Today, it is widely believed that high-performance polymers have a great future potential with regard to their use as framework materials in restorative dentistry. While for a long time, they have been exclusively used for temporary restorations, new application options are created due to the availability of innovative, optimised materials such as polyether ether ketone (PEEK). This material for example can be used successfully for the computer-aided production of long-span, implant-supported restorations.

MATERIAL PROPERTIES
PEEK is an aromatic, semi-crystalline thermoplastic polymer that has been in use as a material for implants in different medical fields (e.g. in orthopedics and oral and maxillofacial surgery) for more than ten years. The thermoplastic production procedure ensures that virtually no residual monomers are released. Due to its semi-crystalline character, the material remains mechanically stable even in an aggressive environment like the oral cavity.

Several years ago, PEEK was used for the first time in dentistry. Since September 2012, PEEK blanks for CAD/CAM production are available as well: Juvora Dental Discs (Juvora, Thornton-Cleveleys, UK). This material is no longer indicated for temporary restorations only. The blanks are sourced from Invibio Biomaterial Solutions that have been successfully used in medical technology for more than a decade. It is specified that the melting point of this material is high for polymers (340°C) and allows repeated sterilisation of frameworks. The modulus of elasticity is similar to that of natural bone. Its flexural strength is 165 MPa, the elongation at break amounts to 40%, meaning that a sample breaks when it is stretched by 40% of its initial length. According to the manufacturer, the consequence is that the material is flexible under load without fracturing - a property that seems beneficial especially from a functional therapeutic perspective. Juvora Dental Discs made from PEEK are recommended for the production of (semi-)removable structures. These include telescope attachments, dentures with precision attachments, claps-retained dentures and implant-supported, screw-retained restorations.

CASE STUDY
This 67-year-old female patient was referred to us with pain in her lower jaw. She had a...

Figure 1: Initial situation
Figure 2: Situation after removal of the existing restoration
Figure 3: The bridge after its removal
Figure 4: Result after extraction of the remaining front teeth and build up of the canines

Written by Professor Paul Tipton and Dr Bernd Siewert

Professor Paul Tipton and Dr Bernd Siewert present a case study using polyether ether ketone (PEEK) for the production of an implant-supported All-on-Four...
combined fixed and removable restoration consisting of a cemented metal-ceramic bridge on teeth LL3 to LR3 and a clasp-retained partial denture in the mandible (Figure 1). In addition, she had an asymmetric occlusion (Angle class II). All six remaining lower teeth could not be retained due to caries and advanced periodontitis (Figure 2). Figure 3 shows the existing bridge after its removal.

The patient was informed about the treatment options and chose a fixed denture on four implants. The All-on-4 concept was used in this case. This involves the insertion of two anterior implants without angulation, while the two distal implants in the posterior region are placed at an angle to allow for optimal use of the available bone and avoid damaging important anatomical structures (such as the alveolar inferior nerve).

In the present case, a minimally invasive implant insertion protocol using a drilling...
template was planned. We also aimed at immediate loading of the implants with a metal-reinforced composite provisional that had been produced prior to the surgery and was to be screwed on the implants.

**IMPLANT PLANNING**

In the first step, the teeth LL2, LR1 and LR2 were extracted. The canines received endodontic treatment and were stabilised with temporary screw in posts and composite (Figure 4). The old bridge with the crowns LL3 and LR3 that were isolated inside was used as a template for the build-up. It was important to temporarily retain the canines since they were to be used for exact intra-oral positioning and safe fixation of the drilling template during guided surgery. In this way, it was not necessary to insert three temporary implants with ball heads. In the next step, a wax set-up was created in order to determine the ideal arch relations and to establish the desired aesthetic appearance of the planned restoration together with the patient. On the basis of the resulting mock-up, a radiographic template was produced using material that contains barium sulphate. The template was subsequently positioned in the patient’s mouth and a three-dimensional X-ray was taken with Galileos (Sirona Dental, A-Salzburg).

The resulting DICOM data set with the radiographic template was imported into the 3D planning software. With the software, the ideal position of the four implants was determined virtually. At this, the planned prosthetic restoration - abutments with an angulation of 0, 17.5 and 35 degrees are available for this purpose - and the anatomical structures were taken into account. Moreover, the implants were positioned in the middle of the alveolar process and an ideal angulation for the distal implants was determined. In general, they should emerge as distally as possible to create the best AP spread. At the same time, the required distance to critical anatomical structures, in this case the mandibular canal, has to be observed (Figures 5-6).

Experience suggests that the benefits of the digital workflow in implant planning primarily result from the chance of taking all required decisions regarding implant insertion prior to the surgical intervention. Moreover, a minimally invasive approach that ensures an accelerated healing process, a minimised duration of the operation and reduced post-operative discomfort is possible. In addition, a long-term temporary can be produced in the laboratory prior to the intervention, so that immediate placement is possible. This enables the designing of a more delicate provisional which allows for a better hygiene and control. Last but not least, the total treatment time is drastically reduced.

After completion of the virtual planning step, the determined positions for the four implants were transferred to the radiographic template and drilling sleeves were integrated to create a drill guide (Figure 6).

