Unfilled PEEK used as framework material for twelve-unit bridges

Metal-free implant-supported restorations in the edentulous jaw

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Successful metal-free implant-supported restorations in the edentulous or nearly edentulous jaw were long considered elusive. The availability of semi-crystalline thermoplastic materials from the PAEK material group, such as PEEK, has filled the void. Over the past few years, the author has delivered a large number of implant-supported circular bridges using PEEK as framework material. The present case study illustrates the author's treatment concept. Special features in this case are the monolithic zirconia veneer and the possibility of making the bridge fixed or removable.

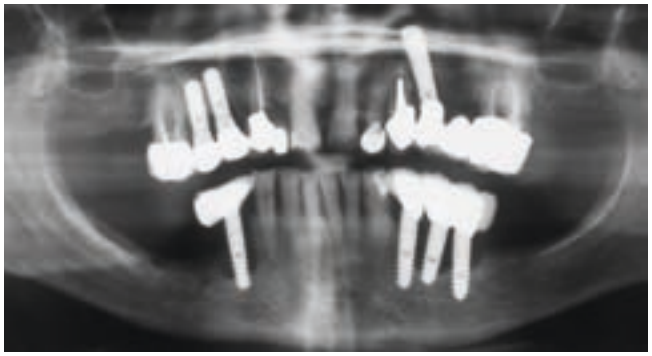
Rehabilitating the edentulous jaw with screw-retained implant-supported restorations has become very popular in recent years [1, 10]. Implantological concepts such as All-on-4 are relatively simple but have proven to be clinically viable. Metal frameworks (for example non-precious alloys, titanium) or – more recently – zirconia frameworks have mainly been used for the prosthetic restoration [12]. Both material groups feature a high modulus of elasticity and therefore result in relatively rigid splinting. Overloading of the implants, screw loosening or fractures of the prosthetic restoration may be the result of this rigid connection [2]. Patients often report an unphysiological chewing sensation. In addition, it was long considered impossible to make completely metal-free implant-prosthetic restorations for the edentulous or nearly edentulous jaw. Especially in the light of increasing patient awareness of holistic treatment modalities and an ongoing trend towards metal-free dental restorations, this significantly limits the dentist's options.

Prosthetic rehabilitation using ceramic implants

Over the past 15 years, ceramic implants have been successfully used in everyday clinical practice. However, screw-retained restorations on ceramic implants do not yet represent the state of the art. Consequently, the prosthetic restoration should be completely metal-free when ceramic implants are used; this is also true of fixed rehabilitations of the edentulous jaw. The proven concept of providing retrievable (screw-retained) restorations on titanium implants should also be applicable to ceramic implants.

PEEK in implant prosthodontics

High-performance polymers of the PAEK (polyaryl ether ketone) class of materials offer an alternative to conventional



1a I Situation at the time of the initial consultation in the author's practice in 2003.

1b I Situation following the insertion with titanium implants and delivery of a new circular maxillary bridge in 2004.

framework materials. The PAEK family includes PEEK (polyether ether ketone) and PEKK (polyether ketone ketone). The author has been using PEEK as a framework material for more than ten years – primarily for restoring titanium implants – and was able to gain extensive experience, particularly in the field of implant prosthodontics. Advantages of PEEK over metal alloys and zirconia include its low specific mass, relatively easy processing and resistance to corrosion [5].

The weight of the restoration as a whole is a frequently underestimated issue. In the edentulous jaw, implants are often placed beyond the area of the tooth roots (in basal bone). As a result, the prosthetic restorations sometimes exhibit an exceptionally high vertical dimension, resulting in massive frameworks. The low specific mass of PEEK is promising in this respect. Another advantage of PEEK (modulus of elasticity: 4 GPa) is the limited transfer of masticatory forces to the bone or peri-implant tissue. Overloading, often encountered with rigid materials such as titanium (modulus of elasticity: 110 GPa) or zirconia (modulus of elasticity: 210 GPa), can thus be avoided. The excellent physical and chemical properties of PEEK and its excellent biological compatibility are also promising when it comes to its use in implant prosthodontics [4,6,7,11,13]. PEEK has very low water absorption and therefore remains odourless even after prolonged wear.

