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Partial Ceramic Crowns: Influence of Ceramic Thickness, Preparation Design and Luting Material on Fracture Resistance and Marginal Integrity *In Vitro*

M Federlin • S Krifka • M Herpich
K-A Hiller • G Schmalz

Clinical Relevance

For fracture resistance and the marginal integrity of adhesively bonded partial ceramic crowns (PCC), the choice of ceramic thickness and luting material are more important than preparation design. PCC fabricated from industrially sintered feldspathic ceramic should have at least a thickness of 1.5-2.0 mm in stress bearing areas.

SUMMARY

This *in vitro* study tested the effects of two different ceramic thicknesses, two preparation designs and two different luting agents on the marginal integrity and fracture resistance of partial ceramic crowns (PCC). Eighty extracted human molars were prepared according to the following preparation designs: a) Coverage of functional cusps/butt joint (n=40), b) Horizontal reduction of functional cusps (n=40). PCC (Vita Mark II, Cerec3 System) were fabricated and the ceramic thickness of the functional cusps was adjusted to 1): 0.5-1.0 mm and 2): 1.5-2.0 mm. PCC were adhesively luted to the cavities with either Excite/VariolinkII (VL) or RelyX Unicem (RX). The specimens were exposed to thermocycling and central mechanical loading (5000 x 5°C-55°C; 30 second/cycle; 50,0000 x 72.5N, 1.6Hz). Marginal integrity was assessed by evaluating dye penetration (fuchsine) on multiple sections in the bucco-oral direction by relating the actual penetration distance to the maximal length of the corresponding cavity wall (100%). Restoration/luting agent (RL)- and tooth/luting agent (TL) interfaces were evaluated separately. The data were statis-

Marianne Federlin, Dr med dent, University of Regensburg, Dental School, Department of Operative Dentistry and Periodontology, Regensburg, Germany

*Stephanie Krifka, Dr med dent, University of Regensburg, Dental School, Department of Operative Dentistry and Periodontology, Regensburg, Germany

Maximilian Herpich, ZA, University of Regensburg, Dental School, Department of Operative Dentistry and Periodontology, Regensburg, Germany

Karl-Anton Hiller, Dr rer nat, University of Regensburg, Dental School, Department of Operative Dentistry and Periodontology, Regensburg, Germany

Gottfried Schmalz, prof Dr med dent, University of Regensburg, Dental School, Department of Operative Dentistry and Periodontology, Regensburg, Germany

*Reprint request: Franz Josef Strauß Allee 11, 93042 Regensburg, Germany; e-mail: Stephanie.Krifka@klinik.uni-regensburg.de

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tically analyzed with the Mann Whitney U-test and the Error Rates Method (ERM), and the fracture rates were analyzed with the χ^2-test. Dye penetration data indicated that ceramic thickness and luting agent had a statistically significant influence upon marginal integrity in general, irrespective of all other parameters (ERM): RX showed significantly lower microleakage along the RL interface than VL. VL revealed significantly lower microleakage at the TL interface than RX. Fifteen PCC of group 1 (0.5-1.0 mm) and two PCC of group 2 (1.5-2.0 mm) were fractured after thermocycling and central mechanical loading, with the difference being statistically significant. PCC fabricated from industrially sintered feldspathic ceramic should have at least a thickness of 1.5-2.0 mm in stress-bearing areas.

INTRODUCTION

Functional and esthetic restorations of extensively damaged teeth require materials that should be biocompatible, mechanically stable for oral use and tooth-colored. In general, ceramic inlays and partial ceramic crowns (PCC), that is, restorations with one or more cusps being restored[1-2] are clinically accepted alternatives to cast gold restorations and amalgam fillings.[3-4] However, failures occur, and the predominant reasons for failures are fractures,[5] one of the major failure mechanisms being damage accumulation.[6]

Fracture toughness of dental ceramics has been mainly tested by basic laboratory, bending and indentation methods, for example, four-point bending test, biaxial flexure test, Knoop or Vickers indentation, where tensile stress is applied on the indented surface of the specimen until fracture.[7-8] These methods use the acute single loading failure as the test methods; however, a lifetime of dental restorations is limited by the accumulation of contact damage during oral function, and the strength of dental ceramics are significantly lower after multi-cycle loading than after single-cycle loading.[6,9]

Fatigue is described as a change of material characteristics over time under cyclic conditions.[6,10] For dental ceramics, microscopic surface flaws and defects, which may develop as a result of thermal, chemical or mechanical processes, act as localized stress concentrators.[11] Subcritical crack growth in ceramics is attributed to "corrosion-assisted" stress at the crack tip or at any pre-existing defect in the ceramic.[12] Cracks have been shown to be sites of fracture initiation and, consequently, failure.[13-15]

These problems have resulted in attempts to improve the mechanical properties of all-ceramic restorations, without compromising the aesthetics of the restoration or causing further damage to opposing teeth and other restorative materials.[16] One approach is to use industrially prefabricated feldspathic ceramic, which is milled using computer-aided design and computer-aided manufacturing (CAD/CAM) device technology,[17-18] that is, the Cerec system. This ceramic possesses a better structural homogeneity and fracture strength compared to laboratory-processed dental ceramic materials.[9,19] Still, in stress bearing areas, the literature generally recommends a minimum ceramic thickness of 1-2 mm.[20-21] However, this recommendation is mainly based on basic mechanical testing, without taking the clinical system into account.

