The Role of Digital Facebow for CAD/CAM Implant-Supported Crowns Workflow

Lenka Vavřičková[1,2,*], Martin Kapitán[1,2], Jan Schmidt[1,2]

ABSTRACT

Recent advancements in digital technologies have transformed clinical workflows in dentistry, ensuring precise restorations. Custom-made crowns and fixed partial dentures (FPDs) now rely on virtual articulation. The digital facebow provides individualized data for CAD settings, streamlining the fabrication via digital workflow.

For the purpose of demonstrating the differences observed during fabrication, we present a case report involving a 68-year-old patient seeking a replacement for missing teeth 24, 25, 26, and 27. The treatment plan involved the fabrication of an implant-supported FPD using monolithic zirconia (ZrO_2). However, technical hurdles emerged during the planning phase, primarily due to spatial limitations posing a risk of mechanical failure over time. Consequently, we pivoted approach towards a porcelain fused to metal (PFM) FPD. For the PFM FPD, individual values from the digital facebow adjusted both virtual and conventional articulators. For comparison, two ZrO_2 FPDs were milled-individual settings and average settings. All restorations underwent assessment for occlusion in maximal intercuspal position and eccentric mandible movements.

In conclusion, the case report showed that individualized PFM FPD required minimal adjustments compared to milled ZrO_2 restorations, whether using individual or average values. Utilizing individual values from the digital facebow reduced operator working time and minimized the intraoral adjustments.

KEYWORDS

digital; facebow; CAD/CAM; implant-supported crowns

AUTHOR AFFILIATIONS

[1] Department of Dentistry, Faculty of Medicine in Hradec Králové, Charles University, Czech Republic

[2] Department of Dentistry, University Hospital Hradec Králové, Czech Republic

* Corresponding author: Department of Dentistry, Sokolská 581, 50005, Hradec Králové, Czech Republic; e-mail: vavrickoval@lfhk.cuni.cz

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INTRODUCTION

In recent years, digital technologies, notably computer-aided design/computer-aided manufacturing (CAD/CAM) and 3D printing, have revolutionized the fabrication of dentures (1, 2). These advancements have significantly enhanced the precision with which restorations are produced, thanks to printing and milling machines capable of exceptional accuracy (3). However, despite these technological strides, challenges persist during the delivery of dentures, often stemming from the reliance on average dental morphology from the general population. Consequently, dental operators frequently find themselves spending significant time adjusting dentures to align with each patient's unique mandibular movements. In response to this challenge, devices have been developed to facilitate the transfer of individual patient data to the dental laboratory, including mandible movements and the position of the maxilla relative to the mandibular condyles (4). One such instrument is the facebow, employed to record the spatial relationship between the maxillary dental arch and an anatomical reference point. This information is then transferred to the articulator's opening axis, enabling accurate simulation of mandibular movements (5).

Traditional facebows are categorised into two primary types: kinematic and arbitrary (6). The kinematic facebow determines the individual hinge axis, representing the axis of pure rotation during the initial stage of mandibular depression (7, 8). On the other hand, the arbitrary axis facebow follows the population average location of the hinge axis, positioned on the line connecting the canthus and tragus (tragal-lateral canthus line) 8 mm forward and 3 mm upwards perpendicularly (9, 10). Both types are integral components of the conventional fabrication process, aiding in the simulation of mandibular movements when used with a dental articulator.

In the digital era, the emergence of a new device, the digital facebow, became necessary to transfer individualized data for virtual restoration design. The digital facebow captures lower jaw movements, determining crucial aspects of morphology such as cusp height, fissure depth, and cusp location on restored teeth occlusal surfaces. These morphological features are influenced by various factors including sagittal condylar inclination (SCI, i.e., angle between the reference plane and the protrusive condylar path), Bennett angle or progressive side shift (the angle between the sagittal plane and laterotrusive movement path of the orbiting condyle in the horizontal plane), and immediate side shift (ISS) (5, 11–13). An immediate side shift refers to a mandibular movement where the orbiting condyle moves essentially straight medially upon leaving centric relation. The proper configuration of both the conventional articulator and its virtual counterpart for modeling can be established using either average population values (e.g., Bennett angle of 15°, a sagittal condylar inclination of 45° with reference to Frankfort's plane, and an ISS of 0) or individualized data. The digital facebow provides these values, essential for precise virtual restoration modeling in CAD software. Absent or inaccuracy in recording these values can result in premature contacts and occlusal interferences in the restorations (11, 14).

