



**Collection of scientific studies on denture acrylics,
teeth and devices.**

Giving a hand to oral health.



KULZER
MITSUI CHEMICALS GROUP

Collection of scientific studies

Pala stands for high-quality artificial teeth, denture acrylics, materials and first-class accessories in dental prosthetics. The Pala process chain includes all products from model analysis through the preparation of prosthetics with denture acrylics and the selection of denture teeth right up to transport. Studies confirm the high quality of the materials and their wide range of functional and aesthetic benefits.

High plaque resistance and colour stability

= facilitate good hygiene & long-lasting aesthetics



High fracture strength

= long life



Low abrasion

= less wear



Reliable adhesive bond

= long life



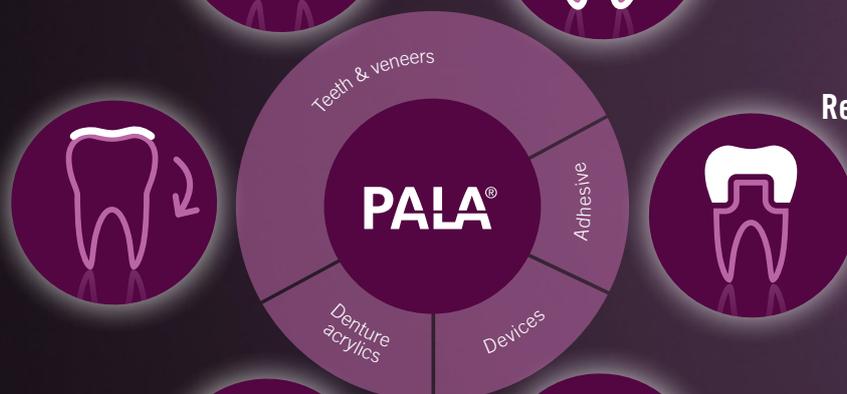
Minor dorsal marginal gaps

= high fitting accuracy



High implementation precision

= precise implementation of the occlusal conditions

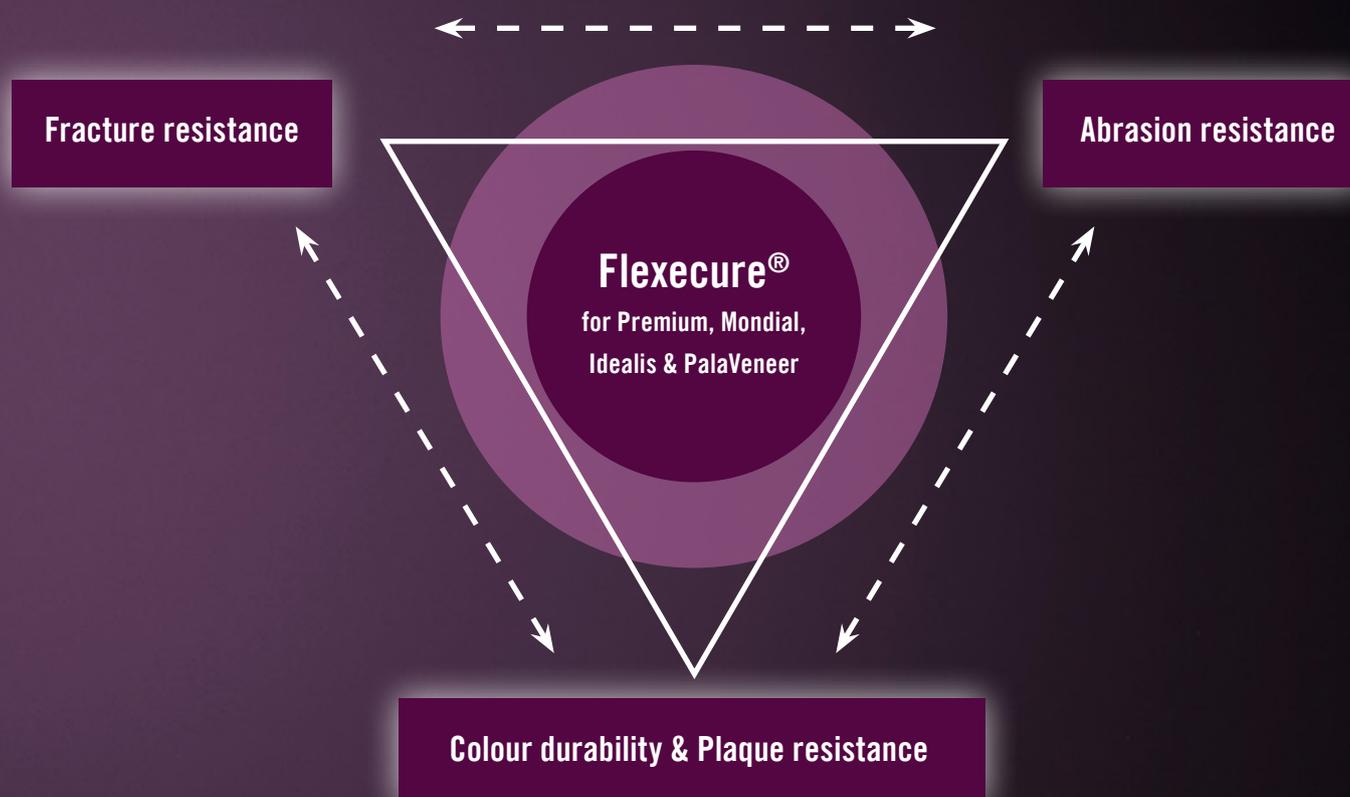


Advantages in balance

The MRT (Material Requirement Triangle) contains the most important properties of artificial teeth: fracture resistance, abrasion resistance, colour durability and plaque resistance.

In principle, every material class should meet all the requirements indicated below optimally. But caution is required: some of the values are diametrically opposed. Thus, increased abrasion and plaque resistance is often accompanied by reduced fracture resistance.

It is therefore about getting the right balance. Pala teeth are outstanding due to their low wear values and maximum fracture resistance (see p. 4 and 5) – advantages in balance for long-lasting and aesthetic restoration results.