Reasons for ceramic restoration fractures, however, may not only be related to mechanical properties of the ceramic, but also to the preparation design and corresponding outline of the restoration. Different preparation designs have been described in the literature. On one hand, preparation designs for PCC have been based on traditional concepts, utilizing a conventional retention form.[22-23] On the other hand, designs that neglect retentive elements have been described, where retention of the all-ceramic restoration depends solely on the adhesive luting agent.[24-25] Again, only limited information is available regarding the influence of the preparation design on the fracture resistance of PCC.

The third factor of interest in this context is the adhesive luting material. Adhesion to both tooth hard tissue and the ceramic have to be sufficient to guarantee high bond strength and guide masticatory forces from the restoration to the tooth.[14] Gap formation may impair this bond and, thus, may promote fractures. Recently, a new self-etching luting material has been marketed. No information is available to date about gap formation and its influence upon fracture resistance of PCC for this and other luting composites.

Therefore, this *in vitro* study evaluated the influence of different ceramic thicknesses, preparation design and luting agents on ceramic fracture and marginal integrity of PCC. It was hypothesized that these three variables would affect fracture resistance and marginal integrity of PCC. Visible cracks in the ceramic have been used as early indicators of ceramic fracture.

METHODS AND MATERIALS

Sample Preparation

Figure 1 summarizes the procedures followed in this study. Eighty extracted human molars, stored in 0.5% chloramine solution after extraction, were cleaned, mounted in Pattern Resin (GC Corporation, Tokyo, Japan) and stored in physiological saline solution until use. The molars were assigned randomly into two groups of 40 teeth each. Diamond burs (Cerinlay Set, Intensiv, Viganello, Lugano, Switzerland) with a taper of ~4-6° in a high-speed handpiece with sufficient water cooling were used to perform one of the following preparations on each tooth (Figure 2):

