Fabrication of a screw-retained implant-supported maxillary restoration

A completely digital workflow

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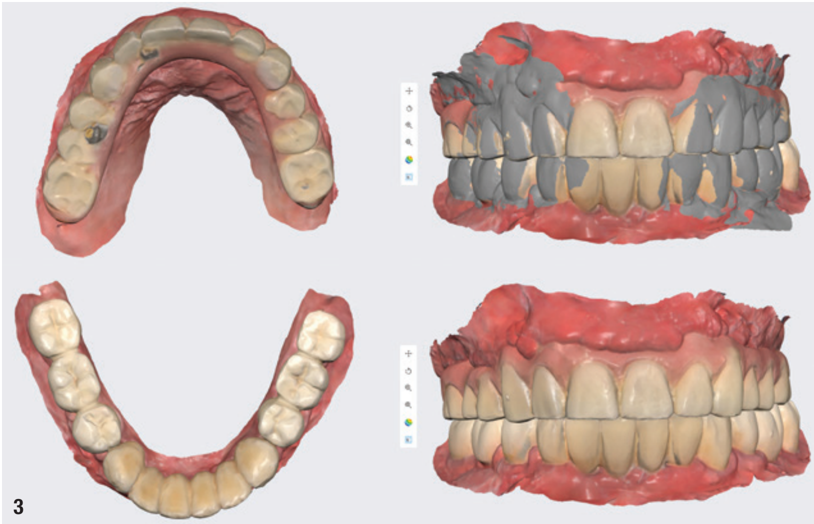


Fig. 1: Initial clinical situation showing inadequate implant-supported maxillary restoration. **Fig. 2:** Occlusal view of the implant-supported mandibular fixed dental prostheses (FDPs). Each of the lateral segments had been restored with a three-unit metal–ceramic FDP. In the anterior segment, a six-unit metal–ceramic FDP had been placed. **Fig. 3:** Basic scans of the existing maxillary and mandibular restorations.

The fabrication of implant-supported full-arch restorations requires maximum precision, whether employing analogue or digital impressions, to achieve a perfect and passive fit. In this context, the application of intra-oral scanners has been a topic of much debate. Through the development of new scanner systems and specially adapted scan gauges for these indications as well as the application of appropriate scanning techniques, these systems allow for improved precision. The EVO+ system (Modern Dental Europe) incorporates these optimisation strategies into a purely digital workflow for the fabrication of removable and fixed implant-supported restorations in edentulous patients.

The present case report describes the fabrication of an implant-supported screw-retained fixed dental prosthesis (FDP) which provided a high level of fitting accuracy and could be fabricated in three appointments only. The patient was highly satisfied with the aesthetic and functional outcome. The main advantage of this technique is the reduced number of treatment steps compared with conventional procedures. However, the lack of long-term clinical data is a current limitation of the EVO+ system.

Introduction

Implant-supported FDPs on four to eight implants or implant-retained overdentures on a minimum of four implants are commonly and scientifically accepted for restoration of the edentulous maxilla.[1,2] The long-term clinical success of these types of restorations has been documented in several clinical studies with observational periods of more than ten years.[1,3,4] Especially the impression taking of multiple implants for the fabrication of a fixed, ideally screw-retained, FDP requires maximum precision in order to guarantee the passive fit of the restoration.[3,4] With regard to biomechanical aspects, an imprecise fit of wide-span FDPs is believed to be a possible source of technical complications in screw-retained implant-supported full-arch FDPs. In this context, a causal connection between an inaccurate fit and screw loosening, screw fracture and fracture of veneering ceramics can be assumed.[5,6]

Over the last several years, different techniques have been introduced in order to improve the passive fit and the precision of a conventional impression (e.g. rigid splinting of the impression copings). These procedures mostly combine screw-retained impression copings, a custom open impression tray and a two-stage procedure; therefore, they are quite time- and cost-intensive.[7] At the same time, inaccuracies in fit due to conventional dental technique fabrication of complex implant-supported FDPs (e.g. distortion and internal tension) could be reduced by CAD/CAM processing.[7,8] In the meantime, CAD/CAM procedures for full-arch FDPs have been clinically evaluated over observational periods of up to ten years, demonstrating lower technical complication rates than conventionally fabricated implant-supported FDPs.[1,3,9]

