Orthodontics

Manufacturing of splint for mobile teeth splinting by digital design and direct metal laser sintering

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Изработване на шина за шиниране на подвижни зъби чрез дигитално планиране и директно метално лазерно синтероване

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Abstract

Teeth have mobility, which is defined as physiological, but under certain conditions this mobility may increase. It may be a transitory phenomenon, related to a momental state such as pregnancy, orthodontic treatment or also a symptom of a pathological process or a dental trauma. A primary component of the treatment plan in the last two cases, is the immobilization of teeth, which may be temporary or permanent. It is accomplished by either removable or fixed splints.

Aim: *The aim of this article is to present a method for digital design and manufacturing of a splint by direct metal laser sintering (DMLS).*

Materials and methods: *Models were scanned with Swing^{TM} (DOF Inc.) laboratory scanner with a 1.3 megapixel camera. Exocad Dental (Exocad GmbH) CAD software was used for construction design. The splint was made of Remanium star CL (Dentaurum) Co-Cr alloy by direct laser sintering with LaserCUSING (DENTAURUM) machine.*

Results: *The result is the introduction of a manufacturing method which ensures precision and reduces the splint manufacturing time. Digital planning enables excellent model visualization and exact construction parameters setting. Thus borders of the construction are accurately designed, considering the anatomic peculiarities and the clinical requirements. The DMLS method allows for the avoidance of possible technological errors and ensures great end-product precision. Thus the construction is easily fixed, its passivity is guaranteed and the clinical manipulation time is reduced.*

Conclusion: *The use of the new dental construction design and manufacturing technologies results in reducing the manufacturing time, minimizing technological errors and increasing end-product precision.*

Key words: *periodontal splint, CAD/CAM, direct metal laser sintering*

Абстракт

Зъбите притежават подвижност, определяна като физиологична, но при определени условия тя може да се увеличи. Това може да бъде преходно явление, свързано с моментно състояние като бременност, ортодонтско лечение или да бъде симптом на патологичен процес или зъбна травма. В последните случаи основен елемент от лечебния план е имобилизирането на зъбите, което може да бъде временно или постоянно. То се осъществява с шини, които могат да са снемаеми или фиксирани.

Цел: *Целта на статията е да представи метод за дигитално планиране и изработване на шина, чрез директно метално лазерно синтероване.*

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Материал и методика: *Сканирането на моделите извършихме с лабораторен скенер Swing (DOF Inc.) с 1,3 мегапикселова камера. За планиране на конструкцията използвахме CAD софтуер Exocad Dental (Exocat GmbH). Шината изработихме от Co-Cr сплав Remanium star CL (Dentaurum) чрез директно лазерно синтероване с апарат LaserCusing (Dentaurum).*

Резултати: *Резултатът е въвеждането на метод за изработване, който гарантира точност и намалява времето за изработване на шината. Дигиталното планиране позволява отлично визуализиране на модела и задаване на точни параметри на конструкцията. Това позволява да се планират точно границите на конструкцията, съобразявайки се с анатомичните особености и клиничните изисквания. Метода на директното метално лазерно синтероване позволява избягването на потенциални технологични грешки и гарантира голяма точност на крайния продукт. Точността на конструкцията улеснява фиксирането ѝ, като гарантира нейната пасивност и намалява времето за клиничната манипулация.*

Заключение: *Резултатът от използването на новите технологии за планиране и изработване на дентални конструкции е намаляване на времето за изработка, намаляване на възможностите за технологична грешка и увеличаване прецизността на крайния продукт.*