Fracture resistance – UKR Regensburg

Dental implants are frequently used to restore oral function and aesthetics. Patients often wish to have an aesthetic temporary restoration already during the implant healing phase. The use of prefabricated artificial teeth may be a simple and cost-effective option for temporary implant restoration.

In the following in-vitro study, wear and fracture resistance of five different artificial teeth lines was investigated in this regard. The study results indicate that prefabricated artificial teeth may be used for temporary implant restoration. Highest values of fracture resistance were measured for Pala Idealis 8 tooth line.

Wear and fracture resistance of artificial teeth on implants

Objective

Aim of the *in-vitro* investigation was to analyse wear and fracture resistance of 5 different artificial teeth lines luted on titanium implant abutments.

Materials and Methods

After appropriate preparation, the upper molars of five different artificial teeth lines were definitively luted onto implant dummies (n = 16). Using a steatite ball as an antagonist, 8 test specimens of each artificial teeth line were subjected to thermocycling and mechanical loading (1,800 cycles 5° C/55° C, every 2 mins, 720,000 x 50 N) in the Regensburg chewing simulator. The fracture resistance of the artificial teeth was determined before and after chewing simulation using a Zwick universal testing machine. Wear of the artificial teeth was assessed visually after chewing simulation.

Results & Conclusion

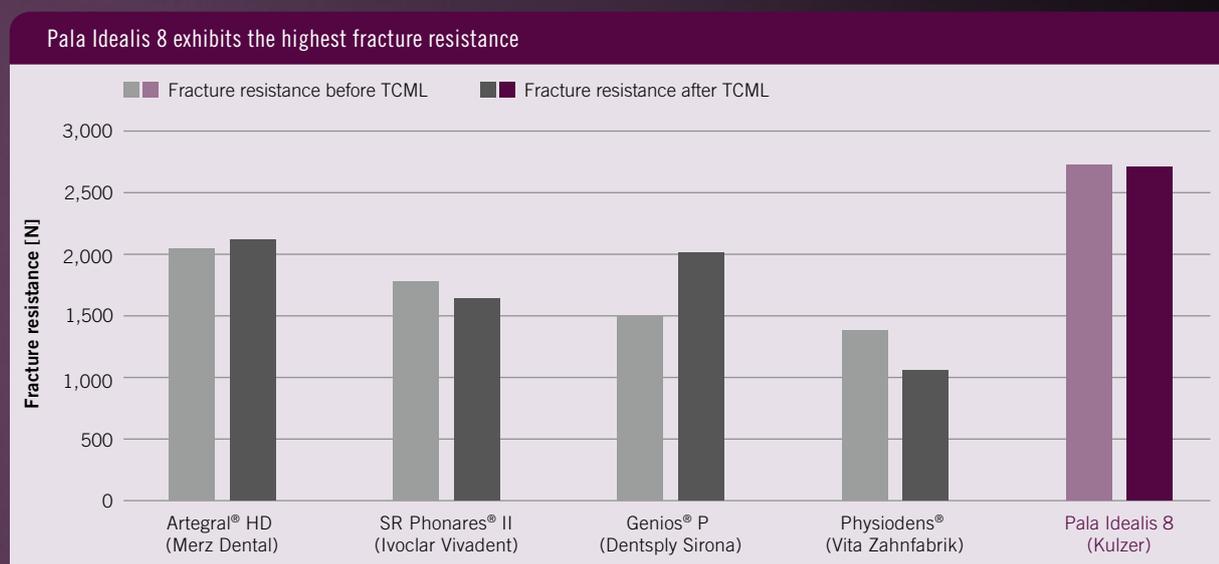


Fig. 1: Median dental prosthetic fracture resistance before and after thermocycling and mechanical loading (TCML).

Visually, all artificial teeth demonstrated comparable signs of wear. All teeth lines tested during the *in-vitro* fracture resistance investigation yielded values that met the requirements for the masticatory region. Highest values of fracture resistance were measured for Pala Idealis 8 artificial teeth line, both before and after thermomechanical loading (Fig. 1). The results obtained indicate that prefabricated artificial teeth may be used for temporary implant restoration.

Source

In-vitro study of wear and fracture resistance of artificial teeth on implants.
Lang R, Schießl D, Quintessenz Zahntech [Pragmatic Dental Tech] 2018;44(11):1502-07.

Fracture toughness – University of Erlangen-Nuremberg Residual monomer content

In everyday life, dentures are exposed to considerable stress and not seldom fracture-endangered. To reduce the fracture susceptibility of dentures, denture base materials with improved impact strength, known as “high-impact” materials, were developed. However, during the fabrication of a denture, unreacted monomers usually remain in the acrylic as residual monomers and can adversely affect both the mechanical properties and the biocompatibility of a denture. So far, heat-curing polymers have always been associated with a lower residual monomer content than cold-curing polymers. Meanwhile on the market available modern auto-polymerizing acrylics and not only can keep up with heat-curing polymers in terms of their mechanical properties, but also have reduced residual monomer content.

The present in-vitro investigations confirm PalaXtreme “high impact” properties and a particularly low residual monomer content.



Fracture toughness measurement of denture acrylics

Objective

Aim of the in-vitro study was the examination of fracture toughness and fracture work of four different cold-curing denture base materials.

Materials & Method

Standardized specimens (n=15) were fabricated from four different denture base materials (two conventional, two so-called high-impact materials) and a defined central notch was introduced into each specimen. Three-point bending testing was carried out with the universal testing machine at a crosshead speed of 1 mm/min. Fracture toughness and work of fracture were calculated according to ISO 20795. Fracture toughness describes the ability of a material to withstand crack propagation. Work of fracture represents the energy needed to fracture a specimen.

