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Inspection of the thickness of resin cements for ceramic veneers

Helder Rodrigues Lopes

Relatório de Estágio conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

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Trabalho realizado sob a Orientação de Prof. Doutor Júlio C. M. Souza

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Eu, “Jùlio Cèsar Matias de Souza”, com a categoria profissional de Professor do Instituto Universitário de Ciências da Saúde, tendo assumido o papel de Orientador do Relatório Final de Estágio intitulado “Inspection of the thickness of resin cements for ceramic veneers”, do Aluno do Mestrado Integrado em Medicina Dentária, “Helder Rodrigues Lopes”, declaro que sou de parecer favorável para que o Relatório Final de Estágio possa ser presente ao Júri para Admissão a provas conducentes à obtenção do Grau de Mestre.

O Orientador

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Agradecimentos

Meus sinceros agradecimentos – a toda entidade representada pela ação positiva e negativa de pessoas, diria muitas, que me possibilitaram a compreensão e aperfeiçoamento como Ser Humano, académico e consequentemente profissional. E dessas não poderia deixar de referir a atenção do orientador Professor Doutor Júlio Souza. E do que me leva a ser melhor, meus amores eternos, minha adorável filha Isadora e minha companheira, esposa, cúmplice Filipa.

Obrigado.

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Resumo

O objetivo principal deste estudo foi realizar uma revisão da literatura sobre a espessura do cimento resinoso após cimentação de facetas cerâmicas. Para a seleção de artigos publicados até fevereiro de 2019, uma pesquisa bibliográfica foi realizada no PUBMED usando os seguintes termos de pesquisa: "veneer" AND resin cement AND thickness" OR "layer".

Os resultados mostram que a espessura do cimento resinoso se mostra mais pronunciada na zona occlusal do dente, com valores que podem variar entre os 50 e 110 µm. Também na mesma zona é onde se pode encontrar a maior concentração das tensões.

O aumento da espessura do cimento tem pouco efeito na variação das tensões provocadas nas facetas cerâmicas. Contudo, o tipo de cimento, a preparação das margens do dente, o tipo e espessura de facetas que vão condicionar o comportamento do cimento, e as forças mastigatórias vão afetar a vida útil da faceta.

Palavras-Chave:

Cimento resinoso, espessura, facetas, cerâmicas

Abstract

The main of this study was to perform a integrative systematic review on the thickness of resin cements after cementation of ceramic veneers. On the selection of studies published until February 2019, a bibliographic search was carried out at PUBMED using the following search terms: “veneer” AND resin cement AND thickness” OR “layer”.

The results show that the thickness of the resin cement is more pronounced in the occlusal zone of the tooth, with values that can vary between 50 and 110 µm. Also in the same area is where the highest concentration of stresses can be found. The increase of the thickness of cement has little effect on the variation of the stresses caused in the ceramic veneers. However, the type of cement, the margins fit, the type and thickness of veneers that will condition the behavior of the cement, and the masticatory forces will affect the lifespan of the veneer.

Keywords

Resin cement, thickness, ceramic veneer

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1. Introduction

Nowadays, the demand for aesthetic restorations has forced the manufacturers to develop new adhesion strategies and aesthetic veneer materials with high strength.[1] The long term success of a veneer restoration is based on the mechanical properties of the veneer materials and on the high bond strength between the veneer and resin-matric cement[1,2,3]. Previous studies on the bond strength of veneer to the teeth surfaces have shown that the resin cement layer is the weakest material in the interface.[2,4]

