

# THE USE OF OCCLUSAL SPLINTS MANUFACTURED WITH «EXOCAD» SOFTWARE IN THE TREATMENT OF TEMPORO-MANDIBULAR DYSFUNCTION

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## Abstract

**Introduction.** The aim of the study was to evaluate the use of 3D printed muscle relaxation splints made with EXOCAD software using a virtual articulator module for the treatment of dysfunctional disorders of the temporomandibular joint (TMJ). **Materials and methods.** We examined 38 patients with disorders of the occlusal ratios of the jaws and clinical manifestations of TMJ dysfunction (ventral dislocation of the articular disk of the TMJ with reposition). All patients underwent axiographic investigation before, during every 3 weeks, and also after the treatment. In group 1 (n=24) we used muscle relaxation splints made in a mechanical articulator, while in group 2 (n=14) the splints were modeled in a virtual articulator in accordance with axiographic findings. **Results and discussion.** The results of treating patients with subluxation of the TMJ articular disc with muscle relaxation splints made with mechanical and virtual articulators shown that the use of a virtual articulator resulted in minimal frequency of positioning errors in the articulator interframe space. We developed a method of occlusal surface modeling using a virtual articulator with loaded individual parameters of the lower jaw movements. It helped to considerably reduce inaccuracies of splint modeling occurring when a standard mechanical face bow with mechanical articulators is used. **Conclusions.** In patients with TMJ dysfunction (ventral dislocation of the articular disc with reposition), the treatment is better with the use of printed tires made in the virtual articulator. The algorithm of the analysis of individual joint trajectories of the mandibular movements according to the axiography data and occlusal contacts in the modeling of muscle relaxing splints allows improving the quality of treatment of patients with dysfunction conditions of TMJ.

**Keywords:** TMJ dysfunction, muscle relaxing tires, axiography, joint trajectories, mechanical articulator, virtual articulator, TMJ internal disorders, lower jaw articulation disorders, occlusion, muscle relaxation splints, axiography, joint trajectories, mechanical articulator, virtual articulator

## 1. INTRODUCTION

Functional jaw disorders take the third place among all stomatological pathologies after caries

and parodontal diseases. Mandibular articulation modification occurs due to the disintegration of dental row and malocclusion [1,2]. Sometimes, patients refer to stomatologists with the disorders caused by the temporomandibular dysfunction, modified position or mobility of the articular disc [2, 3,13].

In cases of dislocation or subluxation, the articular disc occupies an abnormal position toward the mandibular head. The disc may dislocate forward, backward, medially, laterally, ventro-medially and ventro-laterally, related to the mandibular head [4,5]. Here, anterior dislocation of the articular disc occurs in 80-91% of all cases. Although many studies have been dedicated to the diagnostics and treatment of these disorders, no single strategy has been defined yet [7,12,13].

In inner traumas of TMJ caused by malocclusion, the chosen therapy will be prosthetic or orthodontic, particularly with occlusion splints and biteplates [11,12].

The splint occlusion therapy totally affects the dental-facial apparatus, including the teeth, chewing muscles and all components of TMJ [6,9,10,13].

As TMJ dysfunctions incidence is still high and there is no single agreement on the treatment of such patients, searching for new treatment methods seems rather actual.

The aim was to study the efficiency of the myorelaxing splints, produced with new modern modeling methods, using a virtual articulator and a 3D printer, and to compare them with the same splints, produced by a classic method.

## 2. MATERIALS AND METHODS

The study was developed in the Department of Prosthetic Stomatology of the "O.Bogomolets" National Medical University, together with the laboratory of computer modeling and digital stomatology of the Stomatological Medical Center affiliated to the same university. The representative sample includes 38 patients (Table 1), all diagnosed with the TMJ dysfunction (ventral dislocation of the articular disc with reposition and pains in the chewing muscles). Clinical examination of patients observed the international protocol [3]. 37 patients (97.4%) predominantly complained of abnormal sounds expressed as clicking or cracking noticed during movement of the mandible. Limited mobility and discomfort in the TMJ during mouth opening was noted in 19 people (50%), painful syndrome – in 26 (68.4%), while 21 patients (55.3%) stated that their mouth opening amplitude decreased to 3.6-4.0cm. Each patient signed an informed consent.