**PROVISIONAL RESTORATION**

In the dental laboratory, four implant analogs were placed in the desired positions on the mandibular model (Figure 7). Afterwards, the provisional was produced on this cast in accordance with the wax up: the framework was made from chromium cobalt and veneered with acrylic polymer (Figure 8). The inner metal framework prevents the denture from fracturing and allows for a more delicate design than possible for bridges without any reinforcement. One of the four screw canals was integrated and used for pre-fixation in the patient’s mouth after implant insertion, while the other three canals were closed. The temporary had no distal free-end saddles to avoid overloading during osseointegration of the implants.

**SURGERY**

In the clinic the template was positioned on teeth LL3 and LR3. Then, the four implants with 16 mm length and a diameter of 4mm were inserted. Initially, the pilot holes in region LL2 and LR2 were prepared, the template removed

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**Figure 10:** Impression taking with an individual tray

**Figure 11:** Model with laboratory analogs and artificial gingiva

**Figure 12:** Digitised master model with laboratory analogs and artificial gingiva

**Figure 13:** Veneers in their desired position
and the remaining teeth extracted. Then, the template was repositioned and the pilot drills were inserted again in region LL2 and LR2 in order to fix the templates on them and continue the preparation process. After implant insertion, the abutments which had an angulation of 35° (implant in region LL5) and 17.5° (implant in region LR5) were placed and the provisional fixed.

The required chair time for the described procedure of surgery and immediate restoration amounts to approximately two and a half hours. Usually, there are no post-surgery swellings or hematomas. Pain medication is administered during the first 24 hours only.

FINAL RESTORATION
After a four-month healing period, an impression was taken for the production of the final restoration. For this purpose, the four screws were released and the provisional bridge was removed. Since so far, it is not possible to consistently implement the digital workflow for impression taking, the conventional procedure was adopted. A potential weakness of the available intra-oral scanners lies in the correct matching of single images resulting from the capture of large soft tissue areas. Impression copings were inserted (Figure 9) and a stable transfer key was produced using composite
material. The individual, open tray was fitted and an impression taken with a PVS material (Figure 10).

The master model was fabricated using polymer to avoid an expansion that is typical for gypsum. The laboratory analogs were also fixed on the model with a torque of 12 Ncm. On the complete arch, artificial gingiva was placed in order to ensure an error-free scanning of the analogs (Figure 11).

Figure 12 shows the virtual model after digitisation on the screen. With the model being mounted in the articulator, the pre-fabricated veneers were positioned in the predetermined way and in correct occlusion using wax and then scanned.

Figure 13 shows the positioned veneers on the 3D model. Having scanned them once, their geometries can be deposited in the software library. Afterwards, the PEEK framework was designed using the exocad DentalCAD software. Within this context, the software generated a full-contour design proposal which can be modified manually and was subsequently anatomically reduced (Figure 14).

Figure 15 shows the planned framework (blue) and the veneers which will be bonded on the framework in a special procedure (grey). It is possible to modify the shape and size of the framework manually, however, the user is warned if he falls below the recommended minimum wall thickness. In all, the designing with a computer enables the creation of precise full-contour designs with regard to the fit of the veneers, the convex shaping of the basal areas with ideal pressure on the gingiva and a direct design of the screw canals.

After completion of the design step, the data was sent to the CAM software for nesting in the virtual blank, positioning of the connectors (Figure 16) and milling path calculation (Figure 17). Finally, the framework was milled using the machine DWX-50 (Roland DG, D-Willich) in the production center PEEK-O-BELLO (E-Madrid).

RESTORATION PLACEMENT
The PEEK framework (Juvora Dental Disc) was removed from the blank (Figure 18). On the master model, a passive and precise fit was confirmed before the veneers were bonded with the PEEK framework using a special technique involving composite material. After finishing and addition of artificial gingiva (Figure 19), the restoration was tried in. Since a precise fit was obtained here as well and modifications were not required, the restoration was immediately screwed onto the four implants (Figures 20 and 21). The patient had a comfortable feeling during chewing and was highly satisfied with the appearance of the restoration.

CONCLUSIONS
This case description shows how Juvora Dental Discs are used within the digital workflow in order to produce precisely fitting implant-supported restorations. Experience gained with PEEK during the past six years suggests it is very well-suited as a framework material for the fabrication of complex semi-removable dentures. Due to the availability of Juvora Dental Discs for CAD/CAM processing, the benefits resulting from the positive material properties can be combined with those of the digital workflow, such as efficiency and precision. Thanks to the elasticity of the material that is similar to that of cancellous bone, chewing forces acting on the restoration are compensated. Due to its elasticity, PEEK thus serves as a shock absorber and imitates the periodontal ligament that is missing around implants. The clinical experience with this material has shown that the peri-implant bone remains stable over time.

And if a passive fit is not entirely achievable, the inaccuracies are balanced when the PEEK framework is screwed on the implants.
DENTAL PROSTHETICS
ALTERNATIVE TO METAL

WHY DENTISTS CHOOSE JUVORA

26X MORE SHOCK ABSORPTION

- CAD/CAM dental disc made from PEEK-OPTIMA™, a high performance polymer
- An alternative to metal for long-term² fixed and removable prosthetic frameworks
- More shock absorption¹ than Titanium, addressing problems with parafunction

¹ Based on the tendency of a material to deform when opposing forces are applied as expressed by the avg. elastic (Young’s) modulus values of the two materials (Titanium 110 GPa or PEEK 4GPa).