

IPS
e.max[®]

Lithium Disilicate (LS₂)
Scientific Report
February 2011

Preface

The IPS e.max System is an innovative all-ceramic system that comprises lithium disilicate (LS₂) glass-ceramic, and zirconium oxide (ZrO₂) materials for the press and CAD/CAM technologies. Additionally, there is a universally applicable nanofluorapatite glass-ceramic available for veneering all the IPS e.max® System components.

The most prominent element of the IPS e.max System is the patented lithium disilicate (LS₂) glass-ceramic (IPS e.max Press and IPS e.max CAD). It is a glass-ceramic material distinguished from all previous ceramic systems by four specific features:

- **Optical refractive index:** The refractive index of the lithium disilicate crystals is identical to that of the glass in the matrix. Four levels of translucency and unique opalescent shades are achieved with the help of opacifiers and ion coloring.
- **High strength:** To increase strength, any number of crystals can be added to the glass matrix without loss in translucency. With mature crystallization, the LS₂ glass-ceramic features a flexural strength of 360 – 400 MPa (according to ISO 6872). This combination enables monolithic restorations with a highly esthetic appearance.
- **Adjusted coefficient of thermal expansion:** The CTE of the LS₂ glass-ceramic is slightly below 10⁻⁶/K, and thus in the range of zirconium oxide (ZrO₂). Hence, it is possible to use only one veneering ceramic for all the required veneers, characterizations, and glaze firing, for both the LS₂ glass-ceramic and the ZrO₂. This is a clear advantage today particularly with regard to simplicity, effectiveness, and economic efficiency.
- **Innovative processing technology:** Given the processing in its blue intermediate phase by means of the CAD/CAM technology and a short crystallization procedure, IPS e.max CAD is currently the most innovative all-ceramic material for CAD/CAM-fabricated single tooth restorations. The IPS e.max CAD-On technique is the latest development in the field of digital restorations. It combines the advantages of LS₂ and ZrO₂ and marks the beginning of a new generation of bridge technique, which is unequalled in terms of user-friendliness, speed, and overall strength.

Since the beginning of its development, the IPS e.max System has been monitored by the scientific community and many renowned experts have contributed to a vast data base with their studies. The worldwide success story, the ever growing demand, as well as the more than 20 million fabricated restorations of IPS e.max lithium disilicate (LS₂) glass-ceramic are a testament to the success and the reliability of the system. More than 20 clinical (in-vivo) studies and even more in-vitro studies on the IPS e.max System throughout the world show that Ivoclar Vivadent not only supports dental technicians and dentists with this system, but also offers the best possible restorative material for the benefit of their patients. The growing number of clinical studies also indicates the long-term success of the restorations in the oral environment of the patients. This "IPS e.max Lithium-Disilicate (LS₂) Scientific Report" contains a compilation of the most important results of the aforementioned studies.

IPS e.max was created as an all-ceramic system that offers an ideal solution for all indications. It not only works from a functional standpoint but is also backed by a wealth of scientific data.

