

SR **PHONARES**[®]
MODERN MASTERPIECES



Scientific Documentation

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1. Introduction

The majority of resin denture teeth are fabricated of PMMA. During the past years, composite has also been used in the manufacture of artificial teeth. SR Phonares is a denture tooth that is composed of the latest generation of composite material: nano-hybrid composite - or NHC.

1.1 History

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 still preserved dentures were fabricated. While 3,500 years ago, the ancient Egyptians carved false teeth out of mulberry wood and tied them to the adjacent teeth with gold wire, the Etruscans arrived at considerable skill producing constructions made of gold and bovine teeth, which were already guided by principles used in denture prosthetics today. The first porcelain teeth were developed as early as in 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 [1].

With the emergence of polymer chemistry in the early 20th century, the foundation for the widespread use of removable dentures was laid.

The development of acrylates in the nineteen-thirties [2] marks the beginnings of the industrial production of resin materials for dental applications [18]. Plexiglass, an early representative of this category of materials, was used for technical applications. Methyl methacrylate (MMA) – a small molecule – initially exhibited a polymerization shrinkage rate of 21%, which was clearly too high for use in dental restorations and denture teeth. Only after developers found a method of substantially reducing the polymerization shrinkage by adding prepolymers such as splinter polymers [3] or pearl polymers did the success story of MMA in denture prosthetics unfold. Its rise to popularity occurred almost simultaneously in Germany and the United States. First products for dental applications were launched in 1937. In 1946, barely ten years later, 98% of all dentures were manufactured using PMMA [4].

In the nineteen-fifties, Rafael Bowen developed Bis-GMA, also known as “Bowen monomer” [5; 6]. The era of dental composites commenced after a method of mixing Bis-GMA with diluting monomers and adding glass or silicate glass powders to the mixture was developed. The resulting composites showed a rather rough surface texture and an unsatisfactory *in vivo* wear behaviour because of the relatively coarse filler particles.

The introduction of microfiller-containing composites solved the problems connected with a rough surface texture. Having a mean particle size of 40 nm, highly dispersed silicon dioxide appeared to be a suitable material for eliminating rough surfaces. However, the addition of amorphous silicon dioxide increased the viscosity of the material to such an extent that it was impossible to achieve an appropriate filler concentration. The isofiller technology [7] developed by Ivoclar Vivadent helped to overcome this drawback. Isofillers consist of splinter prepolymers, which, in other words, are microfiller compounds in powder form. IsoCap and Isosit from Ivoclar Vivadent were the first materials to incorporate this technology. Even today, Isosite-based denture teeth (SR Orthosit PE) are among the most wear resistant teeth available on the market. As a drawback, conventional composite materials are associated with a tendency to discoloration and plaque accumulation.

The NHC material represents another step forwards in the development of composite materials; the resulting SR Phonares teeth combine the highest demands of material quality and esthetics.

The development of dental composite materials led to extraordinarily successful results. The material grew from an inferior resin restorative material into the material of choice for both esthetic restorative therapy and removable dental prostheses. This interesting upward trajectory was driven forwards by improvements of the material, e.g. filler technologies,

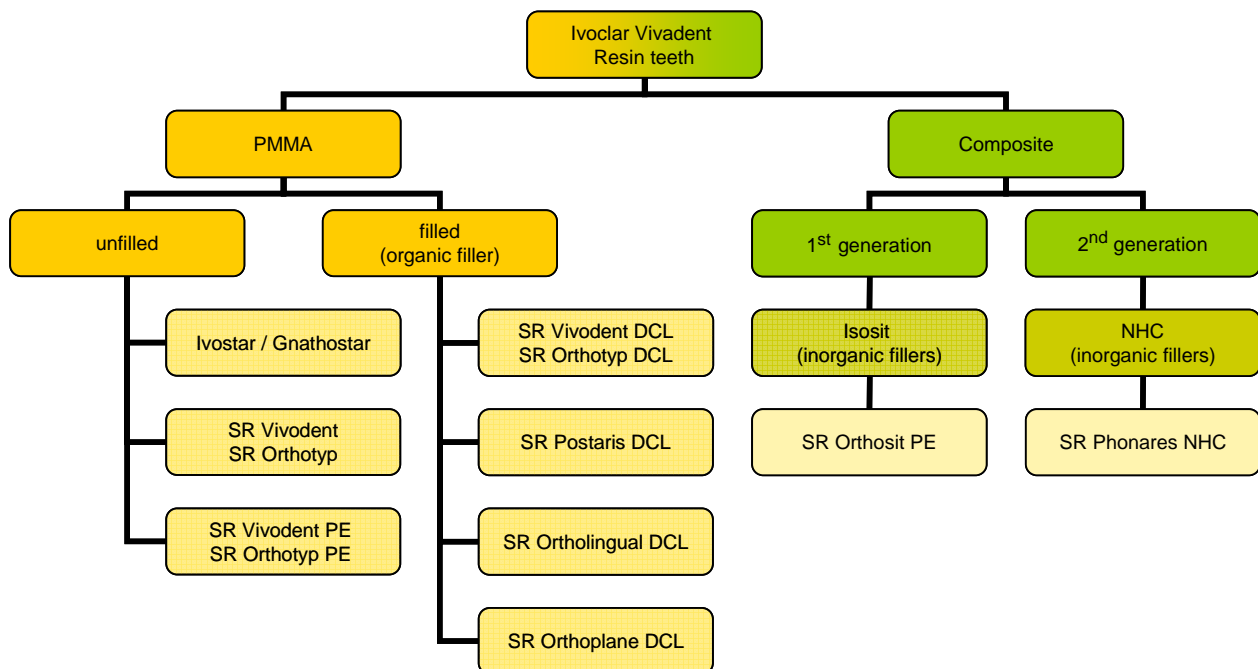
development of new monomers for the matrix and new layering techniques to enhance the esthetic qualities.

The SR Phonares tooth line (NHC material) combines Ivoclar Vivadent's long-standing experience in the manufacture of highly functional composites with the company's tradition in the production of highly esthetic artificial denture teeth.

Today various PMMA-based materials are available for the production of denture teeth; some of these materials contain organic and/or inorganic fillers, which improve the mechanical properties of the teeth. Alongside PMMA-based denture teeth, several composite teeth are also available on the market.

The Ivoclar Vivadent range of resin teeth encompasses both denture teeth made of filled and unfilled PMMA and composite teeth. However, the majority of artificial teeth consist of conventional unfilled PMMA - a material which has a proven clinical track record of more than fifty years.

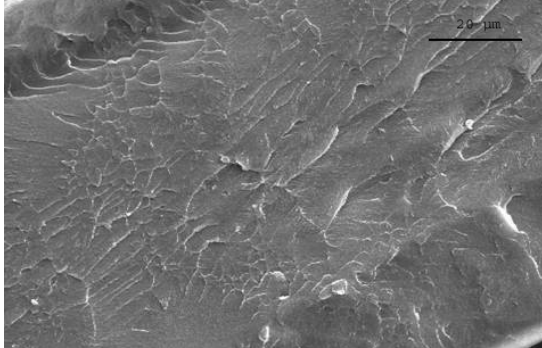
1.2 Overview of Ivoclar Vivadent resin teeth:



1.3 PMMA denture teeth materials

Today, various PMMA-based materials are available for the manufacture of denture teeth:

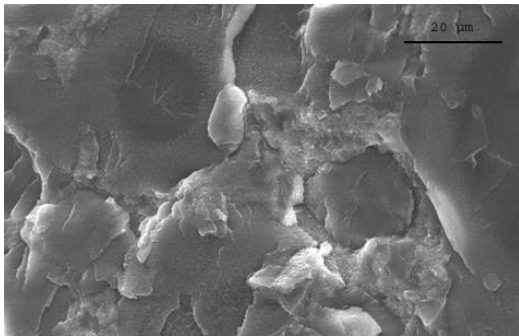
1.3.1 Conventional PMMA teeth (unfilled)



The classic material for the fabrication of denture teeth is polymethyl methacrylate. In the production process, a non-crosslinked linear polymer is mixed with a monomer containing a crosslinking agent and then polymerized in moulds to form artificial teeth.

