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Pekkton® ivory

High performance polymer for definitive
aesthetic restorations on implants:
Scientific documentation.

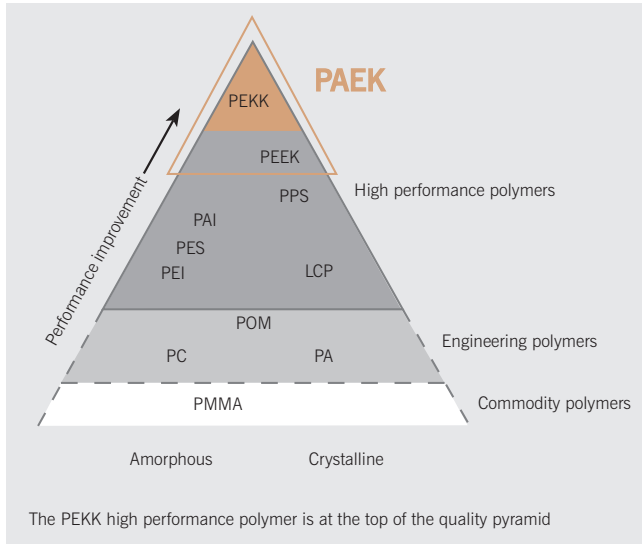


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Introduction.

Pekkton® ivory – A high performance PAEK based polymer with tailored properties for dental use.



The most suitable (relevant) material for human medicine and dentistry

«The structure and composition of teeth is perfectly adapted to the functional demands of the mouth and are superior to those of any artificial material. Therefore, first of all, do no harm.»¹ Pekkton® ivory² is a high performance polymer, based on the raw material PEKK, the cutting edge of PAEK materials at the top of the pyramid of polymers. Capturing the peak of the PAEK family, Pekkton® ivory brings you the best of the world of the polymers for dental indications. Resistance, dimensional stability, toughness are just a few of these attributes. Cendres+Métaux is convinced of the advantages of non-metallic materials and we are today introducing, in exclusivity, the pinnacle of thermoplastic high performance polymers worldwide.



Mimicking nature is the future trend for medical products. Metals and ceramics, even when biocompatible, do not fulfill this claim. For instance, bone modulus of elasticity matching may be important in applications where stress shielding should be minimized. By contrast, polymer-based products are increasingly acknowledged as better alternatives to stiff, rigid metal solutions. Hence, the extensive profile of material properties of Pekkton® naturally makes it ideal for different applications in the dental field.



Pekkton® should not be regarded as a simple material, but as a complete system solution. The PEKK material can easily be compounded to fulfill specific requirements. Different Pekkton® grades can then be used in dentistry for crowns, bridges, model casting, inserts, abutments and solutions for implants. Pekkton® can be simply and reliably processed by conventional lab and/or industrial methods. As an example, Pekkton® is perfectly suited to computer-aided fabrication. It offers the perfect cost effective and time saving solution in comparison to metallic or ceramic materials for the most comfortable product for the patient.

¹ Kishen A. Mechanisms and risk factors for fracture prediction in endodontically treated teeth. Endodontic Topics, 2006; 13(1):57– 83.

² Pekkton® based on OXPEKK® from OPM, Oxford Performance Materials, Inc., USA

a Example of a FDA cleared PEKK cranial implant

b Pekkton® ivory milling blank based on implantable PEKK grade

Material properties and chemistry.

1. Composition

Polyetherketoneketone (PEKK)
Titanium dioxide

2. Physical properties

Glass transition temperature	T _g = 157 °C	ASTM-D3418
Melting temperature	T _m =363 °C	ASTM-D3418
Color	whitish	

3. Mechanical properties

Young's modulus	5.1 GPa	ASTM-D638
Tensile stress@break	115 MPa	ASTM-D638
Flexural modulus	5.0 GPa	ASTM-D790
Flexural strength@5% strain	200 MPa	ASTM-D790
Hardness	252MPa	ISO 2039-1

Values for mechanical properties are based on standard geometries. The values may vary depending on shape, design and processing parameters.

4. Biological testing

Pekkton® ivory as base material is tested and found to comply with USP Class VI biocompatibility standards. It has met or exceed the requirements of the United States Pharmacopeia for biological tests according to:

Cytotoxicity Elution Test according to USP32:2009 <87> and ISO 10993-5:2009
(Study No.: 110042, BSL Bioservices, DE-82152 Planegg)

Intracutaneous Reactivity according to USP 32<88>
(Study No.: 110043, BSL Bioservices, DE-82152 Planegg)

Accute Systemic Toxicity – System Injection Test according to USP 32<88>
(Study No.: 110043, BSL Bioservices, DE-82152 Planegg)

Muscle Implantation according to USP 32<88>
(Study No.: 110043, BSL Bioservices, DE-82152 Planegg)

5. Sterilization

Due to its high glass transition temperature (157°C) above normal steam sterilization temperatures of 121°C to 134°C and thanks to its natural hydrolysis resistance, Pekkton® ivory is particularly suited for steam sterilization without any noticeable changes in mechanical or physical properties.

6. Monitoring

Manufacture, packing and delivery are constantly monitored by the quality management system standards according to ISO 9001 and ISO 13485.

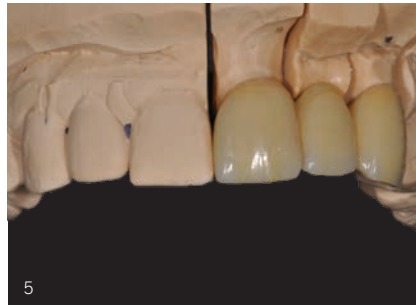
Indications.



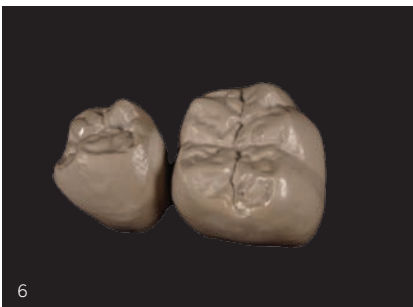
Definitive supported, veneered and screw-retained crowns and bridges on dental implants, with maximum two pontics. Can be veneered with bonded press crowns, with composites or prefabricated acrylic teeth and veneers.



Removable restorations such as secondary constructions on bars and telescopic crowns, transversal connectors, occlusal splints and denture bases.



Definitive supported, veneered single crowns and bridges with maximum one pontic on natural teeth.



Left: unveneered crowns and bridges in the posterior region for a maximum wearing period of 12 months.

Right: unveneered parts e.g. crown margins and backings.

1: BDT, Beaver Dental Technology, GB-Leeds
 2/3: Zahntechnik Wichnalek, DE-Augsburg / Norbert Wichnalek, Robert Bacalete
 4/6/7: Laboratoire Cristou, FR-Paris
 5: Zahnmanufaktur Zimmermann & Mäder, CH-Bern

Biocompatibility.

Scientific background and normative requirements.

To assess biological risks, the procedures and provisions of EN ISO 10993-1:2009 «Biological Evaluation of Medical Devices – Part 1: Evaluation and Testing within a Risk Management Process» were applied. Based upon the criteria set forth in this standard, the product is biologically classified as an «external communicating device» with «permanent» (> 30 days) contact to «tissue, bone or dentin».

Therefore, in accordance with the aforementioned standard and in accordance with EN ISO 7405:2008 «Dentistry – Preclinical Evaluation of Biocompatibility of Medical Devices Used in Dentistry – Test Methods for Dental Materials», the following biological risks were evaluated in particular:

– Cytotoxicity	EN ISO 10993-5:2009
– Irritation	EN ISO 10993-10:2010
– Delayed type hypersensitivity	EN ISO 10993-10:2010
– Acute systemic toxicity	EN ISO 10993-11:2009
– Subchronic systemic toxicity	EN ISO 10993-11:2009
– Chronic systemic toxicity	EN ISO 10993-11:2009
– Implantation	EN ISO 10993-6:2009
– Genotoxicity	EN ISO 10993-3:2009
– Carcinogenicity	EN ISO 10993-3:2009
– Chemical characterization	EN ISO 10993-18:2009
– USP Class VI	USP 34 <88>

For sample preparation and dosing EN ISO 10993-12:2009, respectively USP 34 <88> is applicable.

Results

The potential of cytotoxicity of Pekkton® ivory was investigated in compliance with international GLP regulations. Pekkton® ivory showed no cytotoxic effects and based upon the observed results and under the test-conditions chosen, Pekkton® ivory has been evaluated to have no cytotoxic potential in terms of EN ISO 10993-5 when manufactured and applied in accordance with the manufacturer's instructions for use.

Based upon the results and scientific arguments developed in the aforementioned biological risks evaluated it is concluded that Pekkton® Ivory:

- has no irritant potential in terms of EN ISO 10993-10.
- has no skin sensitizing potential in terms of EN ISO 10993-10.
- meets the requirements of the USP Plastic Class VI.
- has no acute systemic toxicity potential in terms of EN ISO 10993-1.
- has no potential of subchronic and chronic systemic toxicity in terms of EN ISO 10993-1.
- has no potential of inhalation toxicity in terms of EN ISO 10993-11, respectively, in terms of OECD guidelines TG 403 or TG 436 (Acute Inhalation Toxicity), TG 412 (Repeated Dose Inhalation Toxicity) and TG 413 (Subchronic 1 Inhalation Toxicity).
- has no local toxic effects after a long term implantation in terms of EN ISO 10993-6.
- has no genotoxic potential in terms of EN ISO 10993-3.
- is considered to have no carcinogenic, reproductive, developmental or immunotoxic potential pursuant to the requirements of EN ISO 10993-3.

Conclusion

Based upon the study results and evaluation arguments and considering the provisions of the current version of the harmonized standards EN ISO 10993-1 and EN ISO 7405, it is concluded that the dental material Pekkton® ivory can be evaluated as biocompatible if manufactured appropriately and applied in compliance with its intended use as outlined in the manufacturer's Instruction for Use.

Certificate of compliance.



CERTIFICATE OF COMPLIANCE

Testmaterial: Pektkon® ivory

Supplier: Cendres+Métaux SA, Rue de Boujean 122, P.O. Box,
2501 Biel/Bienne, Switzerland

Studies performed: CYTOTOXICITY (USP <87> Elution Test) (BSL Project No. 110042)

USP <88> BIOLOGICAL TEST
(CLASSIFICATION VI/121 °C) (BSL Project No. 110043)

Results: The test item did not show any effect in the USP Class VI – 121 °C test and meets the criteria of USP Biological Tests Classification VI. In the cytotoxicity assay under the given conditions the cells treated with the test item extract showed no reactivity (grade 0). Therefore, Pektkon® ivory met the requirements of the cytotoxicity assay.

BSL BIOSERVICE Scientific Laboratories GmbH
Behringstraße 6/8
D-82152 Planegg

A handwritten signature in blue ink, appearing to read 'Sandra Schmid'.

Dr. Sandra Schmid
Biological Safety Testing
Date: 15 March 2011



Marginal gap.

Purpose: Check of the fitting of crowns pressed in Pekkton®.

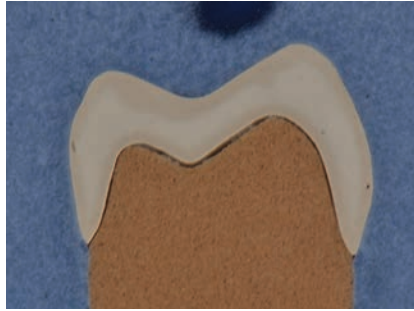
Fitting of the crowns for clinical success should be between 20 and 120 microns¹ or lower. Otherwise, the cement can be removed by brushing and therefore get new bacteria between the restoration and remaining tooth substance, which may lead to secondary caries.

To achieve a good fit by the pressing technique, a mixing ratio (liquid and distilled water) of 75% was chosen. The crown specimens have been produced by the classic pressing technique.

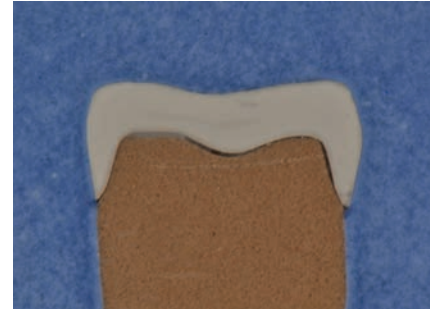
The stumps and the wax crowns have been milled by CAD/CAM.

The mean Value of all measured marginal gaps of the crowns was 20.81 microns.