Thus, the selection of the resin-matrix cements considering the control of the polymerization provide proper optical and mechanical properties of the cementation layer. The degree of conversion of the polymeric matrix determine the properties of the resin cement and therefore the polymerization must be enhanced by using adequate polymerization procedures.[1,3,5] Thus, dual-curing resin cements are the first choice for veneer cementation regarding their polymerization is simultaneously activated by chemical and light modes.[1] In fact, after cementation, the degree of conversion cannot be entirely achieved that is assured by the continuous polymerization regarding the mixture of the chemical compounds. The major factors for failures in the resinous interface are the following: polymerization shrinkage, microstructure defects, thermomechanical fatigue, and the lack of polymerization or mechanical interlocking are.[6,8] Microgaps from shrinkage and fatigue as well as defects like pore and cracks are related to micro- or nano-leakage with the accumulation of acidic substances and bacteria responsible for secondary caries.[2,3,6] Also, those defects are spots for the stress concentration on occlusal loading that can lead to mechanical failures.[2,4] The optimal thickness of the resin cement between the veneer and teeth substrate must be as minimum as possible to prevent failures depending on the resin cement.[2,7] Thus, the inner surface of the veneer must be rough enough to provide the mechanical interlocking of the resin-matrix cement. On the other hand, the roughness and morphological aspects of the enamel and dentin surfaces are well-patterned by etching procedures.[2,3] At last, the thickness of the resin-matrix cement depends on the clinical procedure and roughness of both veneer and teeth contacting surfaces.

The main aim of this study was to perform an integrative systematic review on the thickness of the resin-matrix cement after ceramic veneer cementation. It was hypothesized that the thickness of the resin-matrix cement varies depending on factors related to the clinical procedures and adhesion surfaces.

2. Method

A bibliographic search was performed on PUBMED (via National Library of Medicine) using the following combination of search terms: ''veneer'' AND "resin cement" AND ''thickness'' OR "layer". The inclusion criteria involved articles published in the English language, up to February 2019, regarding the thickness inspection of resin-matrix cements after cementation of ceramic veneers. Also, meta-analyses, randomized controlled trials, and prospective cohort studies were included in the search strategy. The total of studies was compiled for each combination of key terms and then the duplicates were removed using Mendeley citation manager (Elsevier B.V.). Two of the authors (J.C.M.S.; H.L) independently evaluated the titles and abstracts of potentially pertinent articles. Selected articles were individually read and analyzed concerning the main aim of the present study. The following factors were taken into consideration for the present study: authors' name; publication year; type of resin cement; thickness; polymerization mode; microstructure; interface analyses; mechanical properties.

3. Results

The literature search identified a total of 120 articles in PubMed, as shown in Fig. 1. After reading the titles and abstracts of the articles, 107 were excluded because they did not meet the inclusion criteria. The remaining 13 potentially relevant studies were then evaluated. Of those studies, 2 articles were excluded because they did not provide comprehensive data considering the purpose of the present study. After a full reading of the 11 remnant articles, 3 articles were excluded remaining 8 articles that were included in this review.

Of the 8 studies selected, 6 articles (75%) investigated the effect of thickness of luting agent regarding different prosthetic design and resin-matrix cements. Another article (12.5%) evaluated behavior thermal fatigue of resin cement while another one compared the mechanical properties of light-cured and dual-cured. Relevant parameters of the selected studies are shown in Table 1. The most significant results are described as follow:

- Different types of cement were assessed such as a zinc phosphate cement, a polycarboxylate cement, a glass ionomer cement, and self- and dual-cured resin composite cements.[1-8] It should be emphasized that the chemical composition (e.g. inorganic fillers' size) and the viscoelastic properties should be taken into consideration on the resin cement layer thickness;
- On the optical microscopic analyses at x100 magnification, the thickness of resin-matrix cement layer ranged from 50 up to 110 µm in the occlusal, cervical and proximal regions of veneers;[8]
- Regarding the studies that pre-established the thickness of resin-matrix

cement, the thickness values were the following: 10[2], 20[2], 25[6,7], 30[2], 60[2,5], 90[5], 100[2,3,4,6], 120[5], 140[2], 150[5], 180[2], 200[3,4], 300[4] and 500[3] µm. A previous study on finite element analysis reported an optimum thickness at 90 µm to avoid the stress level at ceramic crowns;[5]