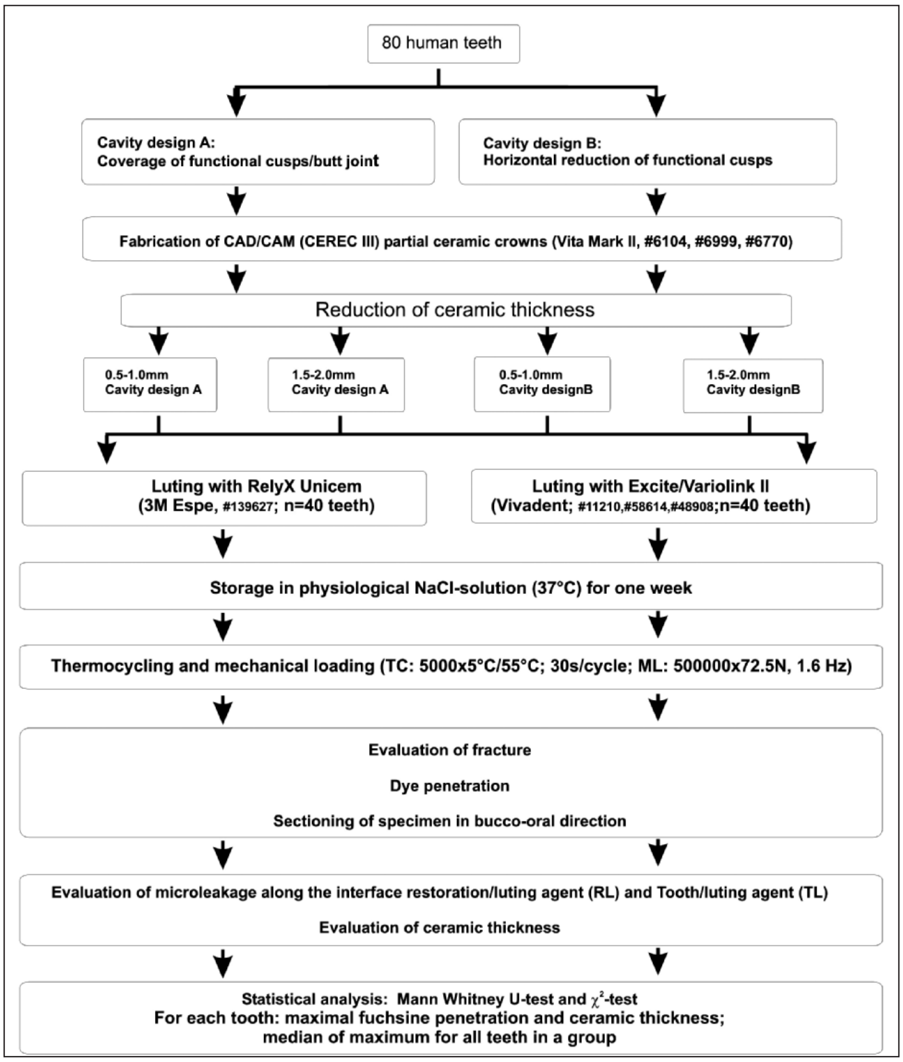

Figure 1: *Flow chart: methods and materials.*

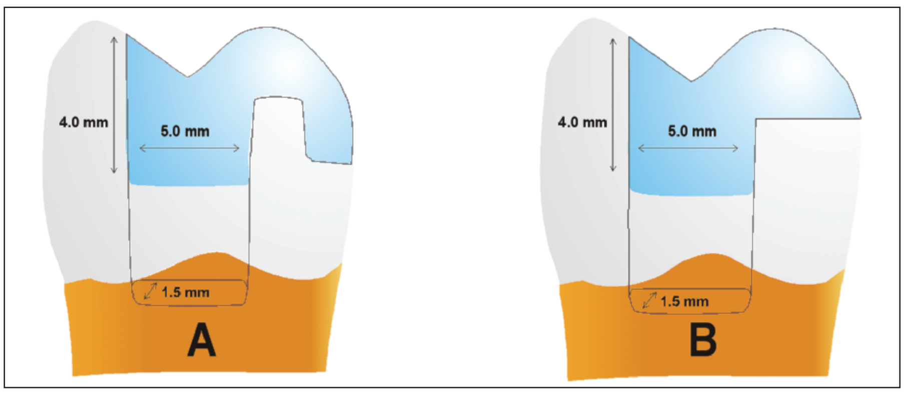

Figure 2: *Schematic drawing of preparations A and B, representing a midline cut in the buccal-lingual direction. (A) Coverage of functional cusps/butt joint preparation, (B) horizontal reduction of functional cusps preparation. Dotted lines indicate proximal boxes below the CEJ.*

Preparation of MOD-cavities (about 5.0 mm in width/about 4.0 mm in depth);

Preparation A: Coverage of functional cusps (lingual cusps in upper molars, buccal cusps in lower molars) about 1.5 mm/divergence angle of buccal and lingual walls ~4-6° plus butt joint preparation about 1.0-1.5 mm/cusp coverage convergence angle ~ 4-6°.

Preparation B: Horizontal reduction of functional cusps about 1.5 mm.

Non-functional cusps were not covered; proximal margins were placed 1 mm below the CEJ within cementum/dentin, the depth of the box being approximately 1.5 mm. Internally, rounded line angles were prepared.

The CAD/CAM method (Cerec 3 software version 1.0, Sirona, Bensheim, Germany) was used to construct and machine-mill the partial ceramic crowns. Mark II ceramic blocks (Vita, Bad Säckingen, Germany) were used to fabricate the PCC using the Cerec 3 system and corresponding software (Sirona Cerec 3 software version 1.0). After fabrication of the PCC, the ceramic thickness of the functional cusps was adjusted to (group 1) 0.5-1.0 mm and (group 2) 1.5-2.0 mm, using diamonds in a high-speed handpiece with sufficient water-cooling.

Following try-in and adjustment to the prepared cavities, the PCCs were finished with Komet finishing diamonds (Brasseler, Lemgo, Germany) and polished with Sof-Lex flexible discs (3M, St Paul, MN, USA), with decreasing roughness under sufficient water cooling. The PCC were inserted using one of the following luting material/bonding system combinations (10 specimens each per luting system, preparation design and ceramic thickness):

VL: Variolink II/Excite (Vivadent, Schaan, Liechtenstein) dual-cured resin composite luting agent.

RX: RelyX Unicem-Universal Aplicap (3M ESPE, Seefeld, Germany) self-adhesive universal resin cement.