Results & Conclusion

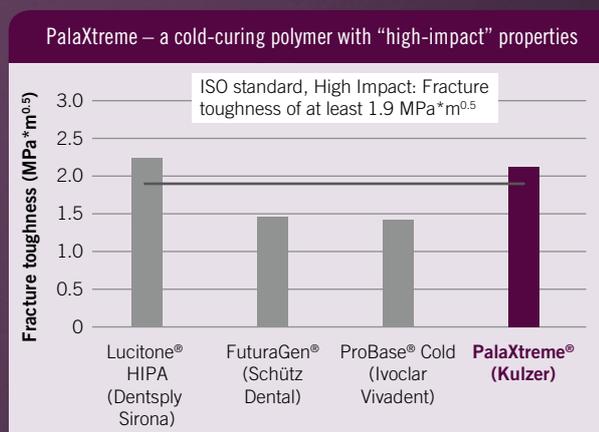


Fig. 1: Average fracture toughness [MPa*m^{0.5}] of the denture base materials tested.

The two cold-curing denture base materials Lucitone HIPA and PalaXtreme meet the ISO standard requirements concerning fracture toughness (fig. 1) and work of fracture for materials with improved impact strength (known as high-impact materials). FuturaGen and ProBase Cold, two conventional materials, are well below the threshold values for materials with improved impact strength. Materials with improved impact strength can better resist the propagation of cracks and are considered less susceptible to fracture.

Source

University of Erlangen-Nuremberg 2018 test report. Unpublished data. Documentation available. The report was summarised. The figures and heading were created by Kulzer.

Determination of residual monomer content in denture acrylics

Objective

The objective of the in-vitro investigation was to determine the residual monomer content of four different cold-curing denture base materials.

Materials & Method

From four different denture base materials (two conventional, two so-called high-impact materials), standardised specimens were prepared. Methyl methacrylate monomer (MMA) was extracted from the polymerised test specimens and analysed using the gas chromatographic analysis method.

Results & Conclusion

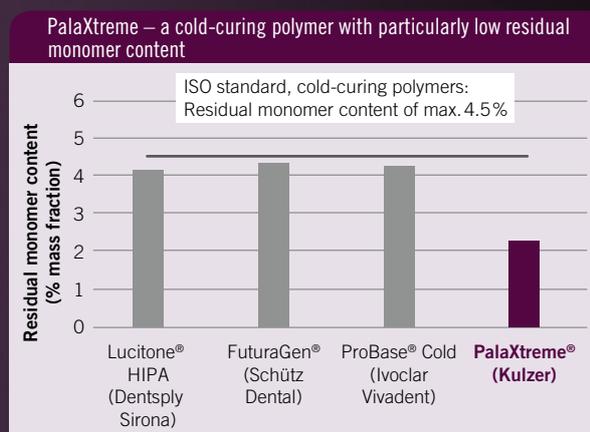


Fig. 1: Mean residual monomer content (% mass fraction) of the denture base materials tested.

All cold-curing denture base materials tested had a residual monomer content below 4.5 % (fig. 1). **This is the only one of the materials tested to be well below the required values.** A low residual monomer content of the denture base acrylic can increase the biocompatibility of the denture and provide a reduced allergy potential.

Source

Research & Development, Kulzer Wehrheim, unpublished data. Documentation available.



Wear resistance and break resistance

High durability of removable dentures primarily depends on the physical properties of the utilized materials. Frequently, the problem arises that high values of one parameter negatively influence another parameter. For dental prostheses, and in particular denture teeth, the balance between wear and break resistance is especially decisive. Dental prostheses should be fully functional as long as possible without having prior damage due to increased wear or breakage.

The following in-vitro examinations support the balance of wear and break resistance of our Flexecure® material technology which is used in our tooth lines Premium and Mondial.

2-Media-Wear Resistance of Denture Teeth in the Chewing Simulator

Objective

Denture teeth are subjected to constant wear in the mouth. The purpose of this examination is the determination of the abrasion strength of various dental materials in the 2-media chewing simulation.

Materials & Method

The 2-media chewing simulation is a common method which was further developed by the University of Heidelberg in co-operation with Kulzer. By using attenuators standard deviations could be noticeably reduced. Prior to insertion of the teeth into the chewing simulator any slight unevenness was leveled with fine abrasive paper. Using Al₂O₃-pellets (diameter of 4.75 mm) as antagonist 200,000 cycles with a horizontal movement of 0.8 mm under 50 N pressure were conducted. Abrasive wear of the teeth was analyzed with a laser scan surface profilometer.

Results

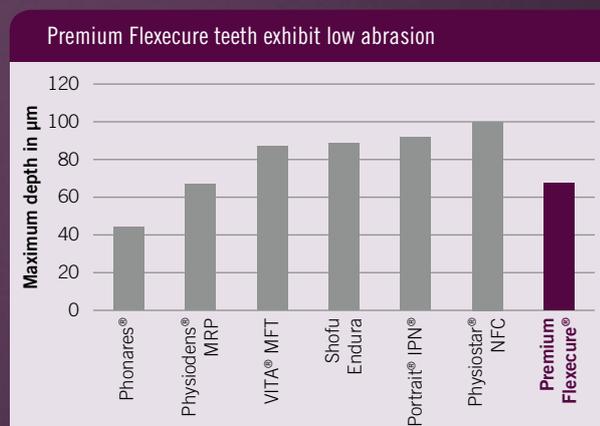


Fig. 1: Maximum depth of wear after chewing simulation in µm.

Conclusion

Premium Flexecure teeth belong to the group of tooth lines that showed lowest abrasion values in this investigation (Fig. 1).

Source

Eck M, Renz K, Ruppert K, Stange F; 2-Media-Wear-Resistance of Denture Teeth in the Chewing Simulator; Kulzer GmbH, Wehrheim/Hanau/Wasserburg, Germany

Break Resistance of Standardized Test Specimens Made of Denture Teeth

Objective

Forces exerted on denture teeth can lead to fracture in extreme situations. Purpose of this examination is the determination of the break resistance of various denture teeth independent from their exterior form.

Materials & Method

Anterior denture teeth were embedded in denture base material and then milled into a cylinder of 6 mm in diameter and 10 mm in height. At a defined location near the cylinder base a predetermined breaking point of 1 mm depth was inserted.