- Finite element analyses revealed different stress distribution values considering the geometric model.[1-7] Equivalent stresses were recorded at 0.3-1.5 MPa for the resin-matrix cement layer by a 2D-model[2,3,6,7] while values around 1.5-9 MPa were recorded by a 3D-model[4,5].
- For the same composite cement thickness with different adhesive conditions and loading situation, the shear stress showed values between 0,133 and 1,604 MPa. The highest stress levels were found with facings lacking adhesion in the periphery and loaded at 0º.[7] Regarding compression loading, compressive stress values were recorded from 0.88 up to 118.52 MPa in which mean values were 22 MPa.[2,3,5,6]

4. Discussion

4.1 Resin-matrix cements

Adhesive agents are commonly used to join ceramic crowns to the prepared hard tissues foundation to increase retention, marginal adaptation and fracture resistance of the restored tooth, because of their favorable physical and mechanical properties like high resistance to compression and wear, relatively low cost and simple application.[5,9] During the curing process, the resin cements transform from a liquid to solid state.[5] Contraction stresses develop due to corresponding volume and thickness changes, which may affect the longevity of the restored tooth.[5]

The composition of resins composite cements is identical to resin composites and mainly consist of various methacrylate resins and inorganic fillers which are often coated with organic silanes to provide adhesion between the filler and the matrix, include bonding agents to promotethe adhesion between resin cement and tooth structure.[10] Many monomers are hydroxyethyl methacrylate (HEMA), 4-methacryloyloxyethy trimellitate anhydride (4-MET), carboxylic acid and organophospate 10-methacryloxydecyl dihydrogen phosphate (10-MDP), with the acidic group bonds calcium ions in the tooth structure.[10] Resin composite cements are used in combination with adhesive systems because create micro-mechanical retention to both enamel and dentin. If we see the surface preparation before the cementation process, resin cements can be divided in three categories: composite resin cement (used with total-etch adhesive systems), adhesive resin cement (used with separate self-etching adhesive systems) and a self-adhesive resin cement (containing a self-adhesive system).[9] This last type simplifier the restoration procedure because it is necessary only in one step to bond without any surface conditioning or pre-treatment.[10]

The organic matrix is made of monomers, that due to polymerization, bond into polymers and form a three-dimensional network, which is filled with fillers, that can include glass or quartz particles or fused glass particles, and in this way the physical and mechanical properties are improved. To increase the overall material quality of resin cements may contain polymerization initiators, various additives, stabilizers, inhibitors and pigments.[9]

In polymerization, the displacement and spatial organization of monomers molecules are responsible for volumetric changes, that leads to losses its ability to flow, its elastic properties increase, that which causes stresses at the restoration-tooth, shrinkage stress.[9] The polymerization efficiency depends from different aspects, like mechanical and biocompatibility of resin cements, an adequate quantity of light is required, and the translucency, thickness, the opacity and shade of restorative materials can affect the amount of light transmission. Exists different types of curing resin: light cured, dual-cured and self-cured. In Öztürk *et al*[1], that relate two light-cured resin cements and one dual-cured resin cement, demonstrate that was this last one type that expresses better performance, because his higher hardness and modulus of elasticity. In the same point of view, in Liu *et al*[5] show that the use of more rigid adhesives can result in a reduction of stress in the veneer.

4.2 Thickness variation of resin-matrix cements

The adhesive cementation is critical to ensure adequate bond strength between the restorative material and tooth structure, because an ill-fitting adhesive veneer is claimed to be the main cause related to micro-leakage and recurrent caries.[2] But the problem is the inexistence of a clear recommendation for the cement thickness for a bonded veneer restoration, so many studies with some variation have been done to determinate the best results possible.

