SR Vivodent® S PE | S DCL

Scientific Documentation

ivoclar vivadent
passion vision innovation

Contents

1. Introduction

1.1 The history of human tooth replacement

Since time immemorial, the replacement of missing teeth has been a medical and cosmetic necessity for human kind. Denture prosthetics has undergone many development stages since the first dentures were fabricated. Whereas 3,500 years ago, the ancient Egyptians carved false teeth out of mulberry wood and tied them to adjacent teeth with gold wire; the Etruscans produced constructions made of gold and bovine teeth – guided even then by principles used in denture prosthetics today. The first porcelain teeth were developed as early as 1709, but their actual production in England was not undertaken until 1837. The first sets of dentures based on rubber and porcelain began to appear in 1846.

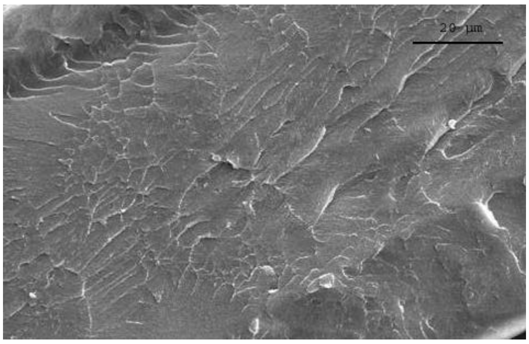
With the emergence of polymer chemistry in the early 20^{th} century, the foundation for the widespread use of removable dentures was laid. In the nineteen-forties, the industrial production of artificial teeth based on polymethyl methacrylate (PMMA) began. PMMA-based materials are still among the most widely used materials for manufacturing denture teeth today. The most important materials are briefly described in the sections below.

1.2 Material portraits

Today, various materials are available for manufacturing denture teeth. Essentially, the world of synthetic denture teeth can be divided into two materials: teeth made of PMMA and teeth made of composite.

PMMA-based materials differ regarding the structure of the PMMA matrix, which may be crosslinked or non-crosslinked. Crosslinked or highly crosslinked polymers are more resistant to certain influences, such as abrasion. PMMA teeth also differ from each other in terms of filler content – PMMA teeth can be filled or contain organic and/or inorganic fillers to improve their mechanical properties.

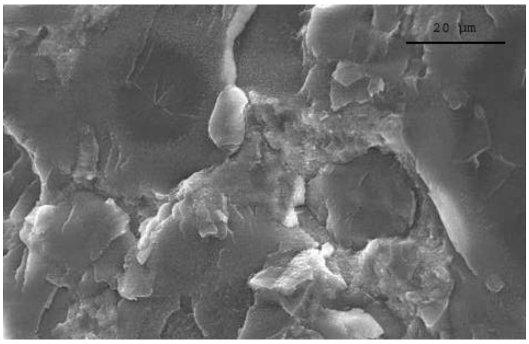
1.2.1 Conventional non-crosslinked PMMA



This is the classic material for manufacturing denture teeth. In the production process, a non-crosslinked linear polymer is mixed with a monomer containing a crosslinking agent and then polymerized.

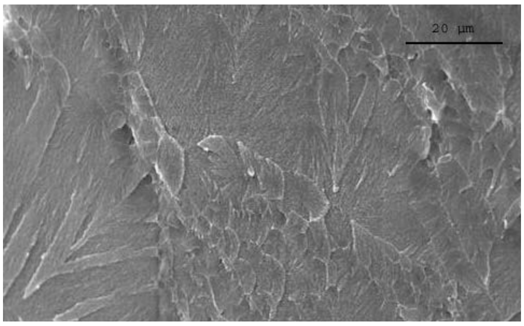
The mixture of monomer and crosslinking agent consists of a methyl methacrylate and a dimethacrylate, in most cases ethylene glycol dimethacrylate. The Ivostar / Gnathostar teeth are examples of this material category.

1.2.2 Inorganically filled PMMA



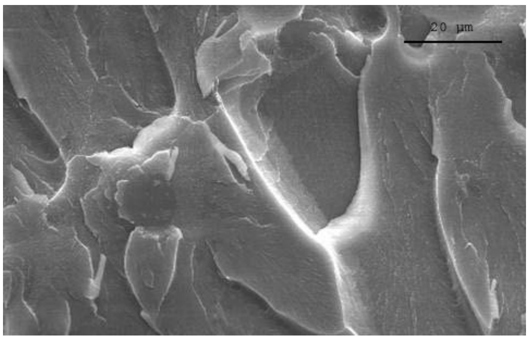
These denture tooth materials are based on polymethyl methacrylates, to which inorganic fillers have been added. The Vitapan tooth (VITA) is a typical representative of this material category.

1.2.3 Highly crosslinked PMMA: IPN



This denture tooth material, which is known as Interpenetrating Polymer Network (IPN), can also be allocated to the category of PMMA materials. To produce this type of material, polymers of a different chemical and physical nature penetrate and become interlaced with each other with the help of swelling processes. The Portrait IPN tooth line from Dentsply is an example of this material category.

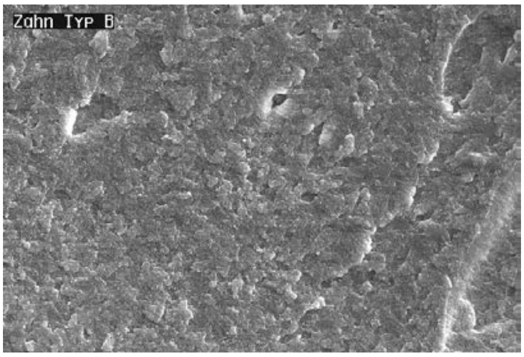
1.2.4 Highly crosslinked, organically filled PMMA: DCL



Double crosslinked PMMA (DCL) is a severely modified variant of polymethyl methacrylate. The polymer filler and matrix are homogeneously crosslinked. The result is a thoroughly crosslinked material system, offering substantial advantages in terms of oral stability and wear resistance.

Representatives of this category of materials are members of the family of DCL teeth (e.g. SR Vivodent DCL, SR Orthotyp DCL) in addition to SR Vivodent S PE / S DCL and SR Orthotyp S PE / S DCL.

