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APPLICATION OF CAD-CAM–FABRICATED OCCLUSAL SPLINTS IN THE MANAGEMENT OF TEMPOROMANDIBULAR JOINT DYSFUNCTION

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The aim of the study was to evaluate possible applications of muscle relaxation splints made with a milling method (with CAD/CAM technologies) for correction of the temporomandibular joint (TMJ).

Materials and Methods. We studied 47 patients with TMJ disc displacement with reduction that causes the lower jaw articulation disorders. All patients underwent axiographic investigation before, in the course of (every 3 weeks), and after the treatment. In group 1 (n=22) we used muscle relaxation splints made in a mechanical articulator, in group 2 (n=25) splints were modeled in a virtual articulator in accordance with axiographic findings.
Results. The results of treating patients with subluxation of the TMJ articular disc with muscle relaxation splints made with mechanical and virtual articulators showed that the use of a virtual articulator resulted in minimal frequency of positioning errors in the articulator interframe space. The study also revealed that higher accuracy of location of virtual models in accordance with an individual location of joint mechanisms of an articulator. We developed a method of loading individual joint trajectories of the lower jaw when the articulation of the latter is impaired. It helped to considerably reduce inaccuracies of splint modeling that occur when a standard mechanical face bow made with mechanical articulators is used.
Conclusion. For patients with TMJ disc displacement with reduction treatment with milled splints made in a virtual articulator is more preferable. The developed algorithm of loading individual joint trajectories of the lower jaw movements and occlusion contacts according to axiographic findings during the process of modeling muscle relaxation splints can enhance the quality of treating patients with dearticulation.

Key words: TMJ internal disorders; lower jaw articulation disorders; occlusion, muscle relaxation splints; axiography; joint trajectories; mechanical articulator; virtual articulator.

Introduction

Changes in the articulation of the lower jaw in most cases occur due to a violation of the integrity of the dentition and malocclusion [1, 2]. However, patients often seek dental care due to problems caused by internal disorders of the temporomandibular joint (TMJ) with changes in the position and movements of the articular disc [2, 3].

In the works of both domestic and foreign researchers, various classifications of internal disorders of the TMJ are proposed, which causes some difficulties both in the diagnosis and in the treatment of this pathology. The main, most common clinical and morphological groups of TMJ dysfunctions were studied in the works of V.A. Khvatova [4]. With dislocation or subluxation, the articular disc is in a non-physiological position relative to the head of the lower jaw. The disc can move forward, backward, medially, laterally, ventromedially and ventrolaterally relative to the head of the mandible. The most common is anterior dislocation of the articular disc - in 80-90% of cases. There are displacements of the articular disc with reposition (reduced) and without reposition (unreduced).

Of practical interest in the diagnosis and selection of effective therapy is the classification of P.G. Sysolyatina, V.M. Bezrukov and A.A. Ilyin [5].

For internal TMJ lesions caused by occlusion disorders, orthopedic or orthodontic treatment, in particular occlusal splints and bite plates, is the treatment of choice.

Occlusal splint therapy has a complex effect on the entire dentoalveolar system, including teeth, masticatory muscles and all structures of the temporomandibular joint [6].

Due to the fact that the prevalence of internal disorders of the TMJ remains high, and there is no consensus on the choice of therapeutic tactics, the aim of the work was to study the effectiveness of myo-relaxing splints developed on the basis of new modern methods - CAD / CAM technology.

Materials and methods. We examined 47 patients with articulation disorders of the lower jaw, including 40 women and 7 men aged 23–39 years. All of them had internal disorders of the TMJ in the form of ventral dislocation of the articular disc with reposition and soreness of the masticatory muscles. The clinical examination was carried out in accordance with the international protocol [3].