An ideal marginal fit is extremely difficult to achieve, so is necessary to study the marginal adaptation between different types of veneers and the thickness variation of cements. Harasani *et al*[8], demonstrate that the thickness of cement was higher at the occlusal than at the cervical location (110 to 50 µm), with the same results for the absolute marginal discrepancy (195 to 88 μm).[8] A high value in absolute marginal discrepancy that is filled with composite cement, can cover the surface of tooth and veneer, may in long term cause both plaque accumulation and an unsightly discoloration of the marginal parts of the veneer.[8]

So early studies showed, for different preparation (shoulder margin and chamfer margin), that the greatest stresses were concentrated at the tip of the facial cusp, and from that point decreased apically, but overall the values for both marginal configurations were approximately the same with values. Increasing thickness from 25 to 100 μm slightly reduced the overall stresses.[6] At the margin was elevated by a factor of two or three. This confirmed the advantage of precise fit, especially for restorations with a shoulder as the gingival finish line. Because posterior teeth receive the greatest functional occlusal load, gingival chamfers may be less desirable when the length and taper of the tooth preparation are compromised.[6]

It's known that increased cement thickness results in reduced veneer thickness (figure 2).[2] This study demonstrate maximum principal stresses were found at the enamel-cement interface at the lingual edge and also increase with increasing cement thickness from 10 to 180 μm, with same results stress concentration within the cement layer. The stress values decreased progressively and uniformly at the incisal region and the labial side. Therefore, under same incisor area, more cement layers results in less veneer thickness that could reduce the bending moment of inertia of the bonding complex.[2]

Others studies demonstrate the importance to understand how stress from masticatory forces is distributed in occlusal veneers.[4] The maximum tensile stress occurs at the outer surface of the veneer and lower surface of the core, it was found that the stress distribution largely depends on the loading conditions. Indicate that neither the restorative material (different elastic modulus)[4], cement material properties nor the cement thickness are important to the overall internal stress distribution of all-ceramic crown when subjected to the same loading condition.[5] The cement thickness was only significant for the stress generated in the cement itself so did not affect the mechanical performance of the restorations. However, the magnitude of maximum principal stress in each layer indeed changes with the cement type and thickness. The concentrated load at the central fossa caused severe tensile stress in the crown. In comparison, the more distributed bite and masticatory loads are much less detrimental to the restored crown. This suggests that the occlusal facets of the restored crown should be shaped according to the profile of the opposite tooth to minimize concentrated contact at a single point during function[5] and thicker occlusal veneer present superior mechanical performance than thinner restorations.[4]

In the same line but for central incisors location, Troedson *et al*[7]*,* showed under the influence of various cervical designs and loading conditions that both in the enamel bond and in the composite cement layer the maximum shear stress appeared when the load was 0^{o} to the long axis of the tooth, and was about 12 times higher with adhesion in the middle part of veneer tan in the other gluing types (adhesion in the middle part of the veneer and full adhesion) under the same load angle.[7] The magnitude of the shear stresses increased with the angle of loading and the area in which they were distributed decreased. This show that it is important to the veneer have a point that allows the stress to be transferred to the tooth, because a lack of adhesion in the periphery the concentration of stresses around it will be zero, so with high magnification of stress in this point could be a risk that the enamel bond can break.[7]

Beside to loading conditions, a veneer bonded to tooth is subjected to the curing contraction of composite cement and significant thermal changes in the oral environment.[3] Magne *et al*[3], demonstrated the increase of temperature reduced the overall stress level. The highest compressive stress was recorded at the incisal interface maybe because the highly curved and concave interface creates a bulk of composite cement and subsequent contraction.[3] The stress pattern was related to the ratio of thickness between the ceramic and the cement (CER/CPR), with the high compressive stresses and thermal conditions had the most important effects when associated with low CER/CPR ratio. Preexisting compressive stresses that was generated by composite cement shrinkage, were attenuated at high temperature (50^{o}C) and exacerbated at low temperature (5^{o}C).[3]

5. Conclusions

In this literary review, important and relevant information was found on influence how thickness of resin cement affects the performance of the veneer. Following conclusions may be addresses:

- Overall, increases the thickness of resin cement have a minimal effect in stress in the veneer.
- The thickness and type of veneer, thickness and type of cement, different preparation of the margins, optical curing, quantity of light and above all the loading conditioning, will affect de lifespan of the veneer.
- Resin cements with highest modulus of elasticity can have a better performance, because of a reduction stresses in the veneer.
- Further studies should be carried out with different resin cements, with different properties and mainly whenever possible relate directly with clinical cases.