1.2.5 Composite

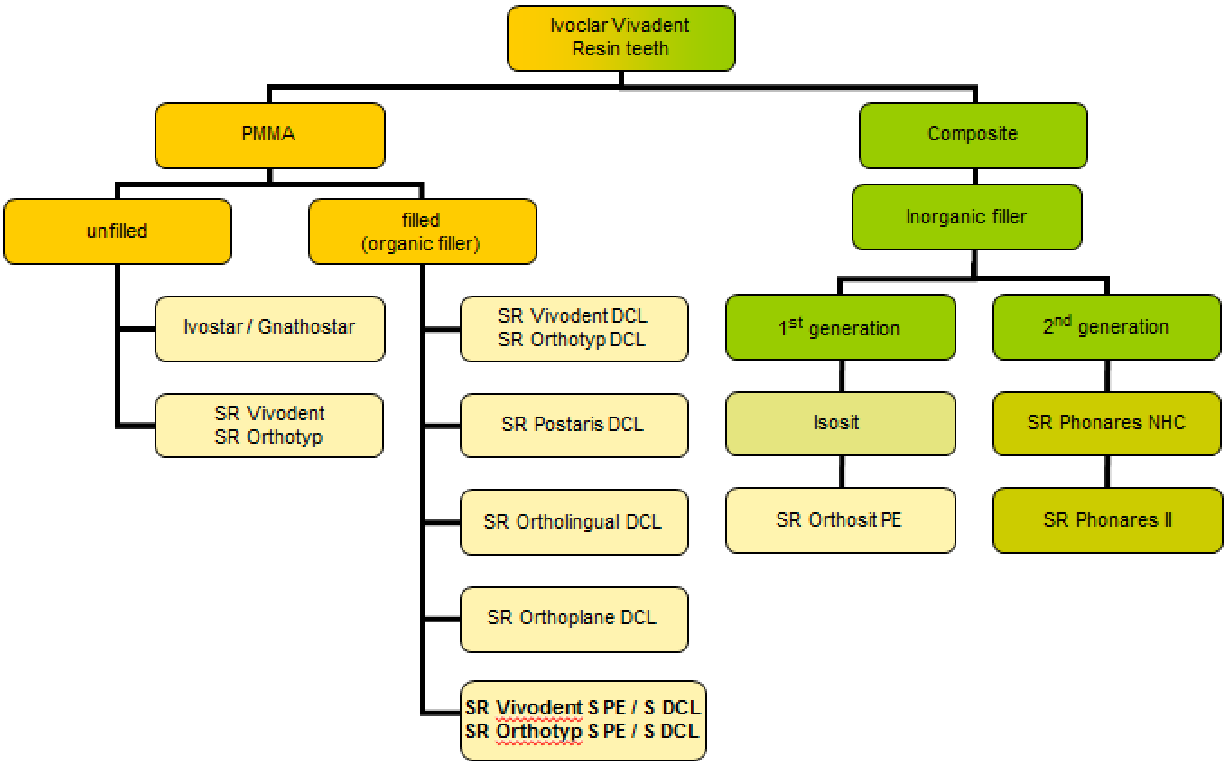


In contrast to the types of denture teeth listed above, composite teeth are not based on PMMA polymers. Instead, they contain a methacrylate matrix as well as a urethane dimethacrylate-based crosslinking agent and inorganic microfillers. In comparison to PMMA materials, the inorganic pyrogenic silica fillers considerably increase the hardness and rigidity.

Composite material is used in e.g. the SR Orthosit and SR Phonares II teeth.

1.3 Overview of Ivoclar Vivadent resin teeth

The Ivoclar Vivadent range of denture teeth encompasses resin teeth made of filled and unfilled PMMA and composite teeth.



SR Vivodent S PE / S DCL and SR Orthotyp S PE / S DCL belong to the category of highly crosslinked, organically filled PMMA teeth.

1.4 The DCL material

Figure 1 is a schematic representation of the DCL material. Various filler clusters are embedded in the crosslinked PMMA matrix, shown as a "grid". These clusters comprise highly crosslinked dimethacrylate fillers that look like crushed stone – particles of varying sizes and shapes. Given their irregular shape, these fillers are difficult to dislodge from the PMMA matrix. Especially so, as the pre-crosslinked polymer is crosslinked a second time with the matrix in the course of the manufacturing process. In the process, the matrix penetrates the filler polymers, creating a homogeneous, virtually seamless composite structure. This manufacturing procedure, known as double crosslinking, is employed to eliminate the weaknesses associated with conventional polymethyl methacrylate teeth, such as the exposure of non-crosslinked and therefore dislodgeable polymer particles during grinding. As a result, these fillers enhance the material's durability and in particular their wear resistance compared to conventional PMMA materials. In addition, resistance to solvents is also optimized. The composite material also includes spherical PMMA fillers which reduce susceptibility to staining.

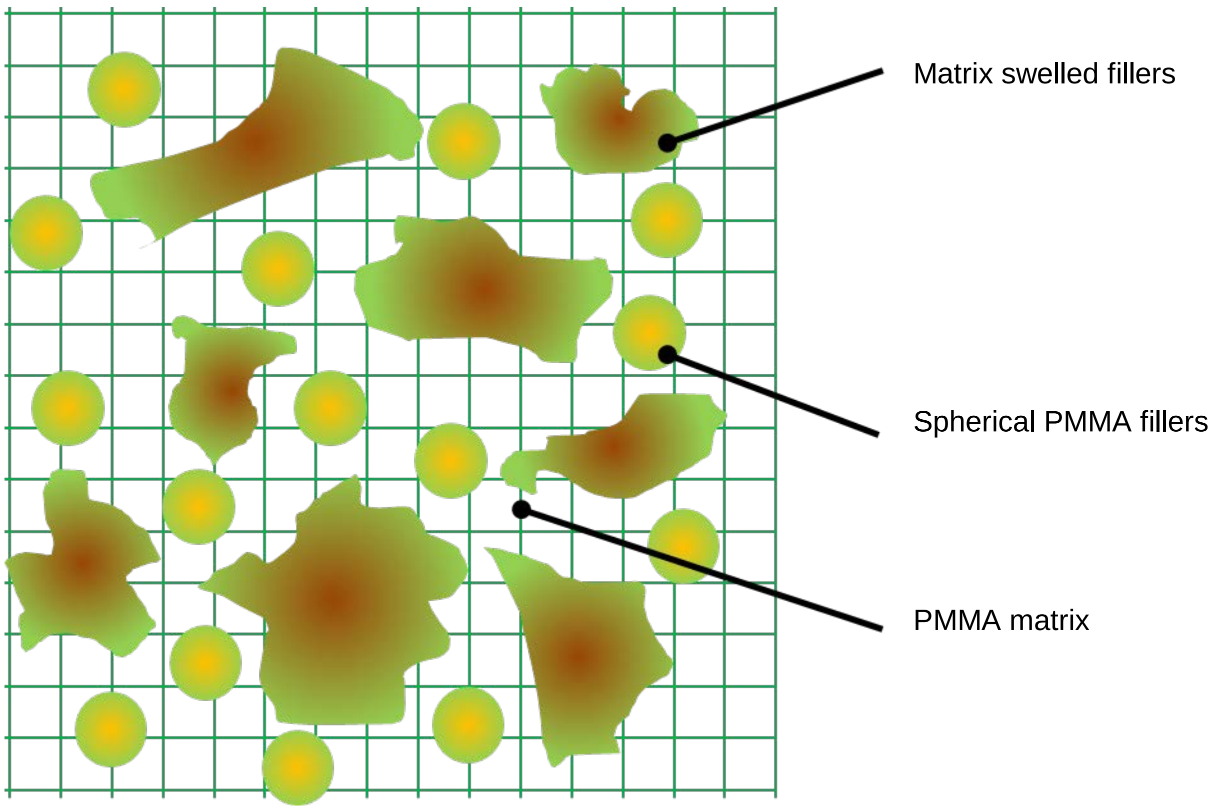


Fig. 1: Schematic of DCL structure

1.5 Tooth moulds

The SR Vivodent S PE / S DCL anterior tooth line contains three basic shapes: square, triangular and oval. Although these are just generic descriptions, each of these shapes is characterized by certain specific features.

Triangular tooth moulds

This group is characterized by teeth having a crown with tapers towards the cervical ridge. The vertical curvature is moderate.

Oval tooth moulds

The teeth of this category have a pronounced curvature. The labial curvature is particularly pronounced.

Square tooth moulds

With this angular shape, the central incisor is dominant. The vertical labial curvature is moderate.

The accompanying posterior tooth moulds, SR Orthotyp S PE / S DCL, feature a semi-anatomic design. Given their straightforward occlusal cusp design, these posterior teeth may be considered the all-rounders of complete denture prosthetics.

1.6 Layering scheme

SR Vivodent S PE / S DCL and SR Orthotyp S PE / S DCL each comprise four layers: incisal, dentin, cervical and back incisal (see Fig. 2 and 3).

The front and back incisal layers are composed of the same material in an identical shade to ensure that the tooth is encapsulated by a uniform layer of material on all sides (see Fig. 4a,4b). This endows the tooth with a true-to-nature appearance without visible transitions or interfaces.

The dentin and cervical layers also consist of the same material as the incisal. The filler size is the only difference between these two materials. Furthermore, the shade of the dentin and incisal layer is slightly different to achieve the desired optical effect.