To date, most cases with complex implant constructions are restored using a hybrid workflow, that is, conventional impression taking, followed by model construction and digitalisation of the model for further CAD/CAM fabrication of the FDP.[1,9] Thus, digital intra-oral impression taking could facilitate the process and eliminate possible sources of error. Furthermore, several studies have shown that patient acceptance and satisfaction rates are higher for digital impressions compared with conventional impressions.[10]

Although current systematic reviews in the last five years agree that the precision of intra-oral impressions for the fabrication of tooth- and implant-supported single crowns and small (three- to four-unit) FDPs equals or exceeds the results of conventional impressions, the precision of full-arch scans is a controversial subject.[9,11,12] On the one hand, the achievable precision depends significantly on the type of scanner and the software used. Up-to-date systems demonstrate improved results compared with previous versions.[13] The precision of full-arch scans depends on various other parameters, as documented in clinical and laboratory studies. The number and angulation of and distance between the implants are decisive:[14,15] an increased number and different angulations of implants and a larger distance between them lead to reduced precision.[15,16]

On the other hand, it has also been reported that the precision of full-arch scans is significantly dependent on the design and material of the scan bodies and the software algorithm that composes (matches or stitches) a full-arch scan from the single scanner images.[16–18] In several studies, it has been documented that the increased reference areas of the scan bodies or the application of additional reference

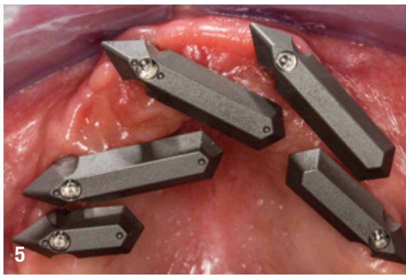
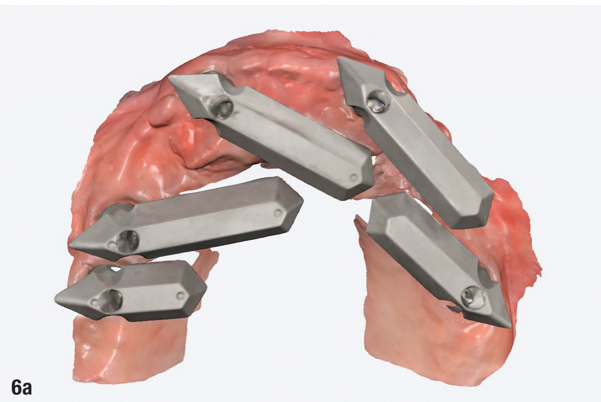


Fig. 4: Occlusal view of the five maxillary implants with multi-unit abutments compatible with the scan bodies. **Fig. 5:** Occlusal view of the scan bodies aligned along the ridge to achieve maximum overlap of the reference surfaces.

marks leads to the greater precision of full-arch scans.[16,17] This is exactly the opportunity to optimise a full-arch scan. Most of the commercially available scan bodies are rotationally symmetric; their size is optimised for the most frequent indication, a single-tooth gap. Therefore, the reference surfaces are comparably small. This is no problem for single-tooth restorations, as additional reference surfaces (e.g. adjacent teeth) are available and allow stitching of intra-oral scanning images with sufficient overlap.[16,19,20] However, if scan bodies are used in the edentulous jaw, the risk of matching errors increases, especially in situations of larger implant distances and/or angulated implants.[13,14,16] This issue could be solved using asymmetric scan bodies with larger reference surfaces, thus reducing mismatches in the edentulous jaw by achieving a scan body layout with wide overlap.[16,19,21]