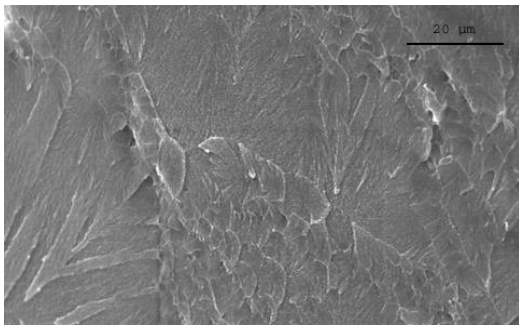
The mixture of monomer and cross-linking agent typically consists of methyl methacrylate and a dimethacrylate, in most cases ethylene glycol dimethacrylate. The SR Vivodent PE and SR Orthotyp PE teeth are part of this category of material.

1.3.2 PMMA teeth containing inorganic filler



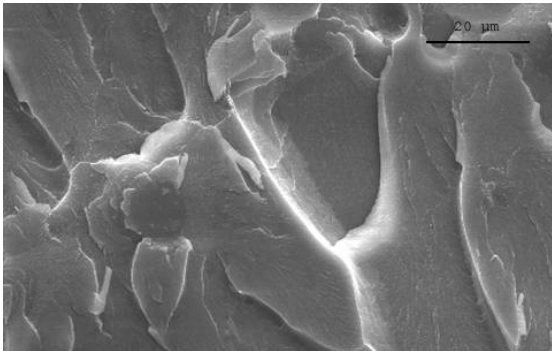
These materials are based on polymethyl methacrylates, to which inorganic fillers have been added.

1.3.3 Highly crosslinked PMMA teeth: IPN



This denture teeth material, which is known as interpenetrating polymer network (IPN) material, can also be allocated to the category of PMMA materials. To produce this type of material, polymers with different chemical and physical natures penetrate each other and become interlaced with each other with the support of swelling processes.

1.3.4 Highly crosslinked PMMA teeth: DCL (organically filled)



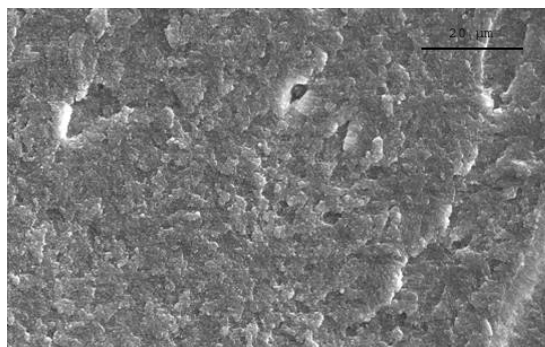
DCL is a severely modified variant of polymethyl methacrylate. The polymer filler and matrix are homogeneously crosslinked. The result is a thoroughly networked material system, which offers substantial advantages in terms of oral stability and wear resistance.

Representatives of this category of materials are members of the family of DCL teeth (e.g. SR Vivodent DCL, SR Orthotyp DCL, etc).

1.4 Composite denture teeth materials

Ivoclar Vivadent uses a variety of composite materials to manufacture composite denture teeth:

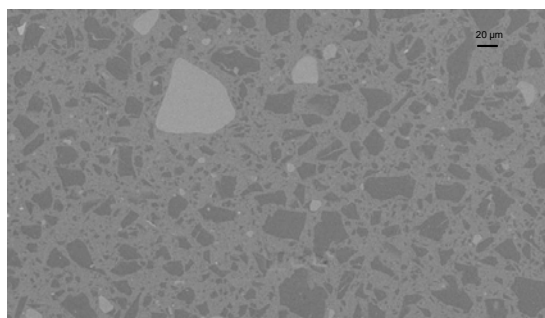
1.4.1 UDMA teeth containing inorganic filler: Isosit



In contrast to the type of materials listed in Section 1.3, the Isosit material is not based on PMMA polymers; instead it is composed of a urethane dimethacrylate-based cross-linking agent, which is reinforced with inorganic microfillers. The inorganic pyrogenic silica fillers considerably increase the hardness and rigidity of the material compared with PMMA-based materials.

This material is used for SR Orthosit teeth.

1.4.2 Nanohybrid composite (NHC) teeth containing inorganic filler



The NHC material is a composite which consists of a urethane dimethacrylate matrix with inorganic fillers, iso-fillers (prepolymer) and PMMA clusters embedded in the structure.

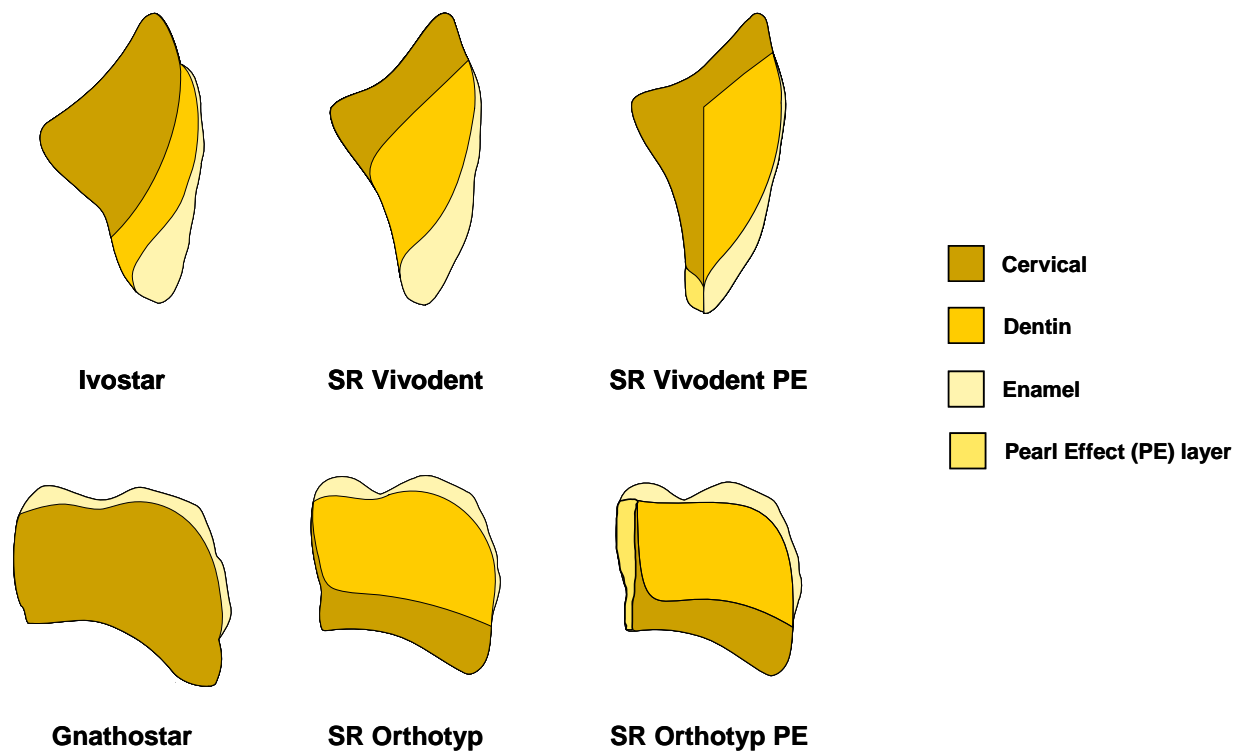
Please see Section 2 for a detailed description of this material.