All test samples were then exposed to an increasing amount of force at an angle of 90° until fracture using a universal testing machine (Zwick). Breaking strength was recorded for all teeth lines.

Results

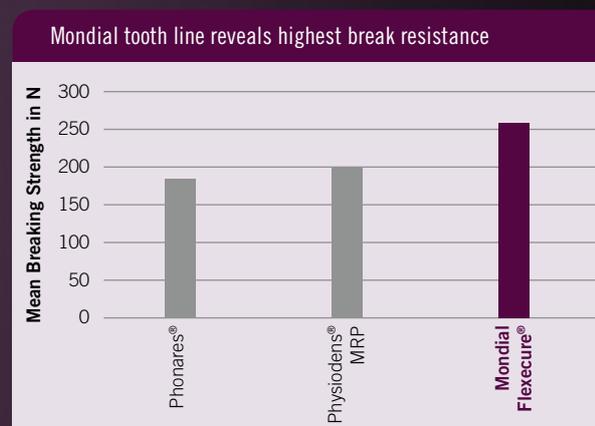


Fig. 2: Mean breaking strength [N] of anterior denture teeth.

Conclusion

Mondial showed significantly highest breaking strength values in this test (Fig. 2).

It is recommended that denture teeth with a high break resistance are used in order to ensure a high durability of dental prosthetic work.

Source

Beyer M, Kerscher K, Renz K, Schönhof N, Stange F; Break Resistance of standardized test specimens made of denture teeth; Kulzer GmbH, Wehrheim/Hanau/Wasserburg, Germany



Fracture resistance – LMU, Munich

The failure of dental work can lead to frustration at the dental office, dental lab and at the patient. One type of failure is the breakage of denture teeth or denture base material. To enhance the fracture resistance of denture work and thus avoid failure and resulting frustration processing technologies and materials are under constant improvement.

The following in-vitro study tests the bonding strength between two anterior tooth lines and a denture base material under various pretreatments of the basal tooth surface and also the fracture resistance of the teeth. Mondial teeth showed fracture resistance values that are far above maximum loads occurring in partial dentures.

Retention of denture teeth on the denture base

Objective

This study examined the influence of macro-retentions and chemical conditioning of the basal surface of denture teeth on the bond strength between denture tooth and denture base and also the fracture resistance of the denture teeth.

Materials & Method

Front teeth of similar teeth lines of two different manufacturers were roughened basally and cervically with a diamond burr of 50 µm grain. The teeth were then divided into the following groups: Pretreatment of the teeth with basal macro-retentions in the form of grooves combined with the respective recommended bonding agent (RP), basal macro-retentions in the form of a hole-retention in combination with the respective bonding agent (LP) and without any further treatment (-). All teeth were polymerized into the acrylic resin PalaXpress. Half of the specimens were artificially aged by thermocycling (10,000 cycles between 5°C and 55°C). All samples were loaded until fracture in the universal testing machine using a 45° angle.

Results

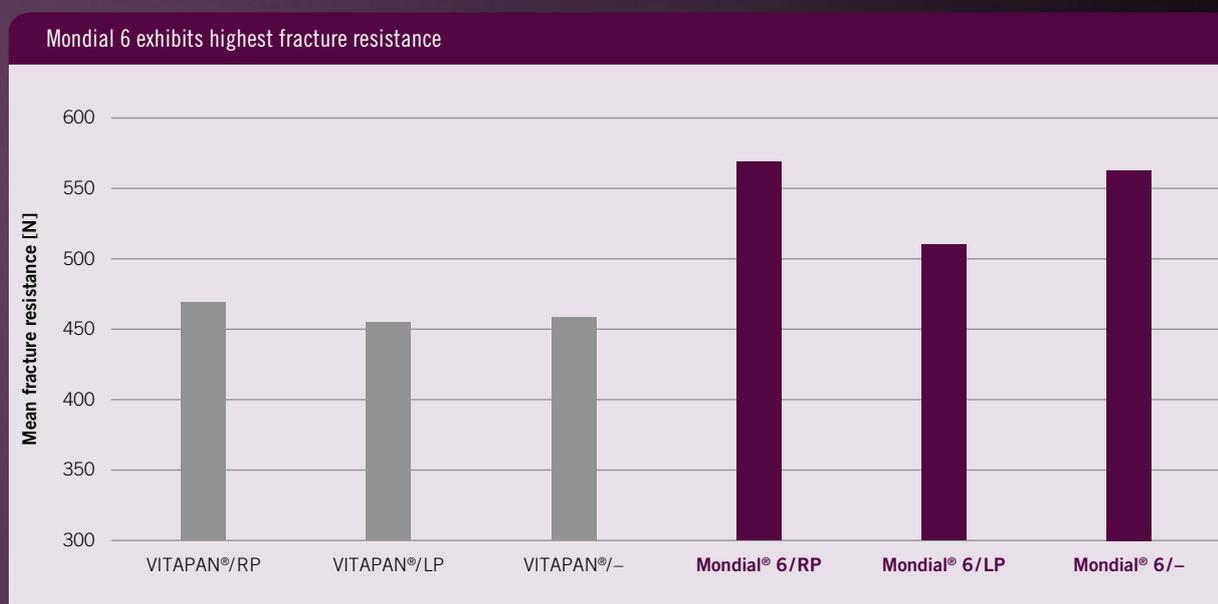


Fig. 1: Mean fracture resistance [N] of denture teeth after pretreatment without artificial aging.

Conclusion

Both before and after artificial aging the Mondial teeth showed significantly higher values for fracture resistance than the VITAPAN® teeth (Fig. 1). The pretreatment of the basal surfaces of the denture teeth only played a minor role in bond strength of the teeth to the denture base. Artificial aging resulted in a general decrease of fracture resistance for both teeth lines. Yet aged Mondial teeth exhibited breaking strength values that are far above maximum loads observed in partial dentures.

