Evolution of a digital workflow

Hand in hand: practice meets industry

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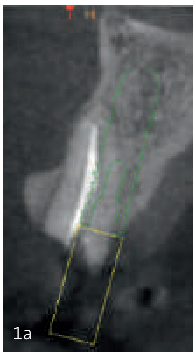
The digital transformation is becoming more and more important in our profession. For more than twenty years, our dental technicians have used CAD/CAM to make zirconia, cobalt chromium, titanium and lithium disilicate frameworks. Plaster cast impressions are scanned with a lab scanner, and the prosthesis is digitally designed and machined. In 2015, following consultation with our dental technicians, we decided to transition to intraoral optical impressions. Our goal was to replace physical analogue impressions with intraoral optical impressions [1–3]. The focus of our activities is mainly on periodontology and oral implantology, so we had to address some shortcomings of our implant system and certain pitfalls caused to the complexity of taking optical impression in implantology [4,5]. This article documents how the abutments and scanbodies of our implant system (Thommen Medical, Grenchen, Switzerland) evolved to adapt to the specific requirements of optical impressions. It demonstrates the benefits of a close cooperation between practitioners and engineers.

When we took our first optical impression (Figs. 1a to i), we also took a physical impression and created plaster casts to validate the process. The milled restoration based on the optical impression showed a perfect fit of the restoration on the plaster cast. For many years we routinely used Ti-base titanium abutments (Fig. 2) to which we cemented zirconia or lithium disilicate frameworks for our implant-supported prostheses.

In the first case we attempted to cement the crown onto the abutment. The Ti-base abutment (Figs. 2a to d) was not designed for bonding without a cast, resulting in three to five degrees of rotation. In the actual case we were able to perform the cementing anyway because we had the additional plaster cast available.

In the light of the difficulties encountered, we contacted the company's engineers to show them that it was impossible to switch to all-digital with the Ti-Base abutment available at that time because its small anti-rotational beak did not allow bonding without a cast. Milling can only produce a curved surface (Fig. 2e), not a flat one, on the tissue side of the restoration, which explains the lack of precision. We were nevertheless able to treat about fifteen cases by using both optical and physical impressions. This allowed us to validate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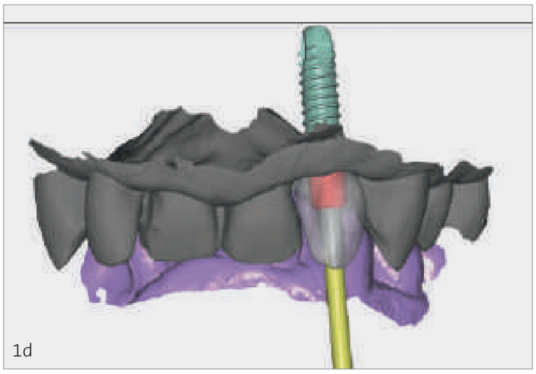
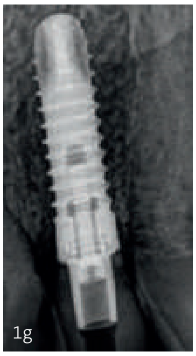
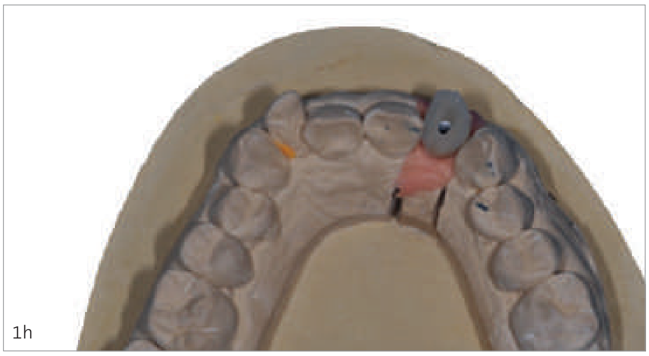


1a to j I First clinical case with CS 3500, Ti-base, and lab scanbody.

a I Pre-implant CBCT.
b I Carestream 3500 camera.
c I Thommen lab scanbody.
d I Prosthetic design in Exocad.
e I Thommen Ti-Base.
f I Lithium disilicate crown directly transferred to the implant.
g I Follow-up radiograph.
h I Bonding on the cast.
i I Completed case.