2. Description of material/Materials science

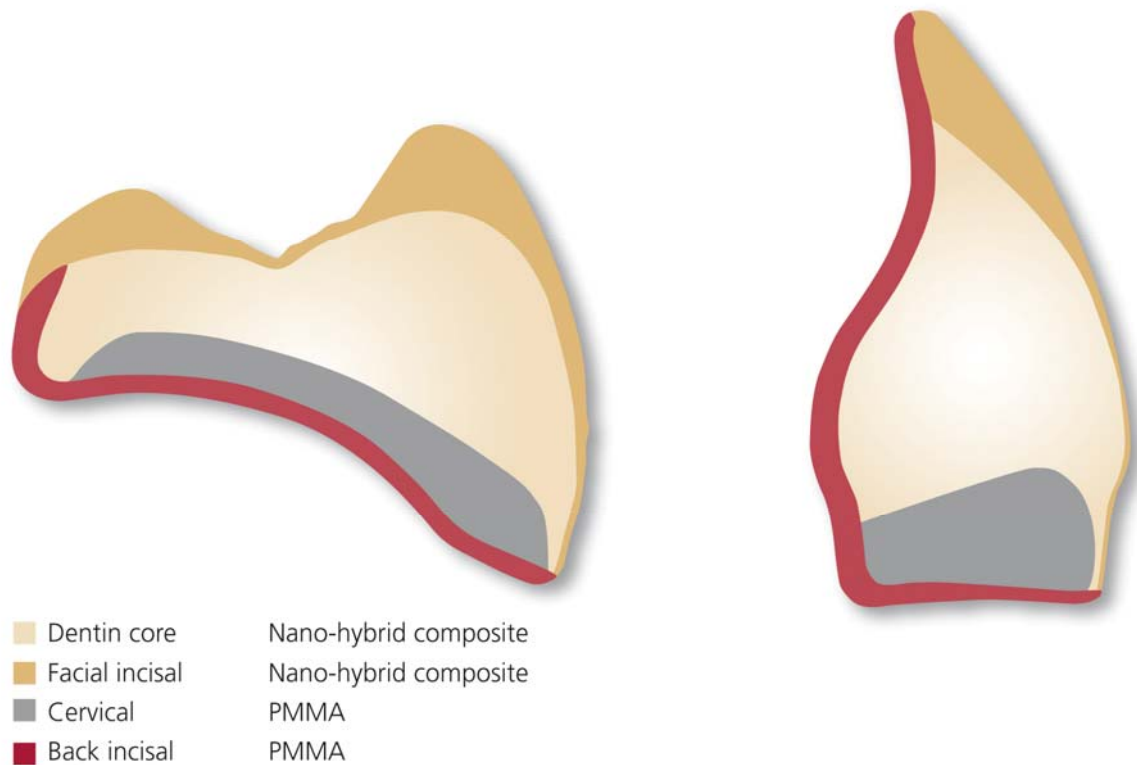
2.1 Layering scheme

The Ivoclar Vivadent range comprises resin teeth that are based on different layering schemes. The tooth lines range from posterior teeth that involve a straightforward two-layer design (e.g. Gnathostar) to highly esthetic teeth consisting of four layers (e.g. SR Vivodent PE anterior teeth) and the new four-layer SR Phonares NHC teeth.

2.1.1 Layering scheme of different Ivoclar Vivadent teeth



2.1.2 Layering scheme of SR Phonares



The true-to-nature shade effect and structure of the SR Phonares anterior and posterior teeth is achieved with four individually shaded layers. The dentin core and facial incisal consist of NHC material, which imparts both high wear resistance and natural esthetics to the tooth. The back incisal and cervical layers are comprised of PMMA material to ensure an optimal and stress-free bond with conventional denture base materials.

2.2 Description of material

2.2.1 NHC material

The SR Phonares teeth consist of NHC material (nanohybrid composite). This material is based on a urethane dimethacrylate matrix, which comprises various types and sizes of fillers as well as PMMA clusters.

Not only the chemical composition but also the size, shape and concentration of filler particles have a significant effect on the properties of a composite. The NHC material falls into the category of hybrid composites. The adjective "hybrid" means that this composite is a compound of different types and sizes of fillers; "hybrid" also means that the material is a combination of two types of material: composite and PMMA.

The NHC material comprises a variety of fillers: highly crosslinked inorganically filled macrofillers, highly densified inorganic microfillers and silanized nanoscale fillers based on silicon dioxide. The macrofillers are mainly responsible for the strength and colour stability of the teeth, while the microfillers enhance the material's resistance to wear.

The optical properties of the nanofillers are fundamentally different from those of larger fillers. For instance, composite pastes which contain fillers of a size smaller than 50 nm exhibit a translucent appearance, regardless of whether or not the refractive index corresponds with that of the monomer matrix. This represents a decisive advantage over conventional fillers, whose refractive index has to match that of the polymerized matrix to attain a high level of translucency. In addition, nanofillers may alter the refractive index of a monomer mixture without decreasing the degree of translucency [18]. This offers additional possibilities in the development of composite teeth, which have to offer true-to-nature esthetic and translucent properties.