Ключови думи: *пародонтална шина, CAD/CAM, директно метално лазерно синтероване*

Tooth mobility is defined as the movement of the tooth in the alveolus under the influence of a particular force. Even in healthy periodontium, teeth have mobility which varies depending on the size and number of roots and is defined as physiological mobility. There are many reasons which may cause increased tooth mobility occurrence. An increased mobility may be established in the stage of tooth displacement during an orthodontic treatment because of the increased width of the periodontal cleft [1]. The tooth mobility level may also be increased during pregnancy and by the use of some hormonal contraceptives [2]. The reason for it may be transitory and normally, when its effect is suspended, the tooth mobility is restored within the physiological norms. Parafunctions cause occlusal trauma, whose consequence might be increased tooth mobility with no loss of attachment [3]. Such changes may also result from primary contacts secondary to poorly occlusally adjusted obturations and prosthetic constructions. Usually, self-correction occurs if these factors are eliminated before they have had a continuous effect. However, the most frequent reason for the increased tooth mobility is related to the occurrence of periodontitis. This is due to the occurrence of destructive processes both in the soft and the hard tooth-supporting structures [4]. Secondary occlusal trauma is frequently seen in periodontally compromised patients [5]. In these cases, hypermobility leads to occlusal instability, impeded masticatory function and decline in the quality of life [5]. Increased tooth mobility should be regarded as one of the first serious signs for the occurrence of a trauma or a pathological change in the attachment apparatus [6].

When hypermobility is a result of a trauma, this requires splinting of teeth for the purposes of its limitation [7]. In the cases of inflammatory etiology and Class 1 tooth mobility according to Miller's classification, a good outcome may be expected by the application of non-surgical methods alone [8]. In Class 2 tooth mobility and higher, splinting of teeth is applied as a part of the treatment plan. The biomechanical role of the splint is to ensure better distribution of stresses, affecting the hypermobile teeth in terms of its allocation over the entire surface encompassed by the splint [9]. Puri et al. classify the splints according to a number of indices. Splints can be fixed or removable according to the type of stabilization, extra or intra coronal according to the splint location and according to the type of material, splints can be metal or non-metal ones (composite, PMMA, etc.) [10]. Depending on the period of stabilization they can be temporary – worn for less than six months, provisional – worn over six months and permanent splints [10]. Extra coronary fixed splints are usually made of wire or fibre reinforced composite. Metal splints are made of Cr-Ni or Co-Cr steel. In the last decades, the use of Co-Cr alloys has been opted for, as the number of individuals displaying hypersensitivity to Ni is constantly increasing [11, 12]. Depending on the manufacturing method splints can be cast or wire-bent. The first method ensures great splint precision, but requires long and expensive laboratory work. The second method is a routine one in retainer manufacturing.

Aim

The aim of this article is to demonstrate the advantages of digital design and splint manufacturing under the direct metal laser sintering method.

Materials and methods

The presented case is of the patient P.M., 48 y/o, complaining of migrated lower front teeth classified by class 1 to 2 tooth mobility according to Miller (Fig. 1). According to the requirements of the consulting periodontist, the patient needed to be manufactured a stabilizing fixed splint limiting tooth mobility. The impression was taken from the patient with Variotime (Kulzer) addition silicone impression material. The dental model was cast with Moldano (Kulzer) hard plaster type 3, suitable for scanning. Models were scanned with Swing (DOF) laboratory scanner with a 1.3 megapixel camera. Exocad Matera (Exocad GmbH) dental technician CAD software was used after the generation of the STL file from the splint model. LaserCUSING (Dentaurum) metal laser sintering machine was used to manufacture the splint. The splint was made of Co-Cr alloy, Remanium star CL – laser melting powder (Dentaurum). The splint was further fixed by Tetric Evo-Flow flowable light-curing composite by Ivoclar Vivadent.

Results

The result of the technology we used is a stabilizing splint fitting both the working model and the teeth in the mouth with utmost precision (Fig. 2).

Figure 1. *Lower front teeth with class 1 to 2 tooth mobility according to Miller*

