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# Polyether ether ketone (PEEK) – a new material for framework fabrication

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# Polyether ether ketone (PEEK) – a new material for framework fabrication

## Part 1: Application and material advantages

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With the introduction of computer-supported manufacturing techniques in dentistry it became possible to fabricate restorations using modern high-performance polymers etc. Many of these materials cannot be processed or can only be processed with great difficulty using conventional methods. One of these materials is the thermoplastic composite polyether ether ketone (PEEK). This two-part article focuses on CAD/CAM-supported fabrication of a restoration using this material. Part 1 demonstrates the procedure by way of an actual case and shows the advantages of PEEK for the patient.

Metal-free restorations are becoming increasingly important in dentistry. This is due to the increased aesthetic demands of patients and (often alleged) material incompatibility. Ever more patients want to avoid incorporation of a metallic material in the mouth. Ceramic materials ideally meet the aesthetic requirements but also have material-technical disadvantages in some cases – e.g. a hard bite, poor damping properties or proneness to fracturing. Polyether ether ketone (PEEK) high-performance polymer has been used in industry for many years and has proven successful in many areas of medicine,



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e.g. as a bone substitute material with defects in the skull cap, finger bones or spinal column.

This material is bioinert, tissue-compatible, non-cytotoxic, electrically non-conductive and thermally insulating. The semi-crystalline, high-performance composite is also gaining an ever-increasing number of adherents and users in dentistry (and dental technology) due to these and other aspects in combination with the very good mechanical properties, high temperature stability and outstanding chemical-resistance. The chemical-resistance of PEEK prevents it being attacked by saliva; there is no reaction intraorally.

## Experiences using PEEK in the dental treatment concept

Due to its good physical properties, PEEK is a material of interest for intraoral prosthetic restorations – medically and economically. We have used PEEK for a long time for operator-removable, prosthetic restorations. For example, in the past six years eleven twelve-unit bridges (PEEK bridge frameworks) have proven perfectly successful clinically. Two of these cases have already been presented in detail in a publication both from a dental medical and dental technological point of view [1]. Further cases will be presented in this article.

## Case 1

A 72 year-old female patient presented in our practice in April 2008 (Fig. 1). The elderly lady was edentulous in the upper jaw and wanted a fixed restoration. The exact diagnosis, anamnesis and findings were unremarkable, except for the fact that the patient smoked. A screw-retained bridge restoration on six implants was planned. We decided to use a PEEK material (PEEK BioXS, bredent, Senden, Germany) as the framework material. The ideal prosthetic tooth set-up was determined using a wax-up and a mock-up fabricated. The implants were placed following planning of the implant positions (region 16, 14, 12, 22, 24, 26). The mock-up functioned as a valuable aid (Fig. 2).

Three months after implant placement stable hard and soft tissue conditions prevailed, which provided an ideal basis for the prosthetic restoration (Fig. 3 and 4). A twelve-unit, screw-retained bridge was

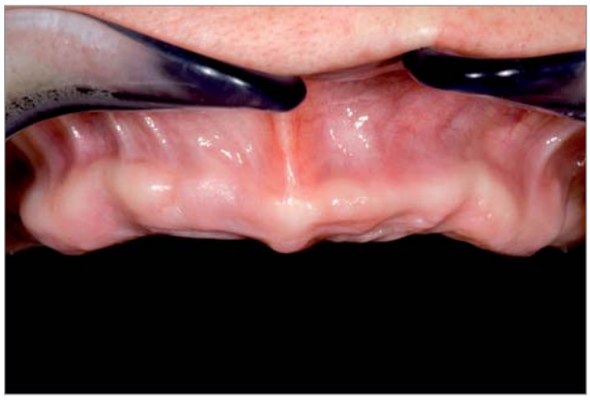


*Fig. 1: Initial situation. The patient wanted a fixed restoration.*

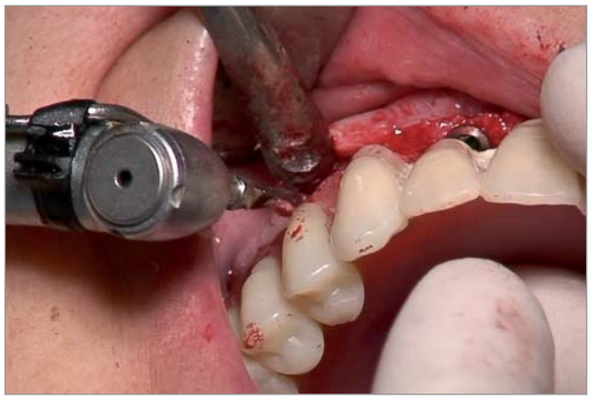


*Fig. 2: Placement of six implants.*

*Fig. 3 and 4: The prosthetic treatment was started three months after implant placement.*

