Correction of Internal Disorders of the Temporomandibular Joint Using Muscle Relaxation Splints Made with CAD/CAM Technologies

DOI: 10.17691/stm2019.11.3.15
Received June 3, 2019

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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 articulation of the lower jaw are mostly caused by dental arch integrity violation and occlusion pathology [1, 2]. However, patients often refer to dentists because of the problems caused by internal disorders of the temporomandibular joint (TMJ) with changes in the position and movements of the articular disc [2, 3].

The works of national and foreign researchers suggest various classifications of internal TMJ disorders and it causes some complications in diagnosis and treatment of this pathology. The main, most frequent clinical-morphological groups of TMJ functional disorders were studied in the works of Khvatova [4]. Being dislocated or incompletely dislocated the articular disc is in a non-physiological position in relation to the head of the lower jaw. The disc can move forward, backward, medially, laterally, ventromedially and ventrolaterally in relation to the head of the lower jaw. The most frequent type is the anterior dislocation of the articular disc accounting for

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80–90% of all cases. There are TMJ disc displacement with reduction (that can be fitted) and without reduction (that cannot be fitted).

From the practical point of view the classification of Sysolyatin, Bezrukov, and Il'in are of interest for the purpose of diagnosis and selection of an effective therapy method [5].

If the TMJ has some internal damage caused by occlusion disorders, the therapy of choice is orthopedic and orthodontic treatment, in particular the one with occlusion splints and bite plates.

Occlusion therapy with splints has a complex effect on the whole dentition including teeth, masseter muscles and all TMJ structures [6].

As the frequency of internal TMJ disorders remains high and there is no common opinion on the selection of therapeutic tactics, the objective of the study was to investigate effectiveness of muscle relaxation splints developed with new up-to-date methods of CAD/CAM technology.

Materials and Methods

We studied 47 patients with the lower jaw articulation disorders. They included 40 women and 7 men aged 23–39. They all had internal TMJ disorders in the form of the disc displacement with reduction and painful masseter muscles. The clinical examination was carried out in accordance with the international protocol [3].

During the clinical examination the main complaint was about clicking and crunching sounds in the lower jaw movements in 45 patients out of 47 (95.7%). 29 out of 47 patients (61.7%) had difficulty in opening their mouth, 34 patients out of all the examined group (72.3%) had a pain syndrome in the TMJ region. About half of the patients (22 patients, 46.8%) had reduced amplitude of mouth opening up to 3.2–4.0 cm.

During the clinical examination all patients had a clicking or crunching sound in the TMJ region when the mouth opened/closed, when the jaw moved forward, laterally and/or protruded as well as on palpation.

To identify morphological changes in joints, identify the position of the articular disc and further diagnosing, the patients underwent MRI. To assess the width of the joint gap, height, and symmetry of the lower jaw heads, the state of their cortical layer we used cone-beam computerized tomography (CBCT).

Based on the analysis of the findings obtained after MRI, the patients from both groups had a changed position of the TMJ articular joint with the mouth closed. It was in the form of the disc displacement with reduction. CBCT showed indirect signs of deflection of the TMJ articular disc in the form of narrowing of the joint gap and asymmetry of head location in relation to the lower jaw.

Registration and analysis of the joint trajectories of the lower jaw movements were carried out on an electronic axiograph Dentograf (Prosystom, Russia).

This is a new generation device for complex functional diagnostics of the lower jaw articulation. It is compact, easy to use and is equipped with a camera. Dentograf is used for extra-oral registration of movements of the lower jaw and consists of the following parts (see the Figure):

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

2) 3-D camera that controls all movements and trajectories. The mean root square deviation of the measurements of the optical system is about 1 μm. To provide maximum accuracy of measurements the system can simultaneously control the position of more than 400 points located on special markers;

3) special markers that can assist in studying of almost any pathology of dentition (descending occlusion, patients with braces): one central sensor to identify an individual position of the prosthetic plane and two lateral ones (one lateral marker is fixed to the upper jaw tooth; the other is fixed to the lower jaw tooth).

The software that was specially developed for the axiograph helps to process the obtained data. This PC software enables you to:

upload CBCT findings into a virtual articulator to create virtual jaw models;

transfer virtual models of both jaws into a virtual articulator;

join virtual models of jaws and trajectories of their movements with visualization in the virtual articulator;

identify spatial location of the lower jaw;

upload the virtual models into the articulator used (Exocad, Zirkonzahn, InLab, Ceramill);

mount a model in the mechanical articulator according to CB CT findings;

set up a special algorithm of work with virtual models that can move them in any pre-set directions.