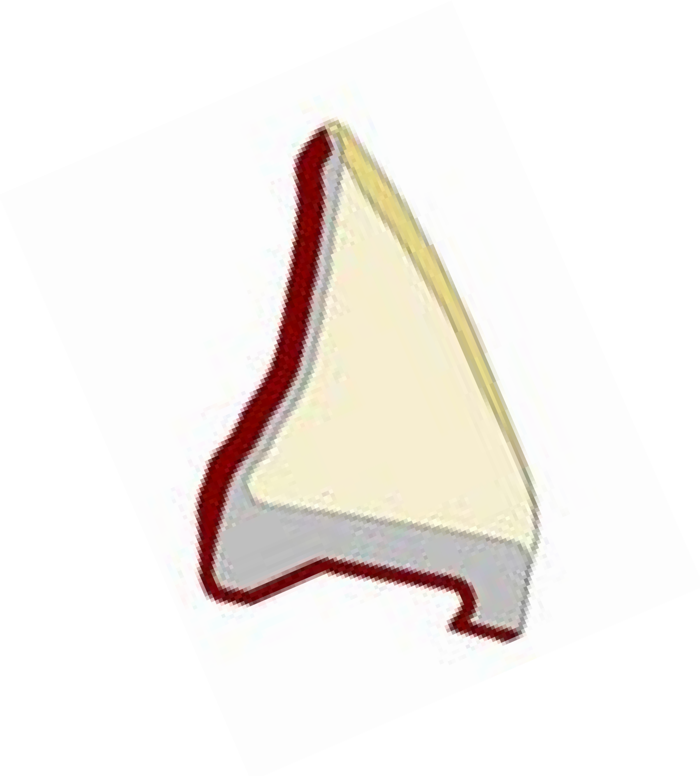


Fig. 2: Layering schemd of SR Vivodent S PE / S DCL anterior teeth

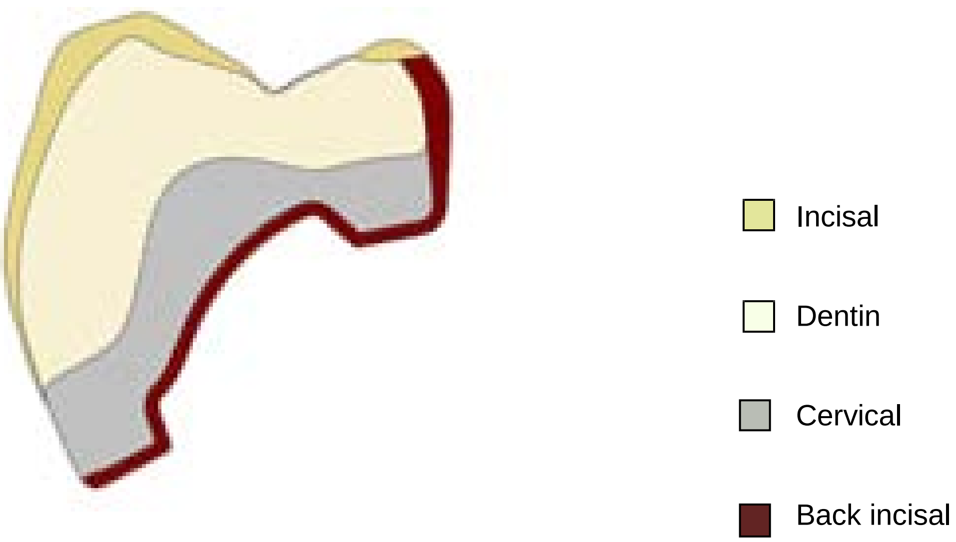


Fig. 3: Layering scheme of SR Orthotyp S PE / S DCL posterior teeth

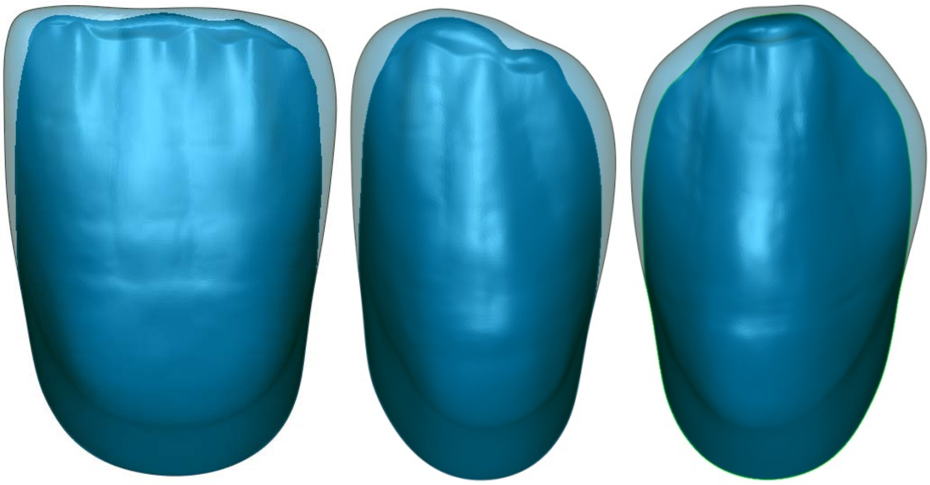


Fig. 4a: Layering scheme of SR Vivodent S PE / S DCL anterior teeth. The coronal area of the dentin core (dark blue) is completely encapsulated with incisal material (light blue) to imitate the composition of the natural tooth consisting of dentin and enamel.

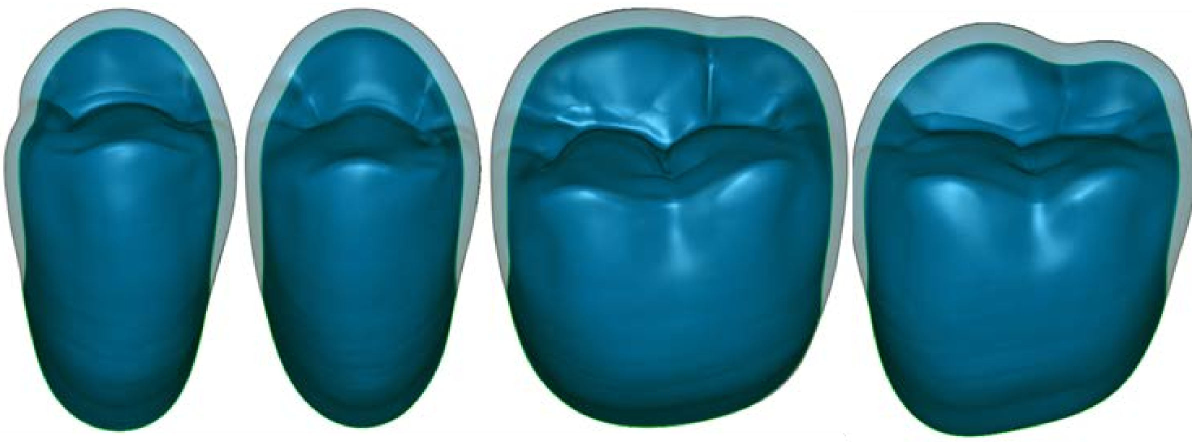


Fig. 4b: Layering scheme of the SR Orthotyp S PE / S DCL posterior teeth. The coronal areas of the dentin core (dark blue) are completely encapsulated with incisal material (light blue) to imitate the structure of the natural tooth consisting of dentin and enamel.