Another optimisation approach could be the application of a modified strategy to scanning of implant positions. The position of the scan gauge is determined by a high-resolution two-step scan, choosing a scanning path in which the camera is moved in one direction only.[18,20,21] One scanning process is directed from the left to the right, and the second one is directed in the opposite direction. Owing to the design of the scan gauges, only minimum panning of the camera is required to capture the reference surfaces.[17,19,21]

Evo+ combines scan gauges (Nexus iOS, Osteon Medical) developed for use in edentulous jaws with an indication-related scanning strategy employing a state-of-the-art



Figs. 6a & b: High-definition scan of the scan bodies **(a)** and separate scan of the soft-tissue situation **(b)**.


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Fig. 7: Facial scan with separate scan to match the basic scans. The facial scan allows for a transfer of the relevant aesthetic reference lines (interpupillary line, centre line and smile line).

scanner, thus creating a completely digital fabrication system for removable and fixed restorations. The following case report describes the clinical and technical procedures required for the fabrication of a screw-retained implant-supported FDP with the Evo+ system.

Case report

A 65-year-old female patient came to our dental clinic requesting the renewal of an implant-supported maxillary FDP that had been inserted six years before. The resin-veneered restoration was cemented on five implants and showed pronounced fractures of the veneering resin, as well as limited accessibility for oral hygiene (Fig. 1). In addition to the aesthetic limitations, the patient mentioned limited chewing ability. The mandible had been restored with three cemented metal–ceramic FDPs on six implants (Fig. 2). The patient was offered two options for prosthetic restoration: a screw-retained FDP or a bar-retained, palate-free overdenture. The patient opted for the screw-retained full-arch FDP. The restoration was fabricated with the Evo+ system in three appointments, using an intra-oral scanner (i700, Medit Corp.) and system-specific scan gauges (Nexus iOS).

First appointment

Full-arch maxillary and mandibular scans were taken with the existing restorations in place (Fig. 3). In addition, two lateral scans were required for fixation of the bite. When using the scanner, a patient case is first opened and the orthodontic option setting is chosen for the full-arch scans. This data is stored and dispatched separately.

In a second step, the existing superstructure was removed. The fixed restoration with the Evo+ system is always fabricated on multi-unit abutments, as the special scan gauges only fit on this type of abutment. In the present case, the multi-unit abutments (Astra Tech EV Multibase, 3.6 mm; Dentsply Sirona) were fixed on five implants with cone connection (Astra Tech EV, Dentsply Sirona). The height of the abutments was chosen to allow a slightly subgingival location of the abutment shoulder, that is, the transition between the abutment and the superstructure (Fig. 4). The scan gauges, which are available in various lengths and heights, were then inserted. When choosing the scan gauge, it is important to avoid pressure on the subjacent soft tissue; ideally, there should be a small gap between the basal surface of the scan gauge and the soft tissue. The scan gauges should be chosen accordingly and aligned along the ridge, resulting in the largest achievable overlap of the reference surface (Fig. 5).

After the scan gauges have been fixed in the appropriate position, the next step of the scanning process is performed by selecting a new case with the orthodontic option in the high-definition scan mode. Data collection of the scan gauges is performed in a unidirectional scanning path from