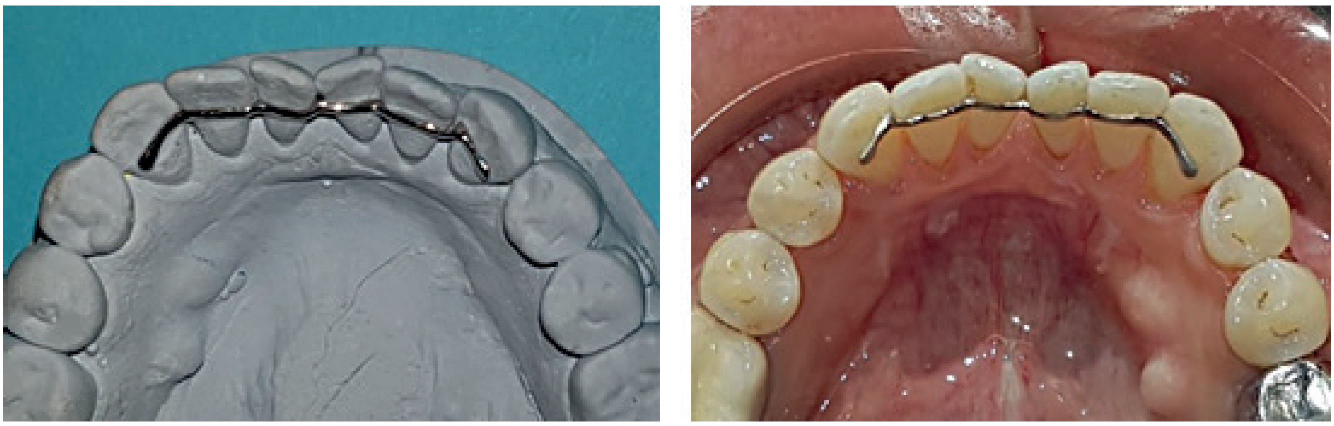

Figure 2. *Stabilizing splint on a model (A) and in the mouth (B)*

Digital design allows for excellent visualization of the model and assigning exact parameters of the construction. This enables the precise design of the construction borders, taking into consideration the anatomic peculiarities and the clinical requirements. The method we used ensures extreme accuracy in the manufacture which allows full fitting of the construction to the teeth surface in a manner which excludes the necessity of using fixation means during cementation. The dislocation risk is minimal and is within the admissible tolerance. The position of the splint with respect to the tooth crowns is precisely set according to the consulting periodontist's instructions, so as to ensure the minimum conditions for an easy access and a trouble-free maintenance of oral hygiene. The splint manufacturing time is reduced and the fixation clinical manipulation time is also significantly lower.

Discussion: Splinting of hypermobile teeth plays multiple roles. It limits mobility by redistributing the occlusal stress on the teeth, fixated by the splint. Furthermore, this assists the healing processes and increases the effectiveness of the periodontal therapy [13]. The periodontal pocket depth (PPD) and the clinical attachment loss (CAL) are also reduced [14]. Splinting increases patient's comfort and makes them feel safe. As the splint is placed in the mouth for a considerably long period of time, and under certain conditions splinting may be permanent, one of the major issue encountered, is to manufacture the splint so that to avoid any discomfort to the patient. From this point of view, fixed splints are much more advantageous. There are various methods known for fixed splints manufacturing: splints made of wire, used for retainer manufacturing, reinforced composite splints, cast splints, etc.

The manufacturing of splints of metal wire for orthodontic retainers has some disadvantages. Usually, these wires are characterized by certain elasticity. The possible risk in this case is, that when the splint is fixed, it may not be absolutely passive against the immobilized teeth. Sifafakis et al. found, that 0.2 mm deformation of the retainer wire results in the generation of 1N force, which is sufficient for a tooth displacement [15]. When such a splint is fixed, a possibility of displacement occurs. Therefore, the use of transfers or ligation with metal or elastic ligatures is recommended [16, 17]. This poses the risk of contaminating the operational field. As regards the reinforced composite splints, the data about their long-term stability are divergent. A number of studies indicates that they have less long-term stability compared to the metal splints [18, 19]. According to other studies, during the four-and-a-half-year study the reinforced composite splints show entirely satisfactory results [20]. It should be taken into consideration, however, that the clinical procedure for this type of splints is significantly longer and more complex. It is related to a specific adhesive protocol and the fine adjustment of the splint is sometimes done during the very manipulation. All of this creates a risk of contaminating the operation field or of certain inaccuracies which could result in failures. Cast splints are usually made under the model casting method, which requires considerable laboratory work thus raising their cost. Another potential problem is that this manufacturing method poses a risk of volumetric changes in the construction and its precision is therefore diminished.

