Jaw biomechanics: estimation of activity of muscles acting at the temporomandibular joint

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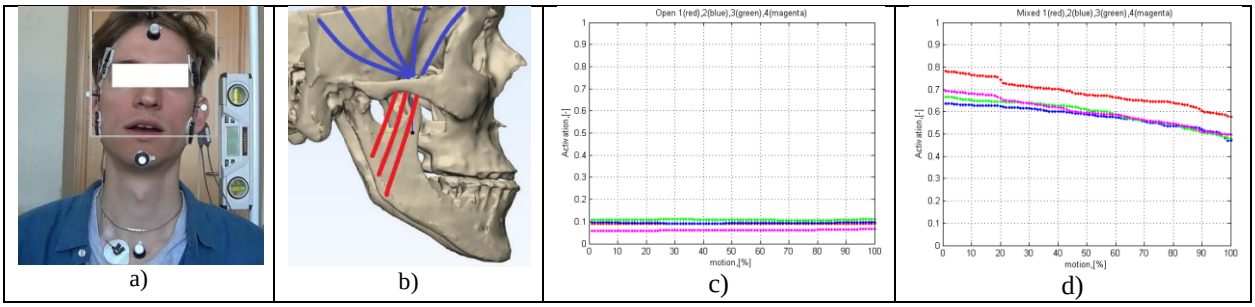
Abstract. The aim of the study was to elaborate a method of estimation of activity of surface muscles acting at the temporomandibular joint of the healthy subjects by using a surface EMG. The scope of the study involved testing chosen jaw motions and process of mastication occurring during eating foods with different toughness.

1. INTRODUCTION

The process of mastication involves activation of muscles acting at each temporomandibular joint (TMJ) formed between a temporal bone, intraarticular disk and the head of mandible. During this process the mandible does a complex motion (both translational and rotational displacements), which depends on the condition of TMJ (health or diseased), configuration of the trunk and head with respect to the gravity forces, toughness (hardness) of the food bitten, external force influence and nervous system acting. That is why the mastication process should be considered by taking into account both biomechanics and motor control principles [1]. The aim of this study was to elaborate a method of estimation of activity of surface muscles acting at the temporomandibular joint of the healthy subjects by using a surface electromyography (EMG). The scope of this study involved testing chosen jaw motions and process of mastication occurring during eating foods with different toughness.

2. METHOD

Ten healthy volunteers took part in the study. To participate in the study each volunteer gave a written informed consent. Each volunteer performed in vision-on mode the following tests: 1) mouth opening-closing motions; 2) protrusion-retrusion motions; 3) motions of lateral deviation of mandible; 4) biting a chewing gum; 5) biting a cereal; 6) biting a raw carrot. All biting tests were performed by asking subject to bite food by using: 1) mixed sides (preferred motions); 2) only right side of the mandible; 3) only left side of the mandible. To perform kinematic analyses the *Templo Contemplas* system was used. To estimate activities of four superficial muscles (right *Masseter* (EMG_1), left *Masseter* (EMG_2), right *Temporalis* (EMG_3) and left *Temporalis* (EMG_4)) the *Noraxon Myotrace 400* device was applied (Figure 1). Using the *Myoresearch XP Master Edition* software, the EMG data were processed, i.e. filtered, rectified and smoothed by applying the root mean square algorithm (rms) with 250 ms window. The processed EMG were normalized with respect to the maximum value of EMG signal registered during each series of testing. Activity of each examined muscle was estimated by applying the authors' scripts implemented in the *Matlab* software. The time scale was normalized to the motion timing and described as a percentage of motion. The phenomenon of muscle co-contraction between the two EMG processed data were calculated by applying a cross-correlation method [1].



a) b) c) d)

FIGURE 1. The subject examined (a). The muscle paths examined (the red paths are *Masseter* actons, the blue paths are *Temporalis* actons) (b). Estimated muscle activities during the mouth opening motion (c). Estimated muscle activities during the biting of the raw carrot by using mixed sides (d)

3. RESULTS

Results of muscle activation were calculated for: 1) mouth opening motion; 2) mouth closing motion; 3) protrusion-retrusion motion; 4) retrusion-protrusion motion; 5) lateral deviation from the start (neutral) position to the right side; 6) lateral deviation from the start position to the left side; 7) biting a chewing gum by using mixed sides; 8) biting a chewing gum by using a right side; 9) biting a chewing gum by using a left side; 10) biting a cereal by using mixed sides; 11) biting a cereal by using a right side; 12) biting a cereal by using a left side; 13) biting a carrot by using mixed sides; 14) biting a carrot by using a right side; 15) biting a carrot by using a left side. Results of activation were calculated as mean ± SD. The muscle co-contraction results for all given motions were calculated by applying a cross-correlation function given in the *Matlab* software. Selected results are presented in Table 1 and Figure 1.

TABLE 1. The cross-correlation results calculated for gum biting test

EMG data	Mixed sides: Cross-correlation R, [-]	Right side: Cross-correlation R, [-]	Left side: Cross-correlation R, [-]
$EMG_1 – EMG_2$	0.999184368532762	0.949232107251672	0.989973834734002
$EMG_1 – EMG_3$	0.993309543986347	0.958310994845264	0.979894929911325
$EMG_1 – EMG_4$	0.996296009398749	0.996500905358004	0.995437865751164
$EMG_2 – EMG_3$	0.993169011280685	0.996438484911126	0.991894171371791
$EMG_2 – EMG_4$	0.995984241203296	0.939742418025139	0.993289219965941
$EMG_3 – EMG_4$	0.998324300280200	0.946074332934284	0.987914321434853

4. CONCLUSIONS

The proposed method of estimation of activity of surface muscles acting at the temporomandibular joint is a non-invasive method. However, this method cannot be used to test deep muscles. This method allows establishing a relationship between muscles examined and motion performed by taking into consideration the superficial muscle activations and motion analysis data. The obtained results of muscle activity will be used to model the jaw biomechanics.

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