The restorative procedures were performed in a device simulating proximal contact to adjacent teeth to match the

Table 1: *Luting Materials, Cavity/Ceramic Conditioning and Procedures of Insertion*

Luting Material	Variolink II/VL	RelyX Unicem/RX
Conditioning of Ceramic	High viscosity, composite luting agent (Vivadent, Germany)	Self-adhesive universal resin cement (3M ESPE, Germany)
	Ceramics Etch gel (Vita, Germany) 60 seconds, followed by rinsing with water	Ceramics Etch gel (Vita, Germany) 60 seconds, followed by rinsing with water
	Monobond S (Vivadent, Germany) applied and dried after 60 seconds	Monobond S (Vivadent, Germany) applied and dried after 60 seconds
Conditioning of Cavity	Total Etch (Vivadent, Germany) dentin 20 seconds, enamel 40 seconds, followed by water spray and gentle blow-drying	
	Excite (Vivadent, Germany) application, after 20 seconds gentle blow drying, light curing for 20 seconds	
Curing Mode	Dual-curing (light application for 40 seconds from each aspect)	Dual curing (light application for 40 seconds from each aspect)

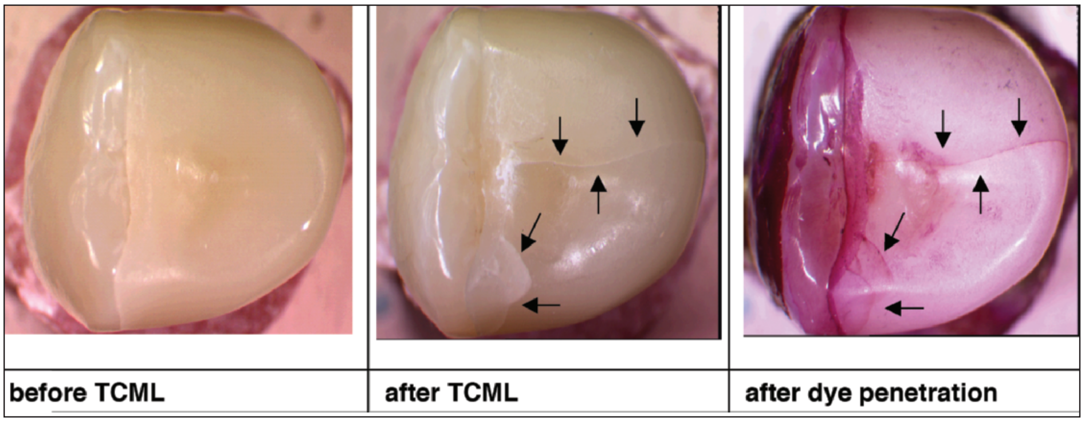

Figure 3: *Example of fractured specimen recorded from the occlusal surface before TCML, after TCML and after dye penetration. Arrows indicate fracture lines.*

clinical situation as closely as possible. Luting material was applied to the cavity surfaces following adhesive conditioning of tooth substances and PCC surfaces. The luting procedure of Variolink II is summarized in Table 1, in comparison with RelyX Unicem.

Excess luting material was removed prior to curing. Following insertion procedures, finishing was performed with Komet finishing diamonds (Brasseler, Lemgo, Germany), and the restorations were polished with Sof-Lex flexible discs (3M). Before thermocycling and mechanical loading (TCML), samples were stored in physiological saline solution at 37°C for 24 hours. The samples were exposed to thermocycling (5,000×5° at 55°C and 30 seconds/cycle) and mechanical loading (500,000×72.5 N at 1.6 Hz) simultaneously. Mechanical loading was performed by means of a cyclic (1.6 Hz) increase in pressure (72.5N) upon a metal stop, representing the opposing cusp. The metal stop was statically placed in the occlusal central fissure of the restoration.

Documentation of Cracks/Fractures

Visible cracks, discernable under a light microscope (Wild Makroskop M420, Heerbrugg, Germany) at 12x magnification, were used as early indicators of ceramic fractures. Before and after TCML (Figure 3) digital images of the specimen were taken from each aspect (mesial, distal, occlusal, palatal). Digital images were also taken after dye penetration (Figure 3), in order to better visualize crack formation.

Dye Penetration

After TCML, microleakage at occlusal and palatal locations and for the ceramic- and tooth-interfaces were determined separately by means of dye penetration. Except for areas within 1 mm of restoration margins, the specimens were covered with nail varnish and placed in a 0.5% basic fuchsine solution for 16 hours at 37°C. After dye penetration with fuchsine, the specimens were cleaned, mounted onto stubs with acrylic resin and longitudinally sectioned in the mesio-distal direction into as many approximately 300 µm thick sections as possible[4-8] using a rotating diamond saw (blade thickness 300 µm) (Innenlochsäge Leitz 1600, Leitz) and water cooling. The sections were approximately 300 µm thick, each section providing two sites for the evaluation of dye penetration. Digital images of the sections were recorded, and microleakage along both the tooth- and ceramic-restoration interfaces was recorded for the multiple sections using an image analyzing system (Optimas 6.1, Stemmer, Munich, Germany). The extent of dye penetration was expressed as a percentage of the entire length of the restoration wall (100% reference), as shown in Figure 4. Data for the occlusal and palatal location of each interface were pooled, because no statistical difference was observed between the two evaluation locations. Thus, for each section, four dye penetration measurements were recorded, rendering between 16 and 36 measurements/tooth (4 x 4-8 sections/tooth). The maximum value was selected for each tooth and used for further statistical analysis.

