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Оригинальное исследование

Разработка персонализированного устройства для исследования жевательных и височных мышц у пациентов с дисфункцией ВНЧС

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АННОТАЦИЯ

Актуальность. В настоящее время золотым стандартом диагностики состояния жевательной мускулатуры является электромиография (ЭМГ).

Данный метод позволяет оценить биоэлектрические потенциалы выбранных для диагностики мышц, биоэлектрический покой, среднюю амплитуду биопотенциалов, время одного жевательного цикла и количество совершённых жевательных движений.

В стоматологической практике используются электромиографы, электроды которых крепятся к коже различными способами: с помощью клея или электропроводимого геля. Для установки часто требуется много времени, в связи с подвижностью датчиков снижается достоверность полученного результата. К тому же при проведении нескольких исследований ЭМГ у пациента на различных этапах лечения нет уверенности в том, что моторная точка будет выбрана в аналогичном месте, из чего следует вывод о неточности полученных данных и их сравнения.

Цель исследования — разработать и применить в клинической практике конструкцию персонализированного устройства для проведения ЭМГ жевательных мышц с возможностью репрезентативного повторения исследования.

Материалы и методы. Проведённый анализ информационных источников научной литературы позволил разработать и произвести устройство для проведения ЭМГ.

Результаты. Техническим результатом является упрощение методики, улучшение фиксации датчиков и сокращение времени проведения ЭМГ, возможность репрезентативно повторять исследование на различных этапах лечения пациента.

Заключение. Разработанное устройство и метод проведения ЭМГ позволяет при меньшем количестве затраченного времени упрощённым способом получить точный результат исследования. При необходимости повторения исследования полученные данные будут репрезентативны.

Ключевые слова: электромиография; бруксизм; гипертония жевательных мышц; 3D-печать; стоматологические CAD/CAM-технологии.

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Original Study Article

Development of a personalized device for the study of masticatory and temporal muscles in patients with TMJ dysfunction

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ABSTRACT

BACKGROUND: The current gold standard for diagnosing a masticatory muscle condition is electromyography (EMG). This method allows us to evaluate the bioelectric potential of the muscle selected for diagnosis, bioelectric rest, the average amplitude of the biopotentials, the time of one chewing cycle, and the number of chewing movements performed. EMG is used in dental practice, and the electrodes are attached to the skin with glue or an electrically conductive gel. Installation often takes a long time and the reliability of the results decreases due to the movement of the sensors. Furthermore, when conducting several EMG studies on a patient at various stages of treatment, the motor point may not be in the same place, suggesting that the data obtained and any comparisons are inaccurate.

AIM: To design and develop a personalized device for performing masticatory muscle EMG with accurate repetition.

MATERIALS AND METHODS: Analysis of information in the literature made it possible to develop and produce a device for conducting EMG.

RESULTS: The technical result was a simplification of the methodology, including improved fixation of the sensors, which reduced the EMG time, and the ability to repeat the study at various stages of a patient's treatment.

CONCLUSION: This device and EMG method provide a simplified way to obtain an accurate result in a shorter time. Thus, the data obtained would be representative if the study was repeated.

Keywords: electromyography; bruxism; masticatory muscle hypertension; 3D printing; dental CAD/CAM technologies.

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BACKGROUND

Diseases of the temporomandibular joint (TMJ) are quite common in dental practice. According to the World Health Organization in 2008, the prevalence of this pathology among people aged 35–45 years was more than 75%. In most cases, patients also have concomitant hypertension of the masticatory muscles. However, few authors have reported the reverse mechanism of the development of TMJ dysfunction and claim that hypertension of the masticatory muscles is the original reason for TMJ [1].

Chronic stress is among the factors affecting changes in the function of the masticatory muscles. A manifestation that affects the functioning of masticatory muscles is bruxism. An increase in activity of the masticatory muscles occurs due to tension in the central nervous system, which is manifested by day or night clenching of the teeth (clenching and bruxism), and disrupted normal operation [2, 3].

The activity of the masticatory muscles is also affected by functional overload, occlusion disorders associated with the presence of premature contact, pathological erasability and nonphysiological movements of the mandible, dental anomalies, deformities of the facial skeleton, fractures, and mandibular injuries [4–6].

Due to the polyetiological nature or unspecified etiology of these pathologies, choosing the correct stage of the complex treatment is important [7–10]. Modern methods to assess the masticatory muscle conditions include surface electromyography (EMG) [11–16].

