Corrigendum: Occlusal splints – changes in the muscular activity (2020 J. Phys.: Conf. Ser. 1859 012046)

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In the References section, the following references are missing:

[10] Dimova-Gabrovska M 2015 Contemporary tendencies and gnathological preconditions in the diagnosis and rehabilitation of craniomandibular disorders dissertation for "Doctor of Science" degree (Sofia)
[11] Dimova M 2015 Thermovisual diagnostics of patients with craniomandibular dysfunctions - test characteristics Cathedra 51 18-22
     Dimova M 2016 Relaxing therapy in patients with CMD – thermographic results Public dental health - achievements, challenges, prospects. Solemn scientific session dedicated to the 25th anniversary of the Department of Public Dental Health (Sofia) 107-12
[12] Dimova-Gabrovska M 2018 Thermographic assessment of structural analysis in patients with temporomandibular disorders C. R. Acad. Bulg. 71 712-16
Occlusal splints – changes in the muscular activity

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Abstract. Bruxism is considered an oral parafunction of involuntary grinding and clenching of the teeth. Occlusal splints are the most common method of preventing bruxism and its consequences. Their application significantly reduces the pathologies of the dental and periodontal structures. Infrared thermography is a noncontact method of temperature measurement whereby the detector is pointed remotely at a single spot. The purpose of the study is registering by means of infrared thermography the changes in the muscular activity during the period of occlusal splint prophylaxis. In the presence of pathological changes, splint therapy aims to return the joint-muscular complex of the masticatory apparatus to normal, which is associated with the activation of the adaptive capabilities of the organism. This dynamic process is associated with a rise in temperature. When achieving balance after wearing the splints for one and three months, a decrease in the registered temperature is naturally observed due to the created preconditions for elimination of the inflammation of the joint and the overload of the muscles.

1. Introduction
In the glossary of terms of the American Academy of Orofacial Pain, bruxism is defined as a “total parafunctional daily or nightly activity that includes grinding, gnashing or clenching of the teeth. It takes place in the absence of subjective consciousness and it can be diagnosed by the presence of tooth wear facets which have not resulted of the chewing function” [1].

In a number of dental terminology dictionaries [2], the authors refer to the main characteristics of bruxism – unconscious clenching and grinding of the teeth. These definitions clearly describe the nature of this disorder, but there is no essential and definite distinction between whether it occurs in the waking state or during sleep. In fact, the habit of clenching, grinding, or gnashing of the teeth while awake is a different nosological entity, probably with a different cause and pathophysiology, and must be distinguished from bruxism during sleep [3].

Over the years, a number of theories have been formulated to explain the causes of bruxism. Due to the contradictory nature of the parafunction, there is still no universal conclusion and its etiology is considered multifactorial [4]. However, the factors can be divided into two main groups: peripheral (morphological) and central, the latter including psychological and pathophysiological factors.
Bruxism may result in abnormal tooth wear, mobility, fracture, intrusion, opening of contacts, drifting, erosion, or pulp pathology. Amongst the effects of bruxism on the dentition are pathologic tooth migration, bone alterations, temporomandibular joint disorders (TMJ) and pain.

The use of occlusal splints for the management of the bruxing patient has been advocated for many years. Since no definitive etiology has been proven and no specific and reliable treatment capable of cancelling bruxism is yet available, all efforts are directed towards the prevention of bruxism’s destructive effects [5]. When designed and produced precisely, they successfully prevent the negative consequences of the parafunction. The primary role of the occlusal splint is the protection of tooth tissue by preventing tooth-to-tooth contact and help reduce muscular activity [6].

Thermology is the study and application of biothermal processes to assess health or disease and thermography employs imaging and visual evaluation of those thermal changes. Since antiquity, bodily heat has been considered as an important indicator of wellbeing, so that the applications of temperature measurement and thermal imaging have continued to evolve. Thermography aids in the assessment and staging of various dysfunctions of the head and neck region. The unique significance of thermography is both qualitative and quantitative assessment, which helps in estimating the progression of a disease in a systematic manner [7].

Based on the method of application, thermography can be classified into the following types. A semi quantitative contact method (using liquid crystals), called liquid crystal thermography (LCT), a quantitative infrared-detecting non-contact method, known as infrared telethermography (ITT) and dynamic area telethermometry (DAT). Infrared thermography imaging consists of an infrared detector, amplifier, a microcomputer and a video display. The infrared detectors used are of different types; they include single element infrared detector, linear array infrared detectors and two dimensional array detectors [8].