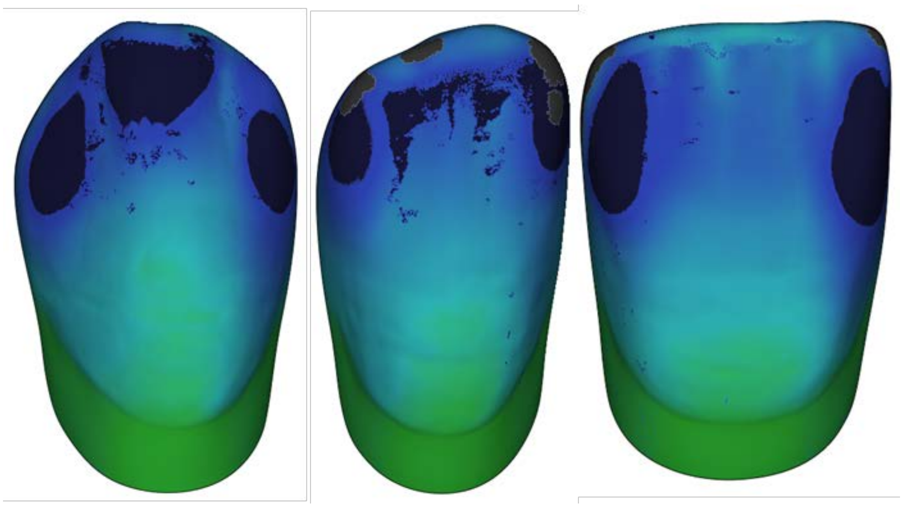


Fig. 5a: Layering of the SR Vivodent S PE / S DCL anterior teeth. Green: dentin; blue: enamel.

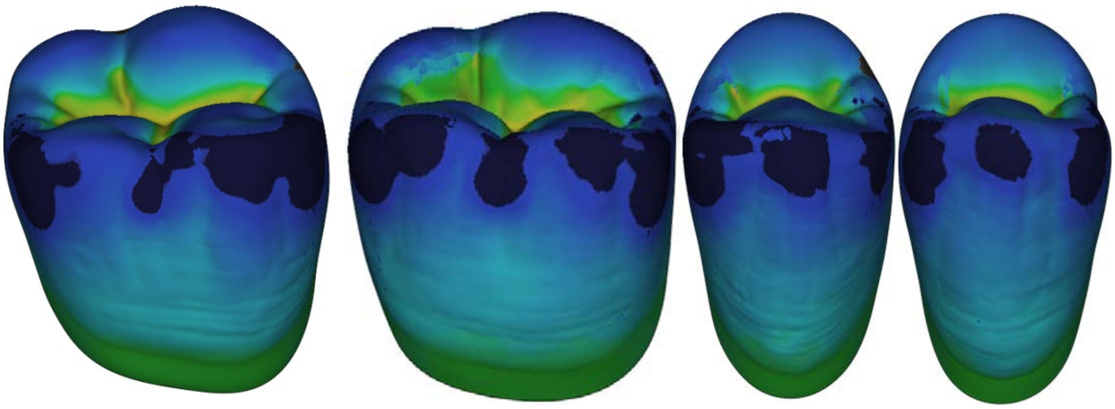


Fig. 5b: Layering of the SR Orthotyp S PE/ S DCL posterior teeth. Green: dentin; blue: enamel.

Figure 5 illustrates the distribution of enamel and dentin material in the tooth. Dentin is shown in green and enamel in dark blue. The darker the blue, the thicker the incisal layer. Those areas where the dentin is overlaid by enamel demonstrate a mixed shade varying from turquoise to yellow. Except for the edge areas, these colour transitions seamlessly merge from one to another, as can be seen on the picture. This bestows a harmonious esthetic appearance to the teeth without harsh transitions between the translucent enamel and opaque dentin.

2. Technical data

Tooth structure: Four layers (incisal, dentin, cervical and back incisal)

Material type: Highly crosslinked PMMA, DCL (double crosslinked)

<u>Standard composition</u> (in % by weight)

Function	Substance	Weight by %
Polymer	Polymethyl methacrylate, Dimethacrylate	95.0-98.0
Crosslinking agent	Dimethacrylate	1.0-4.0
Initiators and stabilizers	Initiator and stabilizer	0.1-0.7
Pigments	Pigment yellow 53, Pigment red 144	0.1-0.5

<u>Physical properties</u>

Property	Unit	Specification
Bonding strength to denture base material	-	conform
Tooth dimensions	mm	Tooth mould chart ± 5 %
Flexural strength	MPa	≥ 80
Water absorption (7 days)	µg/mm^3	≤ 40
Solubility (7 days)	µg/mm^3	≤ 7.5
Ball indentation hardness	MPa	≥ 140
Compressive strength	MPa	≥ 320

3. Material properties

3.1 In vitro wear investigation

The wear behaviour of a material is determined not only by its mechanical properties but is also affected by its structure such as surface roughness, homogeneity, orientation of crystals and inclusions. Antagonist surfaces and the environment also come into play. In this respect, the keywords are coefficient of friction, contact stress, geometry and number of contact points, temperature, fluids and friction length. *In vitro* wear tests simulating real life conditions are often carried out in dental science. The technical specification ISO 14569-2 describes eight types of methods currently used for wear testing in dentistry. None of them, however, is capable of mirroring real-life clinical behaviour. Moreover, the results obtained with different chewing simulators often fail to correlate with each other. The problem is that most chewing simulators can only simulate one or two of the wear mechanisms occurring simultaneously in the oral cavity. Therefore, dental materials should be examined in two or several chewing simulators to obtain results that are more predictable of clinical behaviour in real life. Carrying out only one wear measurement could lead to misleading results.

The DCL material used for the SR Vivodent S PE / S DCL and SR Orthotyp S PE / S DCL teeth was tested in a variety of wear measurement settings and demonstrated a high resistance to wear in all of them.

3.1.1 Two-body wear testing

Investigator: S. Heintze, Ivoclar Vivadent AG, R&D, Schaan, 2014

Method: Eight plane samples were made from molar teeth (SR Orthotyp S PE). These samples were subjected to wear testing against the palatal cusps of artificial premolars as antagonists. The test was run for 40,000 chewing cycles with integrated thermocycling (5°/55°C), 3 kg loading and 3 mm lateral movement without lifting of the antagonist.

Results:

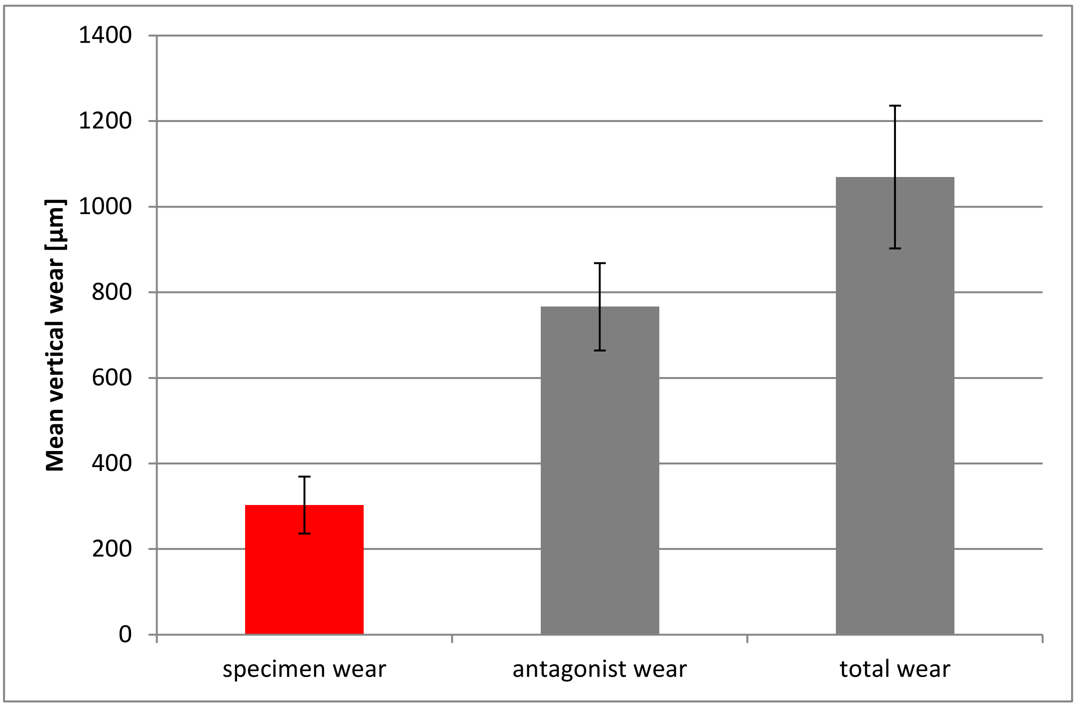


Fig. 6: Mean vertical wear of SR Orthotyp S PE and antagonist in 2-body wear testing.