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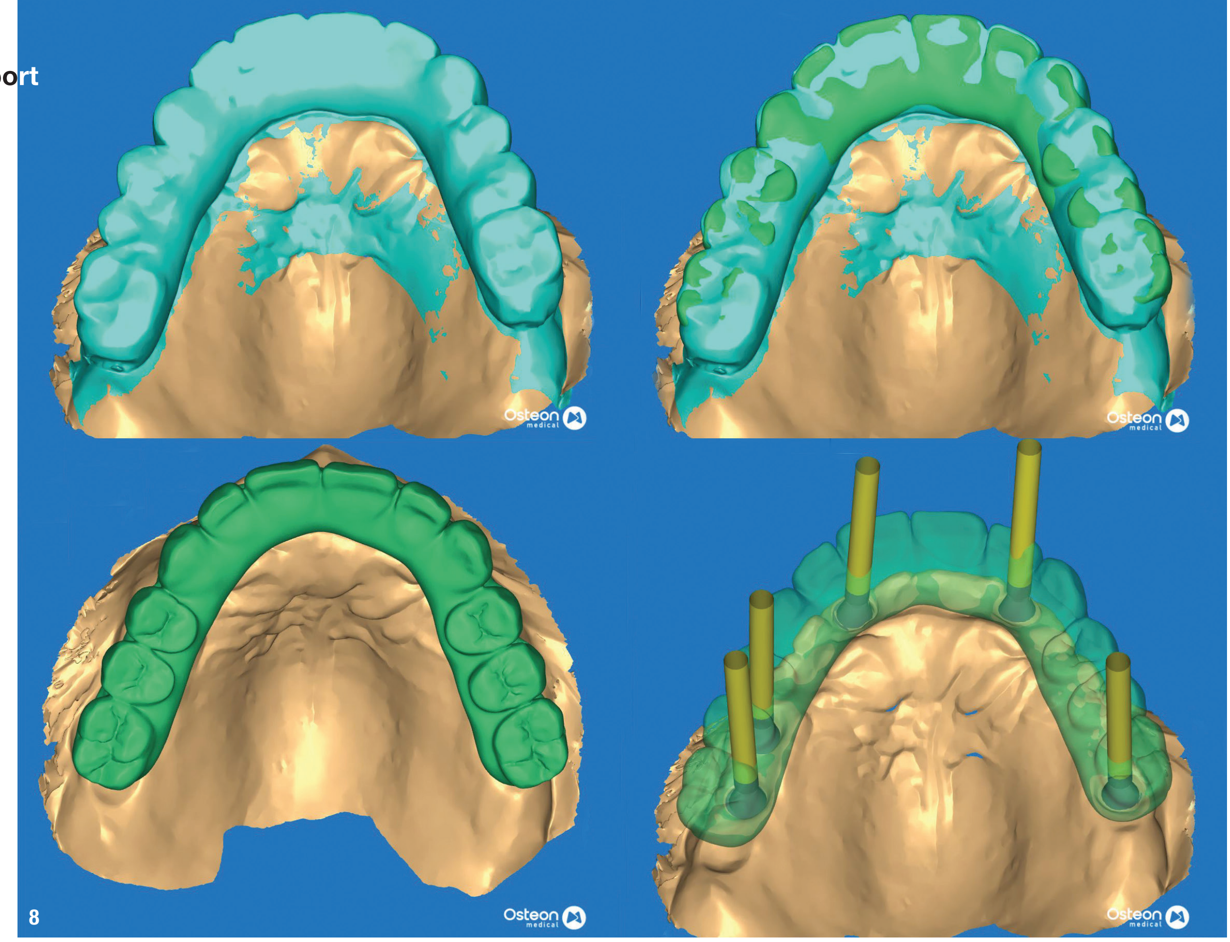

Fig. 8: Data set for the design of the screw-retained temporary restoration.

left to right. It is essential to move the camera in one direction only and to cover all reference surfaces of the scan gauges with slight panning of the camera. After this step has been completed, a new scanning window is opened and a new high-definition scan is performed in the opposite direction. At this point, the scan gauges should have been recorded completely in two separate scans. This data is also stored and sent separately (Fig. 6a). The third and last scanning process with the scan bodies removed again required selecting a new case with the orthodontic option. This clinical situation (implants with screwed multi-unit abutments) was captured in a full-arch scan (Fig. 6b), stored separately and dispatched. This scan can be performed in regular mode; it records the soft tissue of the jaw to be restored.

To determine the relevant aesthetic reference lines and structures (interpupillary line, centre line, lip profile and smile line), a facial scan was taken. In this facial scan, the scans of the existing prosthetic situation were matched (Fig. 7). Alternatively, digital portraits can be sent together with the scan data.