planned, designed according to the Lego principle – as we call it (as follows): A customised bridge framework (PEEK) was prepared using a combination of high-grade, prefabricated, individual units. Fig. 5 shows the procedure graphically (prefabricated and customised): the cream-coloured flat Lego blocks represent the polymethyl methacrylate (PMMA) veneers (neo.lign, bredent, Senden, Germany) in the wax-up (Fig. 5a). The implants (grey high blocks) are placed accordingly (backward planning; Fig. 5b). The abutments (red flat blocks) compensate for any angulation and serve as the basis for screw retention (Fig. 5c). The long grey building block represents the PEEK framework and the only customised element (Fig. 5d).

The screw-retained upper bridge was fabricated and fitted in the mouth according to this "Lego principle"

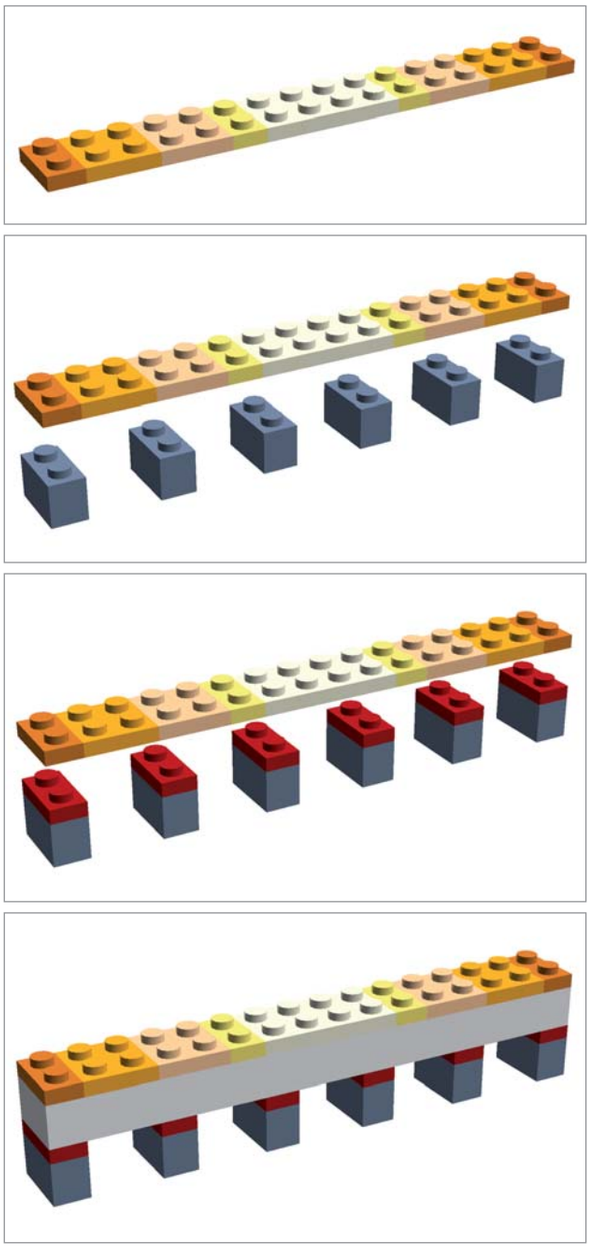


*Fig. 5a: The flat Lego blocks represent the PMMA veneers.*
*Fig. 5b: The grey Lego blocks symbolise the implants.*
*Fig. 5c: The red blocks represent the abutments, which compensate for any angulation.*
*Fig. 5d: The only customised element in this design is the bridge framework (PEEK), which connects the veneers with the implants (abutments) shown here as a grey long bar.*