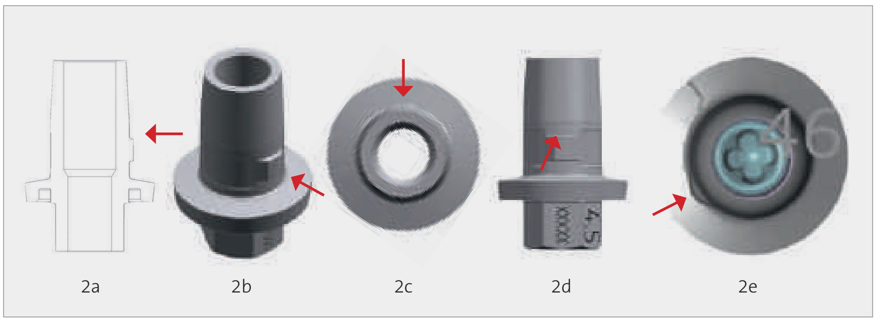




the reliability of this technique for cases with one or two implants.

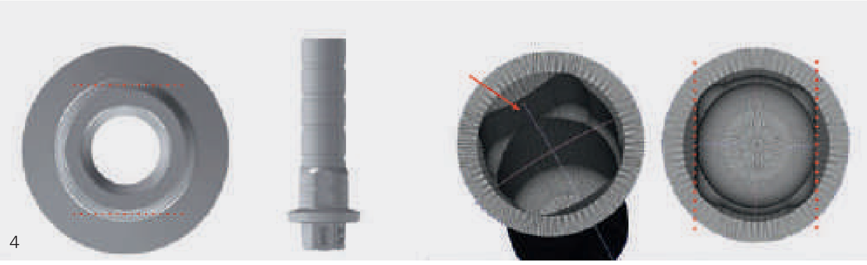
Another challenge with abutments of this type is their low height (Fig. 3). We noted in cases where prosthetic space is important that this abutment has a very low bonding height. For the case shown in Figure 3, this might lead to unfavourable shear forces.

For this first series of impressions we used lab scanbodies [6,7] made entirely of PEEK (cf. Fig. 1c) as there were no dedicated intraoral scanbodies at the time. The problem with all PEEK scanbodies is that they cannot be torqued the same way as abutments (to 25 Ncm) which generates a slight inaccuracy. We asked the engineers to provide scanbodies with a titanium base that allowed torquing at 25 Ncm. PEEK remains the most suitable material for scanbodies, as it is non-reflective white and autoclavable [8]. We also requested changes to the shape of the scanbody, as the lab scanbodies are strictly cylindrical with only a small flat surface, resulting in a lack of landmarks for the intraoral scanner.



2a to e I Ti-base abutment. 2e shows the tissue side of the restoration.

3 I Unfavourable shear forces.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4 I The Thommen Varioflex abutment.


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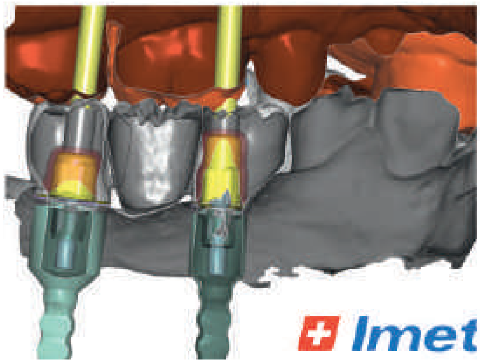
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5a–j I First bridge made with CS 3600 and a Thommen Varioflex without cast. Lab scan-bodies were used. (Laboratoire Mobifix)

a I Osseointegrated implants.
b I Lab scanbodies in place.
c and d I Impression without and with scanbody.
e I Model design in Exocad.
f and g I Zirconia crown attached toTi-base.
h I Follow-up radiograph.
i and j I Final situation.