In a group of patients, diagnosed with bruxism and related cranio-mandibular dysfunctions, thermal imaging was performed twice – before and after relaxing therapy with a temporary self-adjusting oral splint Aqualizer® Ultra Medium volume (Jumar, USA). The data analysis unequivocally shows that thermal imaging is an "appropriate and reliable method for screening patients" [10] and has a place in the diagnostic protocol of patients with changes in the masticatory apparatus – muscles and temporomandibular joints (TMJ), as it “allows visualization of basic structures of the masticatory apparatus both in normal state and in state of pathology”. The author [11] evaluates infrared thermography as "a sufficiently reliable diagnostic method that allows lateral thinking on certain symptoms and digital measurement of the findings" [12].

The objective of the present study is to estimate the changes in the muscular activity in the course of the prophylaxis by a 3D-printed occlusal splint during sleep.

2. Material and methods

2.1. Material and patient selection

The 26 patients included in this research were preliminarily diagnosed with sleep bruxism clinically (interview and observation of attrition signs) and the diagnosis was confirmed with a personal disposable BiteStrip® miniature electromyography device. The patients were aged 23-45 years, with all their teeth in the dentition present (third molars noncrucial) and no prosthetic restorations present.

The material used for production of occlusal splints was Dental LT Clear photopolymer resin (Formlabs Inc., USA), CE-certified as biocompatible Class IIa. It is a monomer based on acrylic esters and contains methacrylic oligomer > 70 % w/w, glycol methacrylate < 20 % w/w, pentamethyl-piperidyl sebinate < 5 % w/w (co-photoinitiator) and phosphine oxide < 2.5 % w/w (photoinitiator). Post processing for this type of resin is crucial for its mechanical properties and biocompatibility.
2.2. Methods

2.2.1. Splint fabrication. By means of additive manufacturing, stereolithography (SLA) in particular, the printer used – Form 2 (Formlabs Inc., USA) fabricates structures with a layer thickness of 25 µm up to 300 µm. An ultraviolet (UV) laser cures the consecutive layers with a power of 250 mW and 140-µm diameter of the laser spot (figure 1 (a)).

The settings for printing occlusal splints with the Dental LT Clear (Formlabs Inc., USA) resin produce a layer thickness of 100 µm.

The fabrication protocol for all 26 splints included the following steps:
1/ Acquiring patient’s data – alginate impressions were taken from the upper and lower jaw. Facebow registration was performed with Artex facebow and along with the registers of the interjaw relationship and the mandible’s lateral movements were transferred into Artex articulator (Amann Girrbach AG, Austria). Plaster models were poured and scanned with a desktop optical scanner (Ceramill Map 600, Amann Girrbach AG, Austria).
2/ Digital design in CAD software – the splint was designed using exocad DentalCAD v. 2.2 (exocad GmbH, Germany). Open STL file export is needed.
3/ Preparation for printing – the design file was imported into the printer’s software PreForm v. 3.4.2 (Formlabs Inc., USA). A few parameters need to be set before printing starts – layer thickness, orientation of the printed object, layout onto the printer platform, adding supporting structures.
4/ 3D printing with the Form 2 SLA printer (Formlabs Inc., USA).
5/ Post polymerization processing consisted of two consecutive steps:
   5.1/ rinsing the parts with 99.5 % isopropyl alcohol (IPA) for 5 min in Form Wash (Formlabs Inc., USA), which removes any uncured liquid resin before post-curing. A minimum of 30 minutes in the open at room temperature is required for the IPA to completely dry (figure 1 (b)).
   5.2/ post-curing with UV light for 20 minutes with 80 °C heating in the Form Cure (Formlabs Inc., USA) polymerization unit (figure 1 (c)).
6/ Removal of supporting structures and polishing of the splint
7/ Adjustment of the splint in the patient’s mouth and instructions for maintenance (figure 2) [9].

Figure 1. Formlabs 3D printing configuration: (a) – Form 2 SLA printer, (b) – Form Wash ultrasonic bath, (c) – Form Cure polymerization unit.
2.2.2. **Infrared thermography imaging.** Thermal and digital images of the patients were taken directly before starting the preventive treatment with the splint, 2 weeks, 1 and 3 months after the start on each control visit in the dental office by a Flir T335 (FLIR Systems, Inc., USA, figure 3) infrared thermal camera (0.1 °C precision).

