The digital axiograph – a novel tool in bruxism prevention

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Abstract. Digital (electronic) axiography is an applicable promising technology with proven accuracy that allows registering the spatial location of the mandible and all lower jaw movements: mouth opening and closing, protrusion, left and right laterotrusion, dynamic function. In spite of bruxism treatment still being a controversial topic, occlusal splint application is proven to be the most efficient way of prevention. The purpose of the study is to develop a protocol of planning and producing preventive occlusal splints for bruxism management by means of digital axiography. The implementation of digital technologies reveals new possibilities in diagnosing, treating and tracking bruxism. With great attention to the individual trajectories of the lower jaw movements, the effectiveness of the occlusal splint prophylaxis is no longer hypothetical.

1. Introduction

Bruxism as a parafunction 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 (TMD) and pain [1].

The use of occlusal splints for the management of the bruxing patient has been advocated for many years. Due to the contradictory nature of the parafunction, there is still no universal conclusion and its etiology is considered multifactorial [2]. Therefore no specific, reliable treatment capable of cancelling bruxism is yet available and all efforts are directed towards the prevention of bruxism’s destructive effects [1]. When planned and produced precisely, occlusal splints in their variety successfully prevent the negative consequences of the parafunction [3].

The axiograph (also known as facebow) records the path of a condylar point or the path of a point in the vicinity of the condyle. Opening, closing, and protrusive movements have been investigated using axiography [4]. The clinical use of axiography includes location of the transverse horizontal axis and the detailed gathering of data needed to adjust a fully adjustable articulator [5].

Digital (electronic) axiography is an applicable promising technology with proven accuracy, equivalent to conventional axiographs. Due to the modern-day technical and software enhancements, it is superior to them in terms of data acquisition and interpretation [6]. Electronic axiography studies allow one to analyze such parameters as quality indicators, quantity indicators (range), symmetry, synchronicity of movement rates (between left and right temporomandibular joints, TMJ) [7].

A number of studies have investigated the diagnostic potential of digital axiographs in relation to programming an articulator according to the individual parameters of the patient’s mandibular movements and its application in the diagnosis of TMJ [8]. There is a variety of systems available: Dentograf (Prosystom, Russia), Zebris (Amann Girrbach AG, Austria), Proaxis (Prosystom, Russia),
Despite the technological differences, digital functional diagnostics and jaw motion registration are integrated in modern-day dentistry [9].

2. Material and methods

2.1. Material

A 42-year old male was clinically diagnosed with sleep bruxism using a standard questionnaire and an oral examination. A BiteStrip® personal disposable miniature electromyography device was used to objectively confirm the diagnosis. The patient’s complaints included visible signs of tooth attrition, stiffness in the masseter muscles area and occasional clicking in the right temporomandibular joint (TMJ). The patient had all teeth of the dentition present (third molars included) and no prosthetic restorations. To exclude any particular temporomandibular disorder (TMD) and for the aims of the digital axiography, cone-beam computerized tomography (CBCT) was administered.

Registration and analysis of the position and the movement trajectories of the mandible were performed by a Dentograph (Prosystom, Russia) digital (electronic) axiograph. A novel device for complex functional diagnostics of the lower jaw articulation, it consists of the following parts (figure 4):

- a three dimensional (3D) camera, embedded in a special head piece;
- a central marker and two side markers equipped with a grid of sensors designed to be detected by the camera on the head of the patient;
- a software program (P-Art, Prosystom, Russia) developed particularly to process the data obtained by the axiograph.

The patient’s upper and lower jaw, intercuspation (occlusal relation) included, were scanned by a powderless intraoral scanner Medit I500 (Medit Corp., South Korea, Figure 1). The scanner has an optimized workflow and interface (Figure 2 and 3) and works efficiently at high speed. It provides a high level of accuracy, which was crucial for the purpose of this study’s scans of the upper and lower dental arch.

The design of the occlusal splint was carried out in Exocad (Exocad GmbH, Germany) – dental software for computer-aided design (CAD). The splint was manufactured by means of 3D printing [10] with Form 2 (Formlabs Inc., USA) digital stereolithography (SLA) printer (Figure 5 (a), with the material selected being Dental LT Clear liquid photopolymer resin developed for particularly for occlusal splint production. For the mandatory post polymerization processing of the material, the attendant Formlabs devices were used (Form Wash – Figure 5 (b) and Form Cure – Figure 5 (c)).
2.2. Methods

To fulfil the aim of this study and based on the instructions given by the manufacturer, the following steps of performing a digital axiography were formulated:

1) Registration with the central marker.

Bite registration additive silicone material is applied onto the axiograph’s bite fork (Figure 6) and with regard to its indentation for obtaining the sagittal plane the fork is fixed to the upper dental arch. The patient closes the mandible until contact with the fork to support it (Figure 7). Preferably, this can be executed by means of two dental cotton rolls. Once the silicone sets, the central marker is switched on and the spatial position of the prosthetic plane is registered through wireless connection (Figure 8 (a) and (b)). Registration is visible in the software simultaneously.