We recorded and analyzed 229 axiograms which revealed specific joint trajectories and signs typical for subluxation of the articular joint during the following functional tests: mouth opening and closing, movement forward, lateral movements of the lower jaw to the right and to the left. The jaw models were scanned on a laboratory scanner S600 ARTI (Zirkonzahn, Germany).

Electronic axiograph Dentograf (Prosystom, Russia)

To control the treatment results an axiographic investigation was carried out every three weeks.

In 17 out of 47 (36.2%) patients the axiograms showed shortening of trajectories of the joint path during the mouth opening (less than 11 mm), protrusion of the lower jaw (less than 10 mm) and lateral movements (less than 8 mm). In 38 out of 47 (80.9%) patients there was no symmetry in the movements of the lower jaw heads on the right and on the left. In the central position of both heads the patients with subluxation of one of the articular discs had simultaneous start of joint condyles movement during the mouth opening; when the disc was reset the axiograms showed zigzag distortion of the joint trajectory and asynchrony in the movements of the lower jaw heads.

The study was conducted in accordance with the Helsinki Declaration (2013) and approved by the Ethical Committee of the Peoples' Friendship University of Russia. Each patient gave written informed consent.

A part of the patients (group 1, n=22) were treated with occlusion muscle relaxation splints modeled in a mechanical articulator Artex CR (Amann Girrbach AG, Austria); for the other group of the patients (group 2, n=25) the muscle relaxation splints were made with a milling machine Coritec 350 (Imes-Icore, Germany). The mechanical and virtual articulators that modeled occlusion splints were adjusted to individual parameters according to the axiography findings.

The method of preparation of occlusion muscle relaxation splints by milling included the following steps:

1) designing gypsum models according to the obtained two-layer silicon imprints;

2) transferring jaw models into a virtual articulator based on the data from the electronic face bow (Prosystom) and the registration of the central correlation according to the electronic axiography findings;

3) optical scanning of the gypsum models of the jaws;

4) splint modeling in Exocad software;

5) milling of a muscle relaxation splint according to the obtained stl-file;

6) final processing and polishing of the splint.

Occlusion muscle relaxation splints were made with a mechanical articulator according to the following method:

1) making two-layer silicon imprints and molding of models;

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

3) designing gypsum models in the articulator Artex CR with a mechanical face bow;

4) modeling and producing of an occlusion splint of colorless cold polymerization plastic.

Results

For the first group (n=22) occlusion muscle relaxation splints were made in the mechanical articulator. After making two-layer silicon imprints the models were designed in gypsum with a mechanical Girrbach face bow. The articulator was adjusted to the individual findings after electronic axiography, joint mechanisms and programmed incisor table surface were also adjusted.

For group 2 (n=25) occlusion muscle relaxation splints were made with a virtual articulator. After making two-layer imprints and molding gypsum models, the obtained models were scanned to be converted to a digital format. Then the findings from the virtual models were uploaded to the axiograph software and united with the CBCT findings according to dentition markers. It was necessary for individualization of dentition location in relation to joint heads. The data obtained from the electronic face bow (Prosystom, Russia) — model inclination in space — were used for further location of models in the virtual articulator with Exocad software in which a technical operator modeled occlusion splints.

In this way, the software can have a three-dimensional display of the position of the virtual dentition about the hinge axis and the incisal stop. Then we entered individual data of every patient into the program, these data included the values of angles of the lower jaw movement (Bennett angles), the articular path, immediate lateral shift, protrusion, retrusion and lateral movements (laterotrusion) of the lower jaw determined on the basis of electronic axiography. Occlusion contacts in every single case were automatically marked with color gradient.

Another axiographic investigation was carried out every three weeks to evaluate changes in articulation of the lower jaw and in the position and movements of the articular disc. In 40 out of 47 patients (85.1%) during the treatment with muscle relaxation occlusion splints in dynamic observation, the registration of joint trajectories of the lower jaw did not show any axiographic signs of subluxation of the articular disc which testified to the fact that it had been fitted. Hence, the effectiveness of treatment in general was 85.1%. However, in group 2 where the patients were treated with milled muscle relaxation splint the effectiveness was higher accounting for 88%, i.e. the subluxation signs were not revealed in 22 patients out of 25 during the repeated axiography. In group 1 these parameters counted to 81.8%, i.e. the lack of the previously observed signs of subluxation of the articular disc was registered in 18 patients out of 22.