This method allows for an evaluation of the bioelectric potential and rest of the muscle selected for diagnosis, the average amplitude of the biopotential, the duration of one chewing cycle, and the number of chewing movements performed [17].

Electromyographs with four or eight sensors are used in dental practice and are attached to the skin with glue, electrically conductive gel, or special solid-gel electrodes. Installation often takes a long time, due to the mobility of the sensors, so the reliability of the results can be low. Furthermore, when conducting several EMG studies there is no certainty that the motor point selected will be in the same place in a patient at various stages of treatment, leading to inaccurate data.

This study aimed to develop and produce a personalized device for performing accurate EMG of masticatory muscles [18–20].

MATERIALS AND METHODS

We analyzed international and domestic electronic databases to develop a personalized EMG device. An EMG method for the lateral pterygoid muscles was reported, including introducing electrodes into the oral cavity, the imposition of surface electrodes on the skin of the face to project the zygomatic bone to the right or left, and determining the frequency and amplitude of the action potentials of the muscle fibers at rest and with physical effort. The first stage was to palpate the lateral pterygoid muscle on both sides. An individual impression spoon was made, so anatomical formations in the palpated area of the lateral pterygoid muscle could be visualized. A correction was made using articulation paper to determine the location of the electrodes after fitting the spoon. A device that contained an individual impression spoon was inserted into the oral cavity and pressed tangentially toward the area of the lateral pterygoid muscle in the palpated area. Semilunar cutouts were made, in which two round electrodes were positioned, the wires from which ran along the outer sides of the spoon and had two fixators in the form of hooks, after which the device was pressed against a hard plate [21].

An EMG method using surface electrodes has been reported. Such electrodes were applied to the skin above the area of the muscle motor point. The skin was wiped with alcohol before applying the electrode and moistened with an isotonic sodium chloride solution. The electrode was fixed over the muscle with rubber bands, cuffs, or a Band-Aid. If a long-term study was necessary, a special electrode paste used in electroencephalography was applied to the area [22].

Elastic tape has been reported for fixing electrodes. An additional piece of elastic tape for fixing the back of the head is on the device. The tape was rigidly fastened to the first piece of tape at an angle of 40°–45° to fix under the chin, and the ends of the tape were equipped with Velcro fasteners [12].

This invention is aimed at performing representative EMG of the masticatory and temporal muscles.

RESULTS

The sensors for the EMG (Fig. 1) were fixed to the patient's head using a locking device that included elastic bands connected (Fig. 2). The study was carried out at rest and under functional loading. The sensors were fixed in the center of the masticatory and temporal muscles, as defined by palpation.

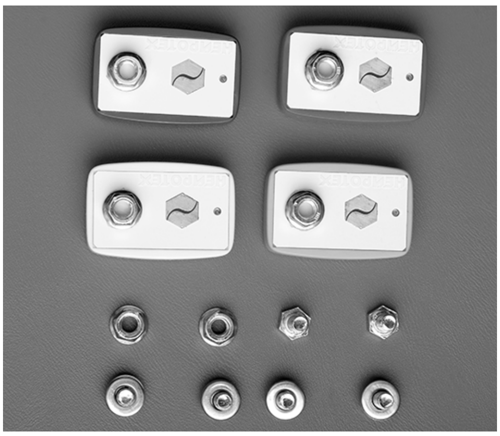

Fig. 1. Sensors for "Kolibri" electromyography (Neurotech LLC, Waukesha, WI, USA) and the clamping screws.

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Fig. 2. Elastic band with transverse tape.

The fixing device was an elastic hoop that fastened around the patient's head and transversely connected along the parietal part of the head with another elastic band. A plastic sleeve was placed on both sides of the projected temporal part of the hoop, which moved horizontally along the hoop. A polymer plate with a rectangular slot was attached to this sleeve with a clamping screw (Fig. 3). The plate could be adjusted by moving the plate along a slot in the vertical direction. A wireless EMG sensor was fixed to this plate with a fixing screw in the projection of the temporal muscle, and tightly pressed by the sensing electrodes to the skin or hair on the patient's head. A smaller plate was fixed to that plate with a clamping screw, in which a wireless EMG sensor was fixed with a clamping screw, and tightly pressed by the sensing electrodes to the skin in the projection of the masticatory muscles. The polymer plates were manufactured to move in vertical and horizontal directions relative to each other, with a graduated centimeter scale along the length of the plates on their outer surface.