Up to 8 Years Scientific Documentation – Summary

- Lithium disilicate (LS₂) glass-ceramic combines high strength (360-400 MPa) with outstanding esthetics.
- The processing of the LS₂ glass-ceramic by means of the PRESS and CAD/CAM technique provides maximum flexibility for the dental team.
- Already more than 20 million restorations fabricated with the IPS e.max lithium disilicate (LS₂) glass-ceramic confirm the clinical reliability of the material.
- The survival rate of partial restorations with more than 1.2 million cycles in the mastication simulator is 100% for all the LS₂ partial premolar crowns tested.
- The survival rate of inlays and onlays made of IPS e.max Press after 36 months was also 100%.
- The monolithic material structure of the LS₂ glass-ceramic permits the fabrication of very durable single tooth restorations with very high clinical reliability.
- Fully anatomical IPS e.max CAD crowns showed to be resistant against fatigue in cyclic fatigue tests. In comparison, crowns made of zirconium oxide failed by fractures in the veneering material at clearly lower loads.
- In mouth motion fatigue testing, IPS e.max crowns showed values comparable to those of the gold standard, i.e. metal-ceramics (PFM).
- Fatigue tests on titanium and zirconium oxide abutments, showed that the groups with the IPS e.max CAD crowns achieve statistically significantly higher fracture load values than the groups with the Vita Mark II crowns.
- Crowns made of IPS e.max CAD also proved their clinical efficiency in several studies over a period of 2-3 years; no fractures or chipping occurred.
- For 236 restorations, the Dental Advisor confirmed that IPS e.max Press is a highly esthetic material with high strength and excellent clinical performance over 4 years. The resistance to fracture and chipping is superior to that of traditional metal-ceramic restorations, as well as many other all-ceramics documented by the Dental Advisor in the past 26 years.
- After an observation period of 48 months, no fractures occurred in the crown-retained bridges made of IPS e.max Press. The four-year survival rate according to Kaplan Meier is 100%. The Kaplan Meier survival rate after 8 years is 93%. Three-unit crown-retained bridges made of lithium disilicate (LS₂) glass-ceramic have proved their clinical efficiency with both adhesive and conventional cementation.
- After 8 years, a Kaplan Meier survival rate of 92.3% resulted for crowns made of lithium disilicate (LS₂) glass-ceramic.
- Crowns made of lithium disilicate (LS₂) glass-ceramic have proved their clinical efficiency with both adhesive and conventional cementation.
- IPS e.max CAD-On restorations were rated very good to good for all clinical parameters (esthetics, function, biological parameters) after 12 months.

In-vitro study abstracts

Monolithic CAD/CAM lithium disilicate (LS₂) versus veneered Y-TZP crowns: Comparison of failure modes and reliability after fatigue

Place of the study: New York University, New York, USA
 Time: 2010
 Authors: Guess PC, Zavanelli RA, Silva NRFA, Bonfante EA, Coelho PG, Thompson VP

Method: The fatigue behaviour and reliability of monolithic CAD/CAM-fabricated IPS e.max CAD crowns were investigated:

Method I: 19 fully anatomical crowns were constructed and milled with a CAD/CAM system (Sirona® inLab®). The crowns were etched with 5% hydrofluoric acid for 20 seconds, silanated with Monobond Plus, and adhesively cemented onto an aged, dentin-type composite stumps. The test specimens were stored in water for at least seven days prior to the fatigue tests. During the fatigue tests, the crowns were subjected to a tungsten carbide piston that moved from the disto-buccal cusp 0.7 mm in the lingual direction in order to simulate occlusal movements. Three different stress levels were used, with the highest load amounting to 1000 N. After the tests, the crowns were inspected for damage under the stereo microscope with polarized light.

Method II: In the second part of the investigation, the crowns were subjected to a "staircase r ratio fatigue" stress test with 1 million cycles. The loads varied from 90 to 900 N, 95 to 950 N, 100 to 1000 N and 110 to 1100 N.

Results:

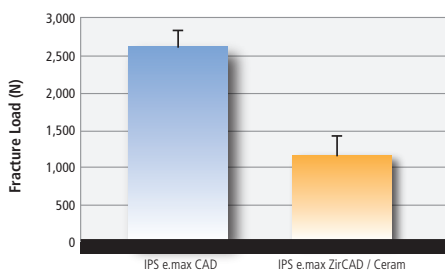


Fig 1: Fracture load of IPS e.max CAD compared to veneered zirconium oxide.

Summary: IPS e.max CAD crowns showed fractures with cracks down to the composite stump at rather high loads (2576 ± 206 N). In contrast, IPS e.max ZirCAD exclusively showed fractures in the IPS e.max Ceram veneering ceramic (1195 ± 221 N).

Conclusion: Fully anatomical IPS e.max CAD crowns showed to be resistant against fatigue in cyclic fatigue tests. In comparison, crowns made of zirconium oxide failed by fractures in the veneering material at clearly lower loads.