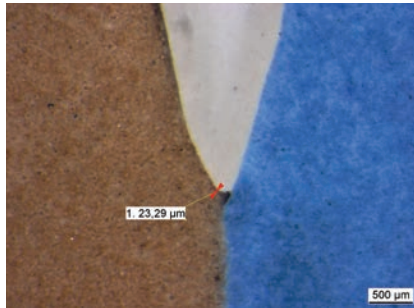
Results



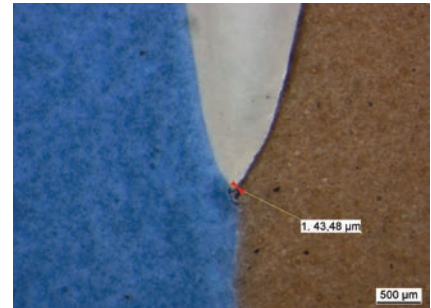
Micrograph of a cross section of one of the measured crowns from lingual and buccal.



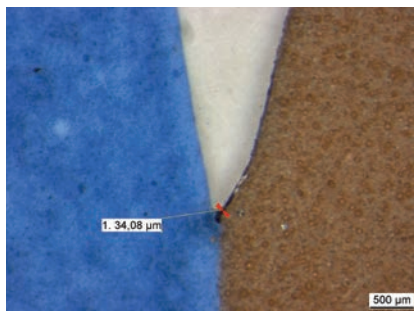
Lingual section of a tested crown. The marginal gap is 43.48 microns.



Buccal section of the same crown. The marginal gap is 23.29 microns.



Micrograph of a cross section of the measured crowns from mesial and distal.



Distal section of a tested crown. The marginal gap is 34.08 microns.



Medial section of the same crown. There is no marginal gap.

Conclusion

All the tested crowns passed the measurement with very good results/values. The result to be achieved are strictly dependent on the precision and the working technique of the dental technician.

Whether pressed or milled, the fitting of Pekkton® Crowns is excellent!

¹ Bindl, A. and Mörmann, W.H. (2005) Marginal and internal fit of all-ceramic CAD/CAM crown-copings on chamfer preparations. Journal of Oral Rehabilitation, 32, 441-447

Aging.

Purpose

To evaluate from injection molded test specimens, the aging behavior of Pekkton® ivory in order to quantify the stability and sustainability of the raw material.

Materials and methods

The Pekkton® ivory was injection molded using a single cavity ASTM type tensile and flexural mold.

Injection molded samples were tested:

1. After manufacture (injection molding);
2. After sterilization by irradiation (Gamma radiation, maximum sterilization doses of 75 kGy);
3. After sterilization + aging (5 years at 90° C artificially).

Chemical stability was checked for each state by FTIR (Fourier Transformed Infra Red Spectroscopy). Aging conditions were estimated using ASTM F1980 as a guideline with aging factor Q10=2. It was established that 9 days at 90° C would be considered equivalent to approximately 1 year at 37° C.

Mechanical, physical properties and chemical structure were measured according ASTM standards:

- Tensile Properties (ASTM D638)- Type I ASTM specimen, Zwick 50kN Universal Tester, 50kN load cell, 0.2 in/min test speed;
- Flexural Properties (ASTM D790)- ASTM Flexural specimen, Zwick 50 kN Universal Tester, 1 kN load cell, 0.01 1/min test speed;

- Compression Strength (ASTM D695), 0.05 in/min, specimen machined from flexural bar;
- Thermal Properties (ASTM D3418), TA Instruments 2920 MDSC, 20° C/min heat, cool, heat;
- FTIR (ASTM E1252), Thermoelectron Magna-IR 750 Spectrometer, ATR method.

Results

Properties	Pekkton® ivory after manufacture	Pekkton® ivory after sterilization	Pekkton® ivory after sterilization + ageing
Tensile strength (yield)	119 MPa	119 MPa	124 MPa
E-Modulus	5.1 GPa	4.8 GPa	5.0 GPa
Tensile elongation (yield)	4.4 %	4.5 %	4.2 %
Flexural modulus	5.0 GPa	4.9 GPa	5.1 GPa
Flexural stress@5%	200 MPa	200 MPa	200 MPa
Compressive Stress@40%strain	246 MPa	251 MPa	249 MPa
Melt temperature	363° C	362° C	363° C
FTIR ATR Method	Checked and confirmed	Checked and confirmed	Checked and confirmed

Conclusion

Pekkton® ivory exhibits constant mechanical and physical properties before and after sterilization and aging treatments. Results remain constant for all three states i.e

- For manufactured samples;
- For sterilized samples;
- For sterilized and aged samples;

There is no identified degradation in the material after sterilization and simulated 5 years aging. Chemical structure is checked and confirmed by FTIR for all three states.

Pekkton® ivory.

Shearbond strength of veneering composites.

Purpose

Pekkton® ivory is a framework material. That means that it is useful to layer the Pekkton® with a tooth colored composite. The aim is to get a bondstrength between Pekkton® and the veneering material higher than 5 MPa and to find the maximum of veneering composites, which are compatible with Pekkton®.

Materials and methods

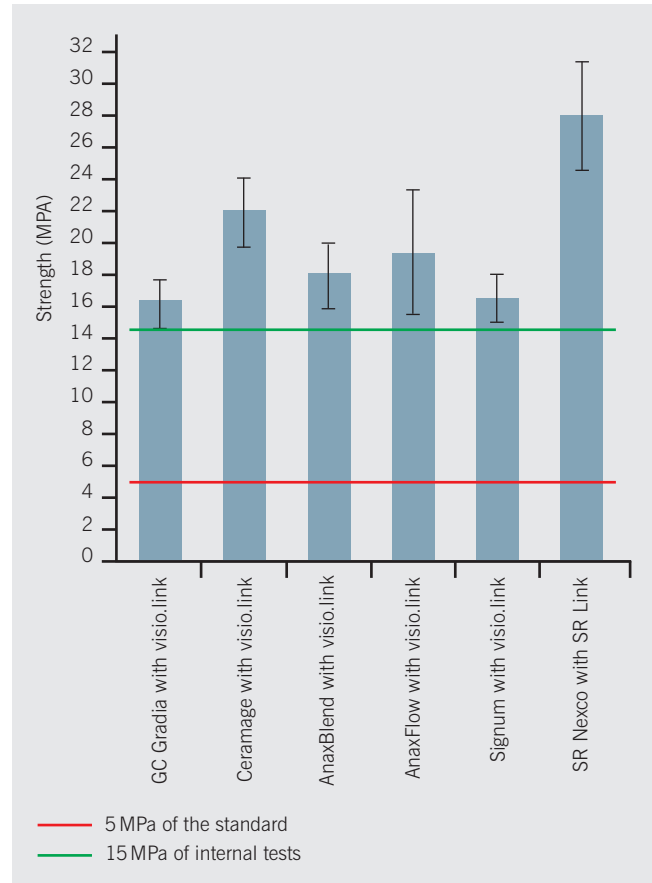
A few composites (already existing on the market) have been tested based on standard ISO EN 10477:2004. Please find the detailed way how the crowns finally have been produced in the instructions for use of the different veneering composites.

The Pekkton® ivory pressing blanks have been embedded into Technovit polymer. After 20 minutes the specimens have been polished. The surface has been roughed by sand-blasting (Al_2O_3 110 μ m at 2 bar). Then treat the surface as recommended by the manufacturer of the bonding system. Apply and cure the opaque resin to the bonding area as recommended by the manufacturer of the polymer-based crown and bridge material. Put the mould onto the opaque layer with the wider opening against the opaque layer. Press the polymer-based crown and bridge material into the mould. Cure the polymer-based crown and bridge material according to the manufacturer's instructions. Thermocycle and test the specimens according to the standard.

The standard states that a value of 5 MPa would be successful but according the clinical experience the minimum bondstrength should be 15 MPa at least.

The specimens have some deviations to the standard. Because the bondstrength to the Pekkton® ivory surface is measured and not the framework strength, for simplicity pressing blanks have been used instead of the specimen described in the standard. This difference is not relevant for the aim of this test.

Results



Conclusion

The surface preparation of Pekkton® ivory before bonding is of prime importance whatever the composite system used. A precise procedure combining mechanical retention and chemical bonding is applied in order to obtain acceptable values. Established composite veneering systems of the market applied following the aforementioned procedure passed the test with common shear bonding values exceeding 15 MPa.

Pekkton® ivory.

Hardness.

Purpose

The hardness is a measure of the penetration of a body in the tested material.

Even if this parameter influences the wearing properties of a restorative material, no clear correlation between both properties can be pointed out.

For dental cured resins, hardness is also important in order to evaluate the degree of polymerization and depth of cure. Since Pekkton® ivory is a thermoplastic resin, this aspect is non-relevant.

Hardness for polymer-based materials is preferably determined by a ball indentation test, but others standards are also used. Comparing hardness values should only be done considering the same standard.

Materials and methods

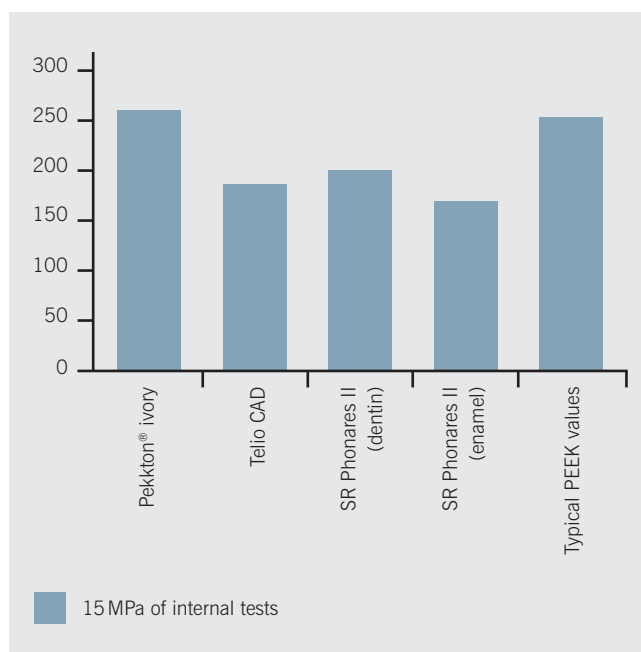
5 Pekkton® ivory discs of 62 mm diameter and 6.4 mm thick have been tested according to DIN EN ISO 2039-1.

Tests were performed with a 5.0 mm ball diameter, a test speed of 5 mm/min under a test force of 960.98 N for 30 s.

Results

Results are given in MPa.

The mean value of the measured hardness is 252 N/mm² (MPa) with a standard deviation of 4N/mm² (MPa).



Pekkton® ivory	252 MPa
Telio CAD	180 MPa
SR PHONARES II (Ivoclar, Nanohybrid material)	170 MPa
Typical PEEK based products	250 MPa

Conclusion

The ball indentation hardness of Pekkton® ivory is comparable in the range, but nevertheless significantly higher in the values to that of competitive advanced PMMA products like nano-hybrid material such as SR Phonares II. Reported values are comparable to PEEK based products.

Fatigue testing of 4-unit veneered dental bridges.

Purpose

The aim of the investigation was to test the mechanical reliability of a dental bridge made of Pekkton® ivory under fatigue loading.

The test should simulate to a certain extent the loading of the bridge under physiological conditions. As a representative model, a veneered four unit bridge on two implants at molar and premolar positions (34-x-x-37) was chosen. The bridges have been cemented on titanium bases.

Materials

Pekkton® ivory was used as a framework material for all tested specimens.

- Five bridges milled by CAD/CAM

Veneering and cementation:

- Veneering material:
 - tooth coloured: anaxBLEND Flow (Anaxdent)
 - pink coloured: ProBase cold
- Cement: Multilink® Hybrid Abutment (Ivoclar Vivadent)

Surface conditioning

- Link to the veneering composite:
 - Sandblasting with 110µm Al₂O₃ and 2 bar of pressure
 - Priming with visio.link (Bredent)
- Link to the Ti-Bases
 - Sandblasting with 110µm Alox and 2 Bar of pressure
 - Silanisation with Monobond Plus (Ivoclar Vivadent)
 - Priming with visio.link (Bredent)

Methods

In order to simulate bending of the bridge due to masticatory forces, the load was applied to both pontics. This is similar to a «four point bending test» which is frequently used for the mechanical testing of materials.

The test environment and the frequency were chosen following the standard ISO 14801 which is a fatigue test for dental implants. The test was conducted in Ringer's solution at 37°C, the frequency was 2 Hz. The maximum number of load cycles was 2 millions.

The force applied for this test was sinusoidal with an upper load of 500 N and a lower load of 50 N.

The remaining strength to fracture after fatigue testing was then determined in a static test.

Results: Fatigue test

Examination of the specimens with a stereo microscope did not show any damage after two million cycles at 500 N upperload.

In some cases, minor abrasion marks in the contact areas were found where the loading was supplied via the steel balls. However, this is not considered as a failure because it is known that the metal-tooth contact is not realistic. The teflon foil did not completely resist 2 million cycles without damage so that there was a certain direct contact between the balls and the surface of the bridge.