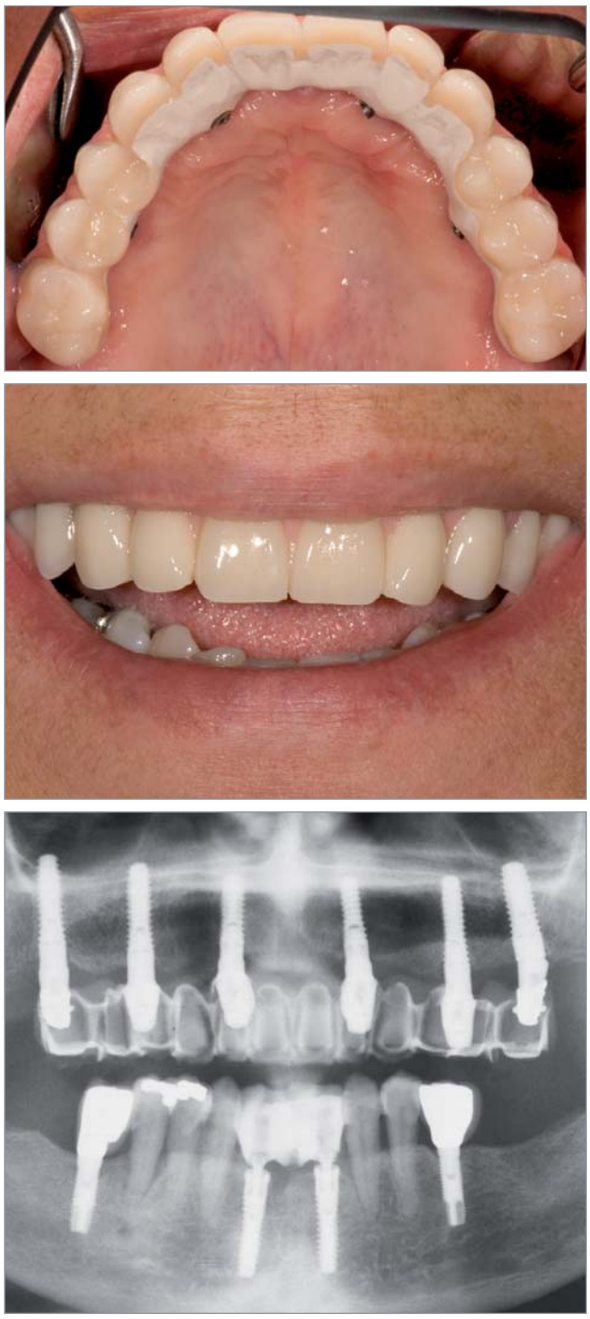


*Fig. 6a: The restoration designed according to the Lego principle. Occlusal view of the screw-retained bridge.*
*Fig. 6b: Anterior view – aesthetic natural appearance.*
*Fig. 6c: The check X-ray after fitting the upper restoration.*

(Fig. 6). From the first moment onwards, the patient was satisfied with the treatment option selected. The regular recall appointments indicated that the PEEK restoration is permanently stable (Fig. 7).

## Material technological advantages of the described procedure

Temporary long-term restorations are often milled from PMMA resin. This is doubtless a tried and tested method; however, PMMA does not have nearly the physical properties of the PEEK material described in this article. Based on our experience the following characteristics of PEEK appear to be relevant from a material technology point of view:

### Elasticity

In all cases which we followed up radiologically the peri-implant bone was stable after five years and exhibited no bone collapse.There were no abnormal probe depths clinically. There was no discharge of secretion when pressure was applied to the peri-implant gingiva. Most of the bridges were fabricated with a free-end unit (cantilever pontic), sometimes with a length of up to twelve millimetres. With some restorations the framework layer thickness in the region of the abutments was less than 1.5 millimetres. Despite these critical parameters no crack formation or even fractures occurred.

### Masticatory comfort

The familiarisation period after fitting the bridges (PEEK framework) was minimal in all cases. The patients already felt comfortable when leaving the practice. The patients did not have the sensation of a hard contact or disturbing "rattling noises" in intercuspation, even on natural or fixed ceramic restorations in the opposing dentition.

### Aesthetics

The industrially manufactured multi-layered PMMA laminate veneers (neo.lign, bredent) have a very natural appearance and enhance the aesthetics (Fig. 8). In the cases checked by us, the veneers remained stable over the long observation period. Even the cement gap around the veneer shows no discoloration.