Reference: (Guess 2010)

Reliability of reduced thickness IPS e.max CAD and thinly veneered IPS e.max CAD crowns / Reliability: reduced-thickness and thinly-veneered lithium-disilicate vs. MCR and Y-TZP crowns

Place of the study: New York University, New York, USA
 Time: 2010
 Authors: Dr. Silva, Dr. Thompson

Method: The fatigue behaviour and reliability of monolithic CAD/CAM-fabricated crowns made of IPS e.max CAD were investigated in comparison with veneered crowns made of zirconium oxide and conventional metal-ceramic (MCR) [4, 5]. On the one hand, there were crowns with an occlusal thickness of 1 mm and on the other hand, crowns with a thickness of 2 mm, a core of 1.5 mm, and a thin buccal partial veneer of 0.5mm. 21 crowns per group were constructed, milled with a CAD/CAM system (Sirona® inLab®), and subsequently glazed. The crowns were adhesively cemented onto an aged, dentin-type composite stump. The test specimens were stored in water for at least seven days prior to the fatigue tests. During the fatigue tests, the crowns were subjected to a tungsten carbide piston that moved from the disto-buccal cusp 0.7 mm in the lingual direction in order to simulate occlusal movements. Three different stress levels were used. After the tests, the crowns were inspected for damage under the stereo microscope with polarized light.

Results:

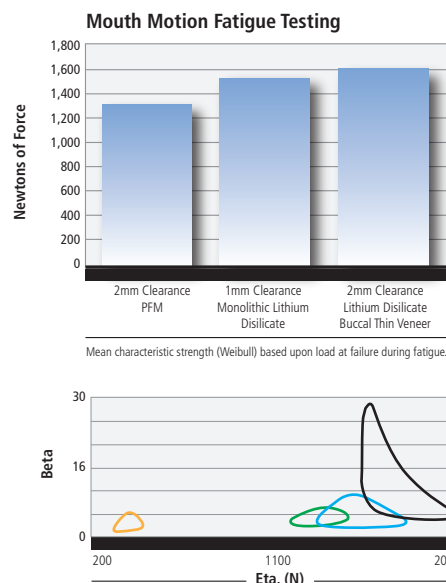


Fig 2: Weibull strength of zirconium oxide (orange), metal-ceramic (green), IPS e.max CAD 1 mm (blue), and IPS e.max CAD 2 mm (black).

Summary: The characteristic strength (Weibull strength) of monolithic IPS e.max CAD was 1535 N for IPS e.max CAD 1 mm and 1610 N for IPS e.max CAD 2 mm. These values are comparable to those of metal-ceramic (1304 N) and higher than those veneered zirconium oxide (371 N) (see Figure 4). The fractures observed were complete fractures for IPS e.max CAD and chipping for the two other groups. The IPS e.max CAD material showed the highest reliability.

Conclusion: In this investigation, IPS e.max CAD crowns showed values comparable to those of the gold standard, i.e. metal-ceramics.

Reference: (Martins 2011)

Survival rate and fracture resistance of all-ceramic partial crowns with different preparation designs after thermocycling and masticatory simulation: An in vitro investigation

Place of the study: University Clinic, Freiburg im Breisgau, Germany
 Time: 2002, 2006
 Author: Dr. C. Stappert

Method: The fracture strength of natural molars with all-ceramic LS₂ partial crowns with different preparation designs was determined. Teeth with and without MOD inlay preparation were used as control group. The partial crown preparations included 1 to 4 occlusal cusps (TK-1, TK-2, TK-3, TK-4). The crowns were placed using an adhesive technique (Variolink II). All test specimens were subjected to masticatory simulation and thermocycling (1.2 million cycles, 98 N, 5°/55°C) and subsequently loaded to breaking point in a universal testing machine.

Results:

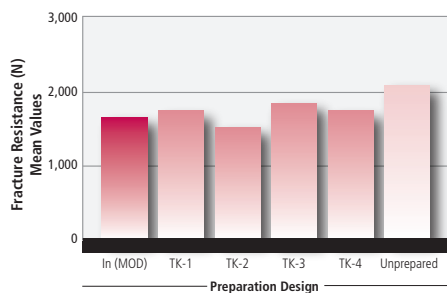


Fig 3: Fracture toughness of natural molars in conjunction with partial crowns prepared according to various preparation designs.