Results: Remaining static strength

After the fatigue measurements, the specimens were loaded in the same loading geometry and under the same environmental conditions until fracture. The loading was applied under displacement control with 2 mm/min in Ringer's solution, 37°C. Before the tests, the specimens were stored for one hour under the same conditions to obtain the temperature balance.

The specimens reached a mean value of >2600 N after cyclic loading.

Conclusion

The fatigue strength of 4 unit veneered bridges by far surpasses the maximum load that may be exerted on the material under natural conditions.

Based on these results, it can be assumed that four-unit bridges made of Pekkton® ivory as framework material, if properly designed, are long lastingly resistant to fracture.



Samples veneered and framework

Numerical simulation of a three-unit bridge in comparison to conventional bridge materials.

Summary

Pekkton® ivory is a novel high performance polymer for use in dentistry. Currently it can be used for fixed restorations (crowns and bridges) and removable dental prosthesis. This study focussed on the mechanical and biomechanical behaviour of a bridge made from Pekkton® ivory, especially in comparison with conventional bridges made from titanium or dental gold-alloys, using the Finite Element (FE) method.

A three-unit bridge (premolar to second molar) together with the surrounding hard and soft tissues was modelled. The model consists of cortical and spongy bone, periodontal ligament (PDL), teeth, cement, framework and veneering. To investigate the behaviour on mechanical loading, a load of up to 500 N was applied on the central unit, either parallel to the tooth axis or in an angle of 30° to this axis. Simulations were performed with three different framework materials: Pekkton® ivory (4.4 GPa), titanium (110 GPa), dental gold alloy (Ceramicor, 136 GPa).

The use of Pekkton® ivory as framework material resulted in a clear reduction of the mechanical stresses in the framework (see Figure 2), while stresses in the veneering increased (Figure 3). The changes in the mechanical behaviour of the bridge had no influence on the loading of surrounding soft and hard tissue (see Figure 4 for determined strains in the periodontal tissue).

Based on these results it can be stated that the mechanical behaviour of Pekkton® ivory allows the use of this material as an alternative to the classic metal framework materials.

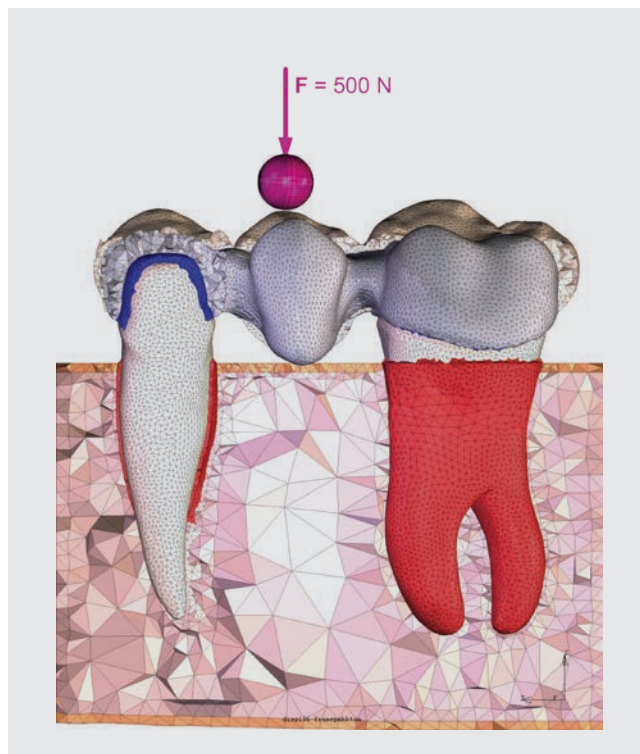


Figure 1: FE model of the 3-unit bridge.

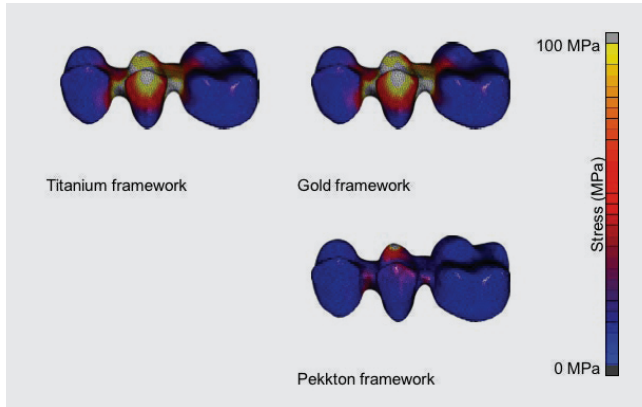


Figure 2: Stresses in the framework for loading with 500N in an angle of 30° to the tooth axis.

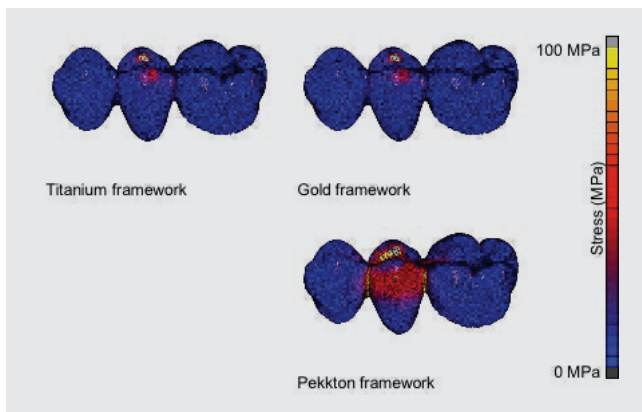


Figure 3: Stresses in the veneering for loading with 500N in an angle of 30° to the tooth axis.

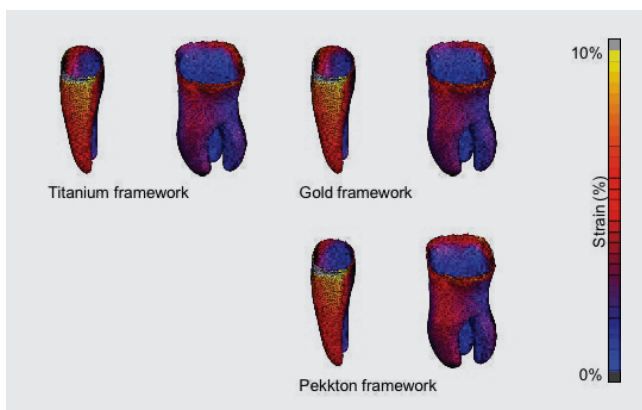


Figure 4: Strains in the PDL for loading with 500N in an angle of 30° to the tooth axis.

Numerical simulation of a four-unit bridge.

Summary

Pekkton® ivory is a novel high performance polymer for use in dentistry. Currently it can be used for fixed restorations (crowns and bridges) and removable dental prosthesis. This study focussed on the mechanical and biomechanical behaviour of a four-unit bridge made from Pekkton® ivory using the Finite Element (FE) method.

A four-unit bridge (first premolar to second molar, see Fig. 1) placed on two implants (4.3 mm x 13 mm, Sison, Switzerland) was modelled.

The model consisted of framework, veneering, cement, abutments, implants, and thrust die. To investigate the behaviour on mechanical loading, a load of 500 N was applied on the

two central units in an angle of 30° to the implant axis. Simulations were performed with Pekkton® ivory (4.4 GPa) as framework material, and veneered frameworks as well as full anatomical bridges were considered.

The simulation of the veneered bridges showed a prominent change in the stresses in the veneering compared to the adjacent framework for the veneered bridges. These high stress changes might cause cracking and chipping in the veneering at higher force levels, and special care should be taken to choose a suitable veneering material. For the full anatomic bridges the stresses within the framework were in the region of the yield limit of Pekkton® ivory at a force of 500 N. The results of these investigations

indicate that the studied high performance polymer is a valid alternative for classical framework materials when using full anatomical bridges. For veneered bridges, design and thickness of the framework as well as material properties and limits of the veneering material are relevant.

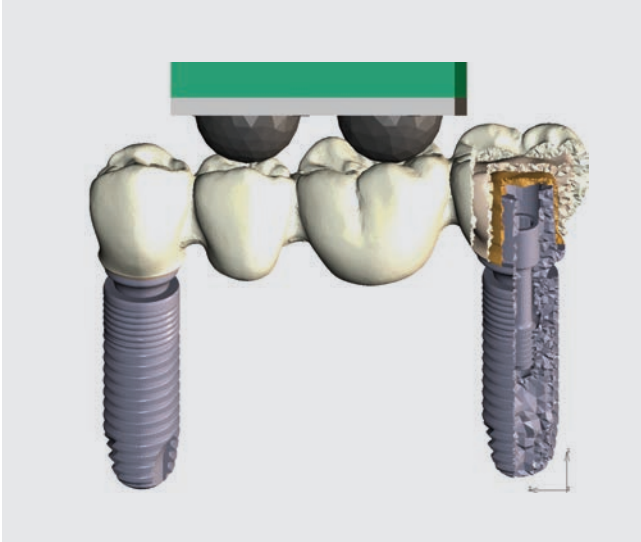


Figure 1: FE model of the four-unit bridge.

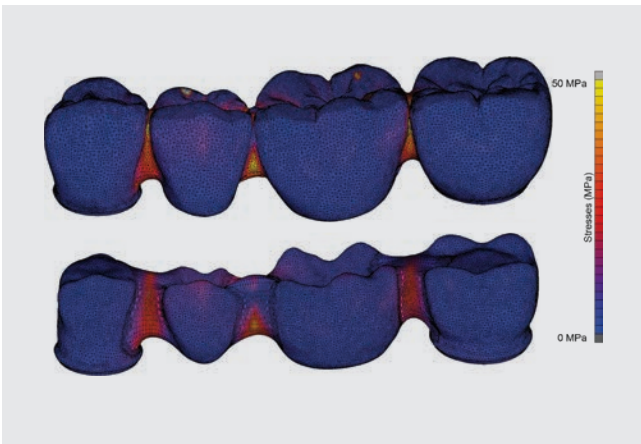


Figure 2: Stresses in the full anatomic bridge made from Pekkton® ivory for a load of 100 N.

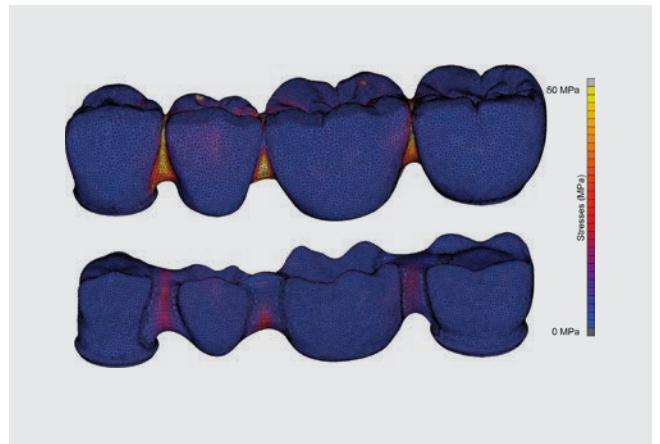


Figure 3: Stresses in the veneered bridge made from Pekkton® ivory for a load of 100 N.

Biomechanics of the All-On-Four concept in the maxilla – A numerical analysis.

Pekkton® ivory is a novel high performance polymer for use in dentistry. Currently it can be used for fixed restorations (crowns and bridges) and removable dental prosthesis. This study was a preliminary comparison of the mechanical and biomechanical behaviour of a full-arch bridge made of Pekkton® ivory on four implants in the maxilla with the same bridge made of titanium using the Finite Element (FE) method. A special focus was placed on the strain distribution in the bone as an indicator of osseointegration of the implants.

An idealised full-arch bridge (first left molar to first right molar, see Fig. 1) placed on four implants (tioLogic, length 13mm, diameter 4.2mm, Dentaaurum, Germany) was modelled. The model consisted of the bridge with abutments, implants, bone and mucosa. The contact between bone and implant was modelled as not osseointegrated to simulate an immediate loading. To investigate the behaviour on mechanical loading, a load of 400N was applied above one of the posterior implants or equally distributed on all four implants. Simulations were performed with two different framework materials: Pekkton® ivory (4.4GPa), and titanium grade 5 (110GPa).

The simulations with the framework made of Pekkton® ivory showed increased strains in the bone compared with the titanium framework (2000 μ strain and 800 μ strain for the Pekkton® ivory and the titanium framework, respectively, when loading one posterior implant, see Fig. 2 and 3), which was caused by the higher elasticity of the polymer framework. A similar increase could be seen for a load equally distributed on all four implants (Fig. 4 and 5).

While bone strains increased by a factor of roughly 2.5 for the bridge made of Pekkton® ivory, these strains were still within the physiological loading regime of up to 4000 μ strain for the bone. Even with the increased elasticity of the framework material, there was no obvious risk of excessive bone loading.

Conclusion

The studied high performance polymer Pekkton® ivory offers a valid alternative for classical framework materials.