Source

Beuer F, Erdelt KJ, Friedrich R, Köbel-Bogai K, Eichberger M, Gernet W: Festigkeit von Kunststoffprothesenzähnen auf der Prothesenbasis. Deutsche Zahnärztliche Zeitschrift 61 [German Dental Magazine], Volume 3 (2006) Page 147 – 150

The study was abbreviated and summarised and all diagrams and titles have been established by Kulzer.



Plaque resistance – UKR
Regensburg

Colour stability – São Paulo
State University, Brazil

As well as natural teeth also denture teeth are susceptible to discoloration and plaque adhesion in clinical everyday life. When choosing denture materials artificial teeth with high plaque resistance and high colour stability should be selected to ensure a good hygiene capability and a long lasting esthetic stability. Reworking in the dental laboratory is reduced as a result.

The following two in vitro-studies prove the excellent plaque resistance and colour stability of our Flexecure® technology, which is used for Premium, Idealis, Mondial and PalaVeneer.

Adhesion of streptococcus mutans NCTC 10449 to artificial teeth

Objective

A high plaque resistance of denture teeth contributes to a good hygiene capability of removable dentures. Aim of this in-vitro study was the determination of adhesion of Streptococcus mutans bacteria to the surface of different artificial teeth.

Materials & Methods

Standardised specimens of 12 different tooth lines (anterior and posterior) were incubated with Streptococcus mutans NCTC 10449 at 37°C for 2.5 h. A fluorometric assay (Resazurin reduction) was used for the quantification of accumulated microorganisms. The relative intensity of the fluorescent signal is directly proportional to the number of adherent microorganisms.

Results

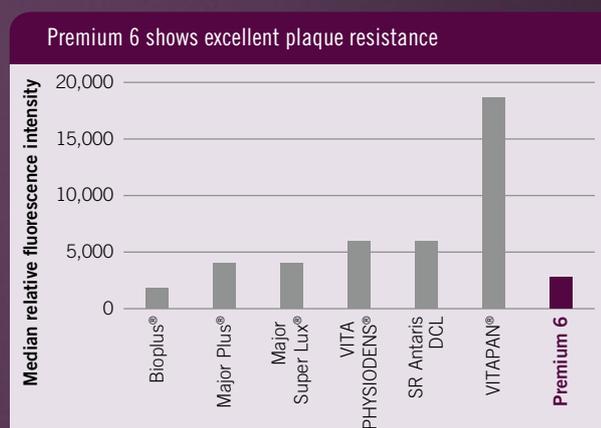


Fig. 1: Median relative fluorescence intensity of anterior tooth lines after incubation with Streptococcus mutans.

Conclusions

Premium 6 and Bioplus® anterior teeth showed the lowest values for adhesion of Streptococcus mutans (Fig. 1). No statistically significant differences were found between Premium 6 and Bioplus®. In order to prevent the development of denture stomatitis the authors recommend dental materials with low susceptibility to plaque accumulation.

Source

Hahnel S, Rosentritt M, Bürgers R, Handel G: Adhesion of Streptococcus mutans NCTC 10449 to artificial teeth: an in vitro study. J Prosthet Dent. 2008 Oct; 100(4):309-15.

Effect of polymerization methods and thermal cycling on color stability of acrylic resin denture teeth

Objective

Discolouration of denture teeth negatively affects the esthetics of removable dentures. Aim of the investigation was to determine the influence of different polymerization methods and thermal cycling on the colour stability of artificial teeth.

Materials & Methods

The colour of ten different tooth lines was measured before polymerization, after polymerization (microwave, 500 W for 3 minutes, or water bath, 7°C for 9 hours) and after subsequent thermal cycling (5000 cycles between 5°C and 55°C) using a spectrophotometer. The respective colour difference (Delta E) was calculated.

Results

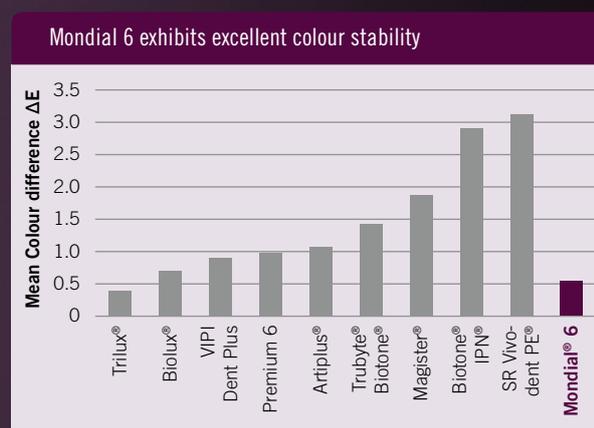


Fig. 2: Mean colour difference ΔE in denture teeth after conventional polymerization between thermal cycling and baseline.

Conclusions

Mondial 6 and Trilux showed the lowest colour differences (Fig. 2). No statistical significant difference was detected between them. All colour differences obtained were assessed as not clinically relevant.

Source

Assunção WG, Barão VA, Pita MS, Goiato MC: Effect of polymerization methods and thermal cycling on color stability of acrylic resin denture teeth. J Prosthet Dent. 2009 Dec; 102(6):385-92.



Bond strength – University of Regensburg

Especially in case of restricted space conditions such as of cover denture works, telescope works or implant-supported constructions the use of prefabricated veneers suggests itself. They offer the possibility to avoid time-consuming grinding of full-contour teeth as well as prevent potentially associated aesthetical impairments [1].

The following in-vitro investigation on the bond strength of prefabricated veneers indicates a stable adhesion of the shells and confirms highest adhesion of PalaVeneer / PalaVeneer Dentine to the metal framework.

Investigation of adhesion between veneer shells and a metal framework

Objective

Aim of the investigation was to determine the bond strength of industrially manufactured veneer shells on a metal framework.