We offer a CAD/CAM method of construction manufacturing. A dental CAD software is used to design the construction. The first step is the importation of the STL file of the model (Fig. 3).

This file may be generated by a direct intraoral scanning or by scanning of the model, previously cast in the laboratory. Irrespective of the reports of minimum differences between the digital and the physical models, these are considered as insignificant as to render both models equally applicable [21-23].

The software indicates the undercuts against the assigned direction of placing the splint (Fig. 4). The borders of the splint are outlined by drawing a curve on the model (Fig. 4). The software enables additional precision of each point's position. After the borders are outlined, the thickness of the splint is to be set.

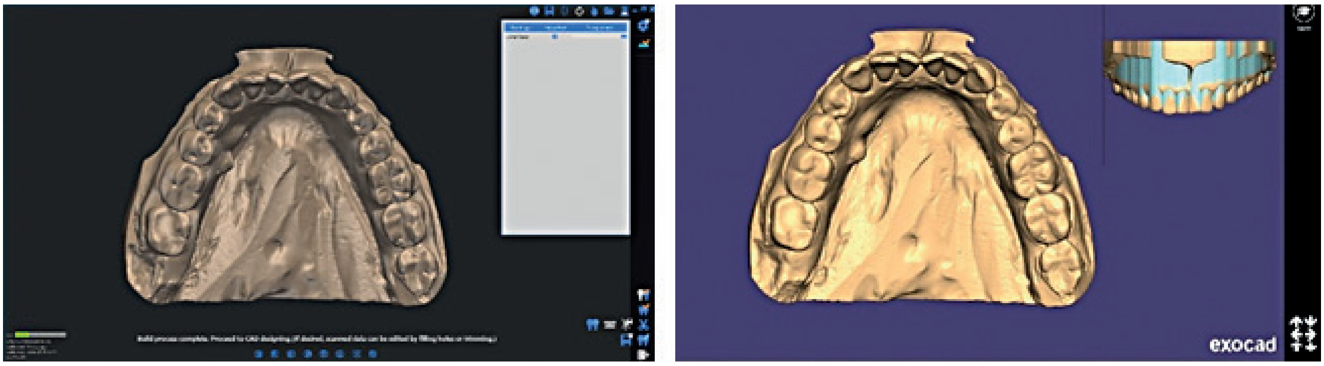

Figure 3 A. Digital image of the model after scanning. **B.** Model imported in the CAD software