Figure 1: Components of the FE model used in this study. The model of the bone is based on a CT scan, while the surface of the mucosa is based on an optical scan of a plaster cast of the same case. Implants were modelled from CAD data, and the idealised bridge was modelled manually.

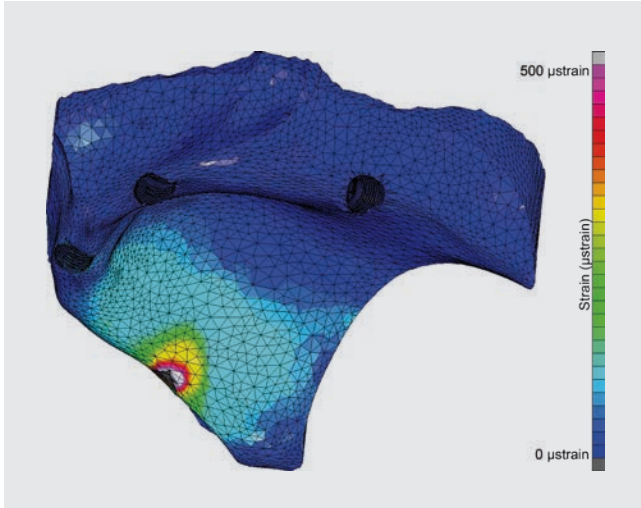


Figure 2: Strain in the bone for the bridge made of Pekkton® ivory with a load of 400 N applied on one posterior implant.

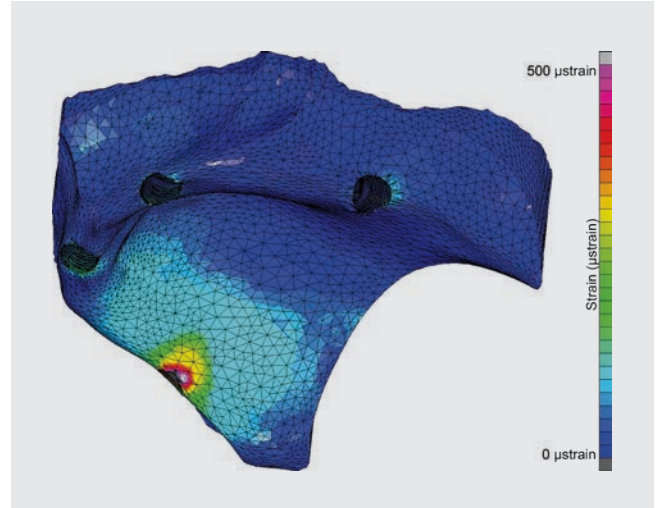


Figure 3: Strain in the bone for the bridge made of titanium with a load of 400 N applied on one posterior implant.

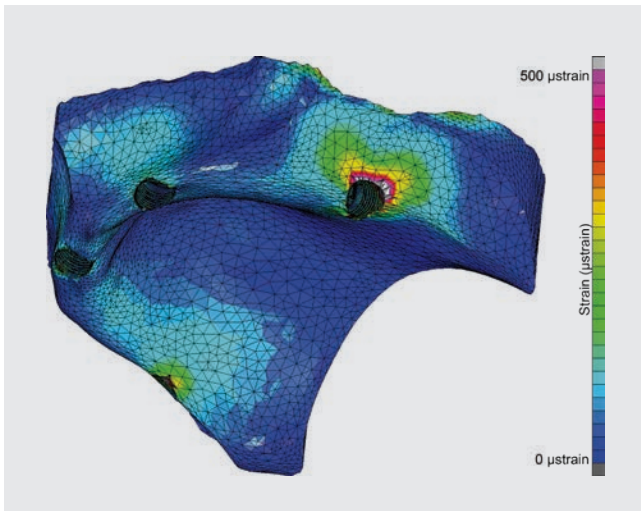


Figure 4: Strain in the bone for the bridge made of Pekkton® ivory with a load of 400 N equally distributed across all four implants.

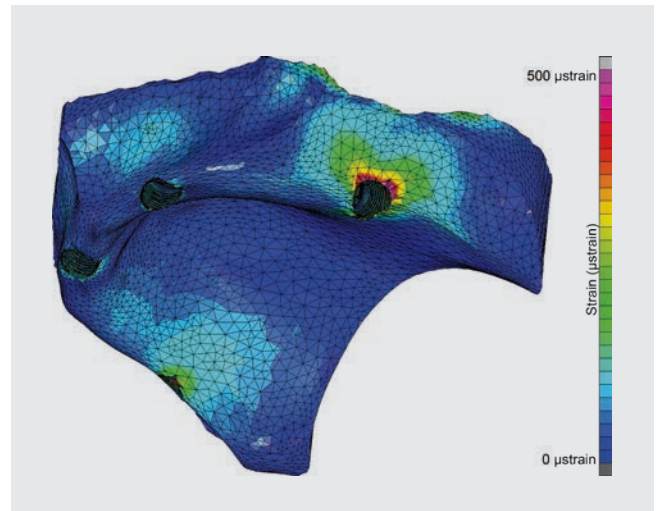


Figure 5: Strain in the bone for the bridge made of titanium with a load of 400 N equally distributed across all four implants.

Dynamic fatigue testing of dental crowns.

Summary

Pekkton® ivory is a novel high performance polymer from the poly-ether-ketone-ketone family for use in dentistry. It was the aim of the presented study to evaluate the fatigue behaviour of crowns made from Pekkton® ivory.

It was decided to perform the tests using a molar crown. To allow a systematic testing of the crowns, identical stumps made from PMMA were used for the crowns instead of natural teeth (see 1). The specimen were embedded in short copper tubes and placed in the specimen holder in a commercial materials testing set-up («Dyna-Mess TP 5kN HF», DYNA-MESS Prüfsystem GmbH, Germany).

As far as applicable, testing environment and parameters for the fatigue testing were taken from EN ISO 14801:2007: Fatigue testing was performed in fluid at a temperature of $37 (\pm 2)^\circ\text{C}$, with a loading frequency of 2 Hz and a total of 2×10^6 loading cycles for each specimen. After preceding static fracture tests, force levels of 600 N to 1200 N in steps of 150 N were tested. Cracks in the veneering and fractures of the crowns were considered as failures.

None of the tested specimens failed for a force level of 600 N. Based on the resulting Wöhler curve, it can be stated that the fatigue limits of Pekkton® ivory crowns in the tested configuration is above 600 N. In similar tests on steel (CoCr) stumps instead of PMMA stumps, a slightly increased fatigue limit of 750 N was determined.

The fatigue limit determined in this study is sufficiently high for the clinical application.



Figure 1: Stump made of PMMA (left), veneered molar crown with Pekkton® ivory framework (centre), and specimen embedded in a short copper tube at the height of the cementoenamel junction (right).

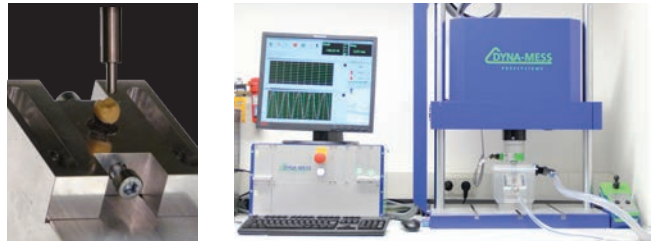


Figure 2: Specimen in the specimen holder; the tip of the thrust die used for loading is located centrally on the occlusal plane (left). Measurement set-up «Dyna-Mess TP 5kN HF» used for fatigue testing (right).

Force level	Successful specimens	Failed specimens (crack / fracture)
1200 N	0	2 (1/1)
1050 N	0	3 (2/1)
900 N	0	3 (2/1)
750 N	2	1 (0/1)
600 N	3	0 (0/0)

Figure 3: Overview on the survival rate for the tested specimens. The numbers in the brackets refer to the number of specimens with cracks and the number of specimens with full fracture, respectively.

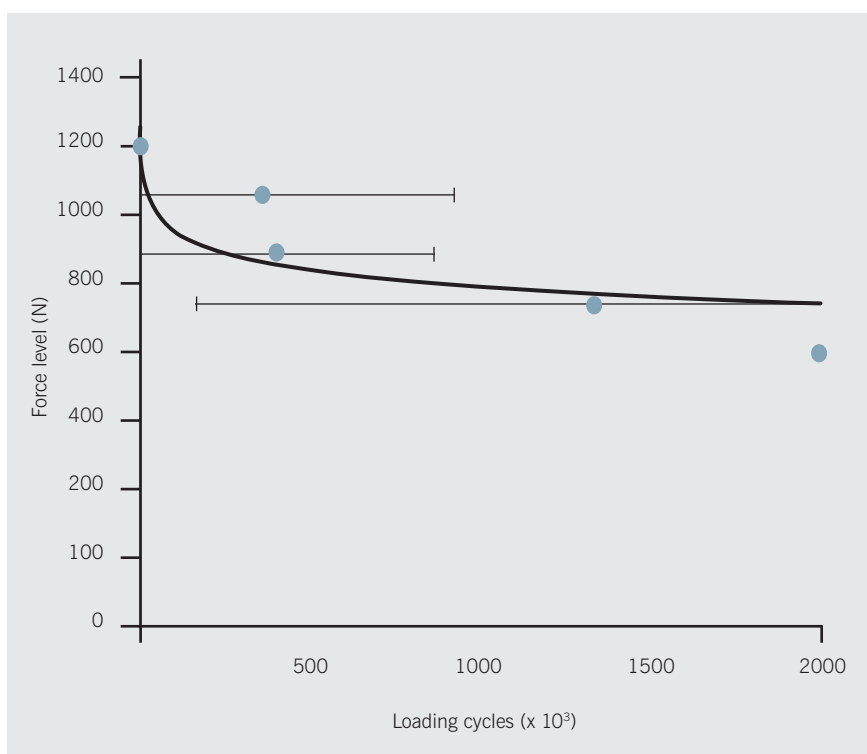
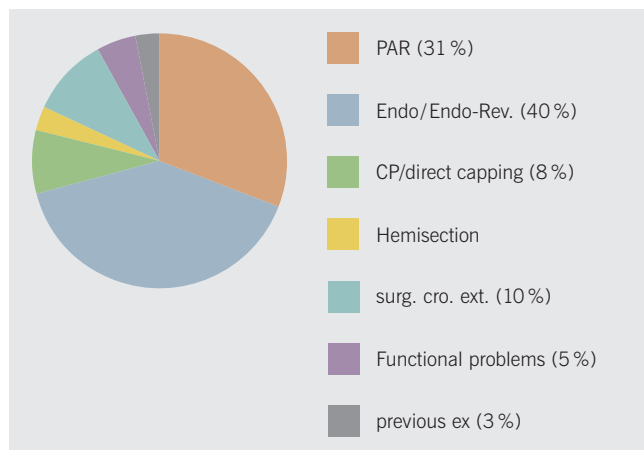


Figure 4: Wöhler curve for the fatigue testing performed.

Pekkton® – A high performance polymer as alternative to conventional dental restorations?

Introduction

In modern dentistry, full ceramic restorations play a significant role. They are distinguished by high aesthetics, biocompatibility, low plaque deposits and lower thermal conductivity when compared with metal-ceramic restorations. So-called high performance polymers could serve as an alternative as they are already in widespread use in medicine due to their good tolerability.



1a

Materials and methods

23 patients at the Centre for Dental, Oral and Maxillo-facial Dentistry at Bonn University, with the indication for long-term temporary restoration (LTTR) prior to final restoration, received individual crowns (n=25) or 3-pontic bridges (n=17) as long-term temporary restorations (Reasons see Fig. 1a). For a period of 3 months each, every patient received a fully veneered resin NEM restoration (Fig. 1c) and a fully veneered resin high performance polymer Pekkton® ivory restoration (Fig. 1b). The temporarily placed LTTRs with Life® (Kerr), were examined during regular check-ups for plaque deposits, vitality, probing depth, loosening, tissue compatibility and wear comfort (OHIP-G 14 questionnaire). After approximately 3 months, the restorations were switched.

Of the 23 patients, 21 could be examined during follow-ups. The evaluation of the plaque index (according to Silness & Løe) at the end of the intraoral retention period of the two framework materials applying the Wilcoxon test, did not result in any significant differences ($p < 0.05$, see 2b and 2c). A comparison of the plaque index (PI) for the initial situation with the respective LTTR restorations also showed no significant difference (see Fig. 2a). If one only compares the plaque index at the respective LTTR restoration, this is not significantly higher for the Pekkton® ivory restorations than for the NEM restorations (Wilcoxon test $p = 0.672$). However, if one compares the plaque deposits of both restoration types with the overall plaque deposit over all teeth, then one observes a significantly higher deposit rate on both types of restorations (Wilcoxon test $p = 0.02$). This is however, largely due to the resin veneering material (see Fig. 2d), as the values for the oral framework garlands were lower than for the measured points of the resin veneers.