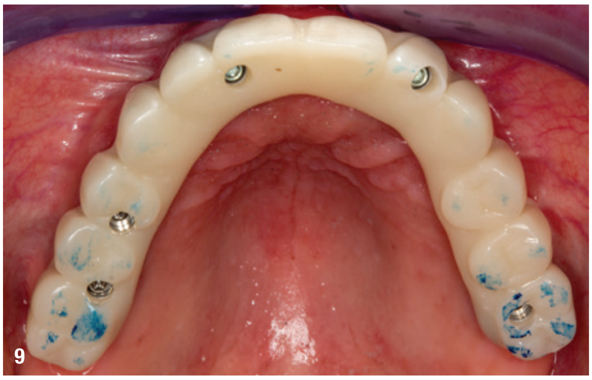

Fig. 9: Fixed temporary restoration with marked occlusal contacts. Minor adjustments were only required in the distal region.

For the fabrication of this fixed restoration, a total of four sets of data were sent to the production facility (Permadental):

- scans of the existing situation: maxilla and mandible with existing restorations, and lateral scans for bite registration;
- two complete high-definition scans employing the correctly aligned scan gauges;
- full-arch scan of the edentulous jaw (with the multi-unit abutments) to be restored for soft-tissue documentation; and
- a facial scan, matched to the scans of the existing prosthetic restorations.

Fabrication of the temporary restoration

Based on the data collected during the first appointment, a digital design was prepared, and after approval, a temporary restoration was fabricated. In the present case, no modification of the position or alignment of the teeth was necessary compared with the existing restoration, so the temporary restoration could be fabricated accordingly. The scan of the existing restoration was used as a shell for designing the temporary restoration. The screw channels were positioned at the same time. At this point, it is possible to design the screw channels with an angle of up to 30° to the implant axis (Fig. 8). The temporary restoration is fabricated as a screw-retained FDP in an additive production process (3D printing) from a tooth-coloured polymer-based material. The fabrication of the temporary restoration is usually completed within five working days, allowing for a second appointment after approximately ten days.

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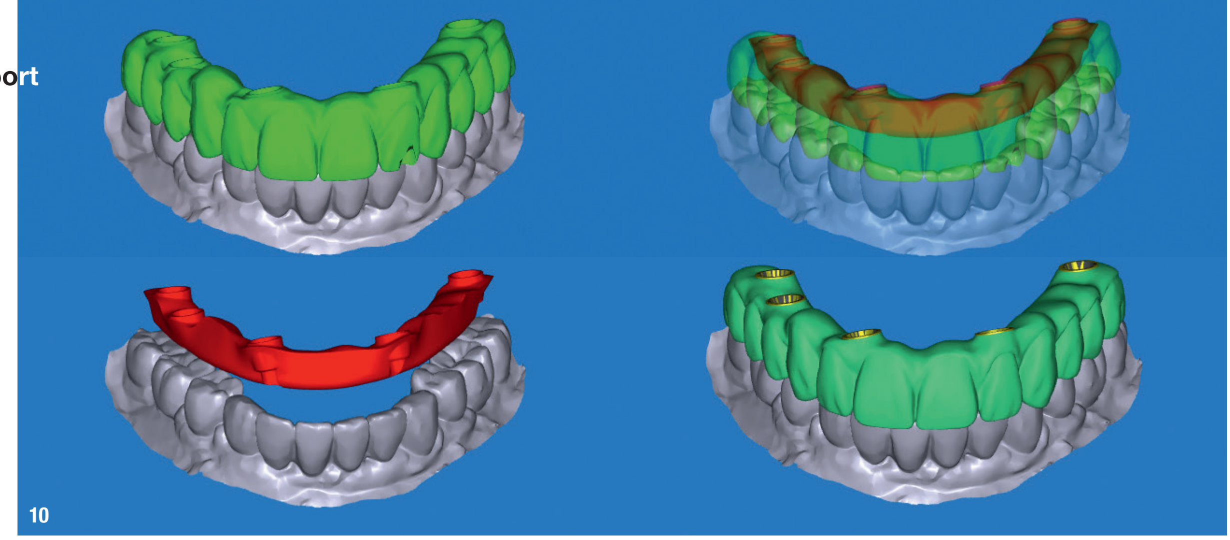

Fig. 10: Design data for the fabrication of the definitive prosthetic constructions: metallic substructure and tooth-coloured overlay construction based on the data of the temporary restoration fabrication.