Conclusion: The DCL material used in the SR Vivodent S PE / S DCL and SR Orthotyp S PE / S DCL teeth exhibits good resistance to wear.

3.1.2 Contact wear (Pin on block)

Investigator: M. Rosentritt, University of Regensburg, Germany, 2015

Method: The wear behaviour of different materials was examined in a chewing simulator using an impact impulse. This pin on block method was performed using either a steatite ball or a denture tooth (of the same material) as the antagonist. Eight samples were prepared, bonded to a sample holder and ground down to a flat finish. Loading was applied in a Regensburg chewing simulator using the following parameters: 50N, 120,000 cycles, 1.2 Hz; 1 mm lateral movement, thermocycling 5°/55°C. The wear surfaces were analyzed using a 3D laser microscope and the maximum vertical depth was determined in microns (µm).

Results: The steatite balls caused more wear than the denture tooth antagonists. The wear of SR Vivodent S PE and the SR Phonares II composite teeth was lower than that of conventional PMMA teeth (SR Vivodent PE) when denture teeth were used as antagonists.

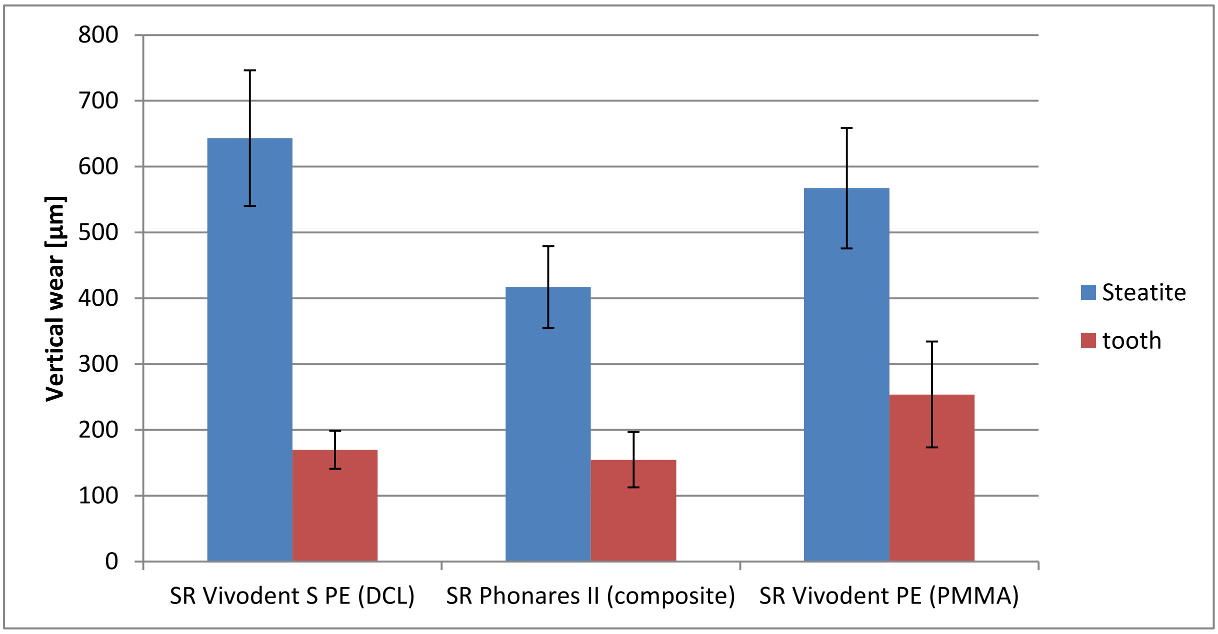


Fig. 7: Wear of SR Vivodent S PE compared with composite (SR Phonares II) and PMMA (SR Vivodent PE) denture teeth in contact wear testing.

Conclusion: The DCL material of the SR Vivodent S PE / S DCL teeth showed a similar wear resistance to the composite teeth when antagonist denture teeth of the same material were used.

3.1.3 Three-body wear (ACTA)

Investigator: M. Rosentritt, University of Regensburg, Germany, 2015

Method: The investigation was carried out in a three-body wear simulator (Willytec). This method uses a sample wheel and an antagonist wheel that rub against each other at different rotational speeds and in opposite directions at a defined contact pressure (15 N) whilst suspended in a slurry. In the process, wear marks are created along the edges of the samples.

Up to six specimens ground from teeth 11 and 12 were used as samples. The slurry consisted of a mixture of millet husks, rice and water. The depth of the worn area was measured at three spots on the individual samples after 50,000, 100,000, 150,000 and 200,000 cycles using a surface roughness tester.

Results: As expected, the PMMA material showed the highest and the composite material the lowest wear. The highly crosslinked PMMA (DCL) used in the SR Vivodent S PE / S DCL denture teeth demonstrated less wear than conventional PMMA.

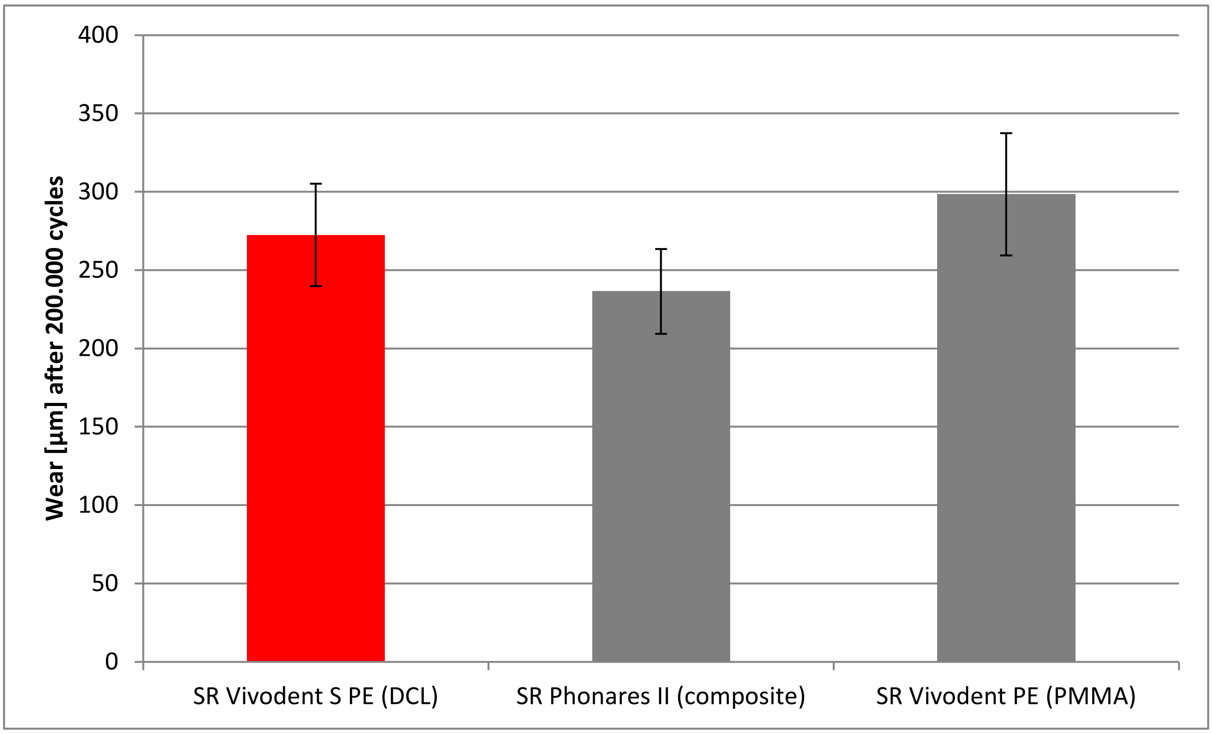


Fig. 8: Wear of SR Vivodent S PE compared with composite (SR Phonares II) and PMMA (SR Vivodent PE) denture teeth in 3-body wear testing.