Summary

None of the teeth lost their vitality. As many restorations presented with preceding periodontitis treatment as indication prior to final restoration, most of these restorations showed an improvement in probing depths, but never any worsening. Pekkton® ivory restorations are suited for clinical use.

A detailed evaluation of this clinical study will be presented as part of an ongoing dissertation.



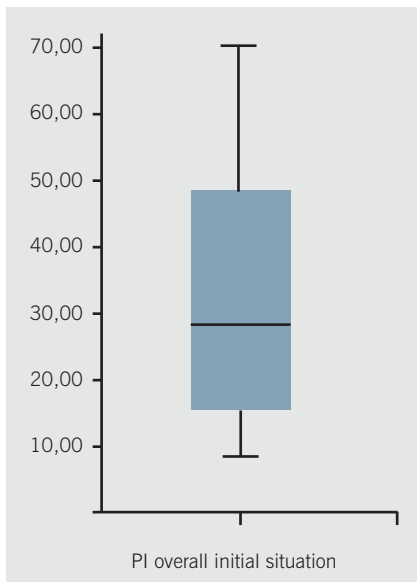
1b



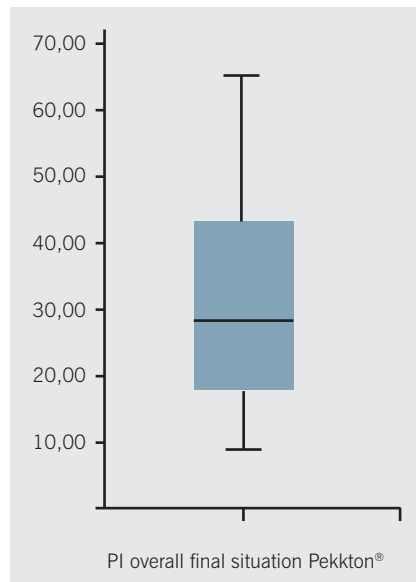
1c



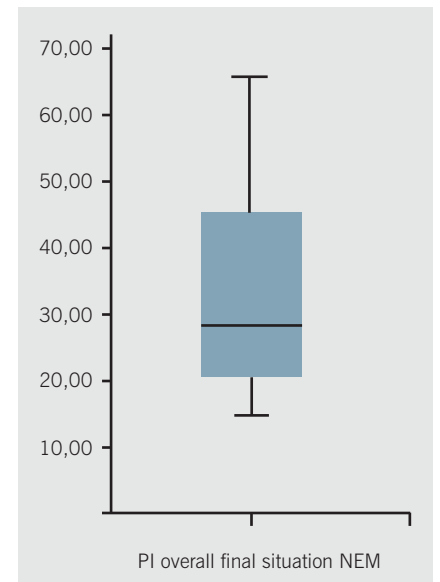
2d



2a



2b



2c

Mechanical conditioning of surfaces in relation to various parameters.

Objective of the test

The quality of the conditioned surfaces of different dental materials (ceramics, metals and PEKK/PEEK) was investigated in relation to blasting pressure, grain size and the distance of the blasting stylus. The surface roughness of the treated surfaces was compared in the process.

Sample preparation

In each case, 10 platelets with an even and polished surface of at least 8 mm diameter and 2 mm thickness were prepared for the study from the different materials. The surfaces to be measured were polished evenly (grain of abrasive paper 800–4000).

Conditioning of the specimens

All specimens were mounted in a special holder at right angles to the outlet of the blasting stylus. The samples were then roughened at two different blasting pressures (1.5 and 2.5 bar), two different distances (5 and 15 mm) and with two different blasting agents (corundum 50 and 110) for 10 seconds each.

Measurements

The blasting time for each measurement was 10 seconds. The specimens were moved to and fro evenly over the sample surface. The sample was mounted to a force sensor (U9A, HBM, Darmstadt) with measuring amplifier (MX840, HBM) so that the force transferred to the sample could be measured continuously. After careful cleaning, the surface roughness (Rz) in the blasting jet was measured with a confocal laser scanning microscope (μ scan, NanoFocus, Oberhausen).

Results

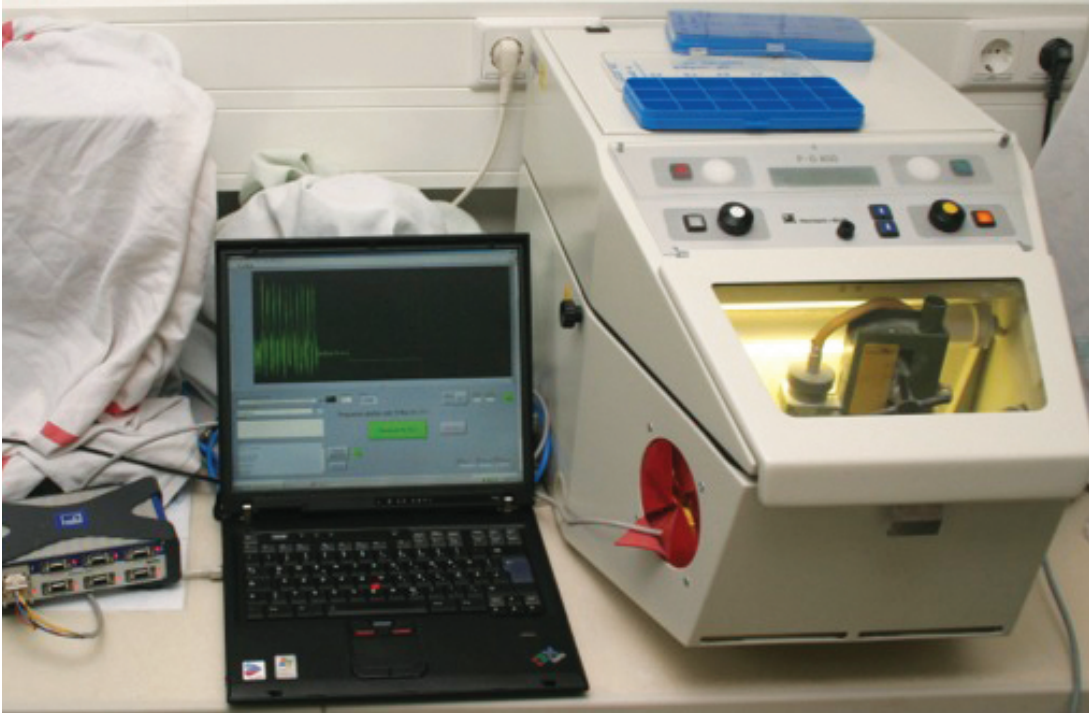
As to be expected, all groups with the larger grain size also demonstrated greater surface roughness. (100 μ m: 14–22 μ m / 50 μ m: 4–13 μ m). The surface roughness of all samples also increased slightly with increased blasting pressure. The blasting distance only appears to have a minor effect on roughness, if at all, whereby the surface roughness increases slightly at increasing distances. However, no differences could be detected in part.

Group	Blasting parameters
a	1,5 bar / 5 mm / 50 μ m
b	1,5 bar / 5 mm / 110 μ m
c	1,5 bar / 15 mm / 50 μ m
d	1,5 bar / 15 mm / 110 μ m
e	2,5 bar / 5 mm / 50 μ m
f	2,5 bar / 5 mm / 50 μ m
g	2,5 bar / 15 mm / 50 μ m
h	2,5 bar / 15 mm / 110 μ m

Finally, it can be concluded that the surface roughness can be adjusted by the grain size in the main, and the blasting pressure as well as the distance of the sample to the blasting stylus only play a subordinate role. This means, the user can adjust the diameter of the blasting spot freely without affecting the result by varying the distance. For the same energy output, the resins abrade quicker than the metals, the ceramics show the least erosion. As the blasting pressure only a slight effect on the achieved roughness, one should work at the lowest possible blasting pressure, as, in the case of ceramics, this avoids the induction of micro-fissures, and for all materials minimizes overall material erosion, in particular for the soft resins.

Conclusions for Pekkton®

To achieve optimal surface roughness with Pekkton® to provide best possible mechanical bonding with minimal erosion, it is recommended to use a grain size of 100 μ m at a low blasting pressure of 2 bar.



Group	Fmax (N)	Rz (μm)
a	0,079 \pm 0,005	7,7 \pm 0,6
b	0,097 \pm 0,001	14,5 \pm 0,8
c	0,087 \pm 0,002	10,1 \pm 1,3
d	0,092 \pm 0,003	15,8 \pm 1,0
e	0,091 \pm 0,003	8,3 \pm 0,6
f	0,161 \pm 0,003	17,2 \pm 1,1
g	0,091 \pm 0,002	10,2 \pm 0,9
h	0,116 \pm 0,005	16,8 \pm 1,5
	PEKK* cristalino	

Bonding strength of established bonding systems to PEKK – Durability and effect of surface conditioning.

Objective of the test

The strength and durability of the Pekkton® ivory bond was investigated for 4 different types of conditioning and adhesive mounting with an established bonding system (Multilink Automix, Ivoclar Vivadent) both initially and after aging through storage in water with simultaneous thermally changing loads.

Sample preparation

In each case, 100 discs with an even and polished surface of 8 mm diameter and at least 3.0 mm thickness were prepared for the study. The variations in pretreatment of the surface included five groups (Figure 1):

The plexiglass tubes filled with composite (Multicore Flow, Ivoclar Vivadent) were glued to the prepared specimens according to the manufacturers instructions. The methodology was an axial tensile test (Kern, M., Thompson, V.P., Dtsch Zahnärztl Z 48, 769-772 (1993)).

Storage/Specimen aging

All specimens were first stored in demineralized water for 3 days at 37°C for complete curing. Then, one third of the samples was immediately tested for bonding, the second third after artificial aging with 10 000 thermal load changes (duration 30 days) and the last third after 37 500 thermal load changes (duration 150 days), all at between 5–55°C.

Results

The adhesion tests showed that silicating with subsequent silanization and priming with a bonding agent on MMA or acrylic resin basis achieved the best bonding forces (Figure 2).

Conclusion

No alternative systems to silicating, silanization or priming were examined.

Taking the existing data into account, the recommendation would be to silicate, silanize and then pretreat the crystalline Pekkton® ivory with a primer. A prolonged exposure time of the primer does not appear necessary here.

Additional approaches to surface activation could still be investigated.

Results

Group	Mechanical	Priming
1. Pre	corundum blasting (2.5 bar / 10 s)	–
2. PrePri	corundum blasting (2.5 bar / 10 s)	Luxatemp Glaze&Bond (20 s exposure time / 20 s light-curing)
3. PrePri+	corundum blasting (2.5 bar / 10 s)	Luxatemp Glaze&Bond (5 min. exposure time in the dark / 20 s light-curing)
4. PrePlus	Rocatec Soft	Monobond Plus
5. PrePlusPri	Rocatec Soft	Monobond Plus, then Luxatemp Glaze&Bond (20 s exposure time / 20 s light-curing)

Figure 1

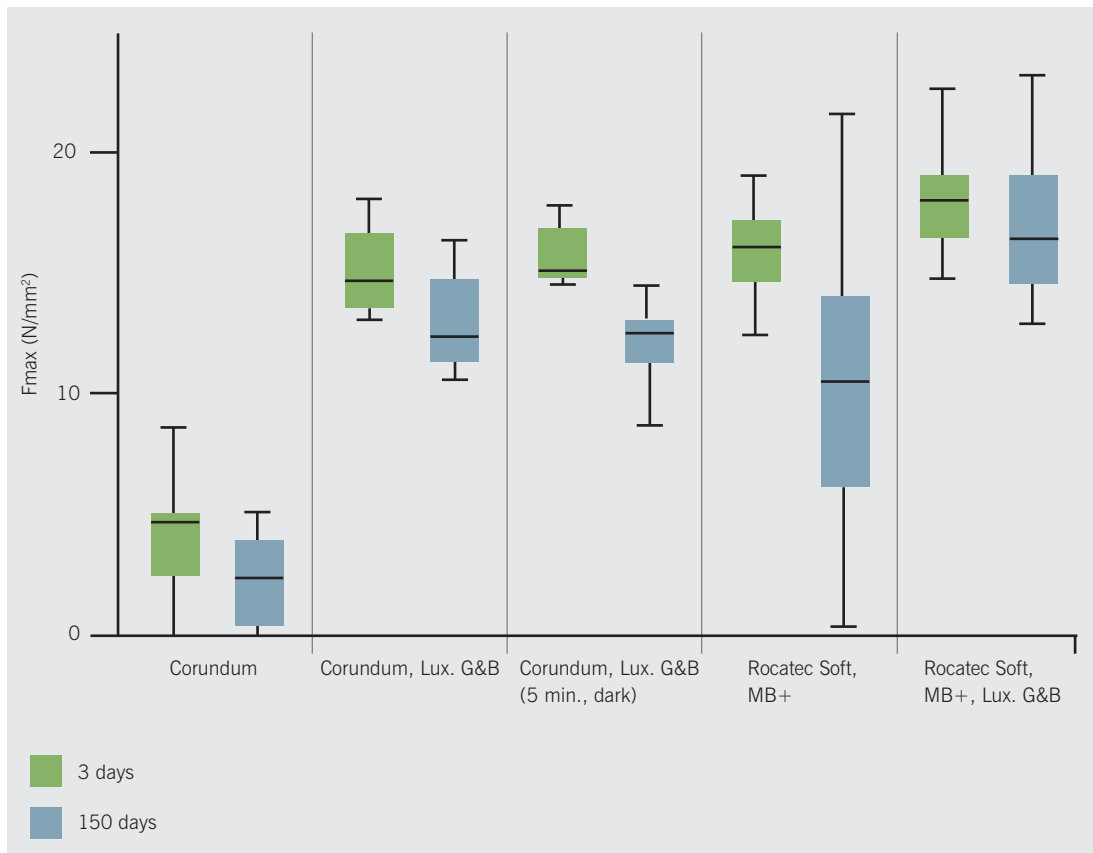


Figure 2

Retention forces and fatigue behavior of clasps made of thermoplastic resins.