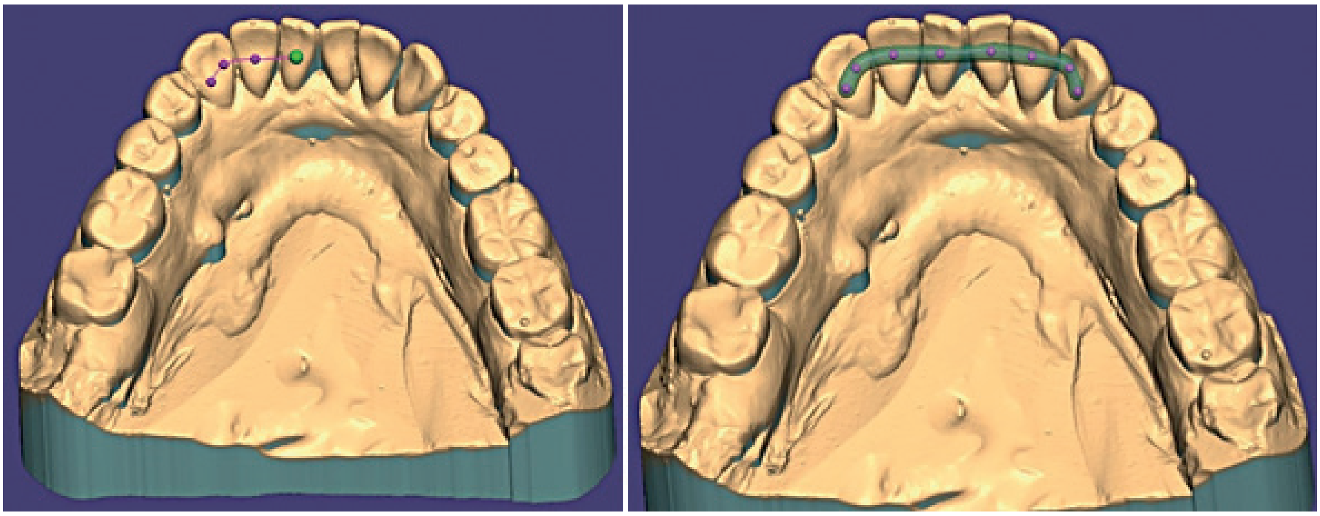

Figure 4 A – Outlining the borders of the splint by drawing a curve. Undercuts are shown in green in the software. **B** – The outlined borders

The software adjusts the assigned parameters to the model. In addition, it provides tools which can make further corrections in particular sections (Fig 5). Given these corrections, an option can be selected for material adding or removing. The strength of the tool in terms of which we remove or add with a single movement, is set in the software. When setting the size of the splint, it should be taken into consideration that following sintering, the metal will undergo mechanical processing, which will remove part of the thickness.

The software allows the construction to be examined at any time, whether or not on the model (Fig. 5). The examination of the construction without a model enables very fine smoothing (Fig. 5B). The image zooming option is extremely useful, thus allowing the visualization of even the smallest details. Another option enabled by the software is the possibility to examine and correct this part of the splint which fits the model, by switching off the model image. This is not possible with the conventional modelling and casting methods.

After the computer design of the splint is completed, the software generates an STL file, which is sent to the metal laser sintering machine. This technology was proposed and patented in the end of the last century by Deckard [24]. As this technology develops, it becomes increasingly integrated into dental medicine, especially in the prosthodontics and implantology. As the thickness of the sintering layers is between 20 and 70 μm, the precision of the finished construction is explicitly high and commensurable with a precisely cast construction [25, 26]. The technological risks in this methodology are considerably fewer. Co-Cr dust was used for the direct metal laser sintering. The sintered construction

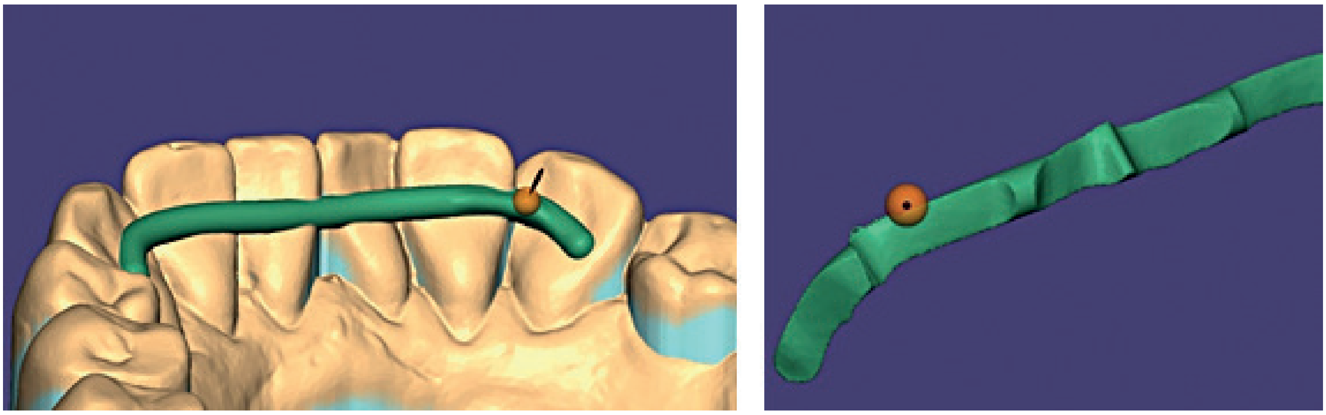

***Figure 5 A** – Splint borders adjusted to the model. Additional corrections are made with the tool manually. **B** – smoothing of the splint borders by removal*