Conclusion: The DCL material used in the SR Vivodent S PE / S DCL denture teeth was more resistant to wear than conventional PMMA material when subjected to 3-body wear.

3.2 Compressive strength

Investigator: K. Hagenbuch and S. Teichmann, Ivoclar Vivadent, R&D, Schaan, Liechtenstein, 2011, 2012 and 2014

Method: Test samples measuring 4 mm in diameter and 6 mm in height were prepared from tooth material using a dental press. The top and bottom surface were ground to a flat finish with sanding paper. The samples were stored in distilled water at 37°C for 24 hours. The compressive strength was measured in 5 samples each using a Zwick universal testing machine.

Results: The compressive strength of the PMMA materials was slightly lower than that of the composite materials. The compressive strength of the SR Vivodent S PE material was comparable (incisal) or somewhat higher (dentin) than that of the conventional PMMA material (SR Vivodent PE).

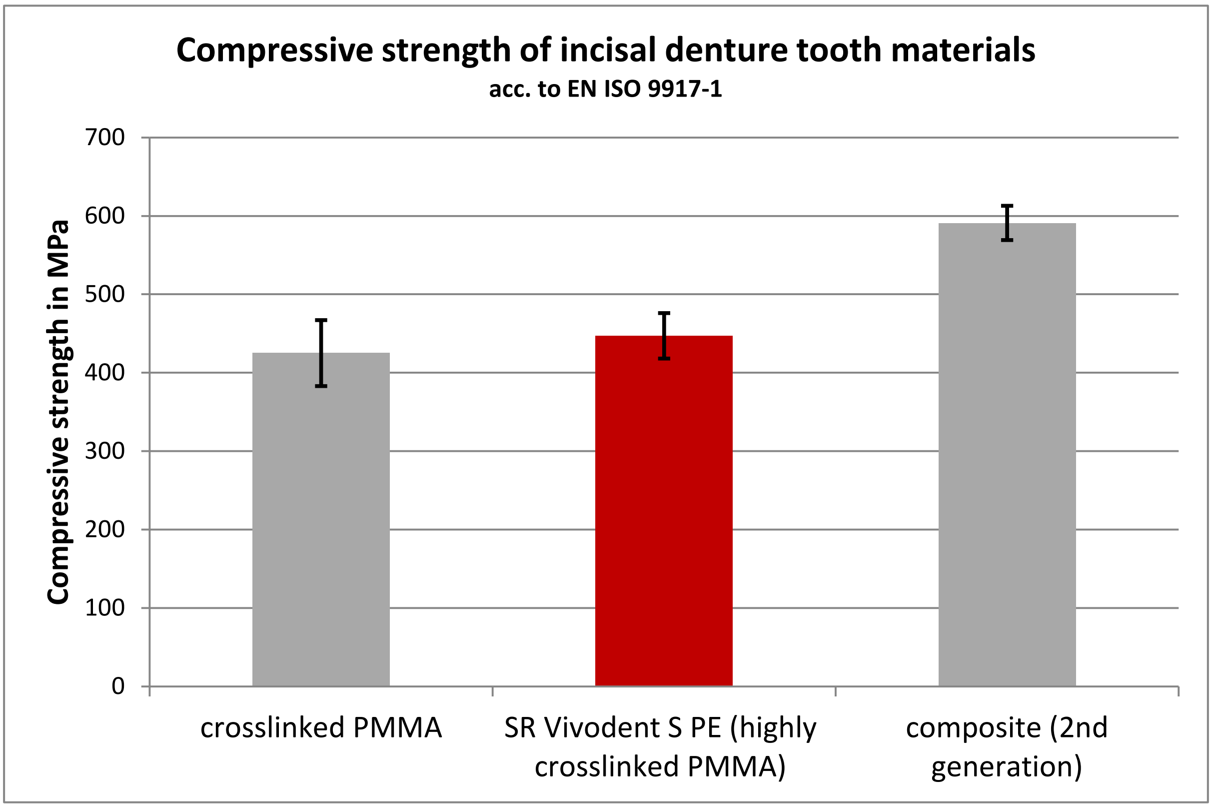


Fig. 9: Compressive strength of denture tooth materials – incisal.

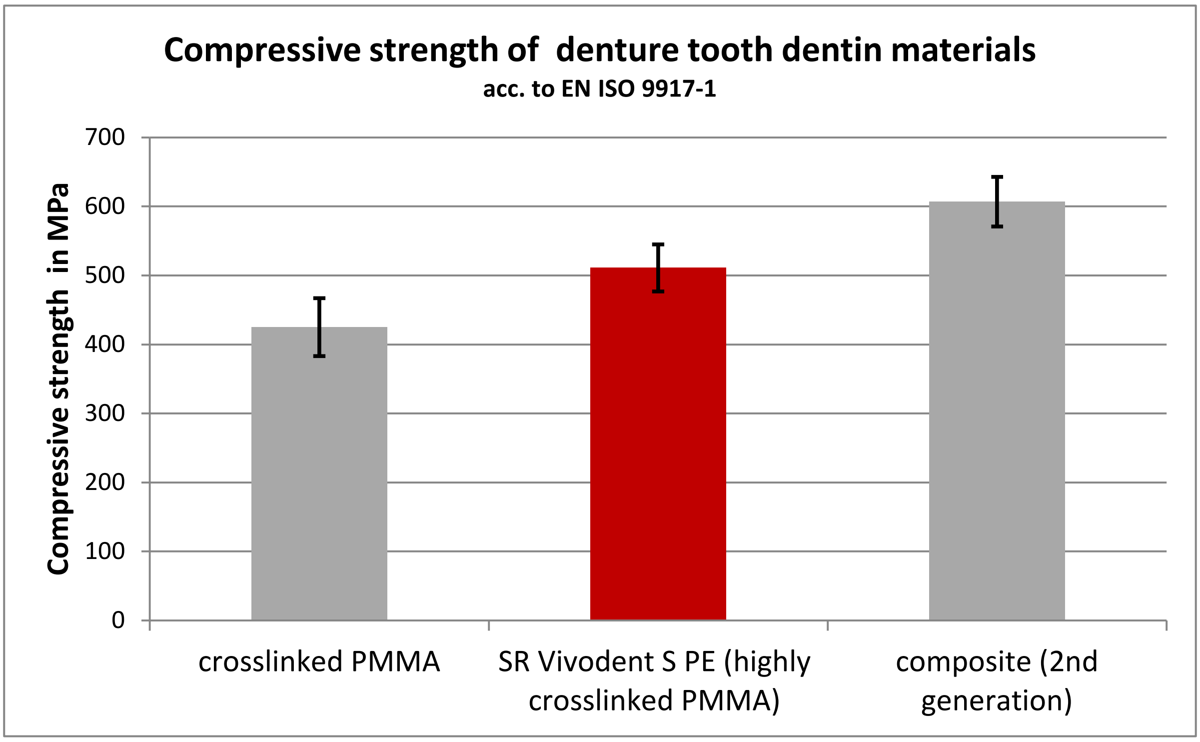


Fig. 10: Compressive strength of denture tooth material – dentin.

Conclusion: Under compressive conditions, a similar or slightly better performance can be expected from the new DCL material compared to the crosslinked PMMA.

3.3 Chipping resistance

Investigator: K. Hagenbuch and S. Teichmann, Ivoclar Vivadent, R&D, Schaan, Liechtenstein, 2011 and 2014

Method: Denture teeth (#15) were secured to metal, mounted on a universal testing machine (Zwick) and loaded at a speed of 5 mm/min (see Fig. 11). The load at which chipping occurred was measured.