Determination of Ceramic Thickness

Digital images of the sections were recorded, and the actual ceramic thickness on the multiple sections was evaluated with an image analyzing system (Optimas 6.1, Stemmer, Munich, Germany). Two points for cavity design A and one point for cavity design B were measured and documented (Figure 5).

Statistical Analysis

Non-parametric statistical analysis was considered appropriate for analyzing the data, because of the lack of normal distribution. Medians and 25% to 75% percentiles for each of the different criteria were determined for all interfaces separately. Statistical analysis was performed using Mann-Whitney U and Wilcoxon's rank sum tests (PC+ version 6.0 software) (SPSS, Chicago, IL, USA) for pairwise comparisons among groups. The level of significance was set at α=0.05. For evaluating the influence of preparation design, luting material, and ceramic thickness in general, the level of significance was adjusted to $\alpha^*(k)=1-(1-\alpha)1/k$ by application of the error rates method (k=*n* of paired tests performed). Differences in fracture rates were analyzed with the χ^2-test (SPSS).

RESULTS

The actual ceramic thicknesses at the covered cusps areas measured after sectioning the teeth ranged from 0.6 mm to 0.9 mm (medians) for subgroups of group 1 and from 1.5 mm to 1.8 mm (medians) for subgroups of group 2 (Table 2). Within each of these two groups, there was no statistically significant difference between ceramic thicknesses of the subgroups with varying preparation designs and luting materials.

An example of visible cracks within a PCC is shown in Figure 6. One can see two crack lines, one which runs centrally from the functional cusp to the non-functional cusp, and the other, which runs at the mesial margin along the ceramic/luting agent interface. The results of the visible crack evaluations are shown in Table 3. All cracks of PCCs occurred after TCML. Seventeen out of 80 ceramic restorations cracked, 15 in

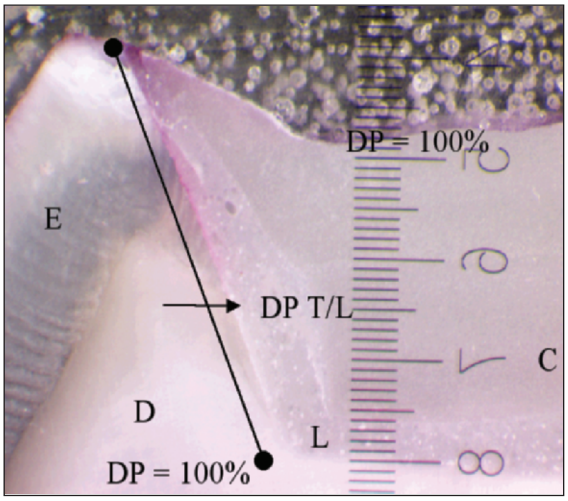

Figure 4: *Example of dye penetration (DP); C=ceramic; E=enamel; T=tooth; D=dentin; L=luting agent; Arrow indicates the end of dye penetration at the tooth/luting agent interface. Line indicates the maximum length of dye penetration.*

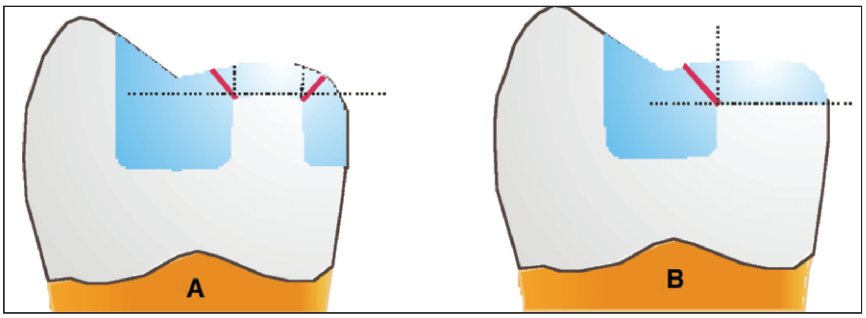

Figure 5: *Schematic drawing of the determination of ceramic thickness in cavity design A and B; red lines indicate measuring distances for ceramic thickness.*

Table 2: Actual Ceramic Thickness, as Measured After Sectioning the Teeth (median and 25–75% quartiles)

Luting Agent	Cavity Design	To Palatal Area			To Central Area			To Palatal Area			To Central Area		
		Group 1 (0.5-1.0 mm)						Group 2 (1.5-2.0 mm)					
		25%	Med	75%	25%	Med	75%	25%	Med	75%	25%	Med	75%
RX	A	0.7	0.9	1.0	0.8	0.9	1.0	1.7	1.8	2.0	1.4	1.5	1.6
RX	B				0.8	0.8	0.9				1.7	1.8	1.9
VL	A	0.6	0.6	0.7	0.5	0.6	0.6	1.5	1.6	1.7	1.4	1.5	1.6
VL	B				0.5	0.6	0.7				1.5	1.7	1.8

group 1 (0.5-1.0 mm), and 2 in group 2 (1.5-2.0 mm). The difference between the two groups, group 1 (0.5-1.0 mm) and group 2 (1.5-2.0 mm), was statistically significant, as was the difference between the groups before and after TCML.