2.2.2 Schematic of NHC microstructure

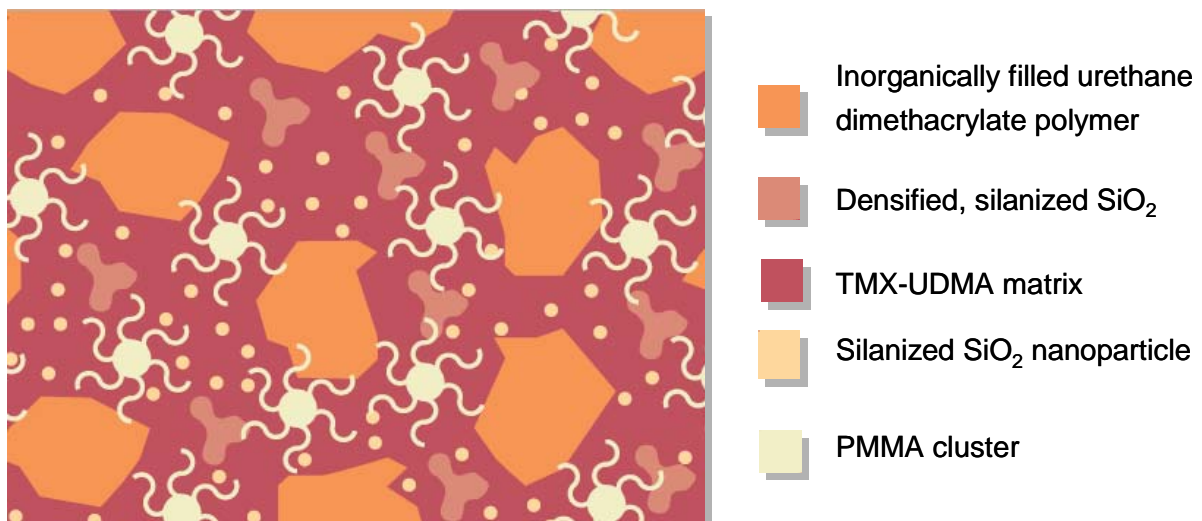


Fig. 1: Schematic of NHC microstructure

2.2.3 Microstructure of NHC material (SEM image)

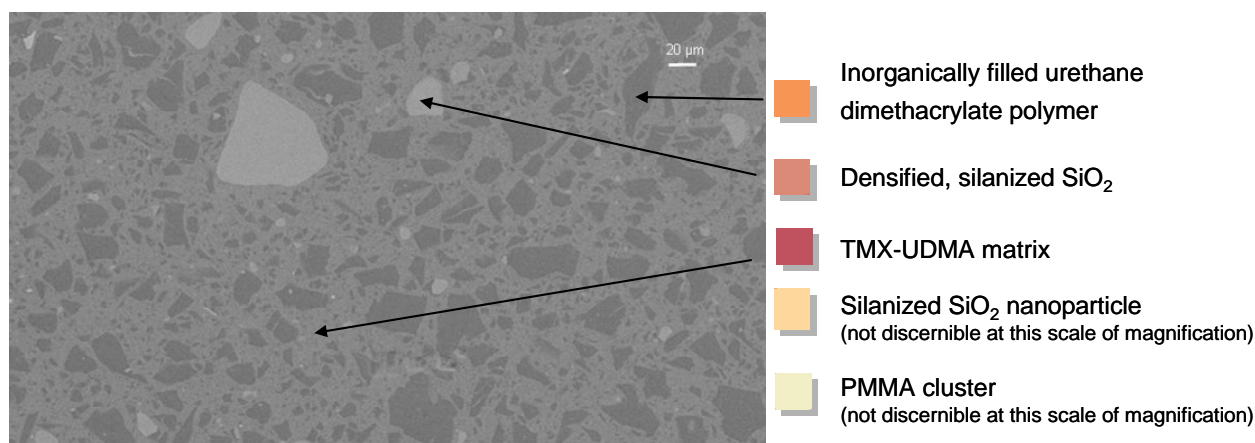
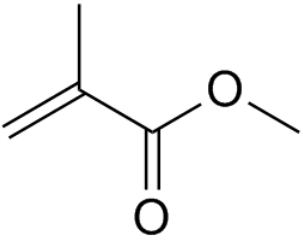
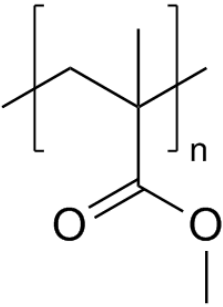


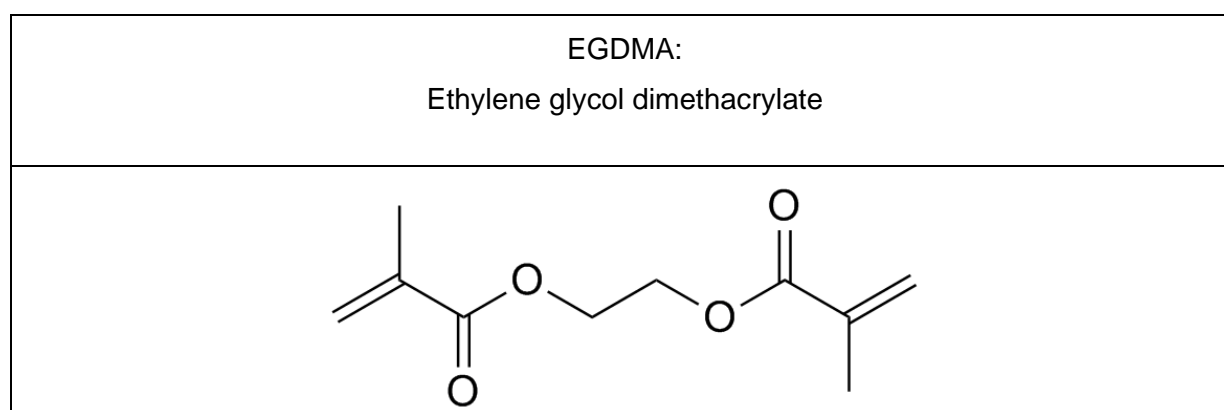
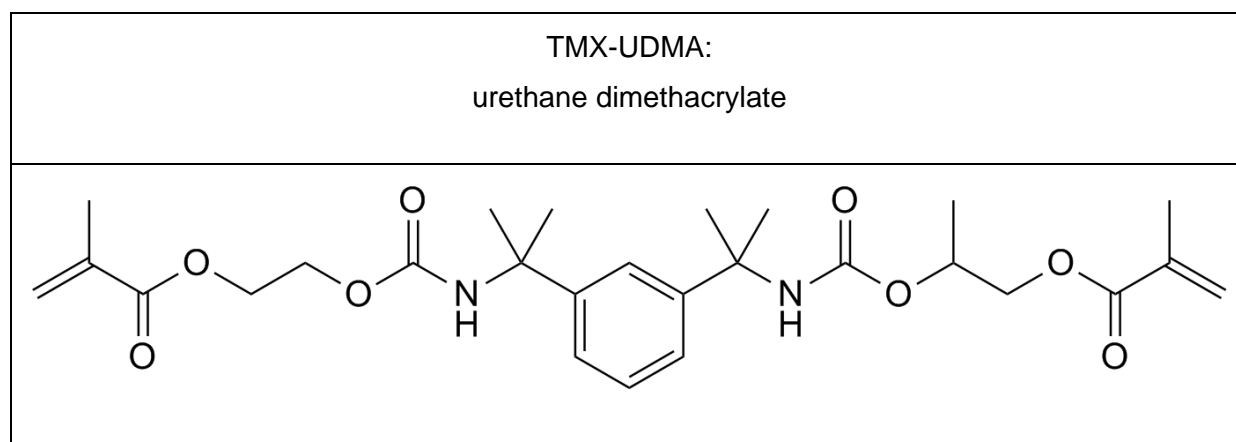
Fig. 2: SEM image of a ground and polished NHC sample

2.2.4 Description of the components of NHC

NHC component	Function	Main advantages
TMX-UDMA (urethane dimethacrylate)	Matrix	The TMX-UDMA matrix is characterized by a high degree of cross-linking. The material structure is very stable and resistant to chemical attacks.
Densified, silanized SiO ₂	Filler 1	This inorganic filler is utilized to strengthen the matrix and increase the material's hardness and wear resistance. It also optimizes the material's refractive index and therefore its true-to-nature shade effect and opalescence.
Silanized SiO ₂ nanoparticle	Filler 2	These nanoscale surface-modified inorganic particles strengthen the composite structure. Because of their nanoscale nature, these particles form homogeneous contact surfaces. This also helps to preserve the opposing tooth structure.
Inorganically filled urethane dimethacrylate polymer	Filler 3 (iso-filler)	These matrix-based prepolymer particles reduce the polymerization shrinkage stress.
PMMA cluster	Inclusions	These PMMA clusters are embedded in the composite structure and reduce the material's affinity for plaque accretion and discoloration.