*Fig. 7a: Clinical follow-up appointment – occlusal view after 59 months in situ. Stable conditions. The patient is still very satisfied.*

*Fig. 7b: Clinical follow-up appointment – anterior view after 59 months in situ. The veneers did not show any signs of splitting off or discoloration.*

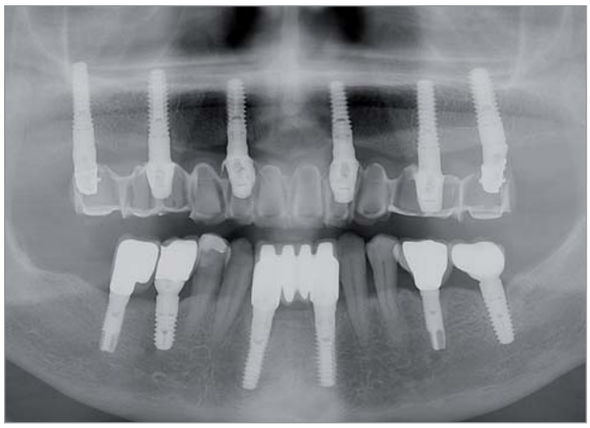


*Fig. 7c: X-ray after 59 months in situ.*

*Fig. 8: Close-up from the anterior aspect. Good, permanent aesthetic properties with PMMA veneers.*

### Low specific weight

The total weight of the twelve-unit bridges on a PEEK framework is between 9 and 15 grams (including adhesive-retained titanium abutments). This low weight cannot be achieved with any other material known to date.

### Metal-free

The soft tissue in direct contact with the PEEK framework shows no sign of inflammation in the cases we followed up. Only in cases of inadequate hygiene was the peri-implant gingiva superficially inflamed and exhibited a slight tendency to bleed. Plaque build-up was low and did not affect the health status of the gingiva in edentulous areas or regions without implants (Fig. 9 to 11). Corrosion is frequently visible on the titanium surface of abutments on bridge restorations fitted to a non-precious framework. This is not the case with a PEEK framework. No galvanic element is created. Plaque build-up is significantly lower than on conventional metal frameworks – depending on the surface roughness. So far we have only observed genuine "growth" of the mucosa onto the framework structure with PEEK frameworks.

### Tribological behaviour

We also checked the palatal aspects of the bridge frameworks where the opposing dentition (ceramic, natural teeth) was in direct contact with the PEEK. Some abrasion was observed with a bruxism tendency and on lateral guidance surfaces (Fig. 12 to 14). This is so minimal, however, that it can be regarded as a physiological process. One female patient with extreme bruxism exhibited abrasion of the occlusal veneer surfaces resulting in the veneer on tooth 12 splitting off after three years in situ (see further versions).

In the second part of this publication (next issue) the author describes the possibility of milling PEEK from industrially manufactured blocks (Juvora Dental Disc, Juvora dental, Thornton Cleveleys, United Kingdom) in the CAD/CAM procedure. The article will present the long-term documentation of a prosthetic restoration in a case of bruxism (Case 2).

*Fig. 9: This patient was treated with a composite-veneered bridge (metal framework). Suboptimal soft tissue situation.*

*Fig. 10: The same patient after fitting a bridge on a PEEK framework. The gingiva has already regenerated.*

*Fig. 11: The same patient after the bridge (PEEK framework) had been in situ for four years. Very good soft tissue conditions. The gingiva virtually "grows" around the bridge material.*

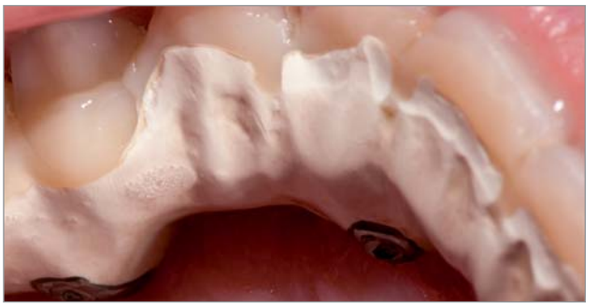


*Fig. 12: This patient (bruxism) was treated with a fixed/removable restoration (metal-ceramic bridge) in the lower jaw. The patient has been fitted with an implant-supported restoration on a PEEK framework in the upper jaw. After five years in situ the "physiological" wear (abrasion facets) on the framework material is clearly visible. There are areas of abrasion but without risk of fracture, excessive loss of material or cracks at the "veneer"/PEEK framework interface.*

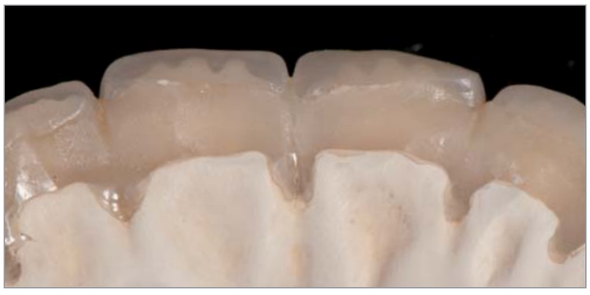


*Fig. 13 and 14: A different patient. Stable conditions without parafunctions. There is no discoloration visible between the composite and veneers. The upper restoration on a PEEK framework is perfect both aesthetically and functionally, even after six years in situ.*

# Polyether ether ketone (PEEK) – a new material for framework fabrication

## Part 2: Comparison of the processing methods and findings regarding long-term use

▸ Dr. Bernd Siewert

Polyether ether ketone (PEEK) high-performance polymer has proven successful in many areas of medicine for a number of years and is also gaining an ever-increasing number of advocates in dentistry thanks to its good physical properties and chemical-resistance. CAD/CAM processing of PEEK also opens new options.