Materials and Methods

Metal carrier for mounting the veneer shells PalaVeneer (Kulzer), novo.lign® (Bredent) and artVeneer® (Merz Dental) were fabricated using a CoCr-alloy (Heraenium CE, Kulzer) and were sandblasted with Al₂O₃ (110 µm, 3 bar). Further conditioning of the metal surface and the veneer shells was conducted according to the respective manufacturer's instructions. The individual corresponding bonding systems PalaVeneer Dentine (cold-curing PMMA resin, Kulzer), combo.lign® (dual-curing adhesive composite, Bredent) and artDentine (cold-curing PMMA resin, Merz Dental) were used to attach the veneer shells to the metal carriers. According to ISO10477 the samples (n = 10) were tested after 24 hours storage at 37°C, after thermocycling (TC: 2 x 5.000, 5°C/55°C) and after 150 days water storage at 37°C in the universal testing machine (Zwick, v=1 mm/min) with the compressive shear test. Statistical analysis was performed using SPSS (univariate ANOVA, Bonferroni Post-hoc, level of significance p<0.05).

Results

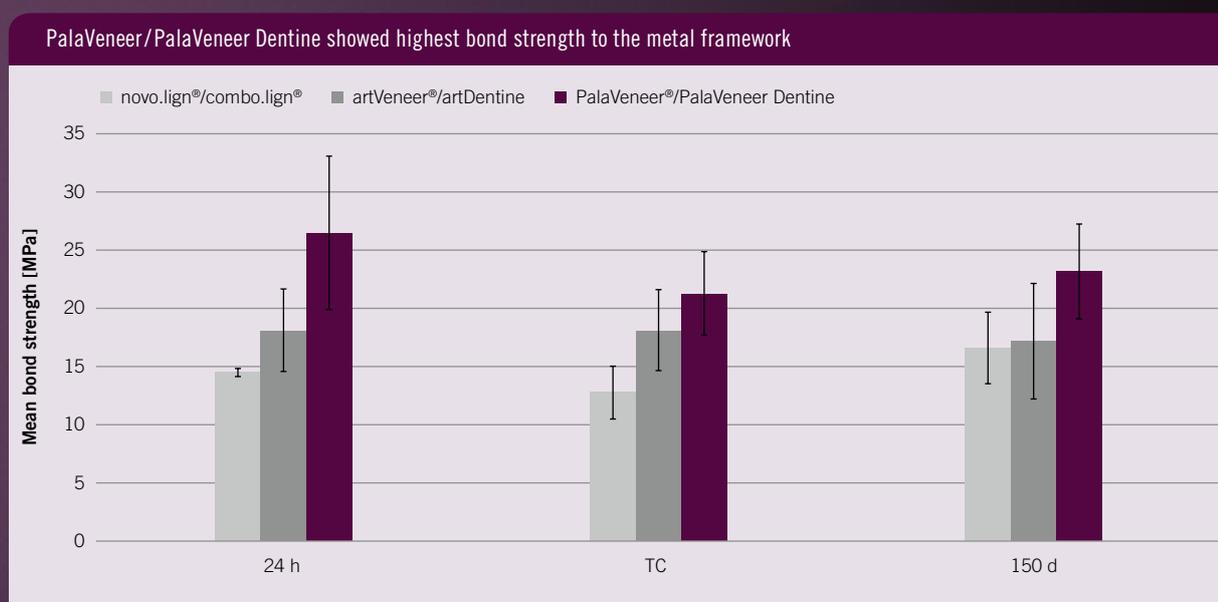


Fig. 1: Mean bond strength [MPa] of industrially manufactured veneer shells in the compressive shear testing after 24h storage, after thermocycling (TC) and after 150 days water storage.

Conclusion

For all tested veneer shells no significant influence of the storage conditions on the bond strength could be found, indicating a stable adhesion of the shells to the metal framework. Overall, the system PalaVeneer/PalaVeneer Dentine showed the highest mean bond strength values in this in-vitro testing (fig. 1).

[1] Mattina C: Dünn, dünner – farbstabil? Das Dental Labor 3/2008

Source

University of Regensburg. Test report 2015. Unpublished data. Data on file.

The study was abbreviated and summarised and all diagrams and titles have been established by Kulzer.



In-vitro study – Freitas *et al.*

Good bond strength between denture teeth and denture base is necessary to avoid debonding of denture teeth. Tooth debonding from full dentures still is a common reason for denture repair. Many factors can impair the bond between artificial tooth and base, thus as excessive stress, fatigue or wax residues at the tooth during denture fabrication. The present *in-vitro* study aimed to investigate the bond strength between different denture teeth and denture base polymerized by two different polymerization methods. Premium 8 denture teeth showed good bond strength values in this test, before and after thermocycling.

Effects on bond strength between denture teeth and base

Objective

Aim of the investigation was the evaluation of shear bond strength between various denture teeth and denture base polymerized by two different polymerization methods.

Materials and Methods

The artificial teeth (Premium 8, Kulzer; Trilux, Vipi Produtos Odontologicos; Soluut, Yamahachi Kota Imports; Biotone, Dentsply) were polymerized into heat-cured polymer that was either conventionally cured in a water bath (Classico, Classico Artigos Odontologicos) or by microwave energy (Onda-Cryl, Classico Artigos Odontologicos). Half of the samples were stored in distilled water (37°C) for 24 hours, the other half was subjected to 5000 cycles of thermocycling (5°/55°C) to simulate 5 years of oral mouth temperature. Afterwards shear bond strength was measured (n=10) in a universal testing machine (5000N, crosshead speed 1.00 mm/min) and the data were statistically analyzed.