PEEK is often the material of choice for sensitive patients with intolerances or allergies. Unlike with polymethyl methacrylate (PMMA), there is no residual monomer that could trigger allergic reactions [3]. Moreover, PEEK does not develop any corrosion products the way, for example, metal alloys do, causing incompatibilities [8].

Processing PEEK

PEEK can be processed in the dental laboratory in various ways. It is available in the form of blanks for CAD/CAM production (for example YuDent; Yunyi Medical, Beijing, China) as well as pellets or granules for pressing. Blanks for CAD/CAM production are industrially prefabricated under standardized conditions (temperature, pressure), generally of uniformly high quality [9, 11].

Indications for PEEK include removable (for example clasps, double crowns, bars) and fixed dentures (crowns, bridges). Due to the high opacity and the greyish-beige colour of PEEK, veneering is usually indispensable in the aesthetic zone. In direct contact with the mucous membrane, the author prefers the pure, unblended material. The surface of 100 per cent pure PEEK is easy to polish and characterized by its low plaque affinity. Direct gingival contact does not cause any significant irritation, even if oral hygiene is not optimal.

Some manufacturers modify the pure PEEK material, for example in order to adapt the shade to prosthetic requirements. Inorganic dyes are used for colouring, for example titanium dioxide (approximately 10 per cent), which must be viewed critically not least from the perspective of holistic dentistry. Whether titanium dioxide particles dissolve during their time in service has not yet been investigated. The author therefore favours unfilled PEEK, which is also used in general medicine (for example for hip prostheses or intervertebral bodies). YuDent (Yunyi Medical), the material used in this case study, is a high-purity material without any additives or admixtures.