The results of dye penetration for RelyX Unicem are summarized in Figure 7A/Table 4. Generally, dye penetration was statistically significantly higher at the tooth/luting agent interface, with medians ranging from 36.9% to 52.7% compared to the ceramic/luting agent interface, with medians ranging from 7.3% to 14.6%. In general, there was no statistically significant difference in dye penetration between the ceramic thickness of group 1 (0.5-1.0 mm) and group 2 (1.5-2.0 mm). In detail, single pairwise comparisons revealed that, only in one case (ceramic/luting agent interface, group 1 [13.5%] vs group 2 [8.1%] in preparation design A) was there a statistically significant difference. Dye penetration was also, in general, not influenced by preparation design. In detail, single pairwise comparisons showed inconsistent results, with preparation design A having more penetration than design B in two cases and, in one case, it was the other way around.

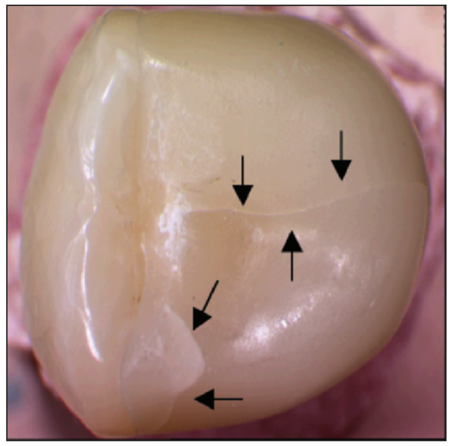

Figure 6: *Example of fractured specimen/fracture occurred after TCML. Arrows indicate fracture lines.*

The results of dye penetration for Variolink II (VL) are summarized in Figure 7B/Table 5. Generally, dye penetration was significantly higher at the ceramic/luting agent interface, with medians ranging from 36.0% to 78.4%, compared to dye penetration at the tooth/luting agent interface, with medians ranging from 12.3% to 19.3%. In general, no influence of ceramic thickness on dye penetration was found. Single pairwise comparisons showed, with one exception, no statistically significant difference between the data of dye penetration of groups 1 and 2

Table 3: *Number of Visible Cracks of PCCs After TCML; Before TCML No Fracture Was Observed*

Luting Agent	Ceramic Thickness	Cavity Design A	Cavity Design B
RX	Group 1 (0.5-1.0 mm)	3	4
RX	Group 2 (1.5-2.0 mm)	1	0
VL	Group 1 (0.5-1.0 mm)	4	4
VL	Group 2 (1.5-2.0 mm)	1	0

Table 4: *Results of the Dye Penetration Test for RelyX Unicem (RX) at the Restoration/Luting Agent (R/LA) and Tooth/Luting Agent (T/LA) Interfaces for Group 1 (0.5-1.0 mm) and 2 (1.5-2.0 mm) and Preparations Design A and B (median of maxima and 25%–75% quartiles)*

	Group 1 (0.5-1.0 mm)			**Group 2 (1.5-2.0 mm)**			**Group 1 (1.5-2.0 mm)**			**Group 2 (1.5-2.0 mm)**		
	Cavity Design A						**Cavity Design B**					
	25%	Med	75%	25%	Med	75%	25%	Med	75%	25%	Med	75%
(R/LA)	9.5	13.5[a,b]	41.4	4.3	8.1[a,d]	12.3	3.7	7.3[b]	10.4	4.0	14.6[d]	21.0
(T/LA)	42.7	52.7[c]	56.6	31.7	36.9	56.3	38.6	42.6[c]	45.6	37.6	40.2	48.7

a,b,c,d indicates statistically significant differences.

Table 5: *Results of the Dye Penetration Test for Excite/Variolink II (VL) at the Restoration/luting Agent (R/LA) and Tooth/Luting Agent (T/LA) Interfaces for Group 1 (0.5-1.0 mm) and 2 (1.5-2.0 mm) and Preparations Design A and B, (median of maxima and 25%–75% quartiles)*

	Group 1 (0.5-1.0 mm)			**Group 2 (1.5-2.0 mm)**			**Group 1 (1.5-2.0 mm)**			**Group 2 (1.5-2.0 mm)**		
	Cavity Design A						**Cavity Design B**					
	25%	Med	75%	25%	Med	75%	25%	Med	75%	25%	Med	75%
(R/LA)	43.9	68.4[b]	90.1	25.8	40.3[c]	63.5	31.4	36.0[a,b]	44.1	54.9	78.4[a,c]	100.0
(T/LA)	8.1	12.3	20.7	11.1	18.7	27.1	10.7	19.3	22.4	9.2	18.0	33.0

a,b,c indicates statistically significant differences.