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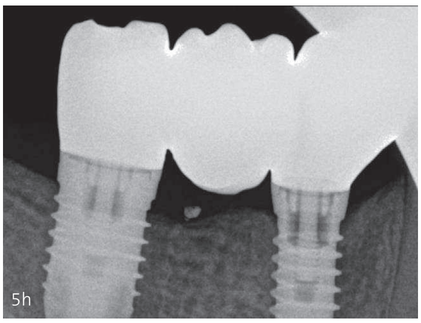
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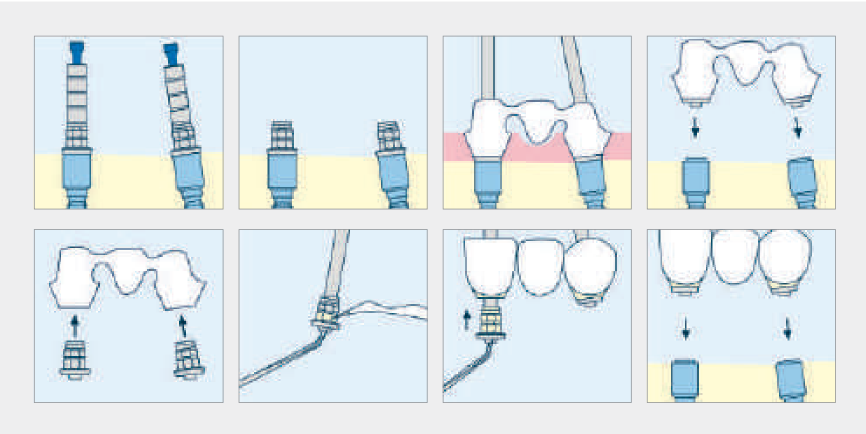
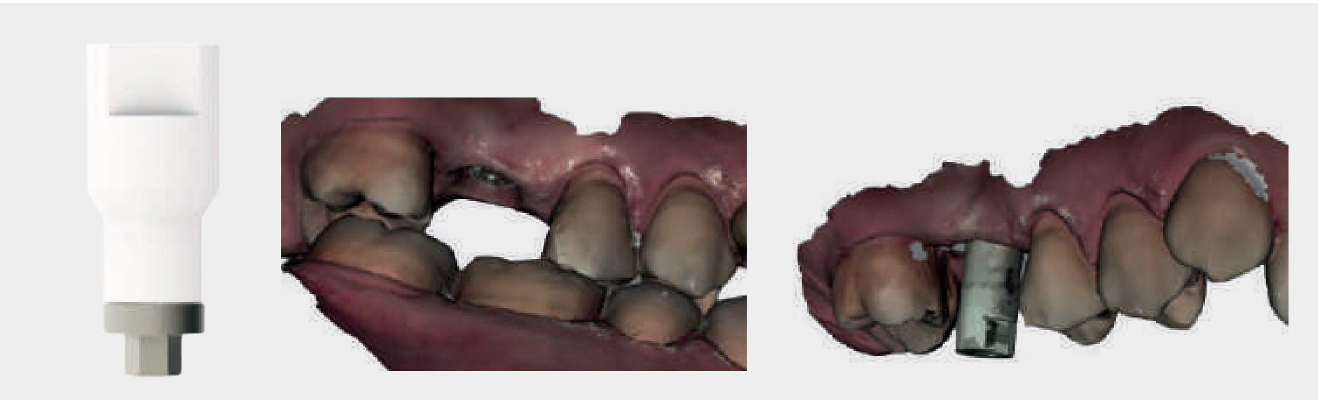


6 I Hybrid prosthetic design: Zirconia framework/abutment.



7a 7b 7c

7a I The new scanbody. 7b and c I Impression without and with scanbody.

In 2016 Thommen Medical launched the Varioflex abutment (Fig. 4), a titanium abutment for hybrid lithium disilicate restorations, castable for pressable ceramics. The height of this abutment can be adjusted at the laboratory, and it has two large opposing flat surfaces. These surfaces help keep the framework from rotating around the abutment. We immediately asked the engineers to create a virtual library to use in our optical impressions. It allowed the dental technician to trim the abutment to the desired height and to change it virtually when designing the restoration.