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Annexs

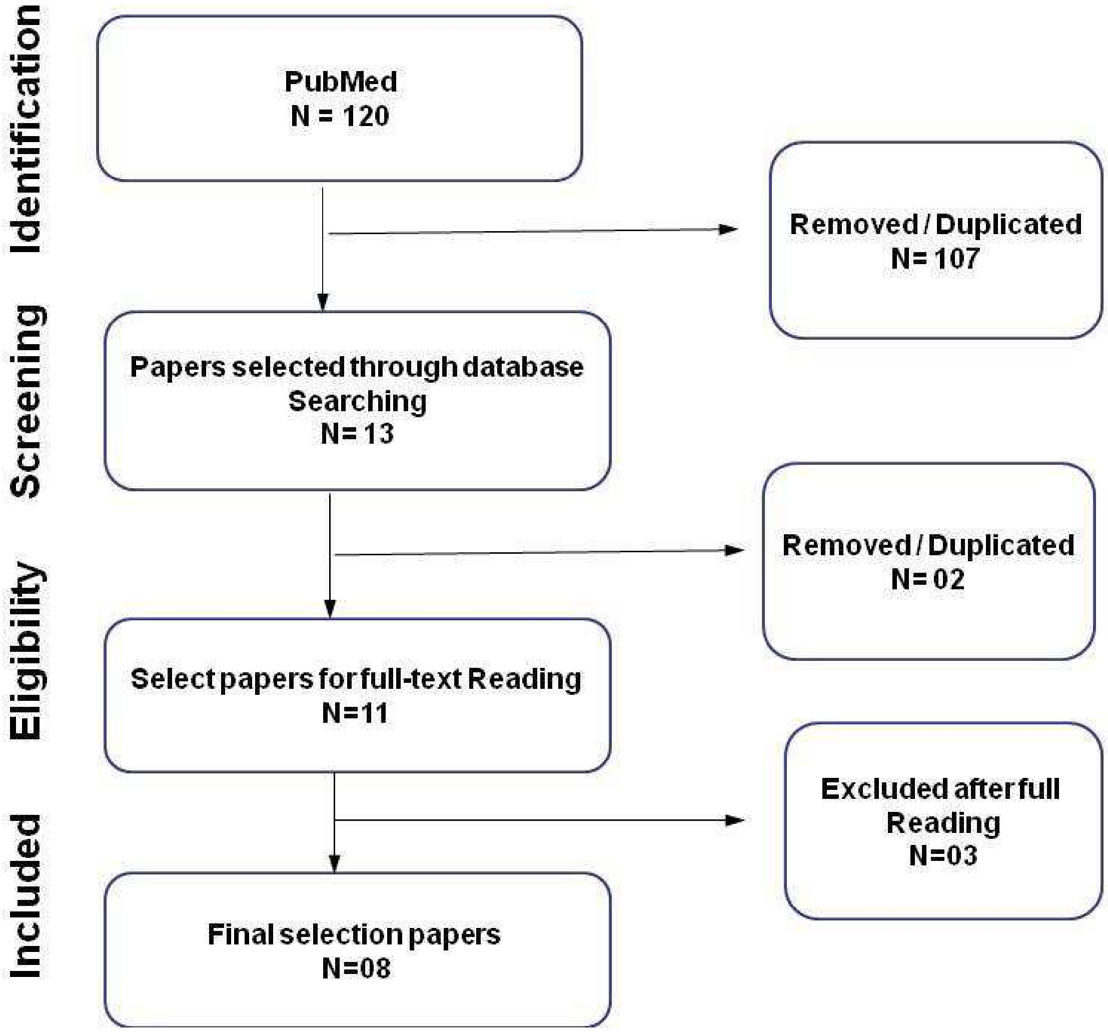

Figure 1 - Flow diagram of the search strategy used in this study.