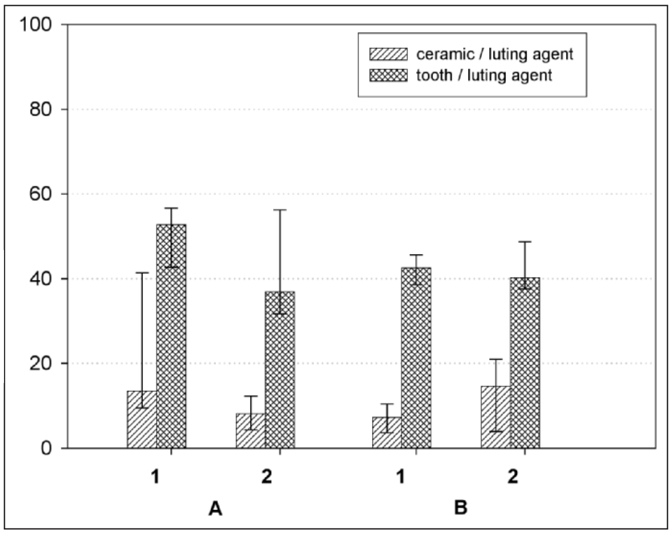

Figure 7A: *Results of the dye penetration test for RelyX Unicem (RX) at the restoration/luting agent and tooth/luting agent interfaces for group 1 (0.5-1.0 mm) and 2 (1.5-2.0 mm) and preparation designs A and B (median of maxima and 25–75% quartiles).*

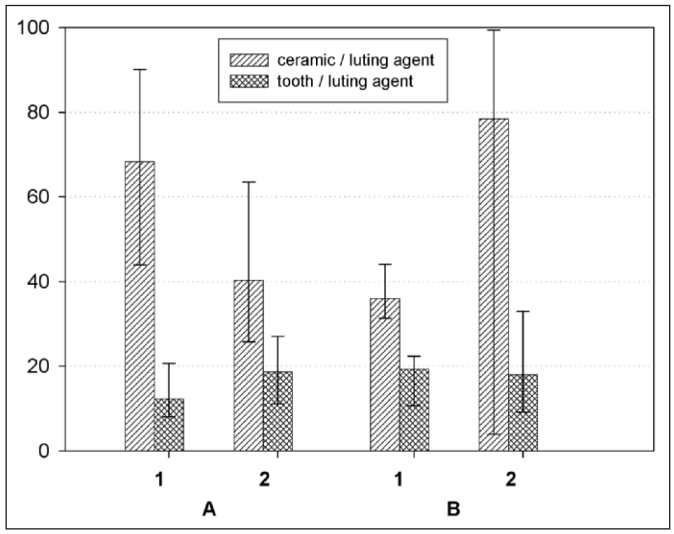

Figure 7B: *Results of the dye penetration test for Excite/Variolink II (VL) at the restoration/luting agent and tooth/luting agent interfaces for ceramic thickness 1 and 2 and preparation designs A and B (median of maxima and 25–75% quartiles).*

at both interfaces. The dye penetration of group 1 (36.0%) was statistically significantly lower than in group 2 (78.4%) at the ceramic luting agent interface of preparation design B. Dye penetration was, in general, not influenced by preparation design. In detail, pairwise comparison showed lower dye penetration data for preparation design A than for design B in two cases (ceramic/luting agent interface, preparation design A (68.4%) vs preparation design B (36.0%) for group 1 (0.5-1.0 mm) and ceramic/luting agent interface, preparation design A (40.3%) vs preparation design B (78.4%) for group 2 (1.5-2.0 mm).

DISCUSSION

Method

In this study, the influence of three parameters (ceramic thickness, cavity design and luting material) on two endpoints (ceramic fracture resistance and marginal integrity) was evaluated.

Methods for Determining Fracture Resistance

In this study, the appearance of visible cracks in the ceramic has been used as an early indicator for ceramic fractures. Ceramics are brittle materials that are susceptible to failure beyond a critical stress, which is dependent upon internal and surface flaw distributions.[7] Fractographic analysis of clinically failed "all-ceramic" restorations has proven that fracture had, in fact, always originated with the formation of cracks.[15,26]

Basic laboratory methods use acute single loading failure, specimen loading until fracture,[7-27] as test methods. Some authors,[7] however, doubt whether prediction of all ceramic materials' performance or long-term success from such data is possible, but it is hypothesized that materials with improved fracture toughness should have better clinical success and longevity.[27] In the patient situation, however, many fatigue-related fractures are observed.[28]