Summary:

- All specimens achieved a 100% in-vitro survival rate in the masticatory simulator.
- Irrespective of the size of the ceramic restoration, the fracture strength measured in the posterior region did not significantly differ from that of natural, unprepared teeth.

Reference: (Stappert, Att et al. 2002; Stappert, Att et al. 2006)

All-ceramic partial coverage premolar restorations. Cavity preparation design, reliability and fracture resistance after fatigue

Place of the study: University Clinic, Freiburg im Breisgau, Germany
 Time: 2005
 Author: Dr. C. Stappert

Method: In natural upper premolars, the effect of various preparation designs and layer thicknesses on the fatigue behaviour and fracture strength was determined in all-ceramic partial crowns and veneers. Teeth with and without MOD inlay preparation were used as control group. The partial crowns were adhesively cemented (Variolink II). All test specimens were subjected to masticatory simulation and thermocycling (1.2 million cycles, 49 N, 5°/55°C) and subsequently loaded to breaking point in a universal testing machine.

The following preparation designs were tested (N=16 per design version):

- Unprepared teeth
- MOD inlays
- Partial crowns with the palatal cusp reduced by 2.0 mm, 1.0 mm and 0.5 mm.
- Partial crowns with the palatal (pal.) and vestibular (vest.) reduced by 2.0 mm, 1.0 mm and 0.5 mm.
- Full veneers: Reduction of the entire masticatory surface and veneer preparation of the facial segment
 - Occlusal layer thickness 2.0 mm / facial segment 0.8 mm
 - Occlusal layer thickness 1.0 mm / facial segment 0.6 mm
 - Occlusal layer thickness 0.5 mm / facial segment 0.4 mm

Results:

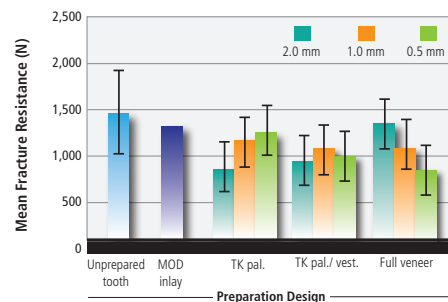


Fig 4: Mean fracture strength in upper premolars in conjunction with partial crowns and full veneers with various preparation designs after masticatory simulation.

Summary:

- The survival rate after more than 1.2 million cycles in the mastication simulator is 100% for all the partial premolar crowns tested.
- The fracture strength of the partial palatal crowns (TK pal.) did not significantly differ from that of the partial crowns for which the entire occlusal surface was reduced (TK pal./vest.) .
- The fracture resistance of MOD inlay preparations, as well as full veneers with an occlusal layer thickness of 2.0 mm and a facial segment of 0.8 mm does not significantly differ from that of unprepared natural premolars.
- In crowns with palatal reduction and premolar crowns in which the whole occlusal surface had been reduced (TK pal./vest.), the layer thickness did not significantly influence the fracture load.

Reference: (Stappert, Guess et al. 2005)

In-vitro study abstracts

Compressive fatigue resistance and fracture strength of implant-supported ceramic crowns

Place of the study: Ain Sham University, Cairo, Egypt/University of Toronto, Toronto, Canada

Time: 2010

Authors: A. El-Dimeery, T. Salah, A. Hamdy, O. El-Mowafy, A. Fenton

Method: A total of 64 implant replicas were divided into 8 groups. Various ceramic materials (Vita Mark II / Vita Zahnfabrik, IPS e.max CAD / Ivoclar Vivadent AG), various abutments (titanium, zirconium oxide), as well as different cementation materials (Tempbond, Panavia) were compared. The molar crowns were cemented to implants and stored in water at 37 °C for 24 hours, before an underwater fatigue test at 55-550 N for 500000 cycles were conducted. The surviving test specimens were subjected to a fracture test.