2.2.5 Chemical structure

MMA: Methyl methacrylate	PMMA: Polymethyl methacrylate
	



3. Technical data

SR Phonares NHC / SR Phonares *Typ* NHC / SR Phonares *Lingual* NHC

Material type: Facial incisal and dentin = Nanohybride composite (NHC)
Back incisal and cervical = Polymethyl methacrylate (PMMA)

Structure of tooth: Four layers: Incisal (I), dentin (D), cervical (C) and back incisal (BI) made of different methacrylate composites

Standard composition: (in % by weight)

	<i>I, D</i>	<i>C, BI</i>
Dimethacrylate	17.0 – 25.0	1.0 – 4.0
Polymethyl methacrylate	19.0 – 24.0	94.0 – 98.6
Highly dispersed silicon dioxide	18.0 – 25.0	-
Inorganically filled UDMA prepolymer	35.0 – 40.0	-
Pigments, depending on shade	0.1 – 0.3	0.1 – 0.4
Initiators and stabilizers	0.8 – 1.2	0.3 – 0.5

Physical properties:

		<i>I, D</i>	<i>C, BI</i>
Flexural strength	ISO 10477	> 125	> 120 MPa
Modulus of elasticity	ISO 10477	> 4500	> 3000 MPa
Ball indentation hardness	ISO 2039-1	> 240	> 170 MPa
Water sorption	ISO 10477	< 23	< 26 µg/mm ³
Water solubility	ISO 10477	0.0	< 0.1 µg/mm ³
Vickers hardness HV 0.5/30	internal instruction	> 260	>190 MPa

4. In vitro investigations

4.1 General

The results of *in vitro* investigations cannot be taken as a direct measure of a material's clinical suitability. However, these results can provide important indications of how the product behaves under certain test conditions.

The values obtained in the process should not be used as absolutes; instead, they should be interpreted/utilized against the test configuration and conditions.

As a consequence, the wear measurements shown in the diagrams of Section 4.3 are not represented in absolute values; instead they indicate the relative wear in comparison with PMMA material.

4.2 The problems of interpreting *in vitro* wear measurements

Interpreting the outcome of wear measurements creates a great deal of difficulty because wear measurements involve complex interrelationships and numerous factors affecting the results.

The wear behaviour of a material is not only determined by its mechanical properties but is also significantly affected by other factors, e.g. surface roughness, irregularities, phases and inclusions, orientation of crystals etc. Furthermore, the type of antagonists, experimental design and environment also play an important role.

The wear resistance of teeth is a frequent topic of publications. Widely varying test methods [8; 9] are described and used in such studies and, at times, contradictory results are measured and published [10; 11]. Heintze et al [8] compared the controversial wear results of *in vitro* investigations with the results of clinical studies. The issues involved in transferring *in vitro* results to *in vivo* conditions are described and discussed in detail in this publication.

Individual methods produce different results and what is more, even the same wear measurement method may provide differing results, depending, for instance, on the type of antagonist material selected for conducting the test. Hahnel et al [12] studied the wear behaviour of different tooth materials in conjunction with different antagonist materials (steatite, steel, artificial teeth) using a two-body wear method (pin on block). This study showed that the material of the antagonist had a significant effect on both the wear mechanism and loss of material. Steatite emerged as the "gold standard" to determine the wear resistance of artificial teeth in this study. Steatite enables a significantly more accurate differentiation of the wear resistance of individual denture teeth when they are tested.

The fact that individual chewing simulators fail to provide results that correlate with each other is particularly worthy of notice. This problem may be attributed to the fact that most methods can only simulate one or two of the different wear mechanisms occurring in the oral cavity at any one time. Therefore, dental materials should be tested in two or more chewing simulators to enhance the clinical relevance of the results. The results of a single wear measurement run may be misleading.

4.3 Wear – *in vitro* investigations

The following graphs illustrate the results of *in vitro* wear measurements obtained with SR Phonares. The results are shown in comparison with different kinds of materials typically used for denture teeth. The illustrations demonstrate the relative wear in comparison with PMMA.

4.3.1 Pin on block

Two-body wear testing – Pin on block

Investigator: M. Rosentritt, University of Regensburg, Germany
 Simulation: Regensburg chewing simulator (“pin on block” method)
 120,000 cycles, 50 N, 1.2 Hz
 Samples: Samples made from denture teeth
 Evaluation: Scanning of plaster replicas using a Willytec 3D laser scanner
 Antagonist: Steatite

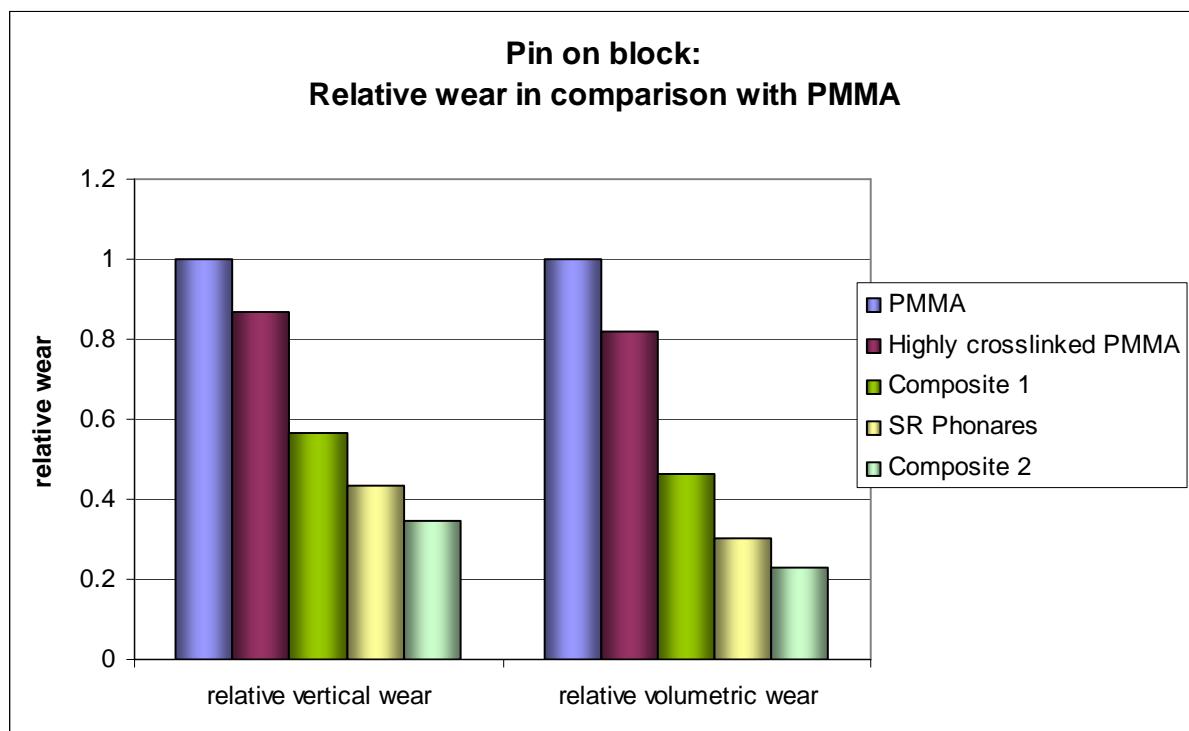


Fig. 3: “Pin on block” method: Relative wear in comparison with PMMA (Measurement: M. Rosentritt, Regensburg, 2009)

The wear of composite teeth is lower than that of PMMA-based teeth. SR Phonares ranks in the middle range of the composites tested with the “pin on block” wear testing method.