The fabrication of a restoration made from this material and its advantages for the patient were described in the first part of this publication. In the following the author demonstrates the possibility of milling PEEK in the CAD/CAM procedure from industrially manufactured material blocks and presents long-term documentation of a second case involving treatment of bruxism by means of a prosthetic restoration. The findings gained from the observation period allow the following statements to be made with regard to comparison of the processing methods.

### Advantages of bridge frameworks fabricated using the injection moulding technique

If industrially manufactured elements are used for an implant-borne prosthetic restoration they can be overmoulded (thermopress system, bredent) with PEEK.

This eliminates the need for additional adhesive retention, which can be of particular advantage where little space is available – e.g. in the anterior region. Furthermore, the injection moulding technique requires lower financial investment than CAD/CAM fabrication of PEEK frameworks. However, the latter technique is impressively efficient.

### Bridge frameworks fabricated using the injection moulding technique

The entire fabrication process of wax-up, investing and finishing is time-consuming. The procedure with the thermopress system was not fully developed technically. In some cases visible voids and cracks were produced in the framework due to the familiar problems of injection moulding. In these cases the complete fabrication process had to be repeated. It was not always possible to maintain the surface contours of the wax-up exactly due to adjustments to the surface which were occasionally necessary.

This is counter productive, in particular with fully anatomically designed bridge frameworks. The transition to the plastic phase (heating and subsequent cooling) impairs the material-technical properties, especially with high-performance polymers such as PEEK. There is the risk of changes in the crystal lattice structure. Despite these factors, which may result in a reduction in quality, no problems with regard to crack formation, material fatigue or even fracture have occurred in the bridges we fitted.

Industrially manufactured blanks with approval for permanent, operator-removable restorations have recently become available (Juvora Dental Disc, Juvora dental, Thornton Cleveleys, United Kingdom). This material has no additives – it is therefore highly pure – and has been used in medicine for many years (Invibio Optima PEEK, Juvora).

### Advantages of CAD/CAM generated bridge frameworks

The advantage of CAD/CAM fabricated bridge frameworks is that the material is not adversely affected, provided it is used correctly. Bridge frameworks, milled from a high-grade, industrially man-

ufactured block (Fig. 15 and 16), undergo no physical changes during the fabrication process and exhibit the same or possibly better material-technical properties (Fig. 17 and 18).

Advantages:

- high-quality bridge frameworks with no material faults
- precise fabrication
- not a great amount of time required
- easily reproducible fabrication process.

The reworking required is limited to high-lustre polishing – provided a correct CAD/CAM chain is employed. This guarantees that the shape contoured during software-supported fabrication is retained exactly.

## Long-term documentation of the prosthetic restoration of a bruxism patient

We would like to demonstrate how difficult and complex the treatment of a physically affected bruxism patient can be using the example of a case

*Fig. 15 and 16: Framework (left: basal, right occlusal), (Juvora Dental Disc) fabricated in the CAD/CAM-supported process.*

*Fig. 17: The veneered bridge on the master model (palatal view).*

*Fig. 18: The bridge in the patient's mouth after ten months in situ. The secondary telescope 16 and bridge pontic 15 have been designed fully anatomically. The shade of the non-veneered PEEK is acceptable for the occlusal surface in the posterior region. The gingival conditions are excellent.*