TCML were used to induce fatigue. It is a method that is usually applied to simulate clinical situations, such as masticatory forces under wet conditions. It has been published that TCML fatigue significantly decreases the fracture resistance of all-ceramic full crowns.[29]

Methods for Determining Marginal Integrity

Marginal integrity was evaluated by dye penetration, which is a commonly applied method to test the sealing of adhesive, tooth-bonded restorations. According to Kidd,[30] microleakage is defined as the passage of bacteria, fluids or molecules between a cavity wall and the restorative material applied to it. Dye penetration after TCML was assessed in order to better simulate the *in vivo* situations. Krejci and others[31] postulated that 120,000 *in vitro* loadings approximated six months of clinical use. The current study should thus simulate approximately 2–2.5 years of clinical use. A definite relationship, however, between *in vitro* dye penetration data and results from clinical (*in vivo*) testing still remains to be established, with problems probably arising due to evaluation deficiencies for both the *in vitro* and *in vivo* methods. However, in this study, dye penetration was also used to evaluate risk factors for *in vitro* crack formation in order to compare the two luting materials.

Discussion of Results—Fracture

Dependency of Visible Crack Formation Upon Ceramic Thickness

The results of this study show a definitive influence of ceramic thickness upon visible crack formation. In the literature, a number of recommendations have been published. Hansen[25,32] indicated a ceramic thickness of at least 1.0 mm (occlusal) for inlay preparations. Jackson and Ferguson[33] described an inlay-onlay preparation with occlusal reduction of at least 1.5 mm.

Based on these reports in the literature and in order to be on the safe side, a thickness of 1.5-2.0 mm was chosen for group 2. The rationale for the selection of 0.5-1.0 mm for group 1 was that, clinically, the final ceramic thickness may actually fall short of the required thickness, because the occlusal adjustment of the restoration is predominantly performed following adhesive luting procedures.

However, all these recommendations have been based on basic laboratory testing, without simulating the clinical conditions. To the best of the authors' knowledge, this is the first experimental indication in a clinical simulation experiment that, for PCC, a minimum thickness of at least 1.5 mm in stress-bearing areas is necessary.

No Dependency of Visible Crack Formation Upon Preparation Design

In the current study, no influence of the two preparation designs on visible crack formation was found. Broderson[22] describes the disadvantages for cavity design A, which create a high amount of stress points in the ceramic restoration and may lead to fracture. This assumption cannot be backed up by the results of the current study. However, the data are in agreement with van Dijken and others,[24] who found no statistical differences among the four preparation types of partial and complete, posterior ceramic restorations employed in their five-year follow-up of dentin/enamel bonded ceramic coverage.

No Dependency of Visible Crack Formation Upon Luting Material

This study indicates no statistically significant influence of the luting materials tested upon visible crack formation. Variolink II is a clinically accepted adhesive luting material, and the results are in line with the accepted idea that adhesive luting is the basis for fracture prevention of dental ceramics.[9,13] This apparently holds also for the new self-adhesive luting material RelyX Unicem.

Discussion of Results—Marginal Integrity

In contrast to the results for visible crack formation, marginal integrity was shown to be independent of ceramic thickness but dependent upon the luting material. However, in line with the data for crack formation, marginal integrity was independent of preparation design. Apparently, there is no direct link between crack formation and marginal integrity.

The mechanism of adhesion seems to differ between the two luting materials, because dye penetration data for the two interfaces (ceramic/luting agent and tooth/luting agent) differed significantly. Variolink seems to better adhere to tooth substrate; whereas, RelyX Unicem has a better adhesion to ceramic. The results of VL are in agreement with other research.[34-36] The authors reported that the adhesion of Variolink to the tooth/luting agent interface is more effective than to the ceramic/luting agent interface. Leakage may result in hydrolysis, loss of the restoration or fracture because of failure.

The tooth substrate in this study was mainly enamel, and it has been shown in several studies[37-40] that adhesion of RelyX Unicem to enamel is less effective than to dentin. This may result in hypersensivity, recurrent caries, eventual pulpal pathoses[41] and loss of the restoration. Morphological SEM and TEM evaluation of the interface by De Munck and others[37] revealed that RelyX Unicem only superficially interacted with enamel. It can be speculated that better adhesion can be obtained here, if enamel is selectively etched before applying RelyX Unicem, as was proposed by DeMunck and others[37] and Hikita and others.[38]

CONCLUSIONS

Within the limitations of this study, it can be concluded that PCC fabricated from industrially sintered feldspathic ceramic should have at least a thickness of 1.5-2.0 mm in stress bearing areas to prevent crack formation and, in the long run, ceramic fractures. The cavity design had no significant influence on both crack formation and marginal integrity. The self-adhesive luting composite was as effective as a conventional multi-step preparation in preventing fractures.

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