Second appointment

During the second appointment, the aesthetic and functional aspects of the digitally fabricated temporary restoration are evaluated. First, the static and dynamic occlusion of the screw-retained temporary restoration are checked. In the present case, only minor adjustments in the distal region were required (Fig. 9). The shape and position of the teeth were in accordance with the previous restoration and could be adapted to the definitive restoration. If modifications are required, they can be performed either by grinding the temporary restoration or by application of a composite material. If the temporary restoration is scanned again, all modifications can be digitally transferred to the production facility; however, in the present case, two lateral scans are required for bite registration. In this phase of the fabrication process, full-face photographs of the patient (smiling and not smiling) and detailed shade information should be transferred. Of course, the modified situation of the temporary restoration can be matched with the existing facial scan—this procedure was chosen for the present case, as it allows good digital transfer of the aesthetically relevant parameters (interpupillary line, lip line and shape of the face). If no alterations of the temporary restoration, or like in the present case only minor ones, are required, the definitive restoration can be fabricated.

Fabrication of the definitive restoration

A screw-retained FDP fabricated with the system used consists of two components. First, a stabilising substructure is milled from pure titanium. It forms the basal surface of the FDP, holds the connections with the implant abutments and splints the implants on primary level. This titanium structure is typically anodised and has a golden yellowish colour. The metallic substructure allows for high precision of fit of the implant–abutment connection and stabilises the entire structure. The surface of the metallic construction is designed with conical and plane fitting areas without undercuts so that an overlay construction made of different materials can be cemented to the construction.

The overlay construction mimics the missing hard and soft tissue and the full dental arch with polymer-based or zirconia materials. In the present case, the overlay construction was fabricated from a multilayer composite material. In *in vitro* studies, this combination of a metallic substructure with a monolithic composite overlay construction has been shown to have a significantly increased fracture strength compared with conventionally manufactured implant-supported metal–composite FDPs.[22]

The data required for the fabrication of the metallic substructure and the overlay construction is produced by a separation reduction of the data used for the fabrication of the temporary restoration (Fig. 10). To produce the definitive restoration, a total of 15 working days should be scheduled. The definitive restoration is delivered with the required fixation screws (Figs. 11 & 12).

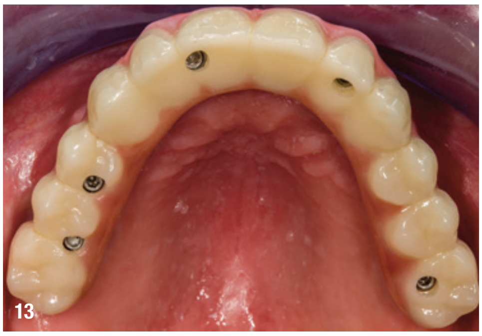

Fig. 11: Occlusal view of the definitive prosthesis. Angulated screw channels allow access to the palatal screw channel in the anterior region. The overlay constructions were fabricated from a multilayer composite material. The gingival parts were coloured with appropriate staining materials. **Fig. 12:** Basal view showing the anodised titanium structure and milled metal implant–abutment connections. **Fig. 13:** Occlusal view of the screw-retained maxillary prosthesis. The access screw channels are sealed after a trial period of seven to ten days after insertion.

Third appointment

During the third appointment, the definitive restoration is inserted. After removal of the temporary restoration, the FDP was fixed to the multi-unit abutments with screws. Here, an additional check of the passive fit according to the Sheffield test is recommended with only one fixation screw inserted into a distal abutment. For this test, the whole construction must not lift off from the other abutments when one screw is hand tightened. If this precondition is met, all fixation screws can be hand tightened (Fig. 13). The patient was highly satisfied with the aesthetic results of the restoration.