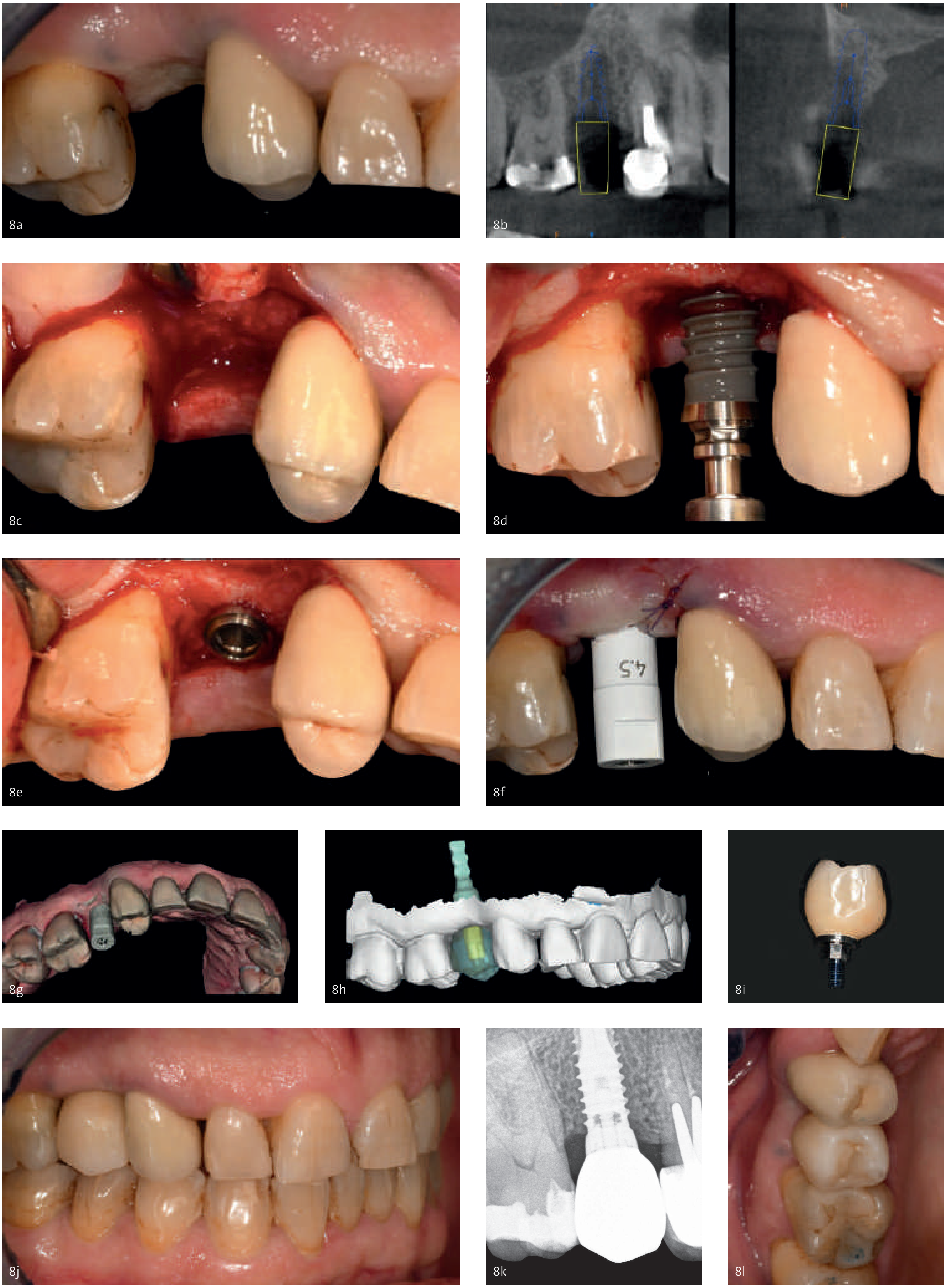
A library was created for all lengths and all diameters. As shown in Figures 5a to j, the bridge made with the CS 3600 oral scanner (Carestream, Rochester NY, USA) is supported by implants 47 (Varioflex; 6 mm diameter; height adjusted to 6 mm) and 45 (Varioflex; 4.5 mm diameter, height adjusted to 8 mm). This significantly increases the bonding height (Fig. 6) and makes this abutment more versatile than a fixed-height abutment. It can be adapted to many different situations, depending on the available prosthetic space. We initiated a series of tests comparing optical and physical impressions. Our use of this new abutment has given us complete freedom from cast models. After a few adjustments, bonding without casts became possible without minimal rotation because of the two flat surfaces.

At the beginning of 2017, we received new scanbodies with titanium bases and PEEK bodies (Figs. 7a to c). They provide greater accuracy as they are connected to the implant. Their added relief is more suitable for an intraoral camera. We then treated a new, conclusive series of 15 cases, with both optical and physical impressions. After that we treated many other cases of different types with fully digital designs without physical casts – 91 in all so far (Table 1).

These cases represent 162 Varioflex abutments, ranging from simple crowns, double crowns and bridges all the way to fully digital all-on-four and all-on-six procedures.

Prosthesis type Frame/abutment	Number of cases
Single crown	52
Two double crowns	14
Three double crowns	8
Bridge, three elements (two abutments)	10
Bridge, four elements (two abutments)	1
Bridge, four elements (three abutments)	3
All-on-four	1
All-on-six	2

Table 1: Detailed table of the number of cases treated.



8a–l I "All in two" implant loaded at four weeks. a I Initial situation. b I Presurgical CBCT. c I Site after Tooth extraction. d I Implant placement. e I Implant in situ. f I Scanbody in place for optical impression. g I Optical impression. h I Model design in Exocad. i I Zirconia crown attached to Ti-base. j I Screw-attached crown in place. k I Follow-up radiograph. 8l I Final situation.