Results and conclusion

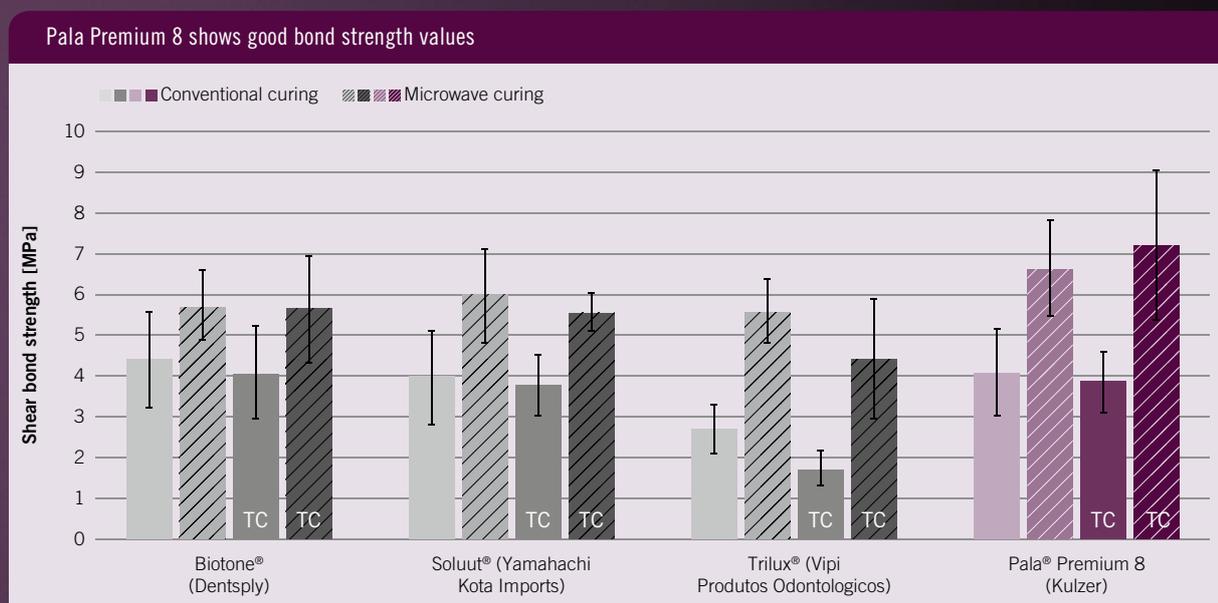


Fig. 1: Mean shear bond strength [MPa] of the tested teeth and polymerization methods without thermocycling and with thermocycling (TC); the whiskers represent the standard deviation.

Microwave polymerization achieved the highest bond strength values between denture teeth and denture base. The varying bond strength values of the different tested teeth exhibited that the chemical composition of the denture teeth influences the bond between denture base and teeth (fig. 1). Premium 8 showed good bond strength values in this test, before and after thermocycling.

Source

Andrade de Freitas SL, Brandt WC, Miranda ME, Vitti RP: Effect of Thermocycling, Teeth, and Polymerization Methods on Bond Strength Teeth-Denture Base. Int J Dent. 2018; 2018: 2374327.



Transfer accuracy – FSU Jena

An important factor in selecting the manufacturing system for full dentures is the accuracy with which the occlusal conditions are transferred from the wax stage into the acrylic stage. This study compared three commonly used manufacturing systems for full dentures: Kulzer Palajet injection process, the Merz Dental PremEco® Line casting process and the conventional press and pack.

The Palajet injection process showed significantly greater accuracy in transferring the occlusion compared to the PremEco® Line casting process and the press and pack technique.

Experimental comparative study on the degree of three-dimensional position changes of acrylic teeth during manufacture of full dentures using different processing technologies

When fitting full dentures to edentulous patients, not only an optimum basal fit is essential, but also the occlusion is of central importance. After the optimum set-up of the teeth in wax, the aim is to transfer the wax model into acrylic as exact as possible.

Materials and Methods

In an experimental comparative study the accuracy of transferring the occlusion was investigated for the Palajet injection process (Kulzer), PremEco® Line casting process (Merz Dental) and the conventional press and pack technique (Tab. 1). For each system 14 templates of a full maxillary denture were invested in the bottom part of the respective flasks (7 new and 7 used). The initial situation of the wax dentures was recorded with a laser-scanner. The final investment and transfer into acrylic were performed according to manufacturer's instructions. After deinvestment the acrylic dentures were laser-scanned while still on the model (approximately 80,000 pixels per measurement). The spatial deviation of the denture teeth was compared to the initial situation by generating a three-dimensional measurement result.

System name	Product	Process	Manufacturer
Palajet® system	PalaXpress®, cold-curing acrylic	Injection	Kulzer, Hanau, Germany
PremEco® Line system	PremEco® Line, cold-curing acrylic	Casting flask	Merz, Lütjeburg, Germany
Press and pack technique	Aesthetic, cold-curing acrylic	Press and pack technique	Candulor, Wangen, Switzerland

Tab. 1: Overview of the tested processing techniques.

Results

The Palajet injection process showed significantly greater accuracy during transferring the occlusion than the PremEco® Line casting process and the press and pack technique. The Palajet injection process yielded the most accurate results with an average deviation of 0.086 mm after transfer of the wax model to the acrylic denture (Fig. 1). No statistically significant differences concerning the accuracy could be detected between the used and the new flasks in any of the three systems. Old flasks tended to achieve lower discrepancies than new flasks.

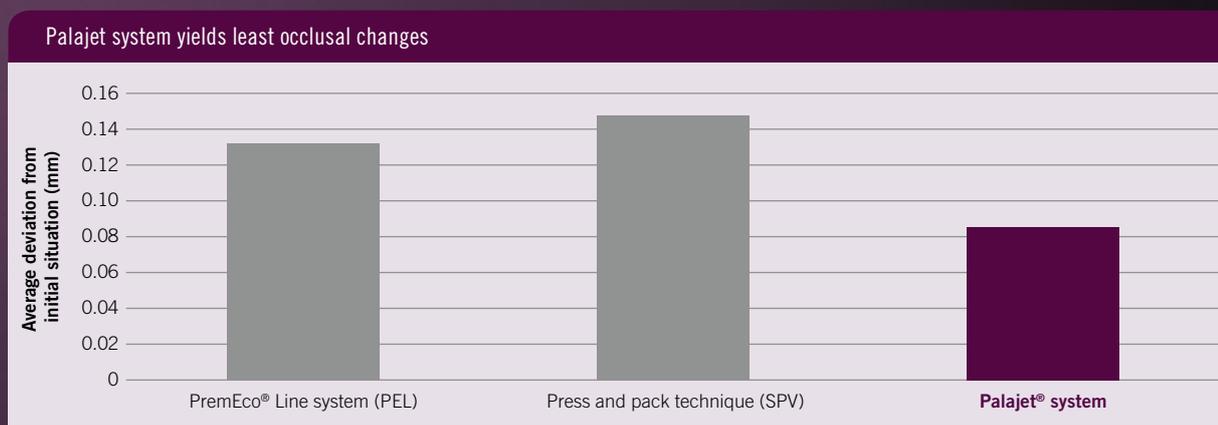


Fig. 1: Average discrepancies between wax model and acrylic denture concerning the occlusion. The Palajet system showed the lowest occlusal changes compared to the initial values.