Pressing the wireless sensor electrodes to the patient's skin using this method made it possible to conduct research under poor fixation conditions with adhesive compounds, such as patients with a beard or hair on the temporal muscles.

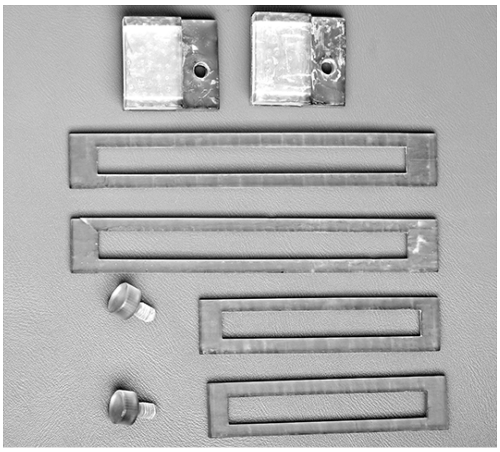

Fig. 3. Polymer plugs created by 3D printing, and horizontal plates with rectangular holes and fixing screws.

This method can be changed for a patient by moving the sensors along the polymer plates in vertical and horizontal directions and fixing them with the clamping screws.

A centimeter scale applied to the outer surface of the polymer plates allowed for repeated EMG during different treatment periods in the same patient, which was important for the representativeness of the data.

The EMG method for the masticatory and temporal muscles was carried out as follows:

- An elastic tape hoop was fixed to the patient's head and transversely connected along the parietal part of the head with another elastic band. Plastic bushings were placed on the elastic hoop on both sides in the projection of the temporal part, the thickness of which corresponded to the thickness of the EMG sensor.
- A polymer plate with a rectangular slot in the central part was attached to the plastic bushings with a clamping screw.
- A wireless EMG sensor was fixed to this plate with a fixing screw in the projection of the temporal muscle, which was tightly pressed to the patient's scalp with the sensing electrodes.
- A similar plate was fixed to this plate with a clamping screw, to which the wireless EMG sensor was fixed with a clamping screw, tightly pressing the sensing electrodes to the patient's skin in the projection of the chewing muscles.
- The middles of the muscles have been previously determined by palpation.
- Perform superficial EMG of the temporal and masticatory muscles.
- If necessary, repeat the studies at different times during treatment by installing the sensors on a graduated scale at the same values.

Clinical case

Patient G, 23 years old, presented to the clinic (Figs. 4–6), complaining of pain in the masticatory muscles during the morning and grinding of teeth at night. The examination revealed signs of hypertension in the masticatory muscles. The patient was referred for surface EMG of the masticatory and temporal muscles.

The elastic band hoop was fixed to the patient's head (Fig. 7) and transversely connected along the parietal part of the head with another elastic band. Vertical polymer plates in the projection of the temporal and masticatory muscles were fixed to plastic bushings with clamping screws. The electrophysiological signals from the Hummingbird wireless monitoring sensor complex (Neurotech, Waukesha, WI, USA) were fixed in the slots of the vertical and horizontal plates with clamping screws, which tightly pressed them to the patient's face with the electrodes, having installed

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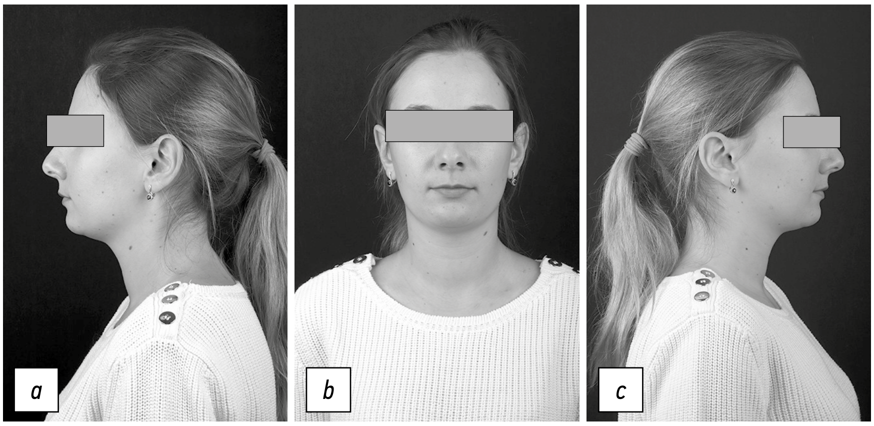

Fig. 4. Patient portrait photographs at the initial appointment: *a* — portrait photo 90 degrees to the right; *b* — full-face portrait photo; *c* — portrait photo 90 degrees to the left.