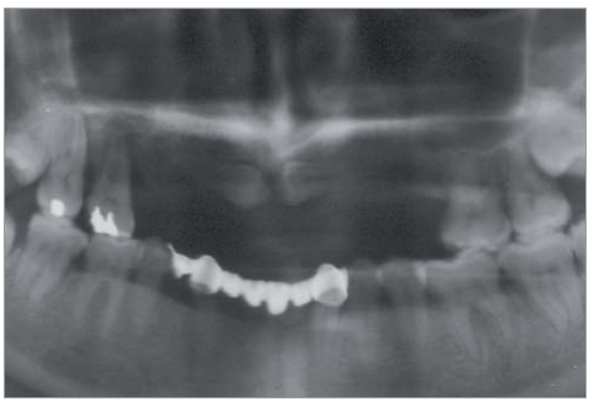
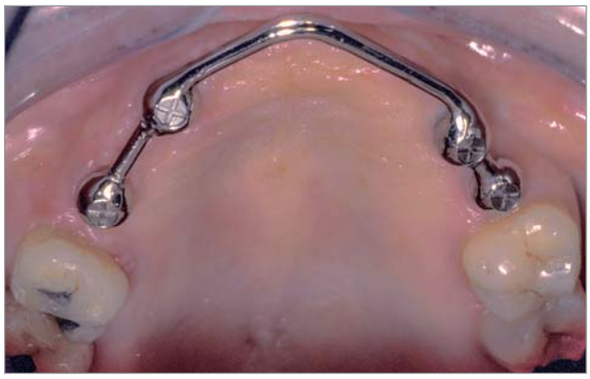


*Fig. 19: Initial situation: partially edentulous upper jaw with retained and displaced canines.*

*Fig. 20a: After removal of the canines and placement of four implants.*



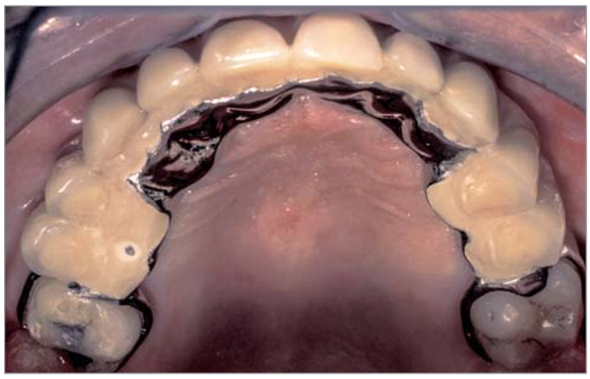


*Fig. 20b to 20d: At that time (1996) the patient was prosthetically treated with a bar-supported denture.*

documented over 17 years. In our opinion the ideal method has yet to be found in the search for an optimal prosthetic solution. Acrylic teeth have a damping effect but are subject to abrasion. Metal or all-ceramic restorations are at risk of fracture and do not provide any shock-absorbing effect to prevent overloading of the patient's natural teeth and the implants.

## First prosthetic restoration

The female patient, who was 55 years old at the time, was provided with an implant-borne upper prosthetic restoration in 1996 (Fig. 19). The bar-supported denture (four implants, Pitt-Easy, Sybron Implant Solutions, Bremen, Germany; formerly Oraltronics) was fabricated and fitted following surgical removal of the retained and displaced canines and simultaneous placement of implants (Fig. 20a to d).

A tendency to bruxism already manifested itself at the initial diagnosis. In 2001 tooth 16, periodontally-involved to a point where it could no longer be conserved, was extracted. Six years later (2007) surgical peri-implant treatment had to be performed on the implant in the 12 region due to the pocket depth of 8 millimetres and discharge of secretion. The oral situation was stable in 2009 (Fig. 21).

## Second prosthetic restoration

After 13 years the overdenture was damaged due to severe bruxism and was no longer sufficient. It was replaced by a fixed, operator-removable, horizontally screw-retained bridge (Friktion Splint, bredent, Senden, Germany; Fig. 22a to 22c). The chrome-cobalt-molybdenum alloy telescope crowns on four implants and two molars were adhesively retained in a bridge framework fabricated using PEEK, BioXS, bredent.

*Fig. 21: Stable situation following surgical peri-implantitis treatment.*

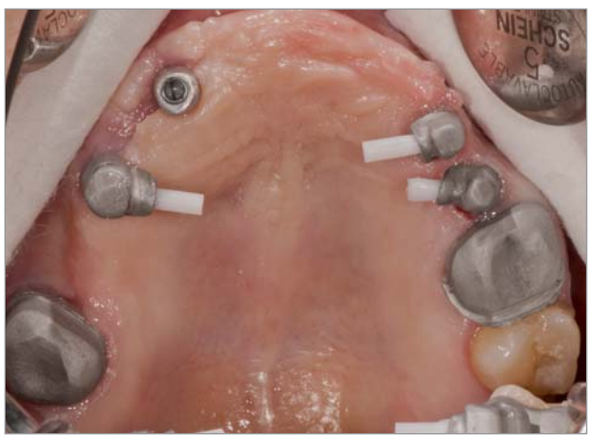


*Fig. 22a: 13 years later. The overdenture had to be replaced ...*

After three years in situ the occlusal surfaces (veneers) had been abraded completely in the posterior region and later the veneers split off tooth 12 due to the bruxism (Fig. 23 and 24).