Conclusion

Compared to the casting process and the press and pack technique, the Palajet system showed the highest accuracy in transferring the occlusion. The age of the flasks was insignificant for the accuracy of the transfer for all three systems.

Source

Naumann K: Experimental comparative study on the degree of three-dimensional position changes of acrylic teeth during manufacture of full dentures using different processing technologies. Diss. University of Jena, 2009. The study was abbreviated and summarised and all diagrams and titles have been established by Kulzer.



Polymerization shrinkage – MLH Halle-Wittenberg

Even though denture base materials are under continuous improvement, polymerization shrinkage still remains an issue. Polymerization shrinkage of denture base resins results in dorsal and lateral gaps, thus reducing the functional fit of the denture base. Dimensional accuracy of different PMMA denture resin materials depending on polymerization and manufacturing technique was evaluated in an in-vitro study. Best results were found for the cold-curing acrylic PalaXpress, processed with the Palajet injection system.

Factors in polymerization influencing the accuracy of PMMA denture bases

Objective

Aim of this study was to evaluate the influence of polymerization type and manufacturing technique on the dimensional accuracy of PMMA denture base materials.

Materials and Methods

With each of seven different PMMA denture acrylics (Tab. 1) ten standardized denture bases were fabricated on identical casts. According to manufacturers and product instructions four different manufacturing technologies were tested (Tab. 1). The dorsal gap between master model and denture base served as an indicator for fit and dimensional behavior of the polymerized denture base. Five marking points (palatal centre, bilateral vertical/horizontal border), engraved in the master-model, were chosen for the measurement of the dorsal gap. To observe the dimensional behavior over time, the measurements were carried out immediately after embedding, after one hour, after one day and after one week.

Product	Type of Polymerization	Process	Manufacturer
PalaXpress®	Auto-polymerizing	Pneumatic injection	Kulzer, Hanau, Germany
ProBase® Cold	Auto-polymerizing	Conventional-flask-technique	Ivoclar Vivadent, Ellwangen, Germany
FuturaGen®	Auto-polymerizing	Manual injection	Schütz Dental, Rosbach, Germany
Polyan®	Melting	Injection-moulding	Polyapress, Altkirchen, Germany
FuturAcryl® 2000	Heat-polymerizing	Manual injection	Schütz Dental, Rosbach, Germany
SR Ivocap®	Heat-polymerizing	Pneumatic injection	Ivoclar Vivadent, Ellwangen, Germany
Paladon® 65	Heat-polymerizing	Conventional-flask-technique	Kulzer, Hanau, Germany

Tab. 1: Overview of the tested PPMA denture base resins

Results

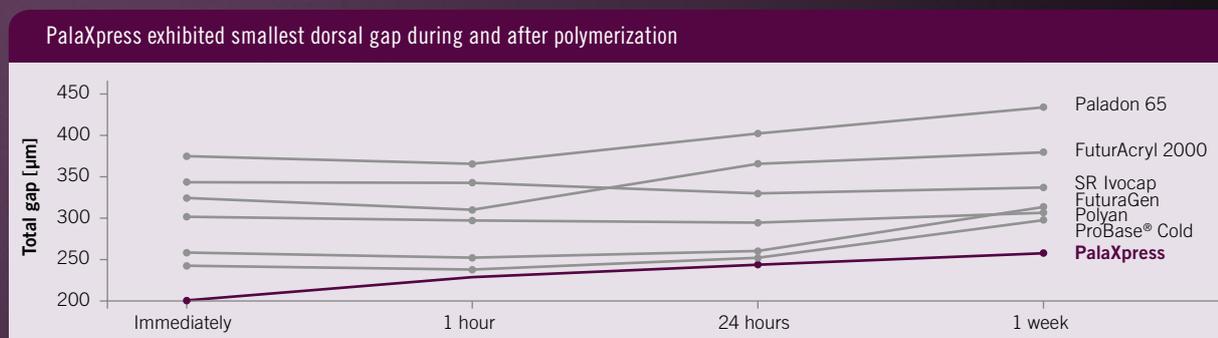


Fig. 1: Total dorsal gaps in µm immediately after embedding and over time

After embedding the tested heat curing denture acrylics showed the highest average dorsal gaps ranging from $317 \pm 57 \mu\text{m}$ to $369 \pm 88 \mu\text{m}$. The cold curing materials exhibited the smallest values ($196 \pm 46 \mu\text{m}$ to $256 \pm 83 \mu\text{m}$). Best results in this study were found for PalaXpress, processed with the pneumatic injection unit Palajet (Fig. 1).

Conclusion

The clinical fit of a denture essentially depends on the dimensional behavior of the denture base resin during and after polymerization. Especially the type of polymerization heavily influenced the dimensional accuracy of the denture base resins tested in this study. Cold curing denture acrylics, like PalaXpress, exhibited the smallest dorsal gaps.

Source

Peters A, Arnold C, Setz JM, Boeckler AF: Factors in polymerization influencing the accuracy of PMMA denture bases. Int Poster J Dent Oral Med 2010, Vol 12 No 1, Poster 476; <http://ipj.quintessenz.de/index.php?doc=html&abstractID=21162>. The study was abbreviated and summarised and all diagrams and titles have been established by Kulzer.

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