During clinical examination, the main complaint was the presence of noise in the form of a click or crunch during movements of the lower jaw - in 45 patients out of 47 (95.7%). Difficulties in opening the mouth were experienced by 29 people out of 47 (61.7%), the presence of pain in the TMJ area was noted by 34 of all examined (72.3%). Almost half of the patients (22 patients, 46.8%) showed a decrease in the amplitude of mouth opening to 3.2–4.0 cm.

During a clinical examination, a click or crunch during opening/closing of the mouth, when moving the lower jaw forward, with its lateral displacements and (or) protrusion, as well as during palpation of the TMJ area, were determined in all patients.

MRI was performed to identify morphological changes in the joints, determine the position of the articular disc, and subsequently make a diagnosis. Cone beam computed tomography (CBCT) was used to assess the width of the joint space, location height, symmetry of the mandibular heads, and the state of their cortical layer.

When analyzing the data obtained after MRI, in patients of both groups, a change in the position of the TMJ articular disc with a closed mouth was revealed in the form of a ventral dislocation of the articular disc with reposition. On CBCT, indirect signs of displacement of the TMJ articular disc were determined in the form of narrowing of the joint space and asymmetry in the location of the heads of the lower jaw.

Registration and analysis of articular trajectories during movements of the lower jaw was carried out on a Dentograf optical electronic axiograph (Prosystom, Russia).

This new generation device is designed for complex functional diagnostics of articulation of the lower jaw. It is compact and easy to handle, it uses a camera in its work. Dentograf is used for extraoral recording of mandibular movements and consists of the following components (see figure):

1) a computer for electronic registration and subsequent analysis of the movements of the lower jaw;

2) a three-dimensional camera that provides control of all movements and trajectories. The standard deviation of the measurement results of the optical system is about 1 μm. To ensure maximum measurement accuracy, the system is able to simultaneously control the position of more than 400 points located on special markers;

3) special markers that allow for research in almost any pathology of the dentition (deep incisal overlap, patients with braces): one central sensor to determine the individual position of

the prosthetic plane and two lateral ones (one side marker is attached to the tooth of the upper jaw, the other - to the mandibular tooth).

The software specially developed for the axiograph allows for complex processing of the data obtained during the examination. The use of the proposed computer program makes it possible to:

upload CBCT results to a virtual articulator to create virtual models of the jaws;

transfer virtual models of both jaws to a virtual articulator;

combine virtual models of jaws and trajectories of their movement with visualization in a virtual articulator;

determine the spatial location of the lower jaw;

upload virtual models to the used articulator (Exocad, Zirkonzahn, InLab, eramill);

carry out plastering of models in a mechanical articulator according to CBCT data;

Electronic axiograph Dentograf (Prosystom, Russia)

establish a special algorithm for working with virtual models that allows you to move them in any given displacement directions.

229 axiograms were recorded and analyzed, on which, during functional tests: “opening and closing the mouth”, “forward movement” and “lateral movements of the lower jaw to the right and left”, characteristic articular trajectories and signs specific to subluxation of the articular disc were revealed. The jaw models were scanned using a laboratory scanner S600 ARTI (Zirkonzahn, Germany). In order to monitor the results of treatment, a second axiographic study was performed every three weeks.

In 17 patients out of 47 (36.2%), the axiograms showed shortening of the trajectories of the articular path when opening the mouth (less than 11 mm), protrusion of the lower jaw (less than 10 mm) and during lateral movements (less than 8 mm). In 38 patients out of 47 (80.9%), there was a lack of symmetry in the movement of the heads of the lower jaw on the right and left. In the central position of both heads in patients with subluxation of one of the articular discs, the movement of the articular condyles when opening the mouth began synchronously; when the disc was repositioned, the axiograms showed a zigzag distortion of the articular trajectory and asynchrony in the movements of the mandibular heads.

The study was conducted in accordance with the Declaration of Helsinki (2013) and approved by the Ethics Committee of the Peoples' Friendship University of Russia. Informed consent was obtained from each patient.