**Table 1. Number of examined patients**

Clinical groups	Total	Women		Men	
		abs .	%	abs .	%
I	24	18		6	
II	14	9		5	
Total	38	27		11	

Clinical examination also revealed clicking or cracking during mouth opening or closing, as well as during forward mandibular movement, its lateral dislocations and (or) protrusion and palpation of the TMJ. The clinical index of dysfunction in these patients ranged within 15-25 points.

To detect the morphological modifications in the joints and define the articular disc position for diagnosing the condition, MRI study was conducted.

Analysis of the MRI data thus obtained detected a modified position of the TMJ articular disc with the mouth closed, as a ventral dislocation of the articular disc with its reposition. Indirect signs of TMJ articular disc dislocation were caused by narrowed articular cavity and asymmetry of mandibular heads position.

Registration and analysis of the articular trajectories of the mandibular movements were conducted and recorded using the electronic axiograph CADIAX diagnostic (GAMMA Medizinisch-Wissenschaftliche Fortbildungs-GmbH, Austria).

This new-generation facility is used for extraoral registration of the mandibular movements as well as for complex functional diagnostics of the articulation.

The specially designed tool for axiograph software provides a complex processing of the received data. The software has been used to record and analyze 78 axiograms obtained with the following functional tests: "opening and closing the mouth", "movement forward", "lateral movement of the mandible to the left and right", which showed the articular trajectories and signs characteristic to articular disc subluxation.

In order to control the treatment, repeated axiography examination was conducted on a monthly basis.

16 out of 38 patients (42.1%) had decreased trajectories of the articular path when opening the mouth (less than 10mm), as well mandibular protrusions (less than 8 mm) during lateral movements (less than 7 mm). In 32 patients (84.2%), asymmetry of the mandibular head movement on the right and left sides was detected. In a patient with dislocated articular disc, the articular heads, both in central position, moved simultaneously when opening the mouth; when reposing the disc, axiograms showed a zigzag-like distortion of the articular surface and an asynchronous movement in the mandibular heads.

Some patients (clinical group 1, n = 24) were treated using occlusion myorelaxing splints, which were adjusted in the mechanical articulator Artex CR (Amann Girrbach AG, Germany); the other patients (clinical group II, n = 14) were treated with 3D printed myorelaxing splints, virtually modeled with the EXOCAD software. The mechanical and virtual articulators to which the occlusal splints were adjusted were individually managed using axiographic data.

The jaw models were obtained using an Identica Light laboratory scanner (Medit, Northern Korea).

The software EXOCAD provides high-precision teeth modeling and adjustment. The following manipulations may be performed with it:

- reproducing virtual jaw models in the virtual articulator after 3D scanning in a mechanical articulator;
- joining jaw virtual models and their movement trajectories, visualizing them in a virtual articulator;
- uploading virtual models into the virtual articulator;

Correction of the external defects of the TMJ produced by EXOCAD splints is realized with a particular virtual model algorithm, so that they may be moved in any direction.

Stages of production of the occlusal myorelaxing splints by the 3D method:

- 1) manufacturing the gypsum jaw models based on the taken two-layer silicone impression;
- 2) attaching the jaw models into a mechanical articulator, according to the facial arch and central relation data;
- 3) optic scanning of the gypsum models in the mechanical articulator;
- 4) modeling of splints *via* the EXOCAD software, using the virtual articulator module and electronic axiographic data;
- 5) 3D printing of the occlusal myorelaxing splint according to the obtained stl-file, using the 3D printer Form 2 (Formlabs, USA);
- 6) final adjustment and polishing of the splint.

The following methods for manufacturing the occlusal myorelaxing splints using the mechanical articulator were employed:

- 1) taking two-layer silicone impressions and casting the models;
- 2) using the mechanical facial arch Artex CR (Amann Girrbach AG, Germany);
- 3) adjusting the models in articulator Artex CR using the mechanical facial arch;
- 4) adjusting and manufacturing the occlusal splint from colorless plastics.

### 3. RESULTS

Occlusal myorelaxing splints were manufactured in a mechanical articulator for one patient from group 1 (n = 24). After taking

over the two-layer silicone impressions, the models were adjusted using the Girrbach mechanical facial arch.

Articulator settings were individually adjusted for programming, with the electronic axiographic data and the joint mechanisms.