Objective of the test

As part of this study, a comparison evaluated the retention forces of clasps, placed as retention elements for removable dentures and made of different thermoplastic resins, with clasps made of an NEM alloy. Special attention was devoted to the diminishing friction forces, in other words, the retention loss for multiple insertion-removal cycles, whereby the load level was selected to correspond with several years of clinical wear.

Sample preparation and test procedure

To keep the comparability of the study as large as possible, two parallel axial sample preparations in standard design were fabricated on artificial teeth for a denture clasp on premolars with the aid of a parallel arm. The undercut was varied between 0.25 mm, which represents the standard, and 0.5 mm. A standard value of 1.4 mm was selected for the strength of the wings for the NEM clasps, and a strength of 2 as well as 3 mm for the resin clasps. These templates were duplicated using the injection molding technique. For the load tests, the prepared sample crowns were formed again and cast in NEM alloy.

The insertion-removal cycles were performed with a Willytec, SDMechatronik, chewing simulator. Recording of the forces during insertion and removal is via force sensors (U9B, Kistler, DE).

A special software was programmed in LabView (National Instruments, DE) to give a complete as possible recording of all cycles. The recording software continuously reads the force signals of all 8 channels at a measuring frequency of 1 kHz, identifies the individual cycles on the basis of pre-defined values for threshold values and hysteresis, and then determines the corresponding maximum and minimum force values for these (Fig. 1).

Dentures are removed and re-inserted approximately four times per day. This corresponds to 1460 to approximately

1500 insertion-removal cycles for one year. If 15,000 cycles are performed in vitro, then this corresponds to approximately 10 years of clinical wear.

Eight specimens were fabricated, measured and evaluated per group. Each material group was divided into 2 subgroups regarding the strength of the clasp arm (2 mm and 3 mm) and these then subdivided again into 2 subgroups regarding the undercut of the preparation (0.25 mm and 0.5 mm). The CoCr-alloy clasps were only fabricated in standardized form in one group for comparison purposes (undercut: 0.25 mm/arm thickness: 1.4 mm).

Discussion

Sato et al.¹ have suggested that a retention force of 5 N is required for the adequate function of dentures with clasps. Frank and Nicholls² demonstrated that 3–7.5 N represent acceptable retention strength for bilateral free-end dentures. The results of this study show that clasps made of thermoplastic resins demonstrate a mean retention strength of 1.7–3.7 N for the 1.0 mm thick clasps, 5.4 to 10.8 N for the 1.5 mm thick clasps, and can thus achieve sufficient retention for removable dentures (Fig. 2). As also shown in this study, earlier studies on the fatigue strength of CoCr clasps have demonstrated a partially significant retention loss due to the permanent deformation of the metal (Fig. 3). The results of this study demonstrate no significant difference between the initial and the final retention values after 15 000 cycles for clasps made of thermoplastic resins.

Conclusion

Within the limitations of this study, it was determined that the thermoplastic high performance polymer clasps demonstrate significantly lower retention strength after 15 000 insertion-removal cycles than CoCr clasps, but proved to be relatively stable over the duration of the cycles and can therefore prove to be adequate for clinical use.

Excerpts from results

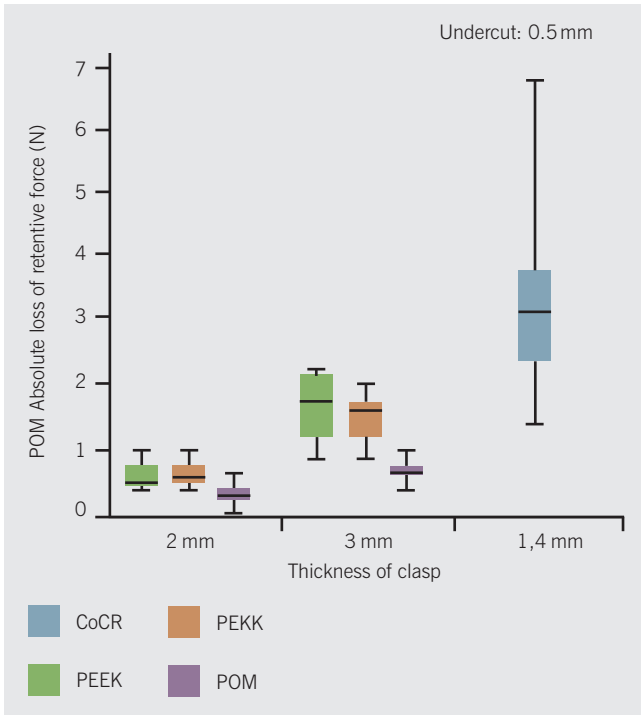


Fig. 1

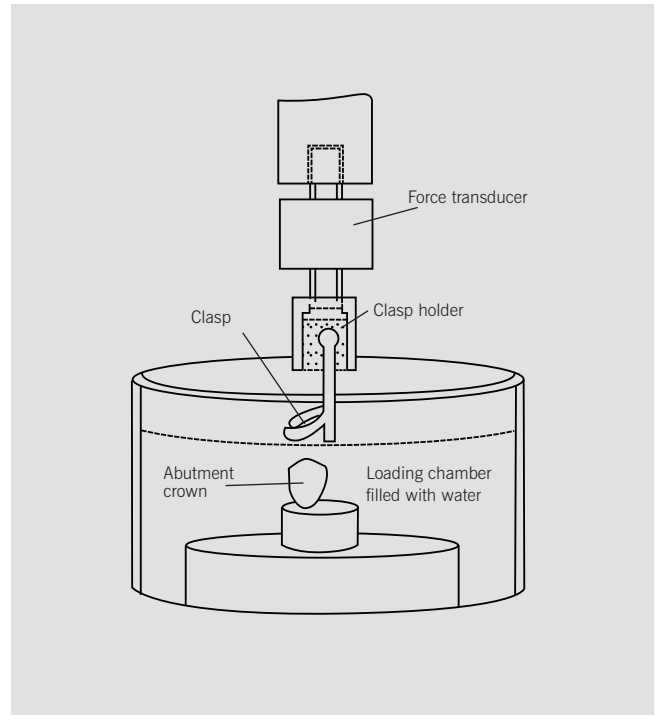


Fig. 2

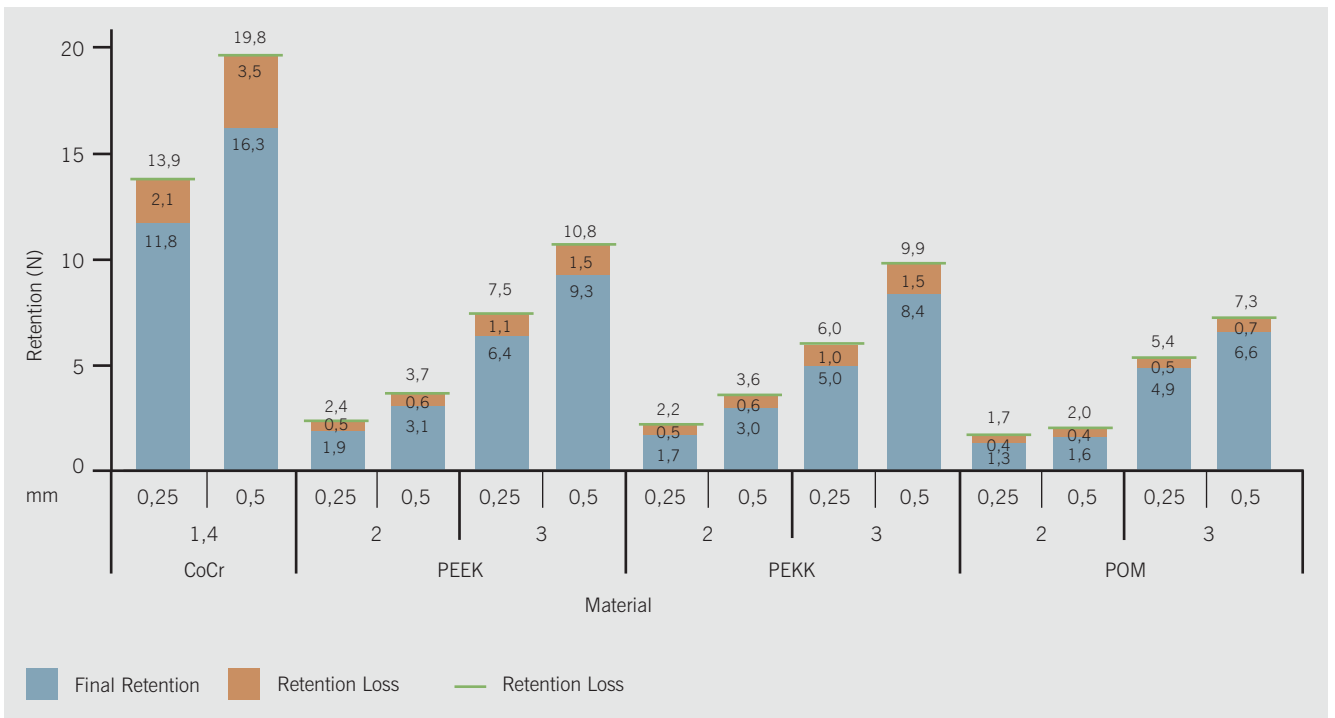


Fig. 3

1 Sato Y, Tsuga K, Abe Y, Asahara S, Akagawa Y. Analysis of stiffness and stress in I-bar clasps. J Oral Rehabil 2001;28:596-600.

2 Frank RP, Nicholls JI. A study of the flexibility of wrought wire clasps. J Prosthet Dent 1981;45:259-67.

Optical properties.

Objectives

To evaluate the spectral reflectance and colour of Pekkton® ivory (PK) as a material used for fabricating indirect restorations when veneered with light cured composite (LC) in comparison with equivalent zirconia-composite (YZ-LC) and zirconia-dental porcelain (YZ-DP) systems to assess the effect of different substructure materials on the same veneering material.

Methods

A spectrophotometer (CM-2600d Konica Minolta Sensing, Inc., Japan) was used to determine the spectral reflectance of each material over white and black backgrounds using a D65 illuminant. CIE L*a*b* colour coordinates and colour difference (ΔE) were determined from the reflectance data.

Samples of substructure materials Pekkton® Ivory and In-Ceram® YZ (Vita Zahnfabrik) and veneering materials LC and DP (VM9, Vita Zahnfabrik) were produced (n=3) at 1.0mm thickness as single layered samples. Bi-layer samples (n=3) were produced using veneering and substructure materials of equivalent shade to 1.3 mm thick (clinical recommendation 0.8 mm for substructure and 0.5 mm for the veneer).

Each group consisted of three samples (n=3) wide enough to cover the spectrophotometer's target mask opening of 3 mm. All specimens were polished under running water using waterproof SiC abrasive paper P400 and P800 respectively in a rotating disc polisher (Metaserv Buehler, UK).

Conclusion

Having a different substructure material did not cause any significant difference in optical properties between both Pekkton® ivory-composite and zirconia-composite groups.