2) Fixing the side markers (Figure 9):
   a. Marker on the maxilla – situated in I. quadrant (right), canine area;
   b. Marker on the mandible – situated in III. quadrant (left), canine area.

Fixation of the side markers can be achieved by using a photopolymer composite (paste consistency) or glass ionomer cement (for fillings). It is recommendable to have a dental assistant retract the lips of the patient until the fixing material used is set. It is important to follow the direction sign in the outer corner of the sensor grid on each side marker – the sign should be distally placed; this gives the proper left and right position (Figure 10).
3) Placing the head piece (3D camera) on the head of the patient and connecting it with the computer.

4) Taking reference frames:
   a. First reference frame – central marker and right (maxillary) marker (Figure 11);
   b. Second reference frame – right and left (mandibular) marker (Figure 12).

5) Axiography record.

   Recording the spatial location of the mandible and all lower jaw movements: mouth opening and closing, protrusion, left and right laterotrusion, dynamic function (can also be achieved by the patient chewing gum). While being recorded, all trajectories are visible in different color in the software.

6) Analysis of the results.

   This final step is executed in the software entirely. We chose to merge all data in the Complex diagnostics module of the program:
   - Upload of individual models of the patient – intraoral scans of maxilla, mandible and occlusion. Occlusal contacts are also made visible;
   - Upload of CBCT scans of the patient – the CBCT findings are united with the models from the intraoral scan according to dentition markers; nevertheless, the scans alone can be used in the software for the creation of virtual models.
   - Alignment of the individual models – using an intraoral scan with the bite fork returned in the patient’s mouth. Part of the fork should be also visible in the scan.

7) Export to CAD software (Exocad).

   After running the analysis, the final step is to export the individual models of the patient in current position, the recorded trajectories of the lower jaw (lower incisal, right and left articular), values of all lower jaw angles (sagittal, frontal, transversal) and the alignment of the upper jaw individual model on the bite fork. By completing the import with these parameters, the need of using a virtual articulator in Exocad is optional.

8) Occlusal splint design in Exocad.

9) Export of the design in Form 2 SLA printer’s software, material selection, printing and post processing.

3. Results

   The methodology described in subsection 2.2. is apporobated and proves fully applicable for functional diagnostics of the position, movement and trajectories of the lower jaw. The validated protocol steps are clearly formulated and the objective of each one is well defined. This protocol has been applied as a complex solution to bruxism cases and proves to be superior and more precise than the methods using average parameters.
4. Discussion
The implementation of digital technologies revealed new possibilities in diagnosing, treating and tracking bruxism and any accompanying TMJ dysfunctions. The higher accuracy of the method used was ensured by the supplementary tomography data.

The axiograph’s software offers the options of importing scanned individual plaster models (semi-digital method) or of calculating individual parameters for mounting plaster models in a fully adjustable mechanical articulator (regular analog method).

The semi-digital method allow one to avoid the use of an intraoral scanner – impressions are taken from patient’s upper and lower jaw with additive silicone impression material, plaster models are poured from the impressions and scanned in a desktop optical scanner (Ceramill Map 600, Amann Girrbach AG, Austria). In cases where it is necessary to work with a virtual articulator, the virtual models from any of the two types of scans can be uploaded and mounted. The movement trajectories can also be visualized and the splint is designed in the CAD software.

In the analog method, the plaster models are mounted in an Artex CR (Amann Girrbach AG, Austria) fully-adjustable articulator. For this purpose, the alignment is used of the bite fork on the special 3D stand preliminarily adjusted according to the values calculated in the software. While the bite fork with the bite registration material from the patient is on the 3D stand, the upper jaw plaster model is placed on the bite fork. Then, the mechanical articulator is adjusted to the angle values given from the axiography. The bite splint can be manufactured from wax directly on the models and then polymerized by means of lost wax technique and polymethyl methacrylate (PMMA) heat curing resin.

If comparing the methods in terms of the number of laboratory steps, the analog method is the most time consuming. At greatest risk of error is again the transfer of the upper jaw’s spatial position giving the prosthetic plane in the mechanical articulator. On the other hand, when the same transfer is done in a virtual articulator, there is no potential risk of error occurrence. If comparing the approbated protocol with the semi-digital approach, the intraoral scans performed are the most accurate. A number of mistakes can be made when taking regular impressions: from mixing and placing the impression material to the angle values given from the axiography. The bite splint can be manufactured from wax directly on the models and then polymerized by means of lost wax technique and polymethyl methacrylate (PMMA) heat curing resin.

5. Conclusion
The developed thorough digital workflow algorithm for treatment of the bruxing patient allows a complete and predictable outcome. With every single individual parameter of the patient considered, the occlusal splint manufactured is in full accordance with the end purpose – prevention of the parafunction. Digital axiography provides the opportunity of repeating the recordings under the exact same conditions, which makes it a proficient method for patient follow up. With great attention to the individual trajectories of the lower jaw movements, the effectiveness of the occlusal splint prophylaxis is no longer hypothetical.

Contemplating the lower jaw’s dynamic behavior has intrigued researchers in the field for many years. With digital axiography, appropriate treatment in accordance with every patient’s individual features is effectively attainable.

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