4.3.2 Leinfelder method

Three-body wear testing – Leinfelder

Investigator: M.A. Latta, Creighton University, Nebraska, USA
Simulation: Leinfelder chewing simulator, 80 N, 1 Hz, rotation +/-30°, 400,000 cycles, slurry (PMMA spherules)
Samples: Samples made from denture teeth
Evaluation: 3D profilometer

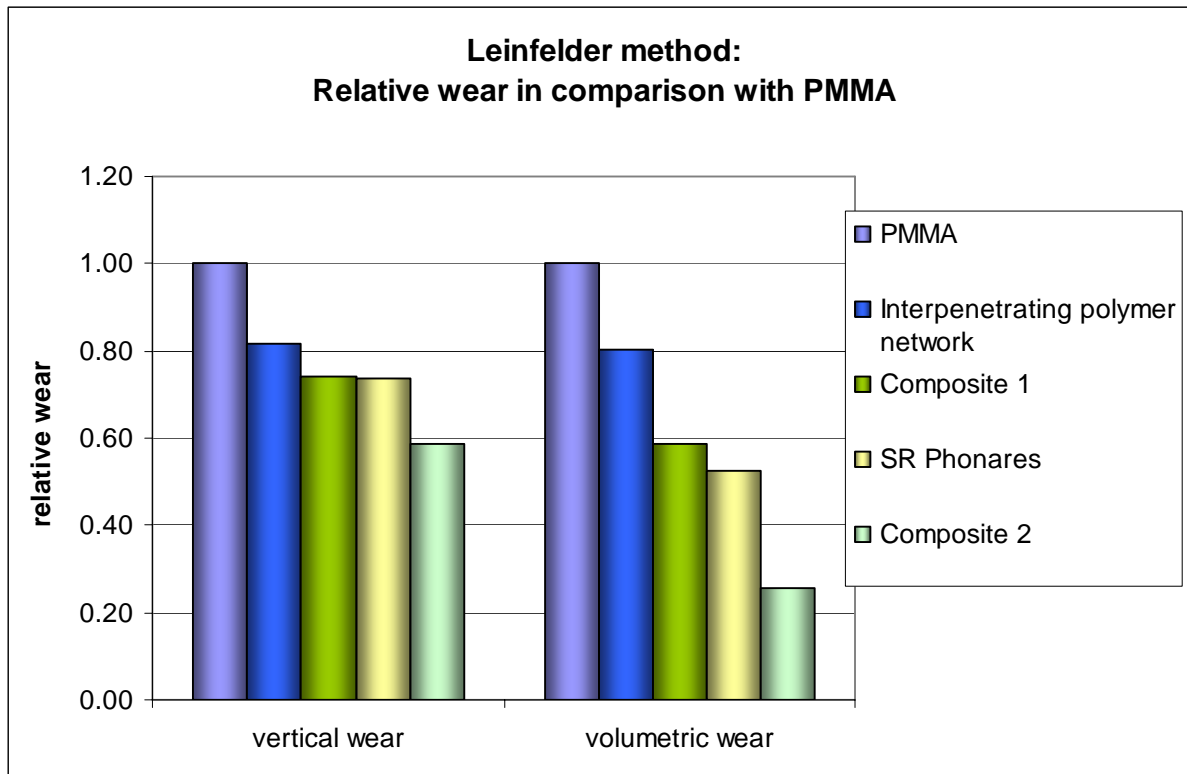


Fig. 4: Leinfelder method: Relative wear in comparison with PMMA (Measurement: M. Latta, Nebraska, 2009)

Composite 2 shows the lowest wear values of all materials tested when subjected to three-body wear testing. SR Phonares and Composite 1 produced statistically similar values after 400,000 cycles and were more resistant to wear than PMMA and IPN.

4.3.3 ACTA

Two-body wear testing – ACTA

Investigator: M. Rosentritt, University of Regensburg, Germany
 Simulation: ACTA, 15 N, 200,000 cycles, millet husk –rice mixture, thermocycling at 5/55 °C
 Samples: Samples made from denture teeth material
 Evaluation: Measurement of the wear facet of the sample in relation to the non-abraded material surface (surface roughness analyzer)

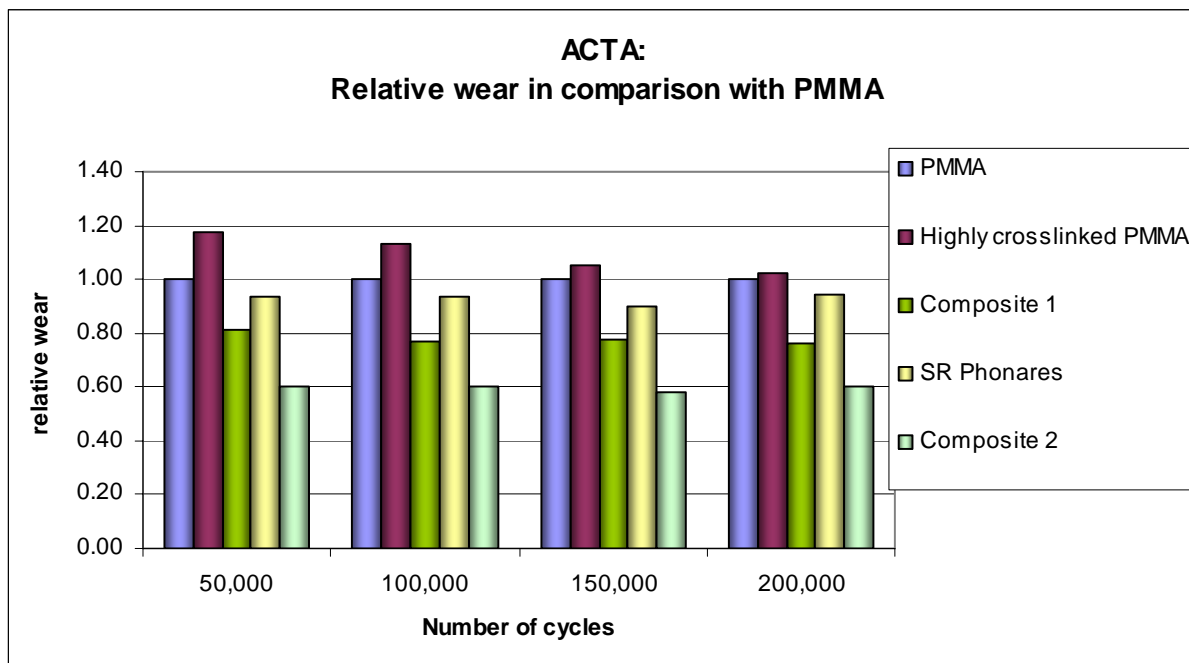


Fig. 5: ACTA method: Relative wear in comparison with PMMA (Measurement: M. Rosentritt, Regensburg, 2009)

The composite materials produced lower wear values than the PMMA-based materials when the ACTA method was used.

When subjected to this method, SR Phonares demonstrated the lowest wear resistance of the composite materials tested.

4.3.4 Willytec chewing simulator

Two-body wear testing – Willytec – Denture teeth

Investigator: S. Heintze, Ivoclar Vivadent R&D, Schaan, Liechtenstein
 Simulation: Willytec chewing simulator, 100,000 mastication cycles, 3 kg loading, 3 mm lateral movement, no lifting, 1.2 Hz, thermocycling (5 °C/ 55 °C)
 Samples: Prefabricated denture teeth, 8 teeth
 Antagonist: Made from prefabricated denture teeth
 Evaluation: Measuring of plaster replicas using a Willytec 3D laser scanner