A remake of the prosthetic restoration was unavoidable. The BioXS PEEK framework material was completely intact. Following abrasion of the acrylic teeth, the framework surface was in direct occlusal contact and there were only minimal signs of wear. No cracks or decementation were observed basally. Neither the implants nor the molars with the cemented primary crowns showed any clinical anomalies (Fig. 25). The following assumption is clear: the composite bridge design of the PEEK bridge framework is also sufficiently resistant to withstand enormous masticatory forces. The acrylic teeth in the posterior region are the weak point in patients with bruxism.

## Third prosthetic restoration

We then decided on CAD/CAM-supported fabrication of a fully anatomical bridge framework for the remake of the prosthetic restoration. The material used was unfilled PEEK, Juvora Dental Disc, Juvora dental, which can be used for fabricating highly precise restorations. The basal region was designed fully anatomically in a convex shape (Fig. 26 to 28). The buccal aspects in the visible areas (teeth 15 to 25) were veneered. As both the protrusive and laterotrusive excursions were to be on the PEEK framework, no prefabricated laminate veneers were placed in this area but rather custom-milled composite veneers (see Fig. 26a and 26b). The occlusal surfaces and functionally generated paths were not veneered (Fig. 28a and 28b).

All critical areas were thus designed fully anatomically:
1. Occlusal surfaces (abrasion)
2. Basal surfaces (mucosal contact)

*Fig. 22b and 22c: ... due to severe bruxism: operator-removable, horizontally screw-retained bridge restoration.*

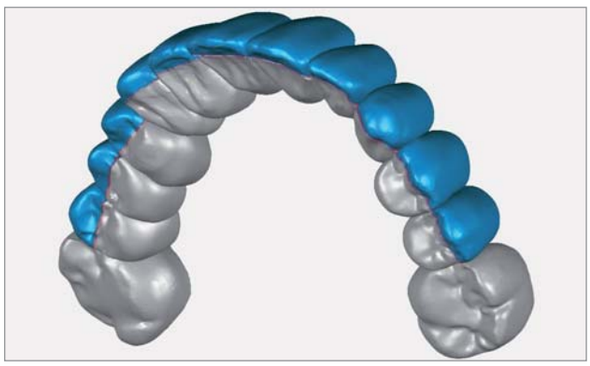
*Fig. 23: After three years in situ the veneers split off again (bruxism) ...*

*Fig. 24: ... the PEEK framework, however, shows no signs of impairment.*

*Fig. 25: Neither the implants nor the molars (primary crowns) show any clinical anomalies.*

We decided on an occlusal screw-retained restoration; it has been demonstrated in the course of routine practice that horizontal screw retention in combination with the telescope principle can be problematic from a hygiene point of view. To ensure that the bridge fitted passively, the four implant copings in the mouth were adhesively retained and then the new restoration fitted. The non-veneered Juvora Dental Disc is barely noticeable as an occlusal surface material. The grey-brown shade of the occlusal and oral sections was accepted by the patient without any problem (Fig. 29a and b).

In such cases the focus is on producing a durable, functioning restoration. The shock-absorbing properties of the new design should protect the implants and the patient's natural teeth against the destructive forces of bruxism. Juvora Dental Disc PEEK ma-



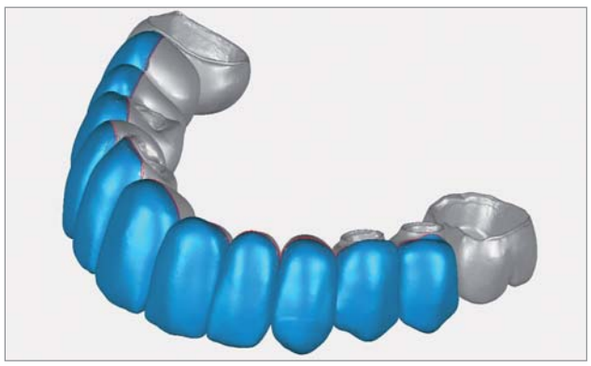


*Fig. 26 and 27: The bridge was remade CAD/CAM-supported.*

*Fig. 28a and b: The finished bridge: The PEEK Optima framework material was designed fully anatomically in the functionally critical areas.*