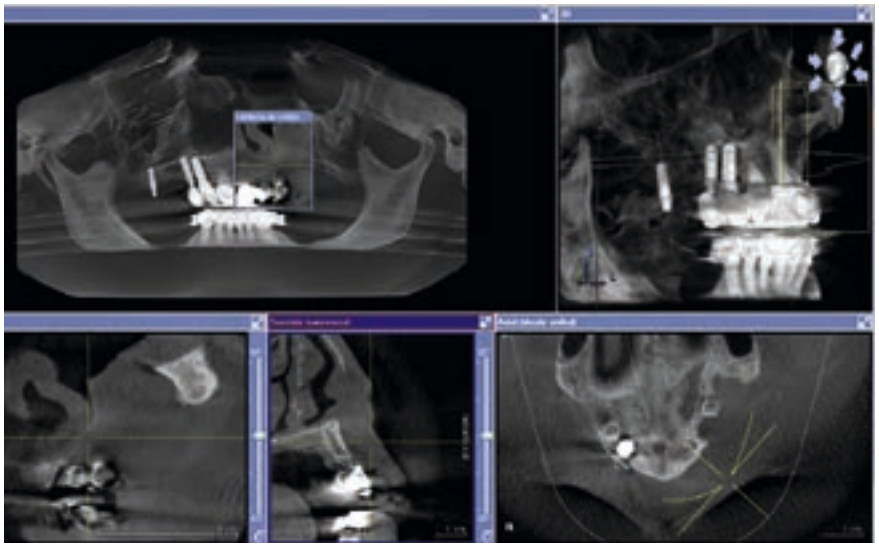
Veneering PEEK

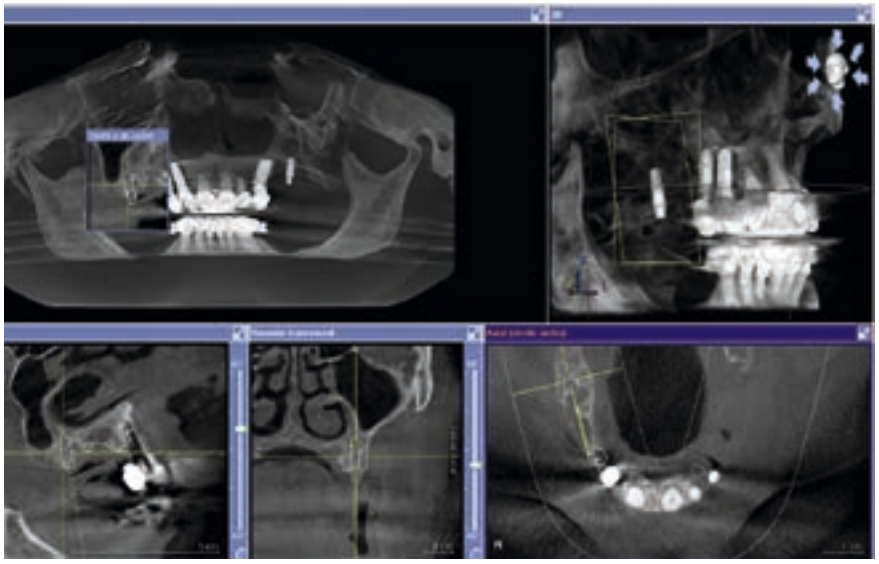
Various veneering methods are available to mask the inherent shade of pure PEEK in aesthetically relevant areas. For example, veneers can be individually built up in composite resin, produced using PMMA veneers, or implemented as adhesively connected zirconia crowns (see case study). All three methods have been used in my own practice in recent years.

1. If the PEEK framework is produced by pressing, veneers are an efficient option that had been used in the laboratory for a long time. Within the CAD/CAM workflow, prefabricated PMMA veneers are technically difficult to use for veneering frameworks. Another disadvantage is the high susceptibility of the PMMA veneers to abrasion during the time in service.
2. Experience with manual composite resin build-ups has been very positive. To achieve an optimum bond, the PEEK framework is sandblasted with alumina, conditioned with a bonder (visio.link; bredent, Senden, Germany) and then built up with composite resin. The thickness of the build-up corresponds to that of a metal-ceramic restoration; the work is performed on a framework with reduced anatomic contours. One disadvantage is the comparatively high amount of time required; moreover, the work is carried out in a semi-digital process.
3. Custom-made monolithic zirconia restorations used to veneer the framework are shown in the following case study. It uses a highly translucent zirconia (dd cube X2; Dental Direkt GmbH, Spenge, Germany), which is available as a multilayer material with a smooth shade gradient (from dentin to incisal). From the authors point of view, digital veneering with monolithic zirconia is the ideal solution. By adhesively connecting zirconia single crowns, the elasticity of the PEEK framework can be maintained to the greatest extent possible. Over the past four years the author has provided several restorations made in this way. The results are stable. No fractures have been observed, nor have there been any signs of wear (abrasion).