Single-unit cases with direct crown implants

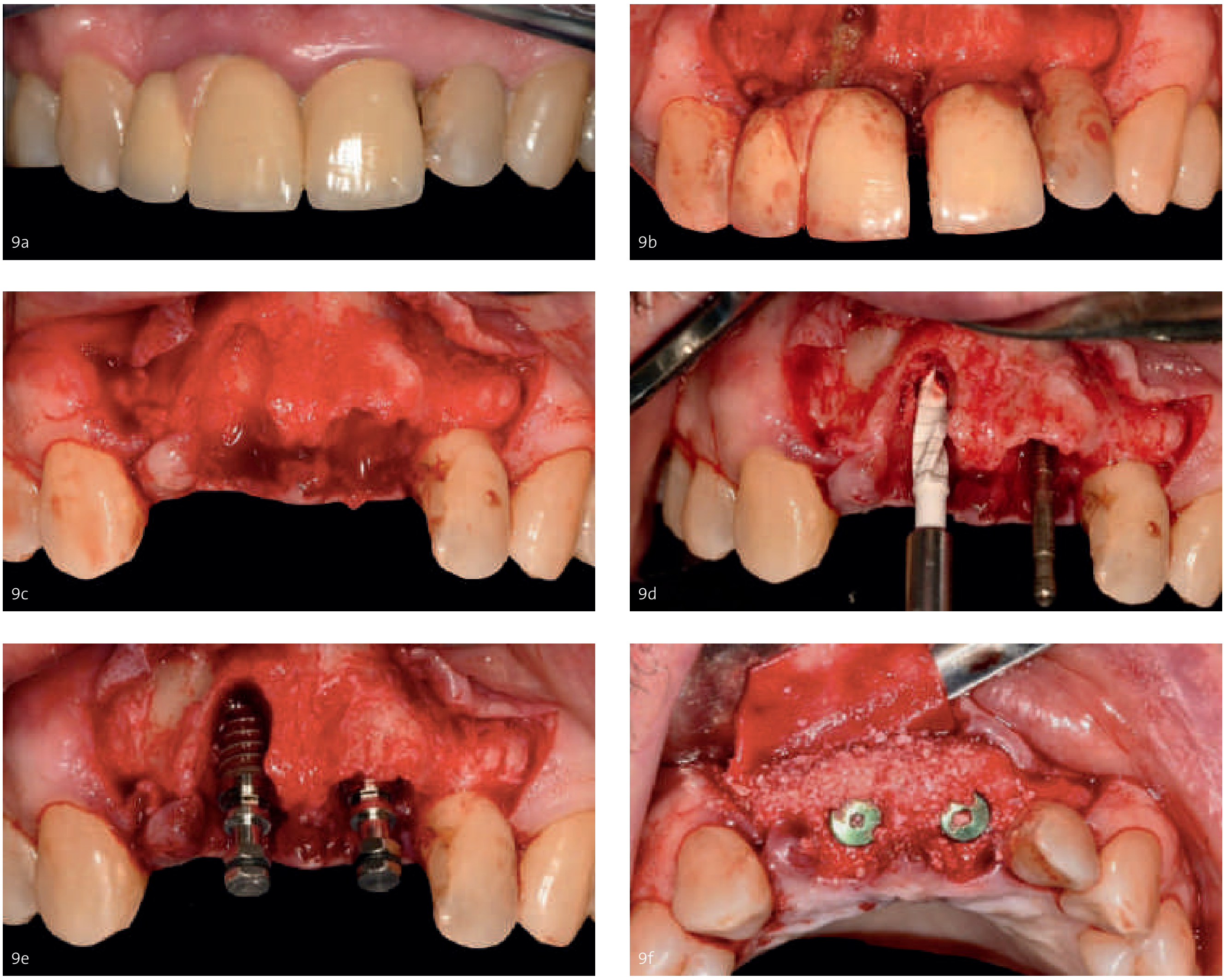
The procedure in these 52 cases is quite simple: taking impressions of the two arches, registering the bite and then taking the scanbody impressions. The results are convincing, although there continues to be a challenge with the insertion axes that might require a proximal adjustment of the restoration. Complexity arises from the double connection (internal hexagon and external stabilization ring on the Thommen implants) and the axis of insertion – but this is equally true of other systems.

Figures 8a to l show a single-unit "all in two" case. The protocol was simple: an optical impression was taken prior to surgery. The gingival area where the implant was to be positioned was reduced virtually. After surgery, an impression was taken with a scanbody. The final screw-retained crown based on this impression was delivered four weeks later [9]. This protocol significantly reduces the number of visits, which simplifies matters for patients travelling from far away. Implant loading at four weeks is possible due to the active surface of the implant.

Multi-unit cases

We treated 40 multi-unit cases with "live" (splinted) implants with two to six abutments. Of these 40 cases, two cases exhibited occlusal imperfections at the end of multi-tooth edentulous spaces. Occlusion was one of the weak points of optical impressions. All the bridges were well adapted. Adaptation was clinically measured on a retroalveolar follow-up x-ray with an angulator.

Figures 9a to p show a case of two incisors with a unilateral distal cantilever. The two central incisors were extracted in one session, followed by guided bone regeneration. Four months later, an optical impression was taken and two crowns with one distal cantilever were fabricated. The restoration was modelled in Exocad, machined in multilayer zirconia at 880 MPa and fabricated by our lab technician. The access hole for a very narrow screw (with a small diameter) allowed a more aesthetic connection and reduced mechanical weakening of the prosthesis. As can be seen on the in-situ x-rays, the fit of the restoration is excellent.