Results

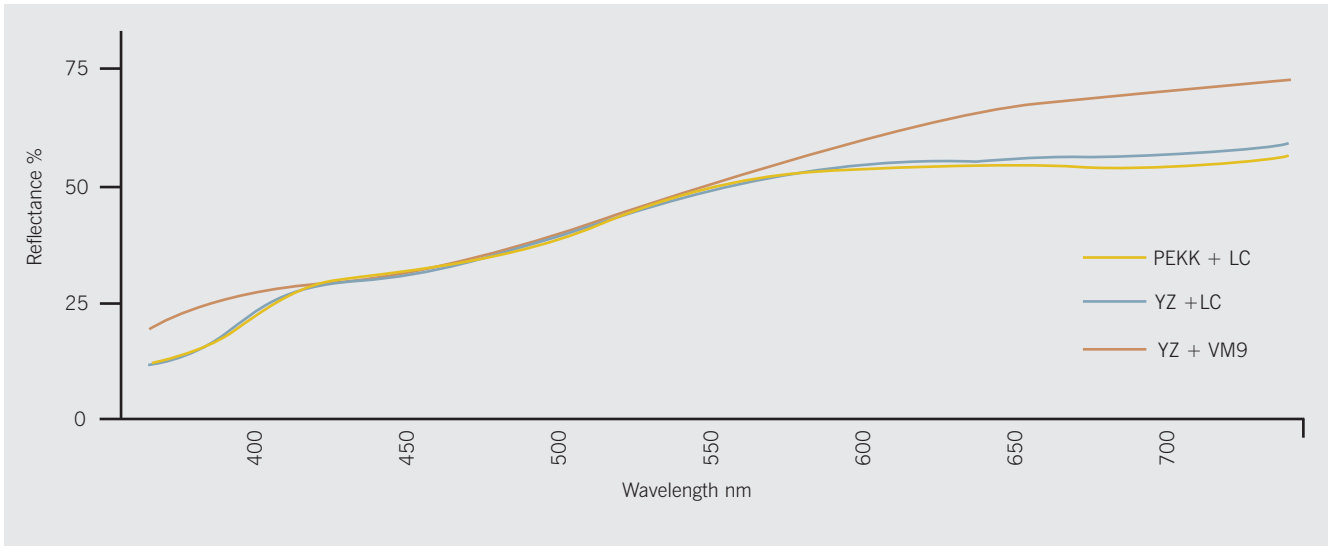


Figure 1: Spectral reflectance data curve of the laminate samples under white background

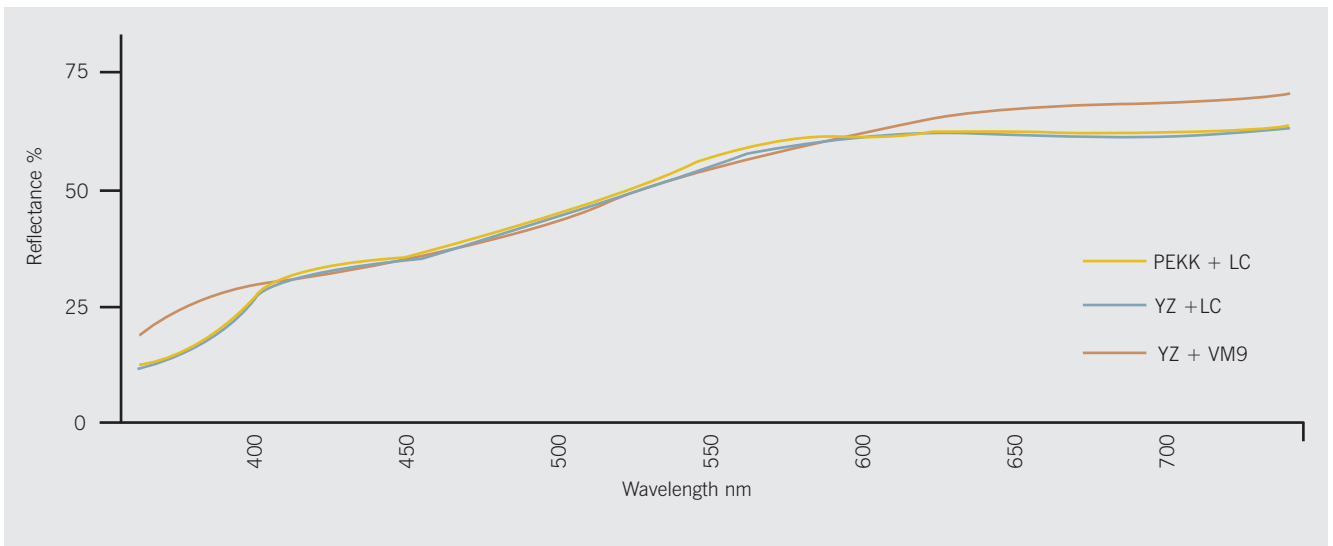


Figure 2: Spectral reflectance data curve of the laminate samples under black background

Material	L*		a*		b*	
	Black	White	Black	White	Black	White
PK-LC	74,26 ^a	74,51 ^a	2,29 ^a	2,31 ^a	17,83 ^a	17,81 ^a
YZ-LC	74,10 ^a	74,67 ^a	2,40 ^a	3,17 ^a	18,65 ^a	19,21 ^a
YZ-DM	73,99 ^a	76,40 ^a	3,85 ^a	6,15 ^a	18,12 ^a	21,64 ^a

Table 1: CIE L*a*b* values of the laminate samples under black and white background*.

* Groups with different superscript letters indicate significant differences ($P < 0.05$) and groups with same superscript letters indicate no significant difference ($P > 0.05$).

Water sorption and solubility.

Objective

According to ISO 4049-2009 standard, water sorption should not exceed $32\mu\text{g}/\text{mm}^3$ for heat-cured or self-cured materials. The loss in mass per unit volume (soluble material) should not exceed $1.6\mu\text{g}/\text{mm}^3$ for heat-cured and $8.0\mu\text{g}/\text{mm}^3$ for self-cured materials. The objective of the test is to determine and compare water sorption and solubility of Pekkton[®] ivory according to this standard.

Materials and method

Water sorption and solubility tests were performed according to ISO 4049-2009 standard.

Specimen disks were dried using two desiccators system cycle, one maintained at $37\pm 2^\circ\text{C}$ and the other maintained at $23\pm 2^\circ\text{C}$.

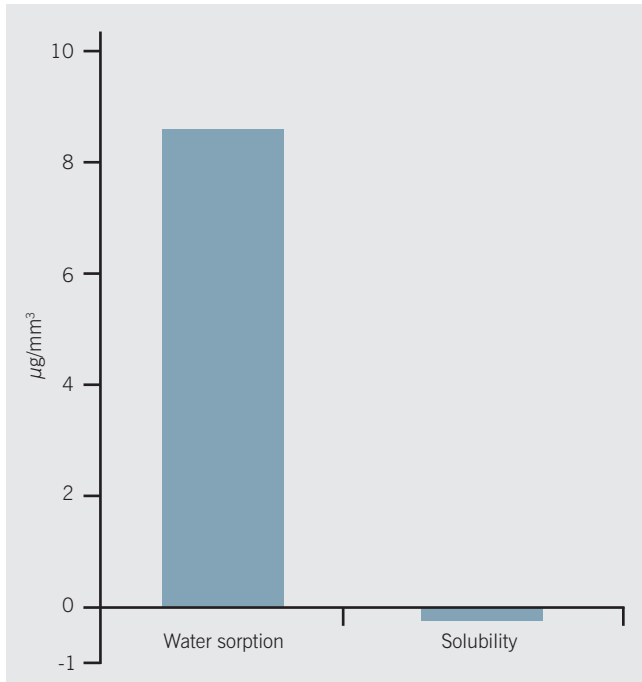
There were six (6) parallel specimens per group. Specimens were weighted and then placed in 37°C desiccator for 22h. After 22h, the specimens were removed and stored in the other desiccator for 2 hours and then reweighted with accuracy of 0.1 mg. This cycle was repeated until the constant mass was obtained, i.e. until the mass loss of each specimen was not more than 0.1 mg at any time point in 24h period (two-desiccator system). After final drying the diameter of the specimens were measured at two locations with an accuracy of 0.01 mm and the mean diameter was calculated. Thickness of the specimens was measured at the centre of the specimen at four equally spaced points on the circumference, to an accuracy of 0.01 mm. Specimens were immersed in water (10ml/specimen) at 37°C for 7 days. After 7 days specimens were removed from water. Before weighting, the specimens were water cleaned, excess water was blot away until specimen was free from any visible water and sample was waved in the air for 15 seconds. The weight of the specimens was measured 1 minute after removal from the water. After weighing the specimens were reconditioned to constant mass using the two-desiccator system cycle again.

Conclusion

Pekkton[®] ivory met the corresponding requirement of ISO 4049 with substantial low values.



Results



	Weight (%)	$\mu\text{g}/\text{mm}^3$
Water sorption	0.59	8.7
Solubility	0.17	-0.2

Clinical cases.

Complete bridge on implants (1).

Restoring a fully edentulous arch by utilising modern materials and traditional techniques.



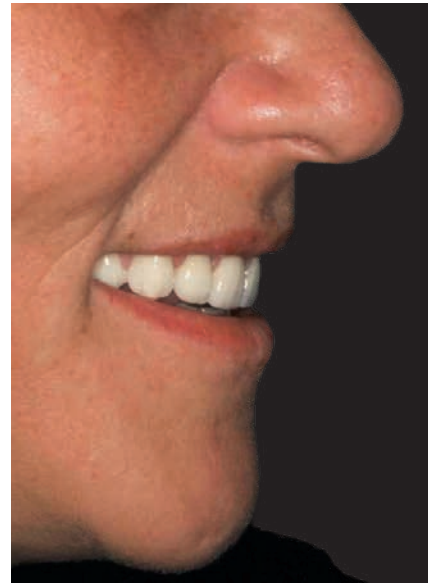
Background

This patient presented after she had lost all her upper teeth due to advanced untreated periodontal disease. After the condition was treated and a good standard of oral health had been re-established, the treating clinician then had a removable prosthesis manufactured. While this approach was successful, something was missing. Most patients struggle with the transition from being dentate to becoming edentulous and our patient was no different. As well as the lack of fixation and stability of the denture, the patient also found life with a plastic palate «uncomfortable». Along side these functional issues, the patient also felt that while the shade of the teeth was «ok», everything else about the denture was «just not right».

The next stage of the patients rehabilitation was for 6 implants to be placed in the maxilla. After all the usual and extremely important planning stages had been completed, it was then time for the important trial smile evaluation. The new set up gives better lip support resulting in a revitalised aesthetic appearance in both facial and profile views. The larger teeth also fit the patients face much better and the repositioning of the teeth now gives a more youthful appearance. Finally the

new vertical dimension was established to give correct facial form and function. At this point, we entered a discussion with the whole team including the patient on the materials we would use to construct the final prosthesis.

Important aspects were: The feel of the restorations, the aesthetics, youthful & bright and overall symmetry (cosmetic). After looking at the options, we decided that this would be a perfect case for Pekkton® ivory.



We had been working with various polymers for many years on similar cases and had perfected a technique to integrate polymers, ceramic & composites all in one prosthesis which we called the BDT bridge. We had a detailed discussion with the whole team on why we should apply this technique the main driving force was the properties of polymers Pekkton® ivory in particular is extremely well suited for this type of application.

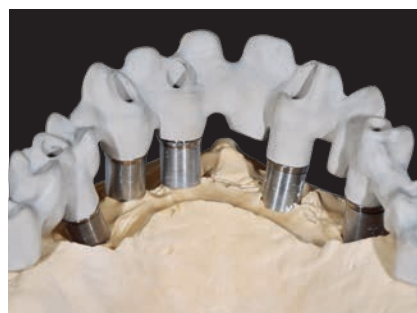
Conclusion

Pekkton® ivory frameworks provide the patient with a lightweight aesthetic and extremely strong restoration that offers a shock absorbing property not found in traditional implant restorative materials.

Clinical cases.

Complete bridge on implants (2).

Screw-retained reconstruction on 5 implants, limited removability, with a bridge framework in Pekkton® ivory.



Initial situation

The 61-year old female patient was no longer satisfied with the existing partial dentures and wished for new restoration. The entire remaining teeth presented with secondary caries and was afflicted with medium chronic periodontitis. The mandible presented with a highly restored, caries-free dentition. The prognosis for the remaining teeth in the maxilla was poor.

The existing model cast denture was insufficient, both functionally and aesthetically. The treatment plan included extraction of the maxillary teeth and the direct conversion of the existing partial denture into a complete immediate denture. Implants with a permanent, limited removable restoration were planned subsequently.



Discussion

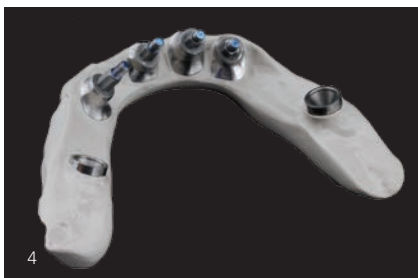
Extensive, implant-supported bridges (so-called «full-arch-implant-prostheses») are fabricated with metal frameworks (precious metal, CoCr or titanium) and ceramic (VMK-bridges), recently also with zirconium. The fabrication of such bridges with high performance polymers such as Pekkton® ivory is on the fore and being discussed increasingly. The material advantages of Pekkton® ivory include minimal flexibility (thus adaptable), good resistance and very easy polishing of the material. The aesthetic options are also excellent. The costs for a Pekkton® ivory reconstruction are considerably more favorable (approximately 35 % less expensive) when compared with veneered work on metal or zirconium oxide frameworks. And this at higher value creation in my laboratory.