Results:

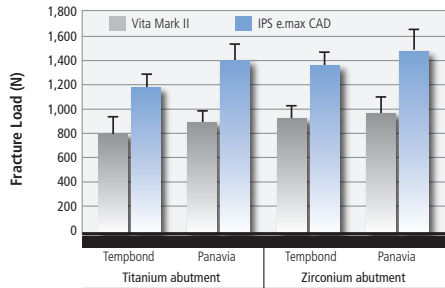


Fig 5: Fracture load of implant-retained crowns made of IPS e.max CAD or Vita Mark II on titanium or zirconium abutments. Cementation was carried out with either Tempbond or Panavia.

Summary: During the fatigue test, 2 Vita Mark II crowns fractured (1 on a titanium abutment, 1 on a zirconium abutment, both cemented with Tempbond). All the other test specimens survived. The group with the IPS e.max CAD crowns achieved statistically significantly higher fracture load values than the groups with Vita Mark II crowns.

Reference: (El-Dimeery 2011)

In-vivo study abstracts

Clinical examination of all-ceramic lithium disilicate (LS2) and CEREC 3-fabricated partial crowns in the mandibular molar region

Place of the study: University Clinic, Freiburg im Breisgau, Germany

Time: 2006-2009

Authors: Dr. C. Stappert, Dr. P. GÜß

Method: Placement of crowns/inlays made of IPS e.max Press (n=40) and ProCAD (n=40). A maximum of 20 non-vital abutment teeth per group were to be stabilized by an all-ceramic post system.

Results:

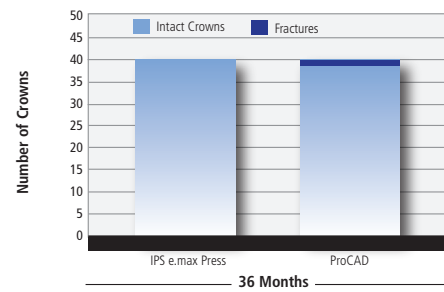


Fig 6: Clinical efficiency of crowns made of IPS e.max Press and ProCAD after 36 months.

Summary: A survival rate after 36 months of 100% was reported for IPS e.max Press and 97% for ProCAD.

Conclusion: All-ceramic partial crowns, either pressed or CAD/CAM-fabricated, represent reliable treatment options for the restoration of larger defects in the posterior region.

Reference: (Guess, Stappert et al. 2006; Guess, Strub et al. 2009)

Prospective 8-year study on all-ceramic crown-retained bridges

Place of the study: University Clinic Schleswig-Holstein, Kiel, Germany
 Time: 2004-2009
 Authors: Prof. Dr. M. Kern, Dr. Wolfart

Method: 36 crown-retained bridges made of IPS e.max Press were seated in 28 patients. Slightly more than half of the crown-retained bridges were placed using a conventional cementation technique. All the other crown-retained bridges were adhesively cemented (Variolink II). As many as 90% of all restorations were placed in the posterior region.

Results:

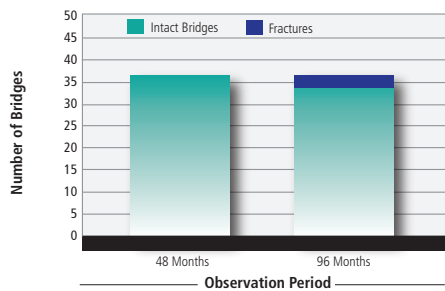


Fig 7: Clinical efficiency of bridges made of IPS e.max Press after 48 and 96 months.

Summary: No failures of the crown-retained bridges were reported after a mean observation period of 48 months. The four-year survival rate according to Kaplan Meier is 100%. The Kaplan Meier survival rate after 8 years is 93%. Two crown-retained bridges fractured. Two crown-retained bridges (6%) showed chipping of the veneering material.

Conclusion: Three-unit crown-retained bridges made of lithium disilicate (LS₂) glass-ceramic have proved their clinical efficiency with both adhesive and conventional cementation.