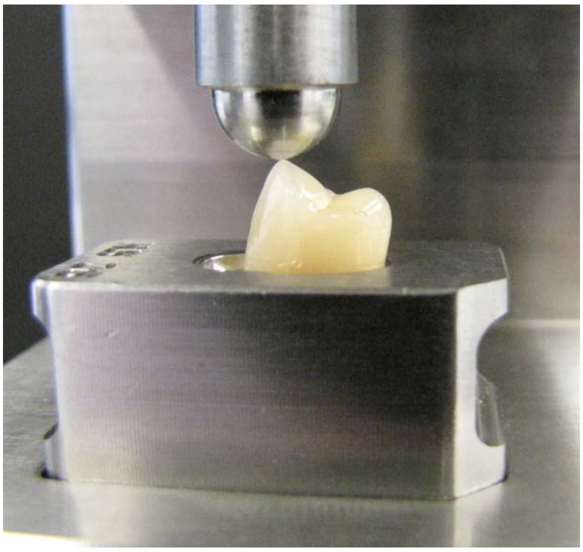


Fig. 11: Setup for chipping test.

Results: Chipping only occurred at forces above 2000 N. The SR Phonares II composite tooth was able to withstand forces above 1800 N (see Fig. 12).

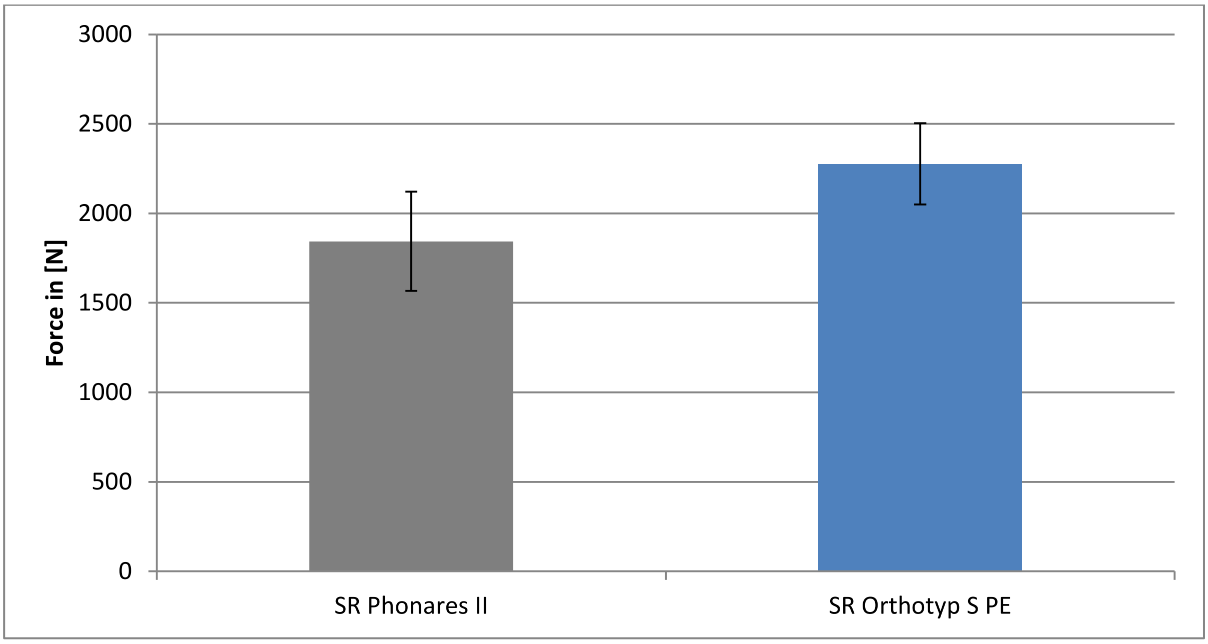


Fig. 12: Load at which chipping occurred in the denture teeth. SR Phonares II: composite material; SR Orthotyp S PE: highly crosslinked PMMA material (DCL).

Conclusion: Chipping occurs in SR Orthotyp S PE teeth only if the material is exposed to very high forces. As expected, SR Orthotyp S PE teeth are more resistant to chipping than teeth made of composite. Having survived loads above 1500 N, the SR Phonares II teeth are also well equipped to withstand average oral chewing forces, which normally do not surpass 600 N.

3.4 Colour stability

Food and beverages can cause staining in both natural and artificial teeth. The tendency to discolouration of a material can partly be simulated in the laboratory by storing test specimens in coloured dye solutions.

Investigator: K. Hagenbuch and S. Teichmann, Ivoclar Vivadent, R&D, Schaan, Liechtenstein, 2014

Method: Denture teeth (SR Vivodent S PE) or test samples made of denture tooth material (incisal material of SR Vivodent PE/PMMA and SR Orthosit/composite) were boiled in 0.1% Safranine T (food colouring) under reflux for 16 hours.

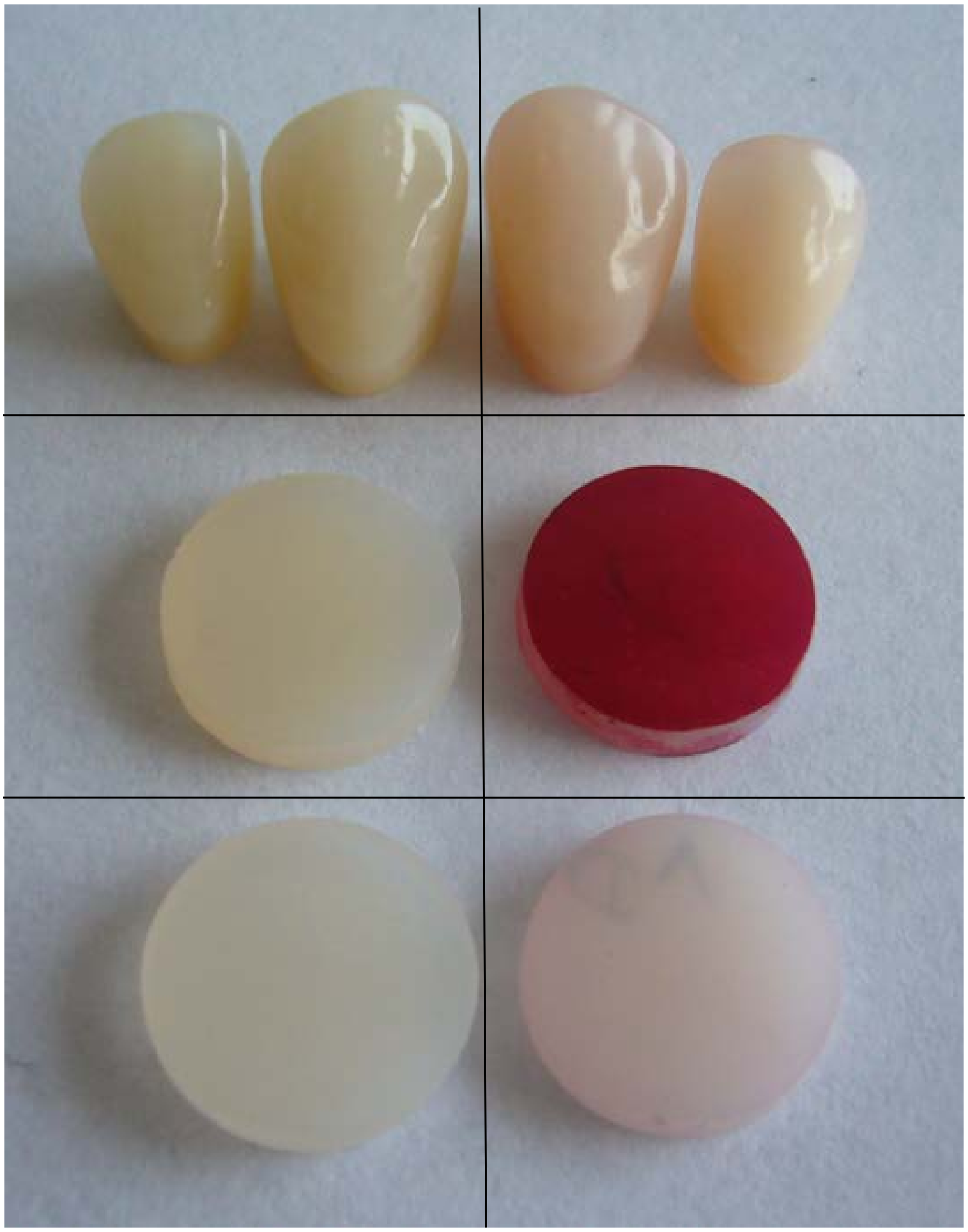
Results: Composite materials of the 1st generation (SR Orthosit PE) were very susceptible to staining. By contrast, the samples made of PMMA (SR Vivodent PE) and the SR Vivodent S PE teeth showed only slight staining (see Fig. 13).