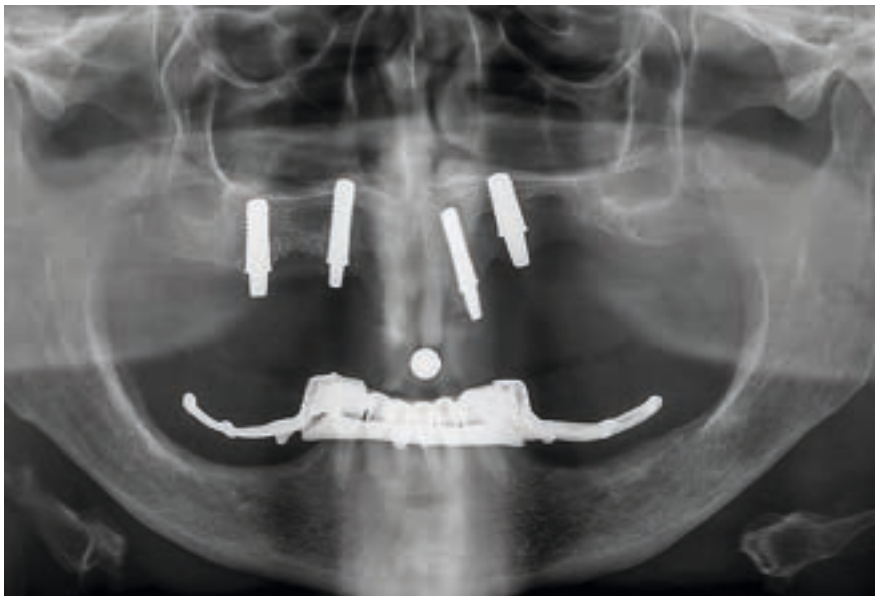
Case study

The patient, who is 71 years old at the time of this writing, suffers from an intolerance to titanium documented in 2015. At the first presentation in 2003, the bone had collapsed due to peri-implantitis around all implants (Fig. 1a). Peri-implantitis was not as clearly defined a condition then as it is today. After healing, the bilateral distal edentulous region in the mandible was treated with a combination restoration, which is still in function today. One implant was removed in the maxilla and two titanium implants were inserted after extraction of the non-salvageable teeth 13 and 26, and a cemented metal-ceramic bridge was delivered after healing (Fig. 1b).





2a and b I Planning the implant positions with the help of a CBCT scan. The reduced bone level in the upper left quadrant is clearly visible.



2c I Situation following the insertion of four one-piece ceramic implants.

Her intolerance to titanium had triggered distinct tissue reactions in the form of serious peri-implantitis and severe bone loss. Despite extensive treatment attempts, the implants could not be preserved and were ultimately lost. The bridge was removed, and the patient was provided with a complete denture as a temporary solution. Once her jaw had completely healed, we discussed the further procedure. I recommended the placement of four ceramic implants and a completely metal-free dental prosthesis based on a PEEK framework. The patient agreed to this proposal. She wanted a fixed denture, but one that she could remove herself if necessary, for example for cleaning.

Implantological treatment

After appropriate pre-treatment, four one-piece ceramic implants (Pure Ceramic; Straumann, Basel, Switzerland) were planned to be placed in the maxilla. Especially in the case of one-piece implants, thorough preoperative planning of the implant positions is crucial for achieving a prosthetically satisfactory solution. In this case, the status of the bone supply was unfavourable due to the previous pathology. Based on a CBCT scan, the implant position was planned to utilize the existing bone supply in the best possible way (Figs. 2a and b). The four one-piece ceramic implants were inserted according to protocol. This was followed by a four-month load-free healing phase (Fig. 2c). The two prepared teeth in the anterior region were prepared for conventional crowns and protected by provisional restorations.

Primary copings: zirconia

Once the implants had osseointegrated, a gingivectomy was performed in the vicinity of the implants, followed by a final impression using special impression copings (Fig. 3a). Exact placement of the copings on the implant is signalled by an audible clicking sound. Next, the implant analogues were inserted into the copings retained by the silicone impression, with proper seating again verified by an audible clicking sound. Around the implants, the material for the gingival

3a I Preparing for the final impression following a gingivectomy around subgingival aspects of the implants.

3b I Returning the implant analogues to the impression copings of the final impression.

4a and b I CAD design of the primary copings.

4c I Zirconia primary copings on the cast.

5a and b I CAD design of the primary framework.

mask was added and the master cast was created (Fig. 3b). To obtain a uniform path of insertion, six primary zirconia telescopes were initially made. They were designed in the form of primary crowns in the CAD software (0°) and milled from zirconia (Figs. 4a to c). The finished zirconia telescopes were tried in intraorally, followed by the final impression. The zirconia copings could then be reworked and polished in the paralleling device with a uniform path of insertion. To design the secondary PEEK framework, the model was digitized with the primary copings.

Secondary framework: PEEK

The framework was designed by CAD in the form of a bridge whose gingival and basal aspects as well as the palatal framework reinforcement (scallops) were designed to full anatomic contour to obtain the final shape in this area without veneering (Figs. 5a and b), unlike the teeth, which were to be veneered. An unfilled PEEK material (YuDent; Yunyi Medical) was used for the secondary framework. Especially in patients with documented material incompatibility issues, it is the dentist's responsibility to use pure materials without additives such as metal oxides for staining the PEEK. The PEEK material used is available in the form of a circular blank suitable for all popular milling machines.