CASE REPORT

A 68-year-old man presented with a request for the replacement of missing teeth in the maxillary left quadrant, specifically teeth 24, 25, 26, and 27 (maxillary left permanent first premolar, second premolar, first molar, and second molar) (Figure 1). Examination revealed teeth 21, 22, 23, and 27 present in the upper left quadrant, while teeth 24, 25, and 26 were absent. Notably, tooth 23 had a prosthetic crown extending distally in a cantilever at location 24. Radiologic examination unveiled a suspicious periapical translucency around the apex of tooth 23. The vitality test of this tooth was negative.

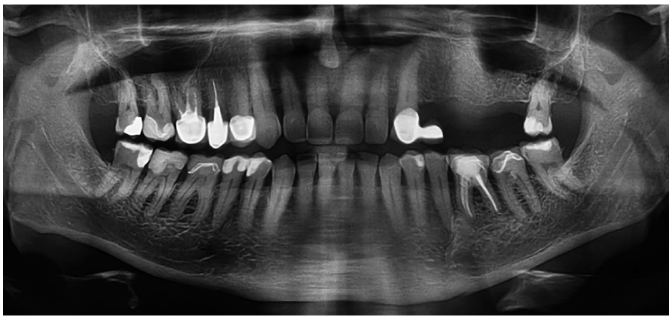

Fig. 1 The orthopantomogram of the initial situation.

The proposed therapeutic plan for upper left quadrant reconstruction included root canal treatment of the maxillary left canine and a new all-ceramic crown for this tooth, followed by a screw-retained, monolithic ZrO_2 (zirconium oxide) implant-supported fixed partial denture (FPD) in locations 24–26. However, implant placement in position 27 was deemed unfeasible due to insufficient bone and a wide maxillary sinus. While a sinus lift was offered as a treatment option, the patient declined due to concerns regarding the healing period and financial considerations.

Initially, treatment of tooth 23 was recommended to be performed by the registering dentist before the insertion of implants. However, the registering dentist modified the plan, treating the root canal system of tooth 23, removing the cantilever at site 24, and postponing the fabrication of a new crown until after the treatment at site 24–26 was completed. In our clinic, two BioniQ® implants (Lasak, Czech Republic), each with a diameter of 4.0 mm and a length of 14 mm, were placed in positions 24 and 26. Following a healing period of four months, digital impressions of the jaws were obtained using 3Shape TRIOS Move+ (3Shape, Denmark) (Figure 2).

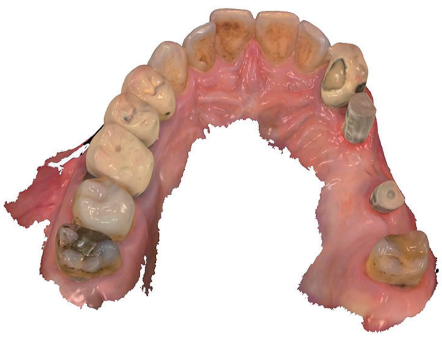

Fig. 2 The digital impression of the upper jaw.