9a–f I Case of two incisors with a unilateral distal cantilever. a I Initial situation. b I Tooth extraction. c I Site after extraction. d I Drilling. e I Implant placement. f I Guided bone regeneration. (Continued on next page.)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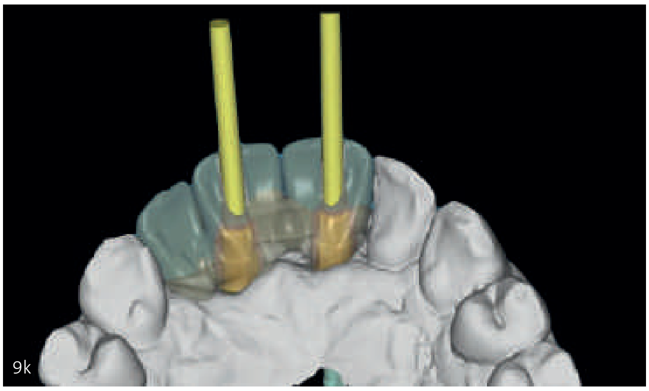
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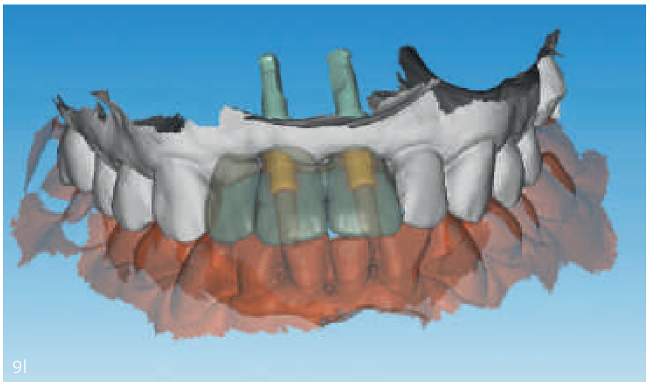
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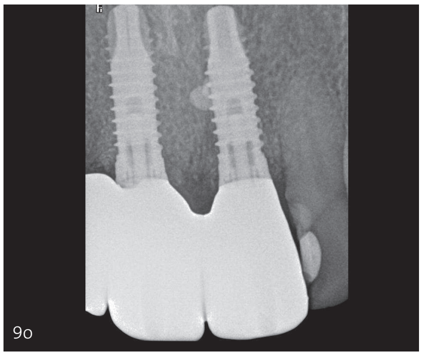
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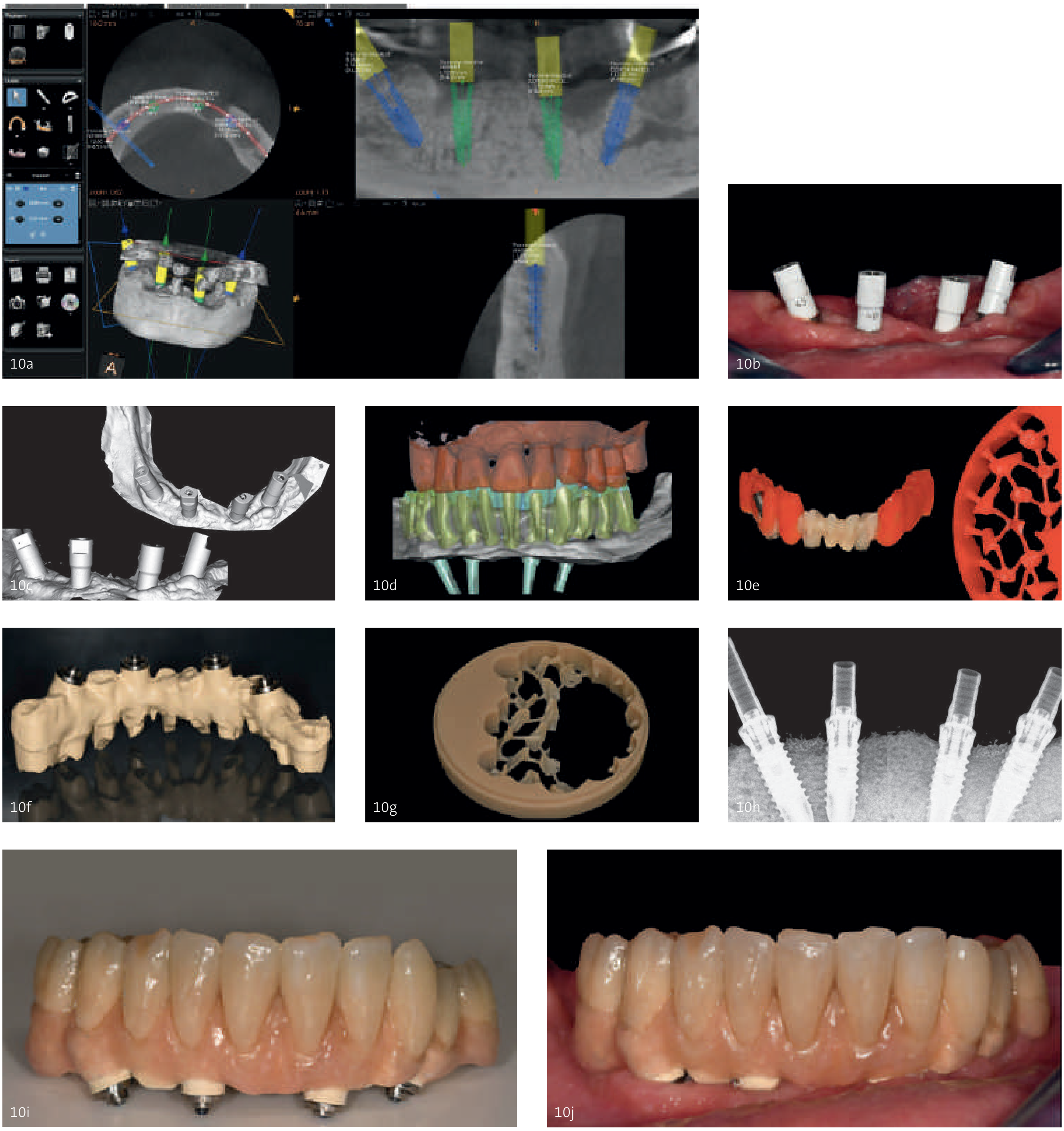
9g–p I Bridge with CS 3600 and a Thommen Varioflex without cast. Dedicated intraoral scanbodies were used. (Laboratoire Mobifix)