The patients from group II (n = 14) had occlusal myorelaxing splints produced using a virtual articulator. After taking over of two-layer silicone impressions and casting the gypsum models, 3D scanning of the models was done, in order to transform them into the digital data format. The virtual model data was uploaded in the EXOCAD. The electronic axiographic data was used for simulating the mandibular movements in the virtual articulator EXOCAD, to which the occlusal splint was adjusted (Fig. 1). The individual parameters of patient's mandibular movement (Bennet angle, sagittal articular way angle, immediate lateral dislocation), as well as the dental row extension parameters were introduced. During the adjustment, the mandible could be virtually moved according to the desired therapeutic position (Fig. 2). The occlusal contacts in each case were automatically marked with a color gradient (Fig. 3).

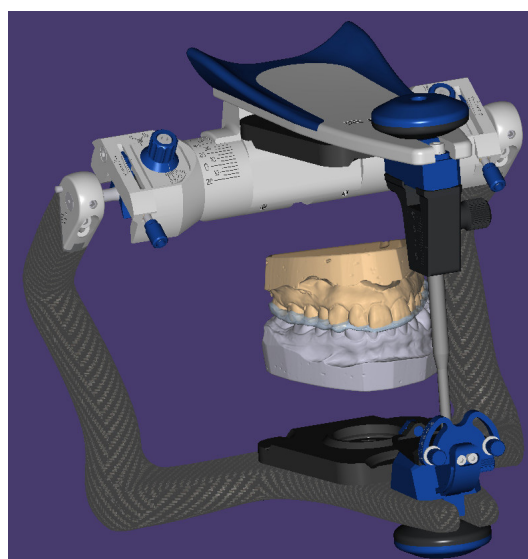


Fig.1. Models in the EXOCAD virtual articulator module (similar to Artex CR) in which the mandibular movements are modeled according to electronic axiography data (CADIAX diagnostic, Gamma)



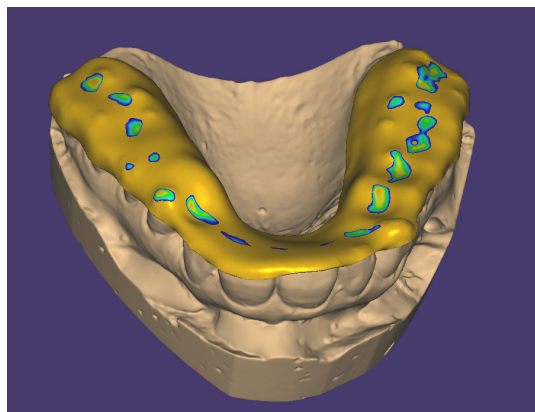


Fig. 2. Modeling of the occlusal splint in EXOCAD (showing occlusal contacts with normal occlusion)

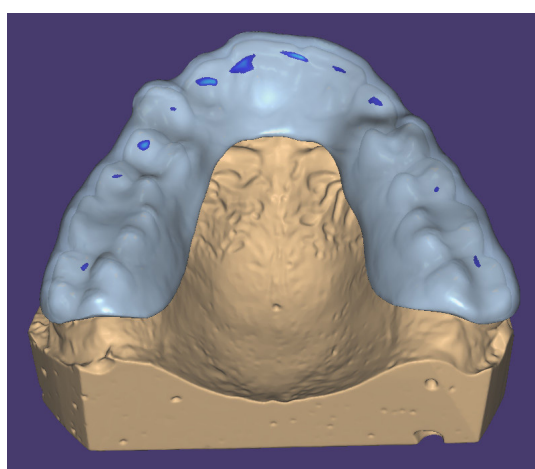


Fig. 3. Models in the EXOCAD program occlusal splint (showing occlusal contacts in the therapeutic position of the mandible)

Repeated axiography was performed once a month, to assess modifications in the mandibular articulation, as well in the position and movements of the articular disc. 33 patients (86.8%) who received myorelaxing occlusal splints showed no axiographic signs of the articular disc subluxation during dynamic registration of the articular movement trajectory, which evidences its repositioning. Consequently, the total efficiency of the treatment was of 86.8%, while, in clinical group II, the efficiency of myorelaxing splints was even higher, about 92.8%, *i.e.* signs of subluxation of the articular disc at repeated axiography were not detected in 12 patients out of 14. In clinical group I, this parameter was 87.5%, *i.e.* 21 out of 24 patients showed no signs of articular disc subluxation.

#### 4. DISCUSSION

Therapy of TMJ dysfunction includes occlusion therapy, aimed at jaw relation correction. To treat this condition, the following splints are used: myorelaxing, which provides a decreased tone of chewing and mimics muscles with subsequent positioning of the TMJ heads into centric position [7]; stabilizing, the action of which includes fixation of the new mandibular position after stabilizing the muscle tone; it also provides decreased TMJ dysfunctions manifestations [8]; disuniting; correct repositioning of the mandibular heads, classified as protrusion and distraction ones.