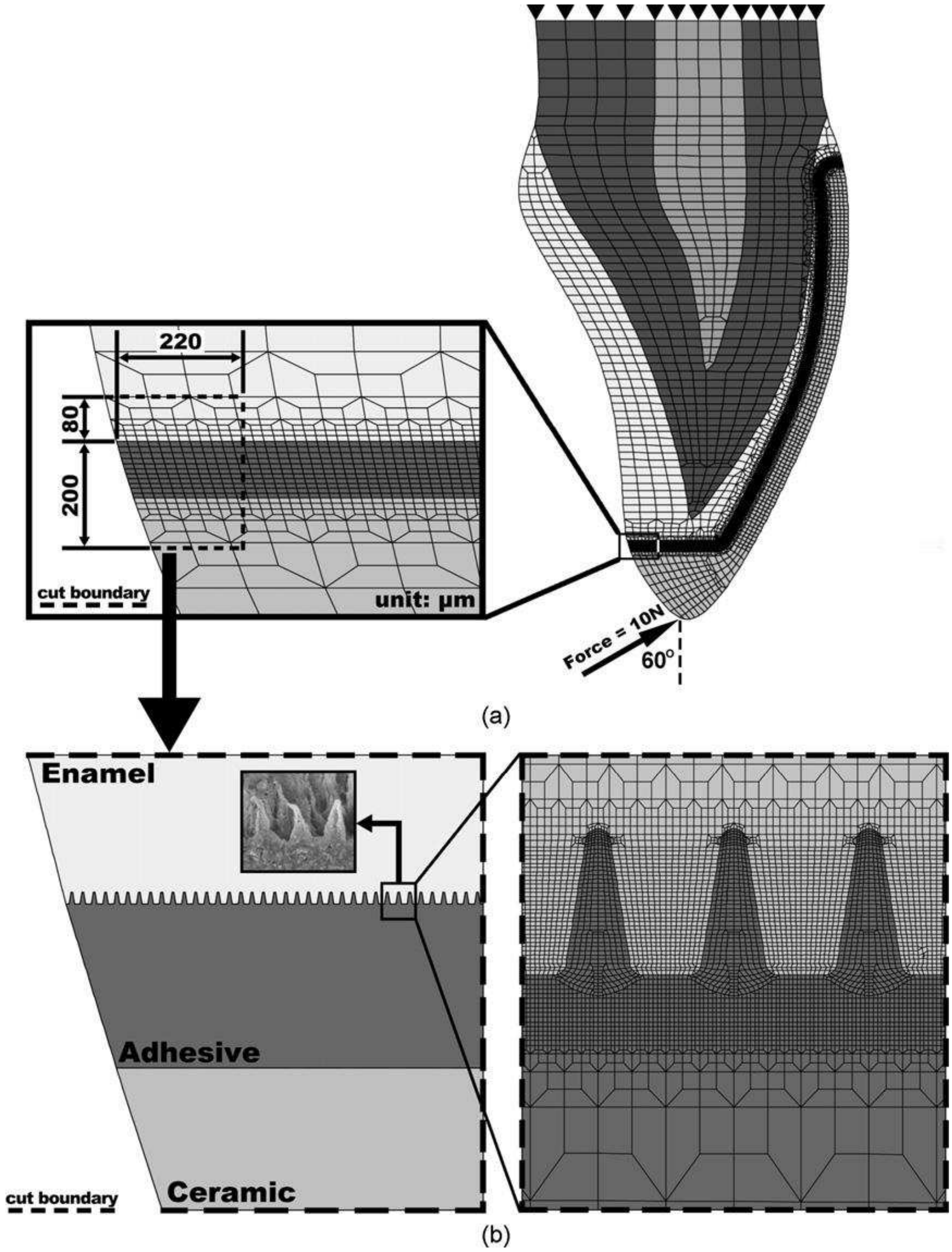

Figure 2 - Schematic figure of configuration, element distribution and boundary conditions of the incisor macro-model in (a) and interfacial micro-model in (b).[5]