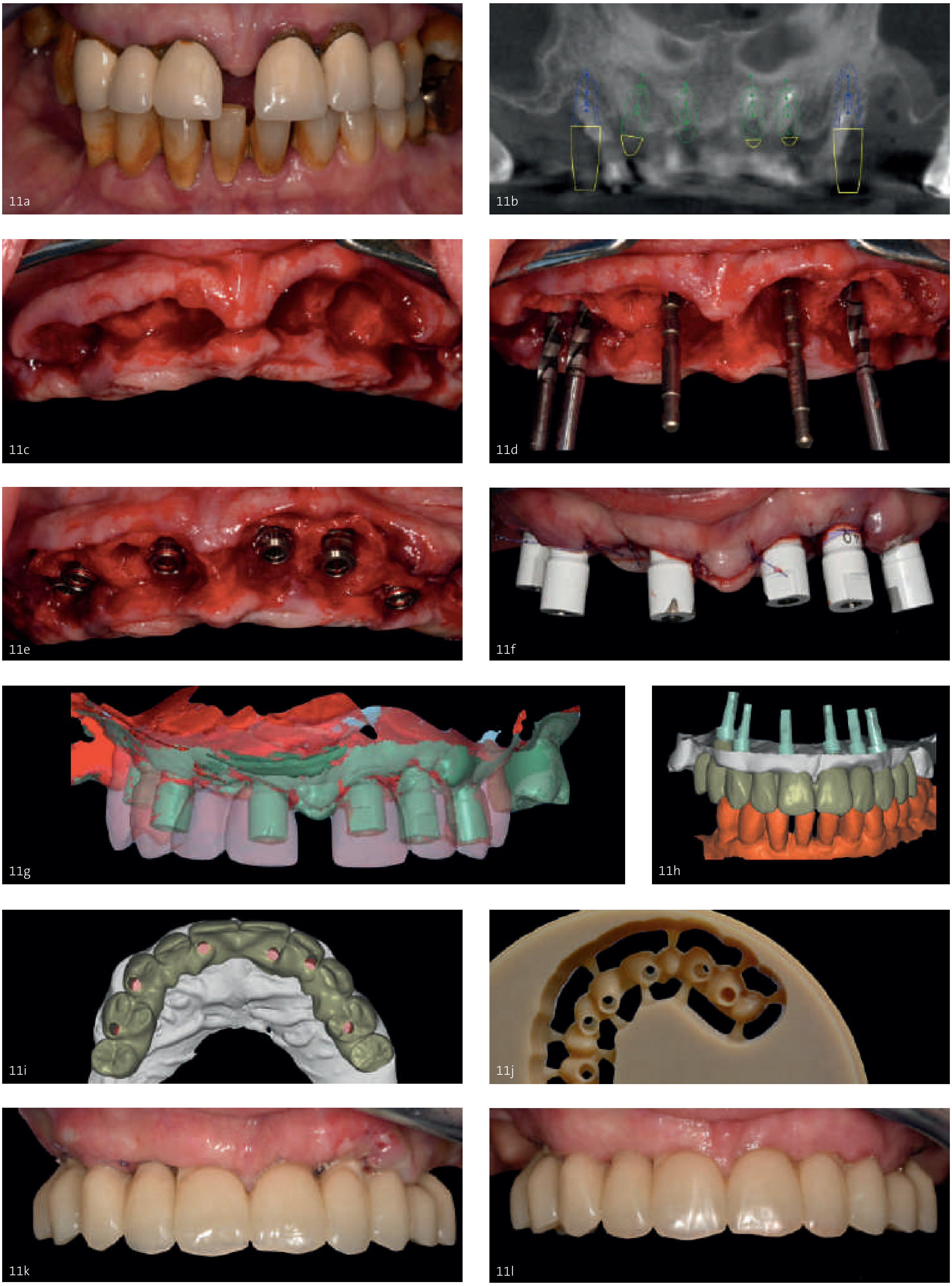
g I Situation at four months.
h I Scanbody in place.
I and j I Optical impression.
k and l I Modell design in Exocad.
m and n I Zirconia crown attached toTi-base
o I Follow-up radiograph.
p I Final situation.