Discussion

The following types of splints are generally used in occlusion therapy of internal TMJ disorders: muscle relaxation types that reduce muscle tone by setting the joint heads in the central position [7]; stabilizing, fixing a new position of the lower jaw after normalization of the muscle tone and reducing the signs of the TMJ dysfunction [8]; occlusal; repositioning, fitting the heads of the lower jaw in the right position, they are divided into protrusion and distraction ones [9, 10].

The use of virtual technologies opens new possibilities

in diagnosis and treatment of various TMJ dysfunctions [11, 12]. The use of a virtual articulator allows obtaining 3D TMJ images and evaluating static and dynamic occlusion [13, 14].

The effectiveness of the therapy with milling occlusion splints was associated with higher accuracy of their production at intermediate clinical and laboratory steps. Milled occlusion splints are modeled in a virtual articulator. An increase in accuracy of virtual models positioning in the articulator was secured by the use of the patient's individual CBCT data. By employing a supplementary CT module of axiograph Dentograf we measured the distance from the incisors of the upper jaw to the joint heads of the lower jaw and then transferred these values to the virtual articulator. We considered the following three parameters: inter-incisal point in the tooth cutting edge of the central incisors of the upper jaw and both heads of the lower jaw. It allowed the models to be placed in the articulator with a high degree of accuracy under consideration of the individual distance from the upper jaw to the joint condyles of the lower jaw which is usually rather complicated in case of using average anatomic face bows.

Thus, the use of a supplementary CT module gives an opportunity of a more effective positioning of jaw models in the space of a virtual articulator taking into account their individual features as well the ability to control the 3D location depending on TMJ state. This method is the most accurate compared to the one using mechanical face bows. When a model of the occlusion splint with dental guides was needed, we used the developed algorithm of uploading movement trajectories of the lower jaw.

For this purpose, the first step performed in the dental clinic with the aid of an axiograph is to register movement trajectories of the lower jaw. Then the obtained findings are electronically uploaded into Exocad software for a technical operator to model a muscle relaxing splint taking into account the individual position and movements of the lower jaw. This new approach, i.e. individualization of the lower jaw movements of each patient, allowed us to improve effectiveness and production quality of occlusion muscle relaxing splints which we used to treat internal TMJ disorders.

After comparison of treatment results for both groups we identified the advantage of using a virtual articulator for high-accuracy production of muscle relaxation splints for patients with internal TMJ disorders. If a mechanical face bow is used errors occur more frequently [15, 16]. Possible errors result from the fact that when models are placed in a mechanical articulator during gypsum molding, the guide is the upper frame of the articulator. The distance from joint mechanisms to models does not always correlate with patients' individual values. Any shift of models (up or down from the upper frame edge) leads to changes in functional tests, as the distance between the model and the joint mechanism of the articulator varies. It is of importance for the production of therapeutic occlusion splints for patients with internal TMJ disorders. At the same time, mechanical face bows are usually located on a patient's face depending on the skin markers of Camper's or Frankfurt horizontal planes. Skin and bone markers have deviations which increase measurement errors.

When a virtual articulator is used for the production of therapeutic occlusion muscle relaxation splints, the minimum number of errors is registered during the transfer of the upper jaw model into the articulator as well as the highest possible accuracy of virtual models positioning in the articulator according to individual parameters of a patient. Thus, at the step of placing models in the articulator we managed to significantly reduce the number of errors occurring when a face bow is used.

Conclusion

The use of milled muscle relaxation splints for treating subluxation of the articular disc is more preferable than the use of splints made in a mechanical articulator (the effectiveness of the therapy is 88 and 81.8%, respectively).

The developed algorithm of modeling muscle relaxation splints with uploading of the lower jaw joint trajectories with dental guides allows us to improve the quality of these splints significantly.

The use of a virtual articulator for the production of muscle relaxation splints offers an opportunity to form them exactly in accordance with a patient's individual parameters. It makes it possible to model muscle relaxation splints with consideration of individual trajectories of the lower jaw movements increasing the effectiveness of treating patients with internal TMJ disorders.

Funding and conflict of interest. The study was not financed by any sources, so there is no conflict of interest associated with this study.

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