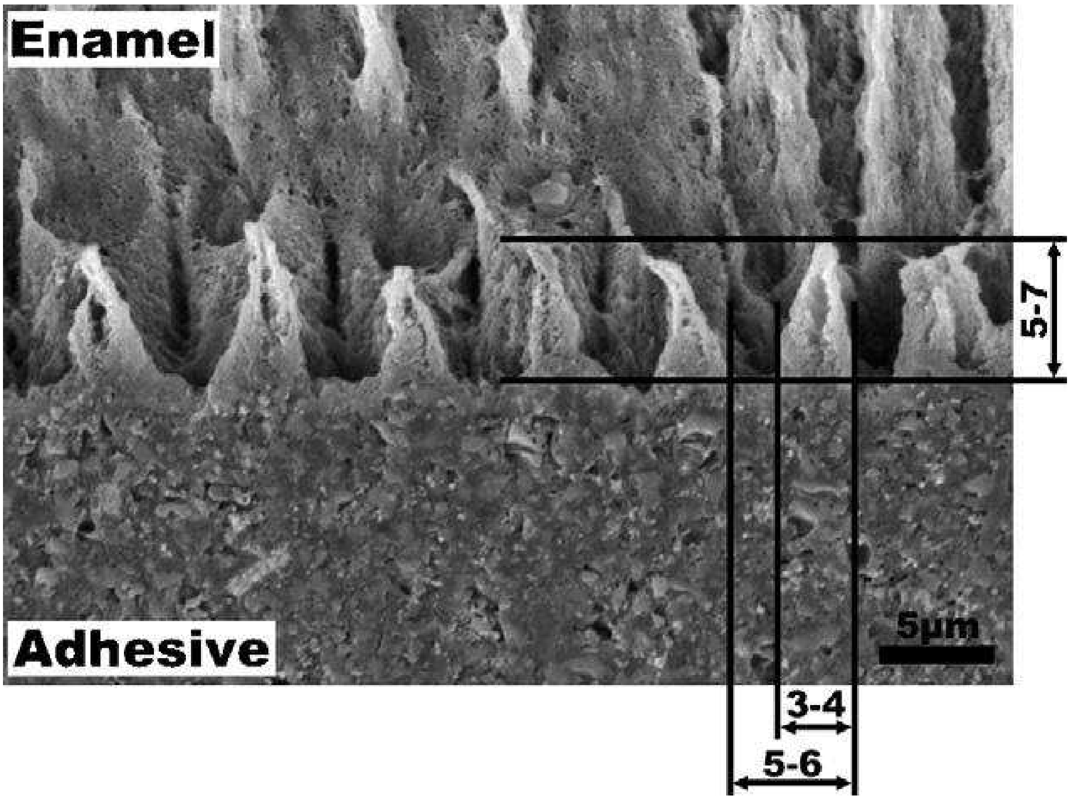

Figure 3 - SEM micrograph of the enamel-adhesive interface. Magnification: 3000x

Table 1- Data on the chemical composition, thickness, methods, and outcomes from the selected articles.

Author (year)	Purpose of the study	Resin cement chemical composition	Mechanical properties of the resin cements	Resin cement thickness (µm)	Methods	Main Outcome
Harasani, M. H. *et al* (1991)[8]	Comparison of the marginal adaptation of indirect composite and porcelain veneers using transmitted-light microscopy.	Kulzer Microfill pontic	E= 5,67 GPa[11]	50 to 195	Transmitted-light Microscopy at a x100 magnification.	Both veneering materials revealed regular fitting free of micro-gaps. Regular and smooth without visible gaps.
Kamposiora, P. *et al* (1994)[6]	Finite element analysis of veneer crowns and related resin cements.	Zinc phosphate Polycarboxylate Glass ionomer Composite resin cement	E= 22 MPa /υ= 0.35 E= 5,11 MPa /υ= 0.35 E= 7,56 MPa /υ= 0.35 E= 12,5 MPa /υ= 0.35	25 and 100	Two-dimensional (2D) finite element analysis (FEA) with a 10 MPa centric axial pressure.	Stresses at the midpoint of the axial walls of crowns cemented with zinc phosphate cement were two to three times higher than those with resin cements. On average, increasing the cement thickness from 25 to 100 µm slightly reduced the overall stresses.