10a–j I Completely digital all-on-four. CS 3600 scanner , PEEK framework, Varioflex abutments and machined resin teeth.
a I Initial CBCT. b I Scanbody in place. c I Optical impression. d I Model design in Exocad. e I Resin framework with milled resin teeth to verify fit and occlusion. f I Framework in PEEK with Ti base. g I Multilayered resin crowns. h I Follow-up radiograph of the framework.
i I Final restoration. j I Final situation. (Laboratoire Mobifix)

Tolerances of the implant/abutment interface varies greatly in the literature, from *Jemt*'s 30 µm [10] to *Klineberg*'s 150 µm [11]. It is therefore difficult to appraise the true level of precision required. Just as in the literature, we encountered more difficulties when the distance between two scanbodies is greater [8] or when there are discrepancies between the scanbodies [12]. Such difficulties tend to diminish as the scanner software improves.

We also attempted more complex types of restorations than reported in the literature – first of all an all-digital all-on-four (Figs. 10a to j). Our lab technician machined a PEEK frame after cutting back the initial prosthetic contour (in Exocad). A framework was machined from a resin ingot to validate the impression. Teeth machined in wax were bonded to this frame. This assembly was tried in intraorally, confirming a passive fit of the framework and an adequate occlusion, this being one of the main pitfalls when attempting to provide all-digital restorations. Subsequently,



11a–l I All-digital all-on-six. CS 3600 scanner, multilayer resin and Varioflex abutment. 11 a I Initial situation. b I CBCT image. c I Tooth extraction. d I Drilling. e I Implant placement. f I Placement of scanbodies after guided bone regeneration. g to i I Modell design in Exocad. j I Milling of the temporary bridge. k I Placing the bridge 48 hours after surgery. 11l I Situation at ten days after surgery. (Laboratoire Mobifix) ceramic-filled composite crowns were machined and bonded individually and gingival resin was affixed (without physical support, which explains the inaccuracies in this complex case). This test was a success that we will attempt to repeat.

We then attempted an all-digital all-on-six (Figs. 11a to l) for immediate loading. The patient presented with a distal edentulous space and required extraction of all maxillary teeth. It was decided to place six implants and immediately load them with a bridge. To accomplish this, we took our initial impression (maxillary, mandibular and bite registration) before the surgery. The teeth were milled digitally. At the end of the surgical intervention, an impression was made using scanbodies. The bridge can be designed based on the volume of the initial impression, which ensures better aesthetic and functional adaptation. The temporary multilayer resin bridge is milled, and the Varioflex abutments are connected. The distal implants were not angulated to make impression-taking easier and to ensure the accuracy of the result. The restoration fit well, as did the definite restoration made using an optical impression.

We attempted two more multi-unit cases that went smoothly. The first featured six implants with two distal implants that were widely spaced and angulated. The second case featured eight implants, of which the most distal ones showed a significant lack of adaptation [13].

Conclusion

The new Varioflex abutment allowed us to proceed to all-digital restorations with no physical casts. It meets all reasonable expectations of a CAD/CAM abutment. Using optical impressions, the accuracy we currently achieve in cases with one to three implants is as high or even higher than with physical impressions. We still need improvement in cases with four or more abutments.

The virtual Varioflex library that the engineers created to improve optical impressions was recently launched on the market. As the software and cameras improve further, it will certainly be possible in future to treat all types of edentulousness.

The references are available at
www.teamwork-media.de/literatur

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