Some patients (Group 1, n=22) were treated with occlusal muscle relaxant splints, which were modeled in an Artex CR mechanical articulator (Amann Girrbach AG, Austria); for other patients (Group 2, n=25), muscle relaxant splints were made by milling using a Coritec 350 milling machine (Imes-Icore, Germany). Mechanical and virtual articulators, in which occlusal splints were modeled, were adjusted according to individual parameters based on axiography data.

The technique for manufacturing occlusal muscle relaxant splints by milling included the following steps:

1) production of plaster models of the jaws based on the obtained two-layer silicone impressions;

2) transfer of jaw models to a virtual articulator according to the indications of the electronic facial arch (Prosystom) and the register of the central ratio according to the electronic axiography data;

3) optical scanning of plaster models of the jaws;

4) tire modeling in the Exocad program;

5) milling of the occlusal muscle relaxant
soup tires according to the received stl-file;

6) finishing and polishing of the tire.

The manufacture of occlusal muscle relaxant splints using a mechanical articulator was carried out according to the following method:

1) removal of two-layer silicone impressions and casting of models;

2) use of a mechanical face bow Artex CR (Amann Girrbach AG, Austria);

3) plastering of models in the Artex CR articulator using a mechanical face bow;

4) modeling and manufacturing of an occlusal splint from a colorless plastic of cold polymerization.

Results. For the 1st group of patients (n=22), occlusal muscle relaxant splints were made in a mechanical articulator. After the two-layer silicone impressions were taken, the models were plastered using a Girrbach mechanical front arc. The articulator was adjusted according to individual data after electronic axiography, the articulation mechanisms and the programmable incisal table were adjusted.

For the 2nd group of patients (n=25) occlusive muscle relaxant splints were fabricated using a virtual articulator. After taking two-layer silicone impressions and casting plaster models, the obtained models were scanned in order to convert them into digital format. Further, the data of the virtual models were loaded into the axiograph program and combined with the CBCT data according to the dentition landmarks. This was necessary to individualize the location of the dentition relative to the articular heads. The data obtained after the electronic facebow (Prosystom, Russia) — the inclination of the models in space — was used for the subsequent placement of the models in a virtual articulator using the Exocad modeler program, in which the technician modeled the occlusal splints.

With such a position, the program has the ability to reproduce in three-dimensional space the position of the virtual dentition relative to the hinge axis and incisal stop. After that, the individual for each patient values of the angles of movement of the lower jaw (Bennett angles), articular path, immediate lateral shift, protrusion, retrusion and lateral movements (laterotrusion) of the lower jaw, which were determined on the basis of electronic axiography

data, were entered into the program. Occlusal contacts in each individual case were automatically marked with a color gradient.

Repeated axiographic examination was performed every three weeks to assess changes in the articulation of the lower jaw, in the position and movements of the articular disc. In 40 out of 47 patients (85.1%), during treatment with muscle relaxant occlusal splints, during dynamic observation, registration of articular trajectories of lower jaw movements did not reveal axiographic signs of subluxation of the articular disc, which indicates its reduction. Thus, the effectiveness of treatment as a whole was 85.1%. However, in the 2nd group of patients with milled muscle relaxant splints, the effectiveness of their use was higher and amounted to 88%, i.e. signs of subluxation of the articular disc during repeated axiography were not detected in 22 patients out of 25. In the 1st group, this figure was 81.8%, i.e. the absence of previously existing signs of subluxation of the articular disc was detected in 18 out of 22 patients.

Discussion. In occlusive therapy of internal disorders of the TMJ, the following types of splints are mainly used: muscle relaxants, which reduce muscle tone with the establishment of articular heads in a centric position [7]; stabilizing, fixing the new position of the lower jaw after normalization of muscle tone and reducing the manifestations of TMJ dysfunction [8]; dissociative; repositioning, setting the heads of the lower jaw in the correct position, which are divided into protrusion and distraction [9, 10].