*Fig. 29a and 29b: The fitted restoration.*

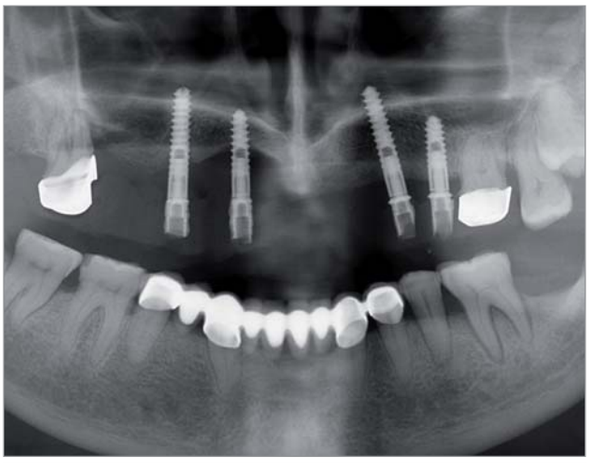


*Fig. 30: The check X-ray image: Juvora Dental Disc is highly pure and free of additives – e.g. barium sulphate – and is therefore not visible on the X-ray*

terial is completely free of additives – e.g. barium sulphate – and is therefore not visible on an orthopantomogram; a detail that one has to become accustomed to (Fig. 30).

## Discussion

Invibio Optima PEEK has been tried and tested as a material for implants in the medical field for over ten years. Its high biocompatibility has been proven in several clinical studies [1]. The low specific weight, bone-like elasticity, metal-free character and toughness combined with virtually non-existent material fatigue make it an ideal material for use in prosthetic dentistry. The CAD/CAM-supported processing of PEEK opens up new possibilities. The physical properties of the material described allow approximately the same design dimensions as those of metallic materials.

To date, approval of the material is limited to removable and operator-removable (screw-retained) restorations. This means that cast metal denture bases, secondary units, superstructures with fixed/removable restorations, implant-supported, posterior full crowns and – as demonstrated in this publication – operator removable, screw-retained bridges can be fabricated using the material described. In the past, long-term clinical results were achieved in patients with bruxism and heavy pressing using a gold alloy on the occlusal surface. A material is now available for these indications, which has the effect of damp-ing masticatory forces and, due to its greyish shade, can also be used for occlusal contours – metal-free and biocompatible.

## Conclusion

The positive clinical experiences using fully anatomical PEEK bridge frameworks, fabricated using the injection moulding technique, can be transferred to CAD/CAM processing. This enables frameworks to be fabricated in a reliable, reproducible production procedure.

Consistent, optimum material quality is also guaranteed. The chemical properties of PEEK exclude any transparent versions. However, it may be possible in the future to add inorganic dyes to reproduce the shades on the Vita shade guide. Full crowns made from this material could then be used with confidence, including with regard to aesthetic parameters. A material has therefore been found that builds on the clinical experience of gold.

## REFERENCES

1 Siewert B, Parra M: Eine neue Werkstoffklasse in der Zahnmedizin. PEEK als Gerüstmaterial bei 12-gliedrigen implantatgetragenen Brücken (A new material class in dentistry. PEEK as a framework material with 12-unit, implant-supported bridges). Z Zahnärztl Implantol 2013;29:148–159. DOI 10.3238/ZZI.2013.0148–0159.

## MATERIALS

**Framework material:**
PEEK Bio XS, bredent, Senden, Germany
Juvora Dental Disc, Juvora dental, Thornton Cleveleys, United Kingdom

**PMMA veneers:**
neo.lign, bredent, Senden, Germany

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Dr. Bernd Siewert studied at the Christian Albrecht University, Kiel, Germany from 1981 to 1986. He spent his two-year assistance time in a practice near Hamburg, Germany. In 1989 Dr. Siewert gained a Dr. med. dent. doctorate (dissertation: Die Verkalkung der Falx cerebri als pathognomonisches Zeichen beim Gorlin-Goltz-Syndrom [Calcification of the falx cerebri as a pathognomonic sign with Gorlin-Goltz syndrome]). He then moved to Spain where he worked in a private practice in Madrid from 1989 to 1991. From 1991 to 1996 he managed a group practice in Malaga with his colleague Dr. Achim M. Vietze. Since 1996 Dr. Siewert has his own private practice in Madrid and specialises in implantological treatment. Since 2007 the experienced implantologist has worked as an instructor at the International Training Center for Dental Implantology (IFZI), Nuremberg, Germany, lectures at a national and international level and is the author of numerous publications.