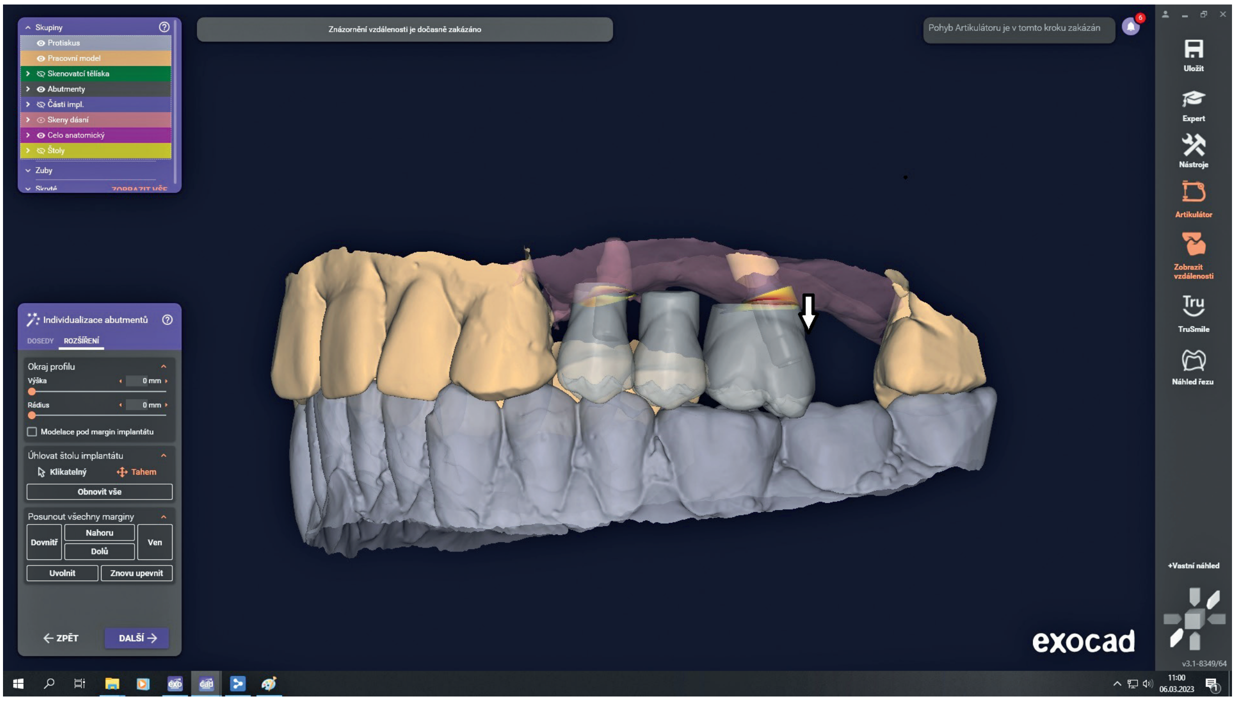

Fig. 3 The planned monolithic FPD design in CAD software. An arrow highlights an area with a notably thin edge.

Fig. 4 The digital facebow placed on the patient's face.

Designing the planned FPD in CAD/CAM software (DentalCAD 3.1 Rijeka software, Exocad GmbH, Germany) proved challenging due to the tilted position of implant 26, aligning with the contours of the maxillary sinus. This complication led to the distal edge of the FPD becoming excessively thin, while the tilt of the screw adit made it unsuitable for accommodating zirconium oxide dental ceramic as the restorative material (Figure 3). Despite considering tilted abutment placement for implant 26, the extreme inclination was impractical, even for angulated abutments. Additionally, the preference for a screw-retained restoration over a cement-retained one necessitated a shift towards utilizing porcelain fused to metal (PFM) for the FPD (15). The patient's mandibular movements and chewing cycle were measured using the digital facebow ARCUSdigma™ 3 (KaVo, Germany) (Figure 4). These values were crucial for adjusting both the virtual articulator, used for designing the metallic framework, and the conventional articulator for ceramic veneering.

The PFM FDP framework was milled using a Coritec 350I PRO+ (IMES-ICORE, Germany) from a cobalt chromium dental alloy (Co 63%, Cr 24%, W 8%, Mo 3%, Si 1%) based on the virtual model designed in the virtual articulator, adjusted with the individual data obtained from the digital facebow (Table 1). The same individual data were used for manually veneering the ceramic layer (VM 13, VitaZahnfabrik, Germany) in the conventional articulator.

Tab. 1 Individual data for mandibular movement received from digital facebow.

Sagital Condylar Inclination (°)	Left 45.6
	Right 43.0
Bennett Angle (°)	Left 9.4
	Right 28.4
Shift Angle (°)	Left 14.6
	Right 20.0
Immediate Side Shift (mm)	Left 0.0
	Right 0.0
Retrusion (mm)	Left 0.1
	Right 0.0
Front Table Inclination (°)	Left 46.7
	Right 54.6
	Sagittal 48.8

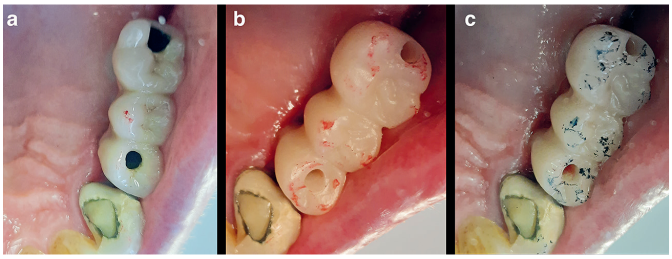

Fig. 5 The extent of necessary intraoral adjustments required in MIP for PFM (a), for M1 (b), and for M2 (c).