Conclusion: Denture teeth made of DCL material, e.g. SR Vivodent S PE / S DCL teeth, show good resistance to discolouration.

SR Vivodent S PE (DCL-Material)

SR Orthosit (composite)

SR Vivodent PE (PMMA)



control (untreated)

Boiling test Safranin-Lösung (0.1% Safranine solution, 16 h)

Abb. 13: Discolouration of denture teeth materials after 16 hours of boiling in 0.1% Safranine solution. Left side: untreated control specimens.

4. Clinical experience

4.1 Natural esthetics

Functional and esthetic aspects come into play when selecting appropriate anterior denture teeth. With regard to esthetics, the teeth should give patients the feeling that they are wearing their own teeth. The artificial teeth should blend in with the remaining dentition, i.e. they should match the existing teeth. To reconstruct the patient’s natural esthetic appearance, the tooth shape, size, shade and position as well as the contours of the tooth surfaces should be taken into account.

When developing SR Vivodent S PE, the focus was placed on designing a natural-looking tooth. To achieve this, a special shade and layering scheme was designed to achieve harmonious transitions between the (back) incisal, cervical and dentin layers (see section 1.6).

The defining features of natural dentition are reproduced in the SR Vivodent S PE denture teeth. This is demonstrated by the pictures below. Photographs of maxillary anterior teeth were taken (Figs 14 and 16) and juxtaposed with pictures of SR Vivodent S PE anterior teeth (Figs 15 and 17). The comparison showed that certain layering, surface and shade effects of the natural tooth could also be observed in the denture teeth examined.

Fig.14: Natural anterior teeth

Fig.15: Anterior teeth made of SR Vivodent S PE (shade 2A, mould A14) set up in wax

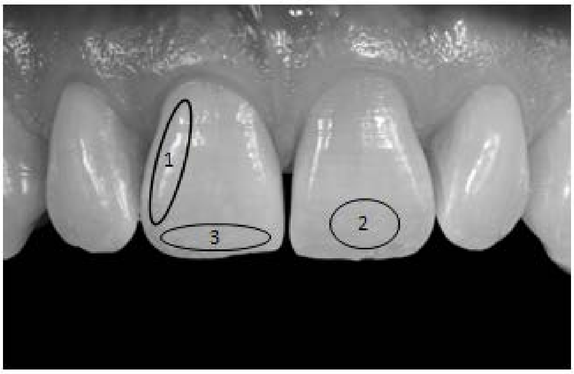


Fig. 16: Black and white image of the natural anterior teeth shown in Fig. 14

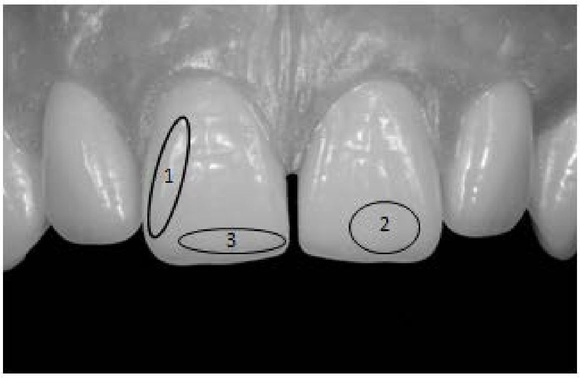


Fig. 17: Black and white image of the SR Vivodent S PE anterior teeth shown in Fig. 15

The SR Vivodent S PE denture teeth (Fig. 17) show similar layering, surface and shade effects tos the natural anterior teeth (Fig. 16). These characteristics include distinctive marginal ridges (1), a chromatic dentin core in the incisal third (2) and a translucent incisal edge (3).

The labial surfaces of both the SR Vivodent S PE denture teeth and the natural incisors shown in the pictures above are confined on both sides by marked marginal ridges (marking 1 in Figs 16 and 17). These ridges convey vitality and individuality to the teeth. Middle-aged teeth exhibit an increased chromatic effect because the dentin mamelons have been replaced with darker and less pronounced secondary dentin, which can be seen as pale yellow to orange swathes in the incisal third (Korson, D. Natürlich gestaltete Keramikzähne, Quintessenz Verlag, 1990, p.74). This is reflected in the SR Vivodent S PE tooth. Given its dark dentin core, it features a shade intensity that causes the incisal third to look more chromatic (marking 2 in Figs 16 and 17).

In natural youthful teeth, the central and lateral incisors demonstrate dentin mamelons that are visible in the area of the semi-transparent incisal edge (Korson, D. Natürlich gestaltete Keramikzähne, Quintessenz Verlag, 1990, p. 74). SR Vivodent S PE imitates this effect to provide the teeth with a natural appearance (marking 3 in Figs 16 and 17).

The surface of a tooth also changes over the course of its life. Wear caused e.g. by regular tooth brushing, results in the enamel layer gradually becoming thinner and smoother. By contrast, youthful teeth normally exhibit a well textured surface. The vivid surface texture of SR Vivodent gives these teeth a highly vital appearance.

Due to the structural, surface and shade effects mentioned, SR Vivodent S PE denture teeth provide natural esthetics for the anterior region.

5. Biocompatibility

5.1 Introduction

Chemically, DCL teeth are based on methyl methacrylate (MMA). Bifunctional dimethacrylates are used as monomers (MMA) and as crosslinking agents in the production of denture teeth. The fillers consist of PMMA and crosslinked PMMA. Additional ingredients are catalysts and stabilizers as well as pigments for esthetic effects.

DCL teeth are layered teeth. An intermediate polymerization step is carried out after the application of each layer. At the end, the tooth is polymerized to its final cure at a temperature of 150°C. During the polymerization process, the MMA and crosslinking agent react with each other, resulting in teeth consisting of completely polymerized polymethyl methacrylate.

In the course of the polymerization process, virtually all the initial ingredients break down or react with each other to form crosslinked PMMA, which is chemically and biologically inactive. Only substances that can be extracted from the material could pose a potential toxicological risk. Given the composition of the DCL material, methyl methacrylate (MMA) may be regarded as the most important soluble substance. The water solubility of the DCL material is, however, less than 1.5 µg/mm^3. This means that only minute quantities of MMA and other substances are dissolved from the teeth. The risk for patients to be harmed by dissolved substances is therefore very low.

5.2 Cytotoxicity

The cytotoxicity of the material was examined in a standard test (according to ISO 10993-5). In this test, aqueous extracts are prepared from the material and applied to mammalian cell culture media. The extracts revealed no cytotoxic potential.

5.3 Genotoxicity

The mutagenic potential was examined according to ISO 10993-3. The material revealed no mutagenic potential.

5.4 Sensitization and irritation

The skin sensitization potential of extracts from the material was tested on a guinea pig maximization test. The test revealed no allergenic potential. The same test also showed that the material had no irritating effect.

5.5 Conclusion

The toxicological data of the initial ingredients and the tests carried out on the fabricated teeth show that the DCL material is a state-of-the-art, biocompatible material.

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Edition: December 2016