The use of virtual technologies opens up new opportunities in the diagnosis and treatment of various disorders of the TMJ function [11, 12]. The use of a virtual articulator makes it possible to obtain 3D images of the TMJ, as well as to assess the state of static and dynamic occlusion [13, 14].

The effectiveness of therapy with milled occlusal splints is due to an increase in the accuracy of their manufacture at intermediate clinical and laboratory stages. Milled occlusal splints are modeled in a virtual articulator. It was possible to improve the positioning accuracy of virtual models in the articulator by using individual patient CBCT data. With the help of an additional CT module axiograf Dentograf, the distance from the incisors of the upper jaw to the articular heads of the lower jaw was measured, with subsequent transfer of the obtained data to a virtual articulator. At the same time, we focused on three indicators: the interincisor point in the region of the cutting edge of the central incisors of the upper jaw and both heads of the lower jaw. This made it possible to place models in the articulator with a high degree of accuracy and taking into account the individual distance from the upper jaw to the articular condyles of the lower jaw, which is very difficult in the case of using mid-anatomic facial arches.

Thus, with the use of an additional CT module, it becomes possible to more effectively place jaw models in the space of a virtual articulator - taking into account their individual characteristics - and control the three-dimensional location, taking into account the state of the TMJ. This technique is the most accurate in comparison with the use of mechanical facebows. If necessary, when modeling an occlusal splint with dental guides, we used the algorithm developed by us for loading the trajectories of the lower jaw movements.

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For this purpose, at the first stage, the trajectories of movements of the lower jaw are recorded in the dental clinic using an axiograph. Then the obtained data in electronic format is

loaded into the Exocad program for modeling by the technician of the muscle relaxant splint, taking into account the individual position and movements of the lower jaw. These innovations in the form of individualization of the movements of the lower jaw of each patient made it possible to increase the efficiency and quality of the manufacture of occlusal muscle relaxant splints, which we used to treat internal disorders of the TMJ.

When comparing the results of treatment in both groups of patients, the advantage of using a virtual articulator for high-precision manufacturing of muscle relaxant splints in patients with internal TMJ disorders was revealed. In the case of using a mechanical front bow, errors in the manufacture of splints occur quite often [15, 16]. The errors are related to the fact that when placing models in a mechanical articulator during their plastering, the reference point is the upper frame of the articulator. The distance from the articular mechanisms to the models does not always match the individual data of patients. Any displacement of models (up or down from the upper edge of the frame) leads to a change in functional tests, as the distance between the model and the articulator articular mechanism changes. This is of particular importance in the manufacture of therapeutic occlusal splints for patients with internal TMJ disorders. At the same time, mechanical facial arches are usually located on the patient's face, taking into account the skin landmarks of the Camperian or Frankfurt planes. Skin and bone landmarks have discrepancies, which increases the measurement error [17,18].

When using a virtual articulator for the manufacture of therapeutic occlusal muscle relaxant splints, the minimum number of errors was noted when transferring the model of the upper jaw to the articulator and the highest accuracy of the location of virtual models in the articulator according to the individual parameters of the patient. Thus, at the stage of placing models in the articulator, we were able to significantly reduce the error that occurred when using the facial bow [19,20].

Conclusion. The use of milled muscle relaxant splints for the treatment of subluxation of the articular disc is preferable to the use of splints made in a mechanical articulator (the effectiveness of therapy is 88 and 81.8%, respectively).

The developed algorithm for modeling muscle laxing splints with loading of the articular trajectories of the movement of the lower jaw with dental guides makes it possible to significantly improve the quality of these splints.

The use of a virtual articulator for the manufacture of muscle relaxant splints makes it possible to form them in strict accordance with the individual parameters of the patient. With its use, a new opportunity arises to model muscle relaxant splints, taking into account individual trajectories of lower jaw movements, which increases the effectiveness of the treatment of patients with internal TMJ disorders.

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