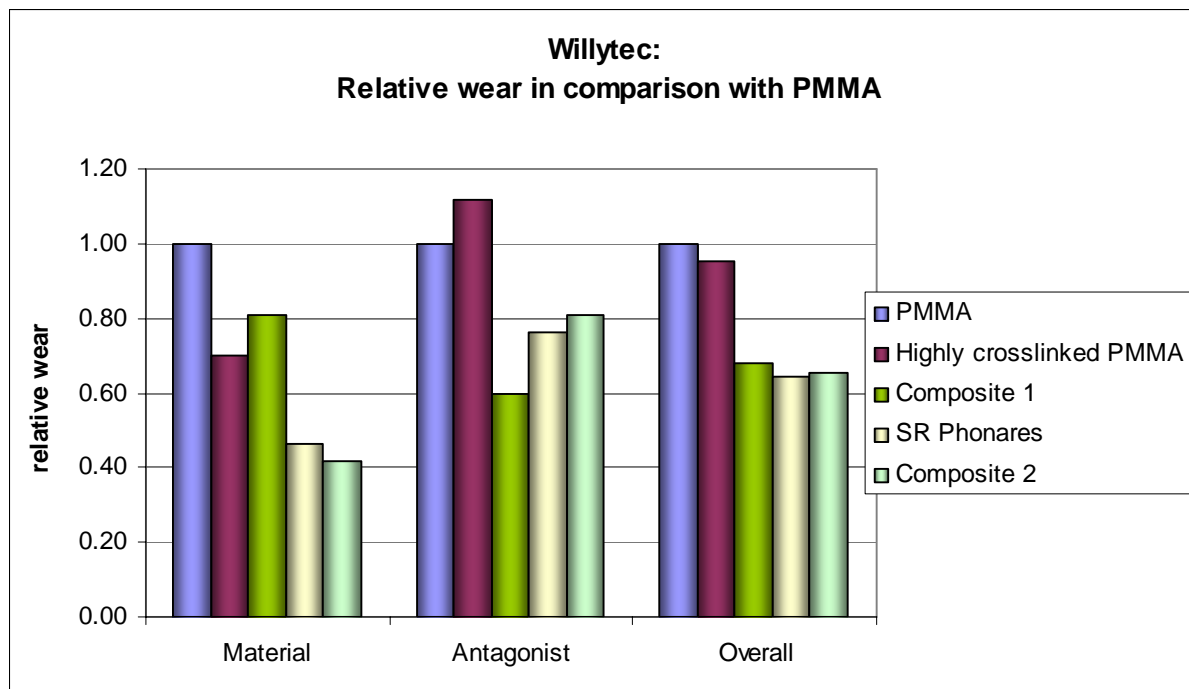


Fig. 6: Willytec method: Relative wear in comparison with PMMA (Measurement: R&D, Ivoclar Vivadent, Schaan, 2009)

When subjected to testing in a chewing simulator, SR Phonares shows very low material wear compared to the other denture teeth materials tested. If these results are combined with the antagonist wear results, SR Phonares and the other composites tested demonstrate a significantly lower overall wear than the PMMA-based denture teeth.

4.3.5 Tooth brush abrasion

Three-body wear testing – Simulated tooth brushing

Investigator: K. Hagenbuch, Ivoclar Vivadent R&D, Schaan, Liechtenstein
Simulation: company's in-house device; simulated tooth brushing with toothpaste
7.5 hours at room temperature
Samples: Samples made from denture teeth material
Evaluation: Volumetric loss determined by loss of weight and density

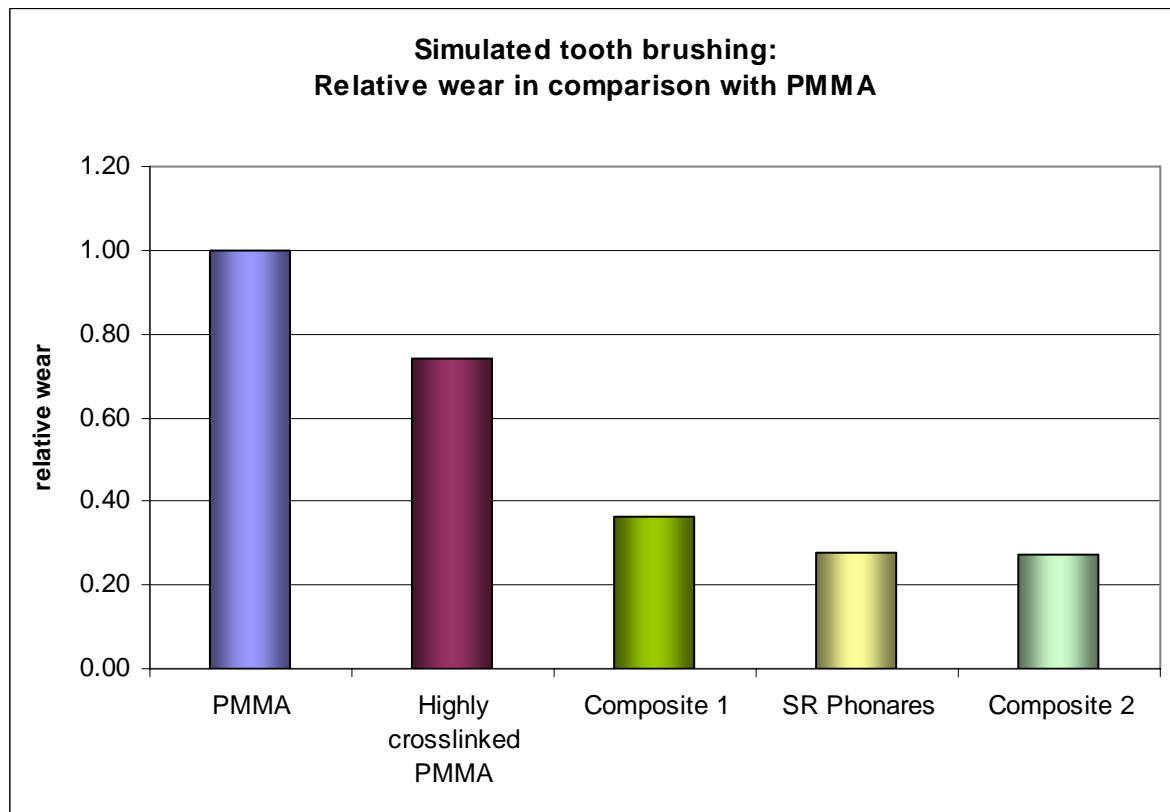


Fig. 7: Simulated tooth brushing: Relative wear in comparison with PMMA (Measurement: R&D, Ivoclar Vivadent, Schaan, 2009)

When subjected to simulated tooth brushing, SR Phonares and Composite 2 show the lowest volumetric substance loss of all denture teeth materials tested.

4.4 *In vitro* wear: summary of results

SR Phonares was subjected to different wear testing methods to arrive at an accurate statement on the material's wear behaviour (Fig. 8). Alongside SR Phonares, several popular denture teeth materials were included in each test method.

SR Phonares and the other composite materials included in the tests demonstrated the lowest wear in conjunction with the wear testing methods applied. The ACTA method showed higher wear values for SR Phonares than for the other two composites; however, these values were still lower than those of the PMMA-based materials.

The variety of methods used and the results obtained with them (Fig. 8) show that SR Phonares may be described as a wear resistant denture teeth material.