Fig. 6 The extent of intraoral enhancements required for laterotrusive movement, specifically for M2.

Fig. 7 PFM FPD in MIP position.

Concurrently, two additional monolithic ZrO_2 FPDs were milled for comparative purposes: one with individual articulator settings and no post-processing improvements (M1), and the other one with average articulator settings and no post-processing improvements (M2). ZrO_2 FDPs were crafted solely for comparison purposes, as their long-term application was deemed unsuitable due to spatial constraints posing a risk of compromised durability.

The occlusion of the FPD was of particular interest, both in maximal intercuspal position (MIP) and during eccentric mandibular movements. The study case report scrutinized the influence of individual values settings on the milling process and assessed the extent of intraoral adjustments required during the delivery appointment, along with the associated time demands.

During the delivery appointment, it was observed that there was a single premature contact on the pontic of the PFM FPD in MIP (Figure 5a). In the case of M1, a greater number of intraoral adjustments were necessary, with premature contacts on functional and non-functional cusps evident in all parts of the FPD in MIP (Figure 5b). Conversely, when no individual data settings were used (M2), a substantial amount of intraoral improvements were required in MIP (Figure 5c) and during lateral and protrusive mandibular eccentric movements (Figure 6). The PFM screw-retained FPD in the MIP position is demonstrated in Figure 7.

DISCUSSION

The current workflow for fabricating of fixed partial dentures (FPDs) offers various methods to achieve optimal individual occlusion. Traditional techniques involving mechanical articulators, conventional facebows, and plaster casts remain viable options. Alternatively, digital and analog methods can be combined, incorporating 3D printed casts and conventional articulators. However, challenges may arise, particularly regarding mounting inaccuracies due to materials, emphasizing the importance of scanner software compatibility for articulator settings (16).

While the fully digital method appears promising (16), a significant hurdle in contemporary digital FPD workflows, and other digitally fabricated restorations, lies in accurately transferring mandibular movement data from the patient to the virtual simulation (17). Numerous methods have been proposed to address this challenge. Some approaches advocate for substituting the digital facebow with standardized photography conditions and utilizing virtual articulators (18). For optimal results, the use the Kois Facial Reference Glasses (KFRG) system is recommended, albeit introducing additional financial costs (19).

Alternatively, smartphones have been explored as 3D face scanners to replace the traditional digital facebow. Smartphones have demonstrated high trueness and precision in capturing the maxilla position, with minimal deviations in linear distance and angulation (20). This suggests a potentially cost-effective and efficient solution for transferring mandibular movement data in digital FPD workflows.

While various techniques are available to substitute the digital facebow, many require substantial experience, highly standardized photographs, and additional devices such as face scanners, facebow forks, or KFRG (17–20). Moreover, some of these methods may necessitate the use of cone-beam computed tomography (CBCT) scans (20–24). A CBCT examination is now considered a standard pre-implantation procedure, and leveraging this data to adjust the articulator does not require additional X-ray radiation exposure. However, in cases where CBCT imaging has not been conducted, utilizing a facebow to adjust the articulator proves advantageous, as it circumvents the necessity for further X-ray radiation exposure for the patient.

In conclusion, the digital workflow for FPD fabrication continues to evolve, offering various methods to achieve optimal individual occlusion. The digital facebow presents a viable and efficient solution to transfer mandibular movement data, providing improved accuracy, saving operator's time, and reduced reliance on CBCT scans. Implementing these advancements can enhance the precision of the digital workflow, streamline the delivery process, and ultimately benefit both dental professionals and patients.

DISCLOSURE

The authors declare no conflicts of interest related to this article. The authors are not in any relationship with the producers of the devices and materials used in this study.

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