Fig. 5. Photograph of the patient's smile.

Fig. 6. Intraoral photographs of the patient in occlusion.

them in the middle of the temporal and masticatory muscles previously determined by palpation. Superficial EMG of the temporal and masticatory muscles was performed. All EMGs were recorded in a sitting position without head support.

The activity of the masticatory muscles was recorded simultaneously from four muscles, including the masticatory and anterior bundles of the temporal muscles on the right and left. The parameters of symmetry between the left and right masticatory and the left and right temporal muscles were calculated, as well as the average bioelectric activity (μA) of all four muscles. The first EMG activity measurements of the masticatory muscles were carried out in a state of relative physiological rest. Then, to assess the effect of an occlusal factor on the bioelectric activity of the masticatory muscles, a study was conducted with usual occlusion and maximum volitional compression of the jaw. All studies were conducted within 10 s.

The locations of the sensors, recorded on a centimeter scale, were recorded in the patient's chart.

We manufactured a muscle-relaxant night mouth guard for the patient based on the results of these studies.

Similar EMG studies were carried out after 3 and 6 months, using the sensors installed that followed the locations recorded in the medical history.

Fig. 7. Fixing the device during electromyography.

In both cases, the sensors retained contact with the skin, and representative EMG values were obtained.

The average μA of the masticatory muscles at rest before the start of treatment was 68. After the start of treatment with an occlusive splint, a decrease of 7% was recorded at rest after 3 months and 11% after 6 months.

The average symmetry indicator value of the masticatory muscles was 91% 3 months after the start of treatment.

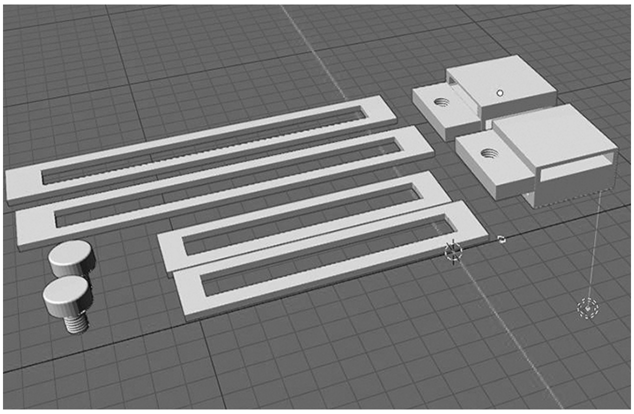

Fig. 8. Modeling of the plugs, horizontal plates, and fixing the screws in the Blender program (Blender Foundation).

Then, the indicator increased slightly by 3%. After 6 months at the end of treatment, a significant increase of 4% in the symmetry of the masticatory muscles was recorded.

The average symmetry index value of the temporal muscles was 90%; however, the work of the temporal muscles became 3% more symmetrical 3 months after the start of treatment and increased by 4% after 6 months.

DISCUSSION

The EMG device designed and introduced in this study to assess masticatory muscles was a flexible loop that incorporated a horizontal strip. This loop features rectangular slots, created through 3D printing, onto which plates were fixed using clamping screws on both sides, facilitated by a plastic sleeve. The horizontal plates were attached to vertically positioned plates with clamping screws. Plates with rectangular slots and plastic bushings were created using Blender 3D modeling software, version 3.4.0 (Blender Foundation) (Fig. 8). The plates and bushings were manufactured using additive technologies and polymer dental material (Harz Labs Dental Tray), which has the necessary physical and mechanical properties.

CONCLUSION

The use of a personalized device for performing EMG of the masticatory muscles allowed for:

- simplification of the research methodology with less time needed to install the sensors;
- increased reliability of the results due to fixation of the sensors and the possibility of generating representative EMGs of the masticatory muscles;
- improved fixation of the sensors under unsatisfactory conditions by fixing the electrodes with an adhesive base.

Further studies are needed to identify the statistical differences in the clinical results.

ADDITIONAL INFORMATION

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Competing interests. The authors declare the absence of obvious and potential conflicts of interest related to the publication of this article.

Authors' contribution. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

ДОПОЛНИТЕЛЬНО

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Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с проведённым исследованием и публикацией настоящей статьи.

Вклад авторов. Все авторы подтверждают соответствие своего авторства международным критериям ICMJE (все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией).

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