Troedson, M. *et al* (1998)[7]	Evaluation of the shear stresses at the resin cement layer and at the enamel interface on loaded porcelain veneers.	Composite cement	E= 6 GPa υ= 0.24	25	Finite element method (FEM). Three models of the tooth were created and were loaded at 0o, 30o and 60o to the long axis of the tooth and the magnitude of the load was 250N.	A porcelain veneer that is kept inside the enamel, with a full lamination, shows fairly low shear stresses in the enamel bond and composite cement and should thus have a good long-term prognosis.
Magne, P. *et al* (1999)[3]	Finite element modeling was used to evaluate the respective effects of luting composite shrinkage and significant thermal changes.	Composite cement	E=20 GPa υ= 0.24	100 , 200 and 500	Finite element model (FEM). A baseline temperature of 20oC was chosen and then applied two different increments: thermal load either from 20oC to 50oC (30o positive thermal load) and from20oC to 5oC (15oC negative thermal load).	Thermal conditions had the most important effects on the stress distribution of veneers featuring the lowest CER/CPR. Preexisting compressive stresses were attenuated at high temperature (50o) and exacerbated at low temperature (5o). The stress pattern was not influenced by the incisal length of the veneer but rather by the facial thickness of ceramic. Only the veneer with a 100 µm

						thick interface was compatible with a natural emergence profile, which did not compromise the CER/CPR configuration.
Liu, H. L. *et al* (2009)[2]	Evaluation of the influence of resin cement thickness on the macro- and micro-mechanical responses in a ceramic veneer adjacent to an incisal overlapped incisor.	Composite cement	E= 6 MPa υ= 0.24	10, 20, 30, 60, 100, 140 and 180	Seven finite element (FE) with a 10N load was applied with an angulation of 60o to the longitudinal tooth axis at the incisal margin. SEM micrograph of the enamel-adhesive interface with 3000x magnification.	Higher stresses were measured at the interface as the resin cement thickness increased. Resin cement thicknesses below 50 µm can decrease the stress magnitude and failures at the interface.
Liu, B. *et al* (2010)[5]	Investigation of the effects of luting cement type and thickness on the stress distribution within all-ceramic crowns.	Panavia F Variolink II	E= 4 GPA / υ= 0.35 E= 8,3 GPa / υ= 0.35	60, 90, 120 and 150	3D numerical analysis - finite element analysis (FEA). Four occlusal loading conditions were considered: conditions I, III and IV a total of	The cement with larger elastic modulus resulted in lower tensile stresses in the veneer and core layers. The shear strength of the cement is critical to maintaining the

					600N bite force was applied, while in condicion II, 255N masticatory force was applied.	intactness of all-ceramic crowns. The thickness of the resin cement did not affect the stress distribution though the all-ceramic crown regarding the same loading and elastic moduli.
Öztürk, E. *et al* (2010)[1]	Assessment of the resin cement after light-curing under the ceramic restoration in comparison to dual-cured resin cement.	Variolink II RelyX Veneer Variolink Veneer	E= 11 ±0.5 GPa HV= 48,2 ±3,2 Cr= 4,3 ±0,1 We/Wtot= 38,6 ±0,7 E=6,9 ±0,3 GPa HV=33 ±2,5 Cr=4,6 ±0,2 We/Wtot=41,8 ±1,0 E=4,4 ±0,4 GPa HV=20,1 ±2,6 Cr=5 ±0,2 We/Wtot=43,7 ±1,3	170	Automatic micro hardness indenter (Fischerscope). The test load increased and decreased with constant speed between 0,4 and 30 mN.	The type of the resin cement had a significant effect on the micromechanical properties of the interfaces, the Variolink II expresses better performance.
Tribst, J. P. M. *et al* (2018)[4]	Evaluation of the stress distribution in occlusal veneer according to the restorative material, restoration thickness, and resin cement layer thickness.	Resine cement	E= 7,5 GPa υ= 0.25	100, 200 and 300	Finite element analysis (FEA). An axial load 600N was applied on the occlusal face for static structural analysis.	The thickness of the resin cement layer did not affect the mechanical performance of the restorations