Reference: (Wolfart, Bohlsen et al. 2005; Wolfart, Eschbach et al. 2009)

Clinical examination of IPS e.max Press veneered with IPS Eris for E2

Place of the study: University Clinic Aachen, Aachen, Germany
 Time: 2002-2010
 Author: PD Dr. D. Edelhoff

Method: A total of 104 restorations (82 crowns in the anterior region, 22 crowns in the posterior region) were incorporated in 41 patients. The majority of the restorations (69.2%) were cemented using an adhesive technique (Variolink II) and roughly one third of the restorations (30.8%) were placed using a glass ionomer cement (Vivaglass Cem).

Results:

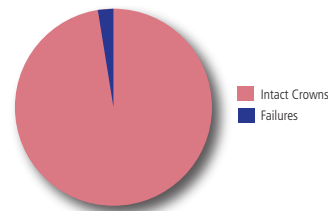


Fig 8: Clinical efficiency of crowns made of IPS e.max Press after 8 years.

Summary: The Kaplan Meier survival rate after 8 years is 92.3%. One failure was caused by secondary caries, another by endodontic complications. Furthermore, 2 crowns (2.1%) showed chipping of the veneering material and one crown (1.1%) demonstrated marginal discoloration.

Conclusion: Crowns made of lithium disilicate (LS₂) glass-ceramic have proved their clinical efficiency with both adhesive and conventional cementation.

Reference: (Gehrt, Rafai et al. 2010)

In-vivo study abstracts

IPS e.max 4-year clinical performance

Place of the study: USA

Time: 2006-2010

Author: The Dental Advisor

Method: Four dentists placed 440 IPS e.max restorations in 260 patients. 236 restorations were examined on the occasion of a recall (the maximum wear period was 4 years). Of these restorations, 42% were molar crowns, 37% premolar crowns, 9% anterior crowns, 7% inlays/onlays, and 5% bridges. A self-adhesive or adhesive cement was used for cementation.

Results:

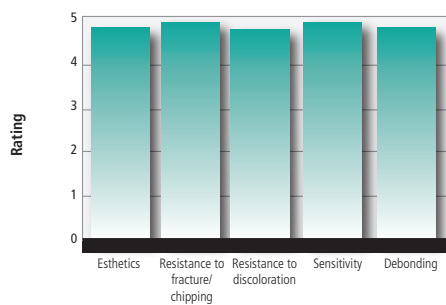


Fig 9: Assessment of important clinical parameters of restorations made of IPS e.max Press after 4 years. 5: excellent; 4: very good; 3: good; 2: sufficient, 1: insufficient.

Summary: Only one fracture was reported out of 236 restorations. Chipping was observed in only 2.5% of the restorations. IPS e.max Press was rated excellent also with regard to marginal discoloration and esthetics.

Conclusion: IPS e.max Press is a highly esthetic material with high strength and excellent clinical performance over 4 years. The resistance to fracture and chipping is superior to that of traditional metal-ceramic restorations, as well as many other all-ceramics documented by the Dental Advisor in the past 26 years.

Reference: The Dental Advisor: IPS e.max 4-year clinical performance June 2010;27(5)

Clinical evaluation of chairside lithium disilicate CAD/CAM crowns 3-year report

Place of the study: University of Michigan, Ann Arbor, USA

Time: 2007-2010

Author: Dr. J. Fasbinder

Method: 62 crowns (premolar and molar) were fabricated chairside with a CEREC 3D System (Sirona®) and cemented using Multilink Automix (n=23) and an experimental cement (n=39).

Results:

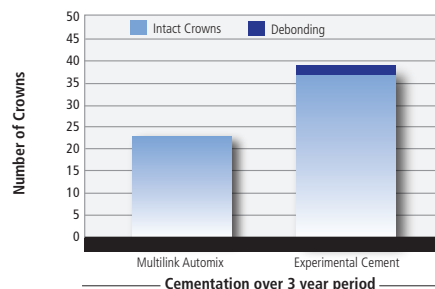


Fig 10: Clinical efficiency of crowns made of IPS e.max CAD after 3 years.



Fig 11: 3-year recall.

Summary: All the crowns seated with Multilink Automix were clinically acceptable; 2 cases of debonding were reported for the experimental cement. Those two restorations were recemented using Multilink Automix.