6 I Milling the secondary framework from unfilled PEEK (YuDent; Yunyi Medical).

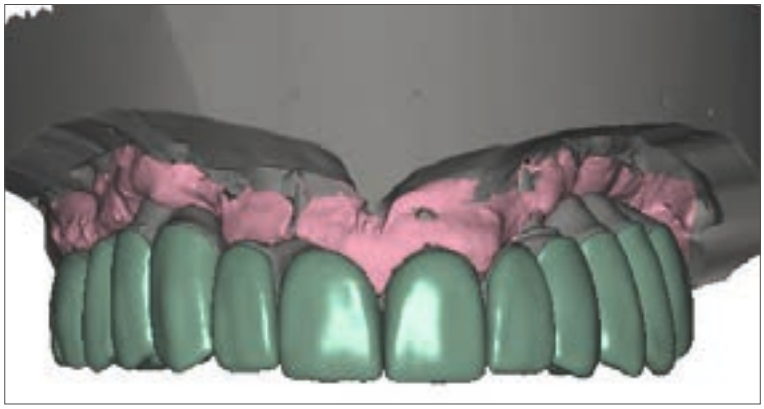
In the present case, milling was performed in a compact five-axis desktop milling unit (Organical Desktop 8; R + K CAD/CAM, Berlin, Germany) that operates quickly and accurately (Fig. 6). The fit, or friction, of the primary copings in the secondary framework was checked before the blank was retrieved from the milling unit. If necessary, the framework can be adjusted in some areas (for example inside the secondary copings) to gradually achieve an optimized fit. PEEK and zirconia can work in perfect harmony, for example when used together in a double-crown-supported restoration. Its soft sliding properties and firm hold ensure maximum wearing comfort. Finishing the PEEK framework after CAD/CAM milling was limited to a few simple measures.

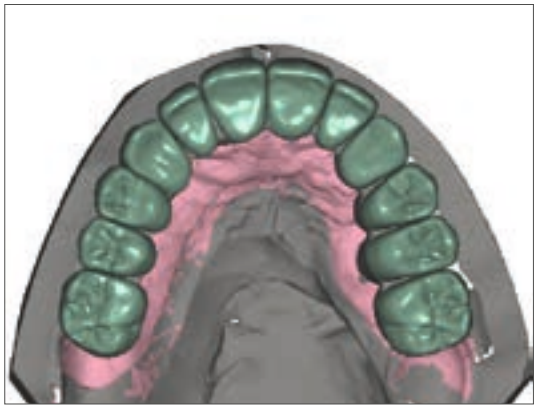
Veneer: monolithic zirconia

For the next step, the cast and the framework were rescanned and the veneer designed in the form of single crowns (Figs. 7a and b). Static and dynamic function as well as tooth shape and morphology were taken into account. The digital CAD veneer was monolithically milled from a highly translucent zirconia material (dd cube X2; Dental Direkt) and completed in only a few steps. The zirconia surface was designed with a high polish, especially where in contact with the antagonist. If at all possible, single crowns or small blocks of splinted crowns are designed for the digital veneering to maintain the flexibility of the PEEK framework. The framework was sandblasted with alumina (50 µm) and covered with a primer (visio.link, bredent) and an extremely thin layer of opaque. The zirconia crowns were cemented with a dual-curing adhesive. In visible areas, the gingival aspects were imitated with composite (Gradia; GC, Bad Homburg, Germany) and the restoration was finished (Figs. 8 and 9).

Delivery

The patient was pleasantly surprised by the low weight of the restoration. The bridge (PEEK framework with zirconia veneer) was inserted over the zirconia primary copings cemented on the implants (Figs. 10 and 11). The fit was excellent. The sliding properties of PEEK on a zirconia framework are reminiscent of the soft glide of double crowns made of a gold alloy. The friction and retention are perfect. There are no signs of wear similar to those seen in connection with





7a and b I CAD design of the veneer.

