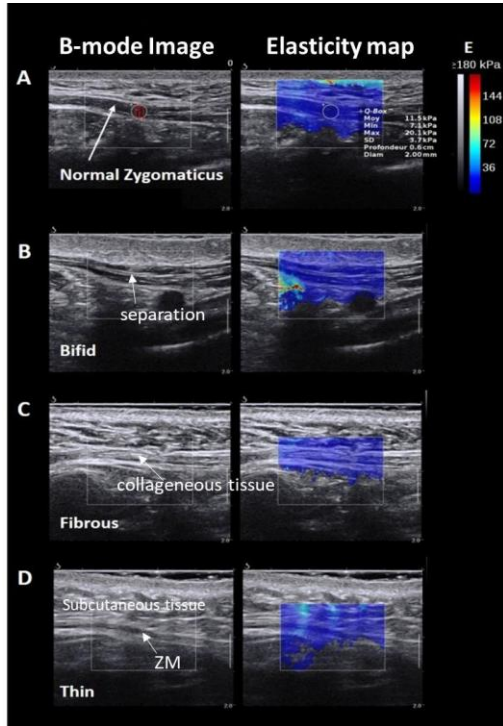4) a *thin structure* (Figure 1D) defined by a muscle thickness lower to 1.5 mm.

Figure 1. B-mode images and elasticity maps of zygomaticus muscle classified in four groups (A: normal, B: bifid, C: fibrous and D: thin).

The color elastogram shows an homogeneous blue color, indicating no muscle contraction. The bifid ZM is significantly thicker compared to the normal group (p = 0.014, two-sample Kolmogorov-Smirnov test), and the fibrous ZM is sligthly thicker than the normal one (Table 1). As expected the thin structure is significantly lower compared to the normal, bifid and fibrous ZM.

Group	Young's modulus (kPa)				Thickness (cm)	
	Mean	SD	Min	Max	Mean	SD
Normal (n = 15)	16.7	1.7	13.1	20.9	0.19	0.03
Bifid (n = 7)	16.5	1.6	11.9	23.8	0.25	0.05
Fibrous (n = 9)	20.6	1.5	15.3	25.7	0.22	0.04
Thin (n = 8)	15.8	1.4	13.3	17.6	0.09	0.01

Table 1. Muscle thickness (MT) and Young's modulus (E) of the different ZM structures.

The elasticity of the fibrous ZM is significantly higher (about 4 kPa) compared to the other structures (p < 0.004, KS-test). However, the cartography is not enough sensitive to highlight this changes. In addition, the relevance of the elasticity for the bifid and fibrous muscles must be considered. Indeed, these structures provide a non linear and anisotropic medium which is not in line with elastography assumptions. While numerous muscle studies in MR and US elastography field have allowed this hypothesis as a first approximation, the high anisotropic behaviour of the fibrous and bifid tissues needs to be taken into account for the comparison of their elastic properties.

4. Conclusions

The originality was to accurately characterize the bifid, fibrous and fine structures of the ZM and to show the feasibility to measure the elasticity of these different structures. The knowledge of the ZM patterns and the mechanical behaviors could help clinicians for facial rehabilitation of patients. However, the limitations of the method must be overcome for facial paralysis characterization

Acknowledgements

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