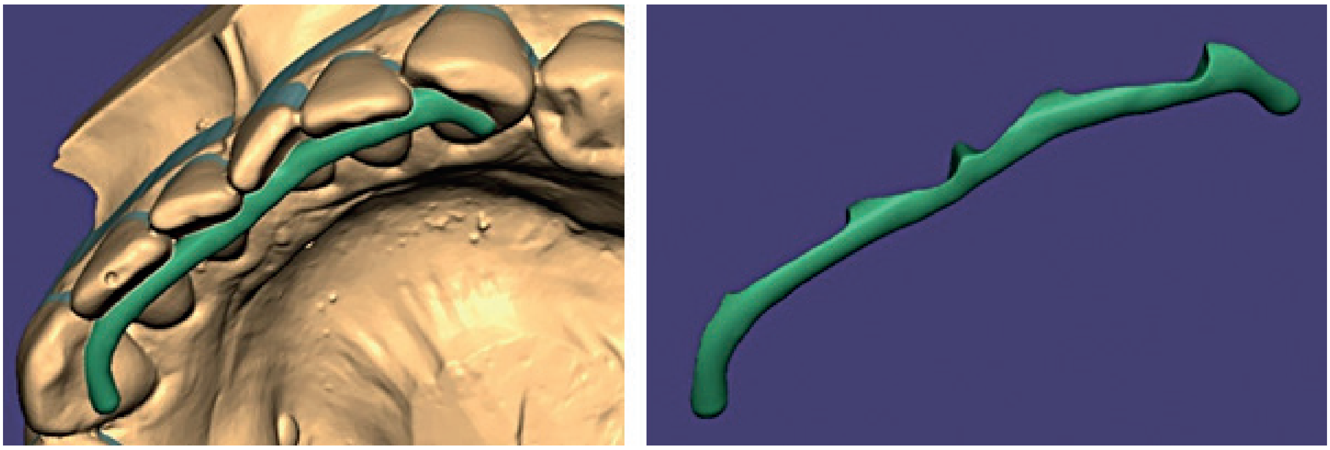

***Figure 6.** Final appearance of the digitally designed splint*

(Fig. 7) made of this material displays far better mechanical and biological characteristics [27].

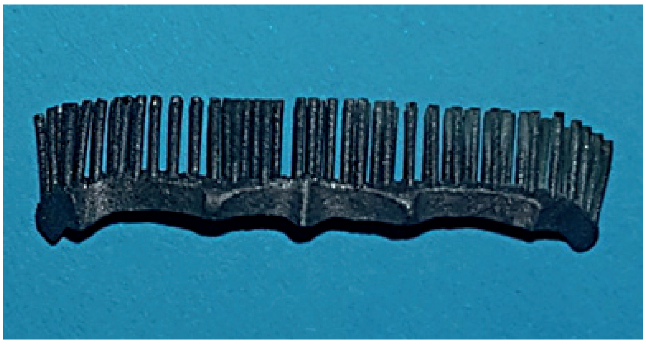

***Figure 7.** The splint with the supports after sintering*

Supports are removed from the splint after sintering (Fig. 7), and its surface is further smoothed through mechanical processing. Flowable light-curing composite was used for cementation and standard adhesive protocol was applied.

Conclusion: Teeth splinting following a trauma or a periodontal injury is a component of the therapeutic plan. Splint manufacturing in terms of CAD software design and direct metal laser sintering offers a lots of advantages compared to the other manufacturing methods. Planning of the splint borders is extremely accurate and is compliant with the anatomic peculiarities and the clinical requirements. There is an option for precise splint size control. The splint so manufactured, is characterized by utmost precision and fits excellently. This further results in another advantage, related to the fixation of the splint. Due to its accurate fitting, the possibilities of any errors during fixation are minimized. For this very reason the time of the clinical manipulation is reduced, which further diminishes the risk of errors in the adhesive protocol. The file of the designed splint is archived and if a new splint needs to be manufactured, the procedure will be very fast. Owing to the explicit precision of the manufacture and the passivity of construction, patients get used to it very quickly. The result of these state-of-the-art technologies in dental construction manufacturing and design is the reduced manufacturing time, the diminishing of the possibility of technical errors and the increased end-product precision.

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