It is recommended that the patient is given a five- to seven-day trial period. During this time, he or she can assess chewing ability and gain a deeper experience of the aesthetic result. Above all, during this trial period, the patient can test the accessibility of the restoration for oral hygiene. Therefore, it is recommended that oral hygiene instructions be refreshed and that the patient be provided with a choice of suitable instruments (interdental brushes).

At the following check-up appointment (seven days after insertion), the patient did not report any discomfort. The restoration was removed and cleaned once again, a good opportunity to check the accessibility for home oral hygiene, which revealed no problems at all. Therefore, the restoration was reinserted and the fixation screws were tightened to the required torque (15 Ncm). The access cavities were then closed with a 1–2 mm thick layer of PTFE tape on top of the fixation screw. Finally, the access cavities were adhesively sealed with a filling composite material in a matching shade.

Discussion

The Evo+ system allows for the fabrication of implant-supported screw-retained FDPs in a fully digital workflow. The core of this system is the application of indication-specific scan gauges with significantly enlarged reference surfaces and the use of a modified high-resolution scan strategy. In the present case, this technology led to a good fit of the full-arch restoration. However, up to now, regarding the improved quality of fit, only manufacturers' studies have been available; validation by external studies is pending.

Using the Evo+ system, an implant-supported FDP can generally be fabricated in three appointments. This means a significant reduction in the number of appointments compared with conventional fabrication of this type of restoration. However, it must be considered that necessary modifications of the temporary restoration may lead to additional appointments. Moreover, the procedures described in this case report are tied to some general preconditions. First of all, it has to be considered that a fabrication is only possible on multi-unit abutments that are compatible with the system-specific scan gauges. It is necessary to check the compatibility of the implant system used. A universal scan gauge kit is available for the 15 most used implant brands, and for other systems, a specific kit can be used. Moreover, the system is only approved for up-to-date intra-oral scanning devices.

The FDP is fabricated as a combination of a metallic substructure and a custom monolithic tooth-coloured overlay construction. This leads to a significantly increased fatigue strength and a lower risk of material fracture compared with conventional FDPs.[22] PMMA, composite or zirconia materials are suitable for milling the monolithic overlay construction, which is adhesively connected to the substructure. The choice of material should be based on the indication, considering the respective advantages and disadvantages.[8,23] PMMA and composite-based structures are less expensive and can easily be modified and repaired.[4] However, they have a higher risk of material wear and discoloration.[4,23,24] Whereas monolithic zirconia materials offer the advantage of durable aesthetics without any risk of discoloration or wear, they are limited in terms of modifications and repairs. Furthermore, if monolithic zirconia restorations are inserted, it must be considered that veneered ceramic restorations in the opposing jaw have an increased risk of fracture of the veneering material.[6,8] In the present case report, a composite restoration was chosen because the patient had been restored with veneered implant-supported metal–ceramic restorations in the opposing jaw. In summary, the system used in this case offers a useful expansion of the possible applications in a digital workflow. However, the collection of sufficient data on long-term clinical success is important.

about the author

Prof. Sven Rinke is specialised in implantology and periodontics, holding an MSc in oral implantology (through the German Association of Oral Implantology) and an MSc in periodontics (through the German Society of Periodontology). In June 2013, he completed his habilitation qualification at the medical school of the University of Göttingen in Germany. In 1997 to 1998, he was a visiting assistant professor at Harvard School of Dental Medicine in Boston in the US. In 2017 and 2019, he was granted the research award of the AG Keramik, a scientifically active working group based in Germany, and in 2019, he was awarded the science prize of the Zahnärztekammer Niedersachsen (Lower Saxony dental association). In September 2021, he was appointed associate professor at the University of Göttingen. Since 2002, he has been practising in a group practice.

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Literature