8 and 9 I The monolithically milled zirconia restorations (single crowns) as cemented on the PEEK framework.

10 I Finished restoration (bridge), intaglio side. PEEK framework with a zirconia veneer.

11 I Clinical situation before delivery of the implant-supported bridge.

12 and 13 I The restoration is completely metal-free. The PEEK bridge with it is zirconia veneer is firmly anchored but can be removed by the patient herself at any time if desired.

gold alloys or electroplated copings, either on the PEEK framework or on the zirconia primary copings.

The patient rated the chewing comfort as optimal, which is in line with the author's experience with this prosthetic concept. Despite the comparatively high material hardness of the zirconia veneers, patients report pleasant wearing properties and high chewing comfort. The PEEK framework seems to dampen the impact of chewing forces well.

Removable or fixed

The bridge is designed in such a way that the patient can decide for herself whether the dentures are removed only at recall appointments or on a regular basis for domestic oral hygiene. The restoration can be cleaned like a screw-retained restoration (Figs. 12 and 13).

Summary

An attempt is generally made to use as few different materials as possible in a prosthetic restoration. This approach is particularly important in patients with high sensitivity to specific materials. Not only metallic materials should be avoided – the risks and benefits of material combinations (PEEK, PMMA, composite resins, multi-component materials, ceramics) should be thoroughly considered and the materials used in small quantities. The presented implant-prosthodontic treatment approach is characterized by a completely digital

14 I The framework areas in direct contact with the gingiva are left unveneered in pure PEEK.

15 I Post-delivery radiograph.

16 and 17 I Follow-up after at four months in situ. The patient did not remove the bridge for domestic oral hygiene. The first time the bridge was removed was for the follow-up.

workflow, metal-free restorations and a short list of materials as well as the restoration being both removable and fixed. The list of materials is short and simple:

- Unfilled PEEK (YuDent, Yunyi Medical) – framework
- Translucent zirconia (dd cube X2, Dental Direkt) – veneering
- Bonder (visio.link, bredent), opaque (Gradia) and dual cement (G-CEM LinkACE, both GC Europe) – bonding of zirconia crowns to framework
- Glass-ionomer cement – cementation of the primary copings on the one-piece implants.

In the case shown here, gingiva-coloured composite resin is additionally used for the gingival aspects of the restoration, a step mandated by the severe bone loss. If possible, the PEEK is left unveneered in the soft-tissue region (Fig. 14). The metal-free concept and basal design of the bridge – with proper oral hygiene – result in well-adapted soft tissue with no signs of inflammation (Figs. 15 to 17).

My experience regarding any discolouration during the time in service has been good so far. PEEK does not appear to be susceptible to plaque retention and discoloration if it has been professionally polished and good patient compliance is ensured. Any discolouration that does occur – for example as a consequence of inadequate oral hygiene – can be easily removed. Basically, plaque seems to be less aggressive on a PEEK framework than on a metal framework, where corrosion can lead to destructive changes to the gingiva.

Conclusion

PEEK offers the dentist a metal-free restorative treatment option that is particularly well suited for complex implant-supported restorations in edentulous or nearly edentulous jaws. Ideally, the PEEK frameworks are fabricated using CAD/CAM. CAD/CAM blanks are industrially prefabricated under standardized conditions (temperature, pressure), generally of uniformly high quality [9,11]. Due to the material properties, masticatory forces are transferred to the bone or peri-implant tissue in attenuated form, protecting the bony structures around the implant. The restoration is also very comfortable to wear.

Ultimately, the excellent chemical properties of PEEK and its excellent biocompatibility make it a highly promising material for use in implant prosthodontics [4,6,7,11,13]. PEEK is the material of choice especially for sensitive patients. Unfilled PEEK materials such as YuDent meet the requirement of high biocompatibility, as no additives such as metal oxides are present.

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

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