The temperature was recorded in the temporomandibular joint and masseter muscle area. The patients were acclimatized for 15 minutes in a temperature of 22 °C preliminary to the imaging in order to normalize the body heat. Images (infrared+digital) were taken perpendicularly at a distance of 1 m from the patient in the following order: frontal, right and left profile. The image data were analyzed by Flir Reporter Pro 9 (FLIR Systems, Inc., USA) software (figure 4, 5 and 6). The digital images were taken for the data analysis in order to eliminate any inflammation of skin origin that may corrupt the results of the investigated area by showing a false positive temperature increase. The infrared and digital images were matched in Flir Reporter Pro before the analysis by means of three reference points. Using infrared thermal imaging and the sensitivity of the method impose certain restrictions:

- No intake of painkillers, anti-inflammatory medicine (at least for the last 3 days), antibiotics (at least 7 days), antihistamines (at least 5 days) or corticosteroids (at least 15 days).
- No intake of coffee, black tea, alcohol and no use of tobacco in the days of thermal imaging.
- No application of cosmetics and no shaving for male patients in the days of thermal imaging.
3. Results
In all 26 patients, a difference in the temperature registered of the left and right TMJs and the two masseters was observed, noting that 77% of the patients (20 subjects) had unilateral symmetry – the increased temperature of the TMJ corresponds to an increased temperature of the respective masseter muscle.

In 73% of the patients, an increase in temperature was registered in both TMJs and masseters after 14 days of splint wear. After 1 and 3 months, there was a gradual decrease in temperature to levels below baseline. In 7.7% of the patients, a decrease in temperature was observed in the second week. On day 14, in 11.5% of the examined patients there was a decrease in the temperature of the one side TMJ and masseter and an increase on the other side. In 7.7% of all patients, there was a slight increase of the temperature after 3 consecutive months of the occlusal splint prophylaxis. The percentage distribution of the most significant changes in temperature registered in 2 weeks and 3 months are given in figure 7.
4. Discussion
In the presence of pathological changes, the splint therapy aims to return the joint-muscular complex of the masticatory apparatus to normal, which is associated with the activation of the adaptive capabilities of the organism. This dynamic process is associated with a rise in temperature. When achieving balance after wearing the splints for 1 and 3 months, a decrease in the registered temperature is naturally observed due to the created preconditions for elimination of the inflammation of the joint and the overload of the muscles.

5. Conclusion
Well-fabricated occlusal splints in patients with bruxism are crucial for relieving the joint-muscular component of the masticatory apparatus and, together with preventing tooth abrasion, are a basic prerequisite for preserving all its functions. In patients who make an exception to this trend, different possible types of pathologies of the joint and muscle complex should be taken into account and the extent should assessed to which they can be affected by splints only. Also, the possible existence should be explored of another, additional etiological factor. Infrared thermography can be considered a complementary diagnostic method and a reliable follow-up tool for registering the changes of muscular activity in the course of splint prophylaxis.

Acknowledgments
The scientific research was funded by Medical University – Sofia under Grant 8327/22.11.2018, Contract 91.

References
[1] Okeson J P 1996 Orofacial Pain: Guidelines for Assessment, Diagnosis, and Management (Chicago: Quintessence)
[2] Harty F J 1994 Concise Illustrated Dental Dictionary ed 2 (Oxford: Wright)
[3] Dofka C M 2013 Dental Terminology ed 3 (New York: Dolmar) pp 135
[4] Gupta P V, Gupta L C and Sarabahi S 2017 Jaypee’s Dental Dictionary ed 2 (New Delhi: Jaypee) pp 80
[5] Carra M C, Huyhn N and Lavigne G 2012 Dent. Clin. N. Am. 56 387–413
[6] Bader G and Lavigne G J 2000 Sleep Med. Rev. 4 27-43
[7] Paesani D A 2010 Bruxism: Theory and Practice (Berlin: Quintessenz Verlags-GmbH) pp 3-60
[8] Luchowski L, Tomaka A A, Skabek K, Tarnawski M and Kowalski P 2016 Information Technologies in Medicine (ITIB 2016 Advances in Intelligent Systems and Computing vol 472)
[9] Porter R, Poyser N, Briggs P and Kelleher M 2007 Dent. Update 34 198–207
[10] Chandra Mouli P E, Manoj Kumar S, Senthil B, Parthiban S, Malarvizhi A E and Karthik R 2012 J. Dent. Med. Sci. 1 39–43
[11] Gratt B M, Anbar M 1998 Dentomaxillofac. Radiol. 27 68–74
[12] Taneva I and Uzunov T 2020 J. Phys.: Conf. Ser. 1492 012018