The use of virtual technologies provides new opportunities in the diagnostics and treatment of various TMJ dysfunctions [12]. The virtual articulator aids to the assessment of the static and dynamic occlusion condition [13].

The effectiveness of the therapy with occlusal splints, produced by 3D printing, is stipulated for an increased accuracy of their laboratory and clinical production. The printed occlusal splints are adjusted in a virtual articulator. We managed to improve the accuracy of adjustment using individual patient data in the virtual articulator. If necessary, when adjusting the occlusal splint with dental lines, an algorithm of the mandibular movement trajectory analysis was used.

To this end, the mandibular movement trajectories are registered using the axiograph during the first treatment stage. Then, the obtained data is uploaded into the EXOCAD software for modeling of the myorelaxing splint, considering individual peculiarities of patient's TMJ and mandibular movement characteristics. This peculiarity regarding the mandibular movements provided an increased efficiency and quality of the occlusion myorelaxing splints, which were used for TMJ disorder treatments.

Comparing the treatment efficiency on both groups of patients, the advantage of high-precise myorelaxing splints production using virtual articulation was revealed. The production of splints using a mechanical articulator was associated with frequent fails [13].

## 5. CONCLUSIONS

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The use of myorelaxing splints produced by the digital protocol for the treatment of the TMJ disfunction is more advantageous compared to the splints produced in the mechanical articulator (therapy efficiency is 92.8% and 85.7%, respectively).

The offered algorithm of adjusting the myorelaxing splints by uploading the axiographic mandibular articular movements improves the quality of splints.

Myorelaxing splints may be adjusted according to the individual parameters of the patient by using a virtual articulator. Its use aids to modeling the myorelaxing splints, considering the individual trajectories of the mandible, which increases the efficiency of the treatment of TMJ intra-articular disfunctions.

### References

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1. Arsenina OI, Popova AV, Gus LA. The role of occlusal disorders in development of temporomandibular joint dysfunction. *Stomatologiya (Mosk)*. 2014;93(6):64-7.
2. Artyushkevich AS. Disorders of the temporomandibular joint. *Sovremennaya stomatologiya*. 2014;1(58):11-4.
3. Schiffman E, Ohrbach R. Executive summary of the diagnostic criteria for temporomandibular disorders for clinical and research applications. *J Am Dent Assoc*. 2016;147(6):438-45.
4. Khvatova VA. Clinical gnathology. Moscow:Meditsina;2005.
5. Sysoliatin PG, Bezrukov VM, Il'in AA. The classification of diseases of the temporomandibular joint. *Stomatologiya (Mosk)*. 1997;76(3):29-34.
6. Yaremenko AI, Korolev VO, Kovalev MI. Modern algorithm for diagnostic and treatment of TMJ pathology. *Institut stomatologii*. 2017;3(76):38-41.
7. Khvatova VA, Chikunov SO. Occlusal splints (current state of the problem). Moscow: Meditsinskaya Kniga; 2010.
8. Meirelles L, Cunha Matheus Rodrigues Garcia R. Influence of bruxism and splint therapy on tongue pressure against teeth. *Cranio*. 2016;34(2):100-4.
9. Adonyeva AV, Ilyin AA, Shchelkunov KS. Repositioning splint-therapy in complex treatment of fitting migration of joint disk of temporal and mandibular joint. *Sib Med J*. 2015; 2:22.
10. Alqutaibi AY, Aboalrejal AN. Types of occlusal splint in management of temporomandibular disorders (TMD). *J Arthritis*. 2015;4(4):1-4.
11. Luthra RP, Gupta R, Kumar N, Mehta S, Sirohi R. Virtual articulators in prosthetic dentistry: a review. *J Adv Med Dent Scie Res*, 2015;3(4):117-21.
12. Anh JW, Park JM, Chun YS, Kim M, Kim MA. A comparison of the precision of three-dimensional images acquired by 2 digital intraoral scanners: effects of tooth irregularity and scanning direction. *Korean J Orthod*. 2016;46(1):3-12.
13. Chkhikvadze TV, Bekreev VV, Roshchin EM, Trufanov VD, Yurkevich RI, Ivanov SYu. Correction of internal disorders of the temporo-mandibular joint using muscle relaxation splints made with CAD/CAM technologies. *Sovremennye tehnologii v medicine*. 2019;11(3):111-4.