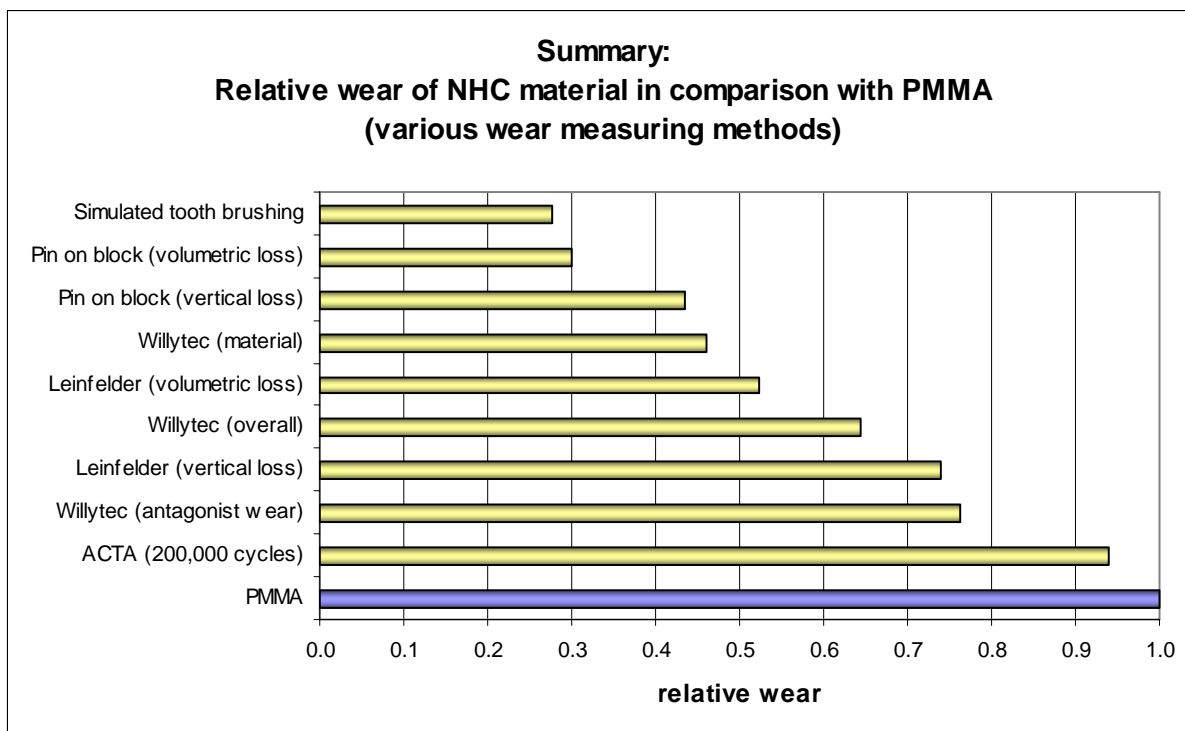


Fig. 8: Summary: Relative wear of NHC material in comparison with PMMA (various methods)

4.5 Colour stability

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

The image below shows a number of denture teeth made of different types of materials which were boiled in coffee or 0.1% safranin T under reflux for 16 hours. It has to be taken into account that the initial colour (shade) was not identical in all test samples.

















Material	Water	Coffee	Safranin T 0.01%	Safranin T 0.1%
PMMA				
Highly cross-linked PMMA				
Composite 1				
SR Phonares				

Fig. 9: Results of discolouration test: denture teeth materials after having been stored in various dye solutions (16 hours, under reflux) (Measurement: R&D, Ivoclar Vivadent, Schaan, 2009)

Generally, composite teeth are more prone to discoloration than PMMA teeth. SR Phonares consists of a newly designed NHC composite material, whose resistance to discoloration is significantly increased over that of conventional composite materials.

5. Clinical investigations

Study centre: - Prof. Dr. John R. Agar, University of Connecticut, Farmington, USA
- Dr. Neal R. Garrett, UCLA School for Dentistry, Los Angeles, USA

Study title: In vivo evaluation of the occlusal wear of new composite denture teeth.

Objective/

Experimental design: Twenty patients received implant-borne complete dentures. The colour stability and the tendency to plaque and calculus accumulation will be rated at regular recalls. In addition, the wear behaviour will be determined (replica technique; surveying with laser scanning equipment) and a photographic documentation will be compiled.

6. Biocompatibility

6.1 Introduction

The basic materials polymerize to a solid material during the production process of the denture teeth. The biocompatible properties of the solid material are different from those of the basic materials. The denture teeth consist of an insoluble polymer which is not accessible to the organism and can be regarded as inert. Only substances that may dissolve from the material could pose a risk of exposure to patients. For this reason, the eluates were subjected to a range of biocompatibility tests.

6.2 Cytotoxicity

The toxicity of the NHC materials was determined by means of an XTT cytotoxicity assay according to ISO 10993. Together with the corresponding media, the samples were subjected to extraction tests and the resulting eluates were examined. The extracts from SR Phonares NHC revealed no cytotoxic potential [13; 14].

6.3 Irritation

The sensitization potential of SR Phonares was tested according to ISO 10993-12 in an *in vitro* test using a skin model (Episkin). The material examined in this test proved to be non-irritating [15].

6.4 Genotoxicity

The NHC material was subjected to an Ames test (Salmonella typhimurium and Escherichia coli reverse mutation assay) according to ISO 10993-12 to assess the mutagenic potential. SR Phonares revealed no mutagenic potential [16; 17].

6.5 Conclusions

On the basis of the data available to date and the present state of knowledge, it can be stated that SR Phonares is biocompatible. If the material is used correctly, it poses no health hazards to patients, dental technicians and dentists.

7. Literature

1. Foser HP. Philosophie und Entwicklung moderner Konfektionszähne. *Dental Spectrum* 1999;15:185-195.
2. Röhm O, Bauer W. Geformte Kunststoffe aus Polyacrylsäure, ihren Verbindungen oder Mischungen. 1928; Patent No. DE656421.
3. Verfahren zur Herstellung von Prothesen für zahnärztliche oder andere Zwecke aus polymerisierten organischen Verbindungen. 1936; Patent No. DE737058.
4. Powers J, Sakaguchi R. *Craig's Restorative Dental Materials*. 12 ed. Mosby Elsevier; St. Louis 2006.
5. Bowen RL. Dental filling material comprising vinyl silane treated fused silica and a binder consisting of the reaction product of Bis phenol and glycidyl acrylate. 1959; Patent No. US3066112.
6. Bowen RL. Method of preparing a monomer having phenoxy and methacrylate groups linked by hydroxy glyceryl groups. 1961; Patent No. US3179623.
7. Michl R, Wollwage P. Werkstoff für Dentalzwecke. 1974; Patent No. DE240211C3.
8. Heintze SD, Schmid-Schwab M, Grunert I, Piehslinger E. Verschleissresistenz zweier Prothesenzahnmaterialien in vivo. *Quintessenz Zahntech* 2009;35:718-726.
9. Heintze SD. How to qualify and validate wear simulation devices and methods. *Dent Mater* 2006;22:712-734.
10. Ghazal M, Steiner M, Kern M. Abrasionsfestigkeit von Prothesenzähnen. *Quintessenz Zahntech* 2008;34:1016-1019.
11. Ghazal M, Yang B, Ludwig K, Kern M. Two-body wear of resin and ceramic denture teeth in comparison to human enamel. *Dent Mater* 2008;24:502-507.
12. Hahnel S, Behr M, Handel G, Rosentritt M. Two-body wear of artificial acrylic and composite resin teeth in relation to antagonist material. *J Prosthet Dent* 2009;101:269-278.
13. Heppenheimer A. Cytotoxicity assay in vitro: Evaluation of materials for medical devices (XTT-Test). harlan Report No. 1239503. 2009.
14. Heppenheimer A. Cytotoxicity assay in vitro: Evaluation of materials for medical devices (XTT-Test). harlan Report No. 1239501. 2009.
15. Heppenheimer A. In vitro skin irritation test: Human skin model test. harlan Report No. 1253905. 2009.
16. Sokolowski A. Salmonella typhimurium and Escherichia coli reverse mutation assay. harlan Report No. 1239504. 2009.
17. Sokolowski A. Salmonella typhimurium and Escherichia coli reverse mutation assay harlan Report No. 1239502. 2009.
18. The Secrets of Composites. Report No.18. Ivoclar Vivadent AG. 2007

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Ivoclar Vivadent AG
Research and Development
Scientific Service
Bendererstrasse 2
FL-9494 Schaan
Liechtenstein

Contents: Petra Bühler-Zemp
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