Conclusion

The implant-supported bridges made of Pekkton® ivory are of high aesthetic quality, with a very attractive price, and therefore promising for the future. The Pekkton® ivory restorations are checked regularly in the dental practice. The good condition after prolonged wear is remarkable. Long-term prognoses can be positive with average oral hygiene. The reason is probably given by the low elasticity of the bridge construction, the good properties of the veneering materials and the passive fit through bonding of the abutments.

Clinical cases.

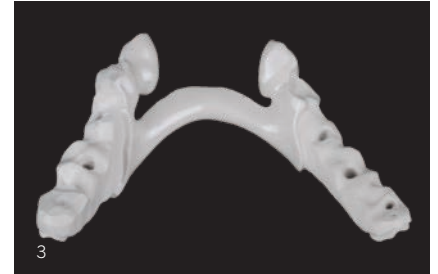
Implant-supported, screw-retained reconstruction in maxilla and mandible.



- 1 Initial situation: implants with individually milled implant abutments
- 2 Negative situation of tooth set-up
- 3–4 The finished milling result of the Pekkton® ivory framework for the maxillary restoration
- 5 Application of the prefabricated teeth to the Pekkton® ivory framework using tooth-colored resin, without opaquing of the framework
- 6 Completed work with pink resin (without pink opaquer)
- 7 Detailed view of the maxillary work
- 8–9 Work in situ

Clinical cases.

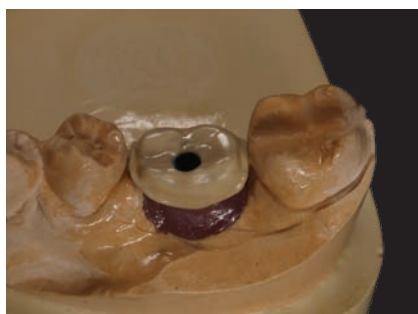
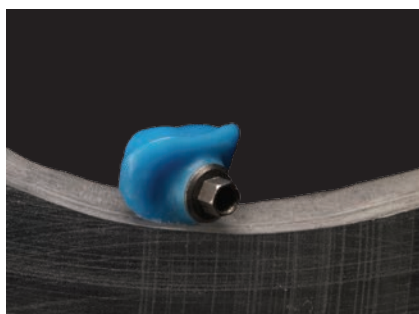
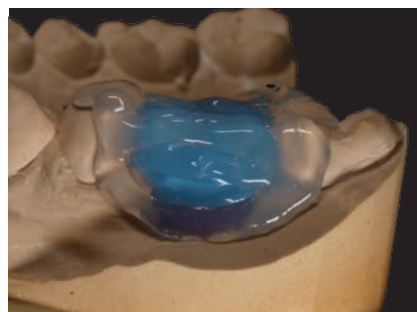
Mandibular telescopic prosthesis with sublingual bracket.



- 1 Initial situation with the milled zirconium inner copings
- 2 The Pekkton® ivory milling result. The inner copings were scanned with the tactile DS10 Renishaw scanner and overall with the Zirkozahn S600-ARTI scanner
- 3 The final polished Pekkton® ivory framework
- 4-5 The completed work
- 6-9 Work in situ

Clinical cases.

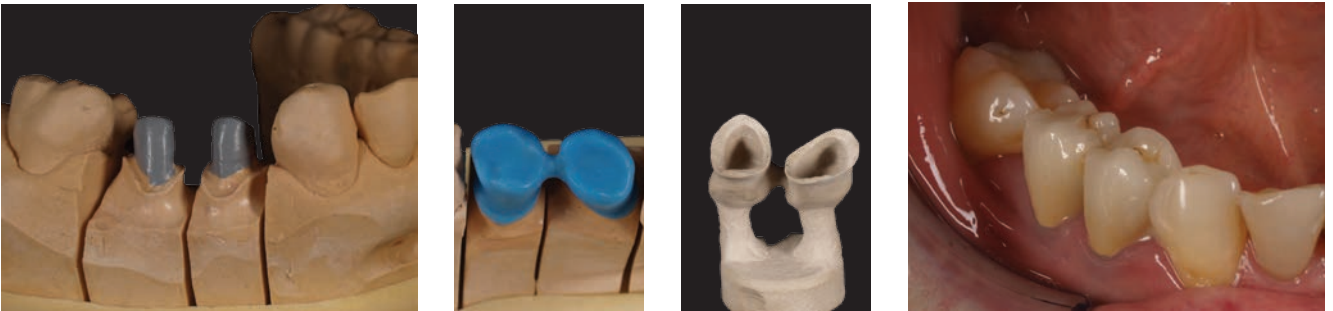
Molar crown screwed on an implant.



The practitioner decided that a patient, aged approx. 50 years, should undergo a stage of temporary treatment of several months prior to implementation of the final restoration. We therefore opted for a Pekkton® ivory restoration on an implant with a metal base.

Clinical cases.

Two premolars together on natural teeth.



60-year-old patient for whom Pekkton® ivory restorations were selected due to their absorbent properties as this is a fully antagonist bridge.

Clinical cases.

Crown restorations on natural teeth.

Background and objectives of treatment

The 39-year old female patient presented in our polyclinic with the wish for renewal of her prosthetic restorations on teeth 17, 16, 15 as well as 46 and 47 following expert assessment. Since integration of the crowns alio loco, discomfort was present at the teeth and surrounding gingiva. Clinically, the gingiva was slightly reddened. Functional findings were inconspicuous.

Medical history and findings

The X-ray showed apical brightening of teeth 46 and 47. The determined periodontal status resulted in a maximum probing depth of 5 mm and a furcation grade I for tooth 17, also 5 mm for the 16 and a furcation grade II, 4 mm for the 15, and 5 mm and grade I for the 46 and 4 mm and grade I for the 47.

Treatment plan

First, teeth 46 and 47 were treated endodontically. The existing crowns were removed and all 5 teeth restored with Pekkton® ivory as well as NEM as part of a clinical study with long-term temporary dentures. Endo-recall and repeated periodontal re-evaluation were conducted after 6 months. The patient was free of complaints after 6 months.

Comments and conclusion

In the above mentioned study, no significant differences were observed with regard to the subjective oral hygiene-related quality of life (OHIP-G 14) when wearing NEM or Pekkton® ivory long-term temporary restorations. For the female patient presented here, the subjective wear feeling was better for the Pekkton® ivory restoration.

In principle, it can be stated that the Pekkton® ivory restorations appear to be suited for clinical use.

Description of figures

- a: Situation maxilla at initial presentation
- b: Situation mandible at initial presentation
- c: Situation maxilla/mandible at initial presentation
- d: X-ray initial situation 46, 47
- e: Pekkton® ivory framework on model
- f: Finished veneered Pekkton® ivory crowns
- g: integrated Pekkton® ivory long-term temporary restorations
- h: X-ray endo-recall after 6 months 46, 47



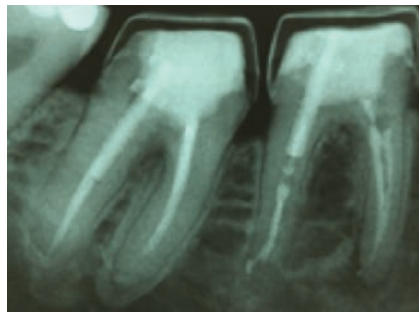
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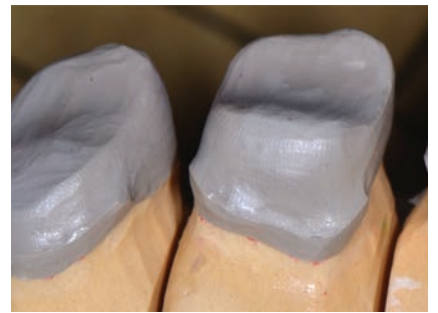
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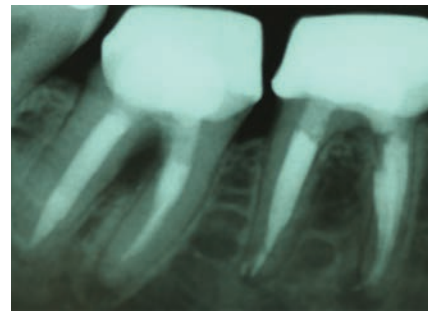
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



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Glossary.

Amorphous		In the amorphous form the macromolecules of Pekkton® are entangled, similar to a disorganized ball of thread.
Aromatic ring		An hydrocarbon chain with alternating double and single chemical bonds between carbon atoms forming rings.
Aryl		The term aryl refers to any functional chemical group or substituent derived from an aromatic ring.
Chemical Functional Group		A functional entity consisting of certain atoms whose presence provides a certain property to a molecule.
Compounding		Blending and/or mixing polymers with additives in a molten state.
Crystalline		In the crystalline form the macromolecules of Pekkton® comprise linear carbon chains which are unbranched or show minimal branching. They are joined together by weak physical bonds. These bonding forces are more effective when the carbon chains are arranged in parallel. The crystalline material is chemically more resistant and stiffer.
Ether		Chemical group with the structure, where R and R' are alkyl or aryl groups.
Glass Transition Temperature		This temperature called T _g refers to a reversible transition in amorphous materials or more generally in amorphous regions within semicrystalline polymers from relatively brittle state into a more rubber-like state.
Ketone		Chemical group with the structure, where R and R' can be a variety of carbon-containing substituents.
Macromolecule		A very large molecule created by polymerization of smaller subunits. The individual constituent molecules of polymeric macromolecules are monomers.
Melting Temperature (T _m)		The temperature at which a substance changes from solid to liquid state.
Molecule		An electrically neutral group of two or more atoms held together by chemical bonds.
Monomer		A molecule that may bind chemically to other molecules to form a macromolecule.

PAEK	refers to the family name of PolyArylEtherKetone polymers. PAEK are commonly described in terms of an «E» and a «K» which means the sequence of ether and ketone group units in the structure of the polymer. Today the most common PAEK are polyetheretherketone (PEEK) and polyetherketoneketone (PEKK). Others polymers like polyetherketone (PEK), polyetherketoneetherketoneketone (PEKEKK),... also exist.
PEEK	PolyEtherEtherKetone
PEKK	PolyEtherKetoneKetone
Pekkton®	Trademark of our exclusive PEKK based materials solution for dental applications.
Pekkton® ivory	Trademark of our exclusive PEKK based material for fixed restorations (crowns and bridges) and removable dental prosthesis.
Polymer	A polymer is composed of a large number of macromolecules.
Polymerization	A process of reacting monomer molecules together in a chemical reaction to form polymer chains.
Thermoplastic	A polymer which can be shaped above a specific temperature T_m and solidifies upon cooling. Thermoplastic polymers are commonly produced in pellets and shaped into their final product form by melting and pressing or injection molding. Unlike thermoset polymers, Thermoplastics differ from thermosetting polymers, which form irreversible chemical bonds during the curing process.
Thermoset	A polymer that irreversibly cures. The cure may be induced by through different ways, heat, chemical reaction or suitable irradiation. Thermoset materials are usually liquid prior to curing and designed to be molded into their final form. Once cured or hardened a thermoset cannot be reheated and melted to be reshaped. Thermosets do not melt, but decompose and do not reform upon cooling.

Product portfolio.

Image	Description	Cat. No.
	Pekkton® ivory milling blank Ø 98.5/16 mm (with steps)	01060011
	Pekkton® ivory milling blank Ø 98.5/20 mm (with steps)	01060020
	Pekkton® ivory milling blank Ø 98.5/24 mm (with steps)	01060022
	Pekkton® ivory milling blank Ø 95/16 mm (compatible with Zirkonzahn®)	01060028
	Pekkton® ivory milling blank Ø 95/20 mm (compatible with Zirkonzahn®)	01060030
	Pekkton® ivory milling blank Ø 95/24 mm (compatible with Zirkonzahn®)	01060032
	Pekkton® ivory – press ingots / 10 p.	01060003
	Disposable press-stamp (Ø 12 mm)/50 p.	08000626
	Disposable press-stamp (Ø 26 mm)/20 p.	08000627
	PEKKpress muffle former set 200 g	08000628
	PEKKpress muffle former set 600 g	08000629
	CM-20 investment (50 x 160 g)	083872
	Liquid 1L	083739
	PEKKpress – pressing unit	70202393
	PEKKtherm – temperature stabilisation and melting furnace	70202394

The most current overview of available blank shapes and thicknesses can be called up on our homepage www.pekkton.com.

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14. Keilig L., Stark H., Bourauel C.: Biomechanics of Three- and Four-Unit-Bridges Made of Different Framework Materials – A Numerical Study. EAO 2014, Rom.
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Clinical cases by different authors can be viewed on our website www.cmsa.ch/en/dental/products/Highperformancepolymer