Conclusion: Crowns made of IPS e.max CAD proved their clinical efficiency over a period of 3 years; no fractures or chipping occurred.

Reference: (Fasbinder, Dennison et al. 2010)

Clinical performance and fit of a milled ceramic crown system

Place of the study: Boston University, Massachusetts, USA

Time: 2005 - 2008

Author: Prof. D. Nathanson

Method: 31 crowns (23 anterior crowns, 8 posterior crowns) were placed in 14 patients. They were veneered with IPS e.max Ceram and cemented using Multilink or Multilink Automix.

Results:

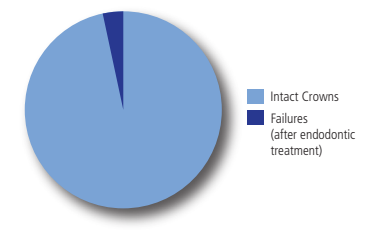


Fig 12: Clinical efficiency of crowns made of IPS e.max CAD after 3 years.

Summary: After an observation period of up to 3 years, only one crown placed after endodontic treatment showed a fracture.

Conclusion: Crowns made of IPS e.max CAD proved their clinical efficiency over a period of 3 years.

Reference: (Nathanson 2008)

Clinical performance of CAD/CAM-fabricated lithium-disilicate restorations

Place of the study: Policlinic for dental prosthetics, Munich, Germany

Time: 2007-2009

Author: Dr. F. Beuer

Method: 38 fully anatomical and partially reduced IPS e.max CAD restorations were fabricated using KaVo Everest (36 crowns, 2 bridges) and veneered with IPS e.max Ceram. Cementation was performed with Multilink Sprint.

Results:

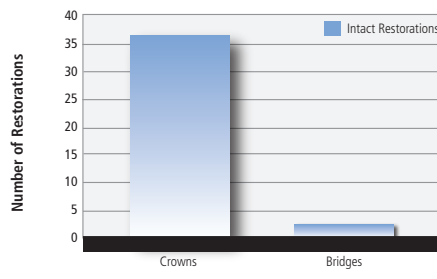


Fig 13: Clinical efficiency of crowns and bridges made of IPS e.max CAD after 2 years.



Fig 14: Lithium disilicate crowns 36 months after incorporation.

Summary: No failures of the restorations seated thus far were reported after a mean observation period of 2 years.

Conclusion: Crowns and bridges made of IPS e.max CAD proved their clinical efficiency over a period of 2 years.

Reference: (Richter, Schweiger et al. 2009)

In-vivo study abstracts

12 months clinical performance of IPS e.max CAD-on-restorations (lithium disilicate fused to zirconium oxide framework)

Place of the study: Ivoclar Vivadent AG, Schaan, Liechtenstein

Time: 2010-2011

Authors: R. Watzke, Dr. A. Peschke, Prof. J.F. Roulet

Method: 25 restorations (20 crowns, 5 three-unit bridges) were fabricated with a new type of CAD/CAM technique. The frameworks were fabricated of IPS e.max ZirCAD, the veneers of IPS e.max CAD. The framework and veneer were fused by means of Ivomix and IPS e.max CAD Crystall./Connect. The restorations were conventionally cemented.

Results:

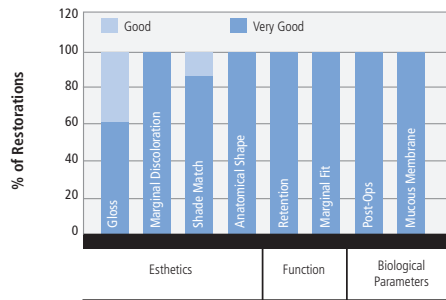


Fig 15: Clinical efficiency of IPS e.max CAD-On crowns and bridges after 12 months.

Summary: The IPS e.max CAD-On restorations were rated very good to good for all clinical parameters (esthetics, function, biological parameters) after 12 months.

Conclusion: The IPS e.max CAD-On technique permits the fabrication of reliable restorations with high esthetics, which prove their clinical efficiency after an observation period of 12 months.

Reference: (Watzke, Peschke et al. 2011)

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