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In-vitro Fatigue Resistance of Bonded Posterior Occlusal Veneers: A Systematic Review

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Abstract

Objectives: To determine the fatigue resistance of occlusal veneers and whether it can be a successful mean of restoring erosive or attrite posterior teeth. **Methods:** Search was made in 2 databases including PubMed and LILACS, the terms "occlusal veneers", "table tops", "overlays", "non retentive all ceramic full coverage restorations", "fatigue resistance", "masticatory fatigue", "stresses", "fatigue failure" and "fracture strength" were used, title and abstract were screened; giving the exclusion and inclusion standards articles which did not follow the inclusion standards were excluded. Incorporated papers are then read thoroughly for a second stage filter, this was followed by manual searching. **Findings:** The search resulted in 6 included papers, 3 papers regarding the fatigue resistance of occlusal veneers made of composite and glass ceramic blocks, 1 paper measuring the fatigue resistance of occlusal veneers made of two different glass ceramics, 1 paper comparing occlusal veneers made of resin nano-ceramic with those made of composite blocks and 1 paper simulating five years of clinical service on occlusal veneers made of one type of glass ceramic. From the included studies occlusal veneers were found to be a successful mean of restoring erosive or attrite posterior teeth regarding fatigue resistance.

Keywords: Composite and Resin Nano-Ceramic, Fatigue Resistance, Glass Ceramics, Occlusal Veneers

1. Introduction

An ultimate restorative material must fulfill functional and esthetic desires. It has to also offer continuing reliability in addition to teeth preservation[1-3].

Through enhancements in the biocompatibility, esthetics and the mechanical properties of ceramics, the use of all-ceramics with metallic restorations is defensible[2]. Production methods such as heat press or CAD/CAM (computer assisted design/computer-assisted machining) procedures are used to manufacture also inlays or onlays (small all-ceramic restorations) with high fracture resistance[4].

With huge carious defects, many studies have well documented the worthy durability of ceramic onlays[5-7] and crowns[8,9].

With mal positioned teeth or occlusal abrasion with no caries occlusal restorations is essential. Orthodox treatments were partial crown preparations or retentive inlay[10,11]. Though, a less aggressive non-retentive preparation design is promising when adhesive cementing methods are used[12].

Progressive reduction of enamel breadth is a biological state as a result of aging[13]. Though, the accelerated and premature enamel loss by Gastro Esophageal Reflux Disease (GERD) or bulimia nervosa can happen in childhood or adolescence, with damagingcosts[14,15]. On the other hand, as mineral loss is sluggish, slow and usually trouble-free, dental erosion is frequently overlooked. It is usually diagnosed at a progressive stage, once a significant loss of enamel has arisen[15,18].

The management of dental erosion must be concentrated on the cause and inhibition of additional damage, the restorative phase needs a cautious method, dependent on the grade of destruction[15].

Initial lesions require simply a clinical follow-up, non-invasive dentin sealing with a bonding agent, or direct composite resin restorations. Nevertheless, management of patients with wear and generalized erosion is further multifaceted[15].

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In-vitro tests have boundaries and do not essentially determine the clinical success of all-ceramics; though, they signify the greatest obtainable information about dental restorations. In-vivo data has been inadequate until now due to ethical and practical reasons. Thus, this review will concentrate on systematically evaluating the fatigue resistance of occlusal veneers made of different materials.

2. Materials and Methods

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement[19] was followed as much as possible.

2.1 Data Collection

Two online databases were systematically searched: PubMed (NLM—National Library of Medicine) and LILACS (Virtual Health Library). The search terms "occlusal veneers", "table tops", "overlays", "non retentive all ceramic full coverage restorations", "fatigue resistance", "masticator fatigue", "stresses", "fatigue failure" and "fracture strength" were used to search in vitro studies up to December 2015. The electronic search was not restricted. The last search strategy was tweaked using the help of a librarian.

2.2 Criteria for Inclusion of Studies

From the search outcomes according to titles/abstracts related to topic, studies were nominated founded on these inclusion standards:

Inclusion:

- Occlusal veneers
- In-vitro studies

A complete copy of a study was evaluated for inclusion, when a related title with no abstract was available, as explained below. Two independent reviewers assessed the studies' titles and abstracts of possible studies. All abstracts that seemed to meet inclusion criteria were chosen and full articles or full theses were acquired. Manual search was used to complete the literature search within the reference lists of nominated full-text studies. Only articles that met with the inclusion standards were additionally reviewed. Two reviewers reviewed independently full copies of articles to decide if the exclusion standards applied. Besides the preliminary selection the subsequent exclusion standards were only considered at this stage:

- Onlays.
- Inlays.
- Endodontically treated teeth.

2.3 Data Extraction

The materials were extracted shown in Table 1, the experimental conditions shown in Table 2, as were the results shown in Table 3. For any incomplete/missing information, the articles' authors were communicated. Evaluation of study risk of bias was conducted with individual information collected in Tables.

Table 1. Materials

Paper title	Materials						
	Extracted molars	Finite element	CAD/CAM			Heat pressed	
			Empress	e.max	Composite	Empress	e.max
Clausen et al [12] in 2010	64					√	√
Magne P. et al [20] in 2010	30		√	√	Paradigm MZ 100		
Schlichting et al [21] in 2011	40		√	√	Paradigm MZ 100 and XR		
Magne p. et al [22] in 2012		√	√	√	Paradigm MZ 100		
Skouridou N et al [23] in 2013	10		√				
Johnson AC et al [24] in 2014	60		Lava Ultimate		Paradigm MZ 100		

Table 2. Methodology

<table>
<tr><th rowspan="2">Paper title</th><th colspan="2">Preparation</th><th rowspan="2">Thickness of Occlusal veneers</th><th colspan="3">surface treatment</th><th rowspan="2">Cementation</th><th rowspan="2">Tests</th></tr>
<tr><th>beveled F.L.</th><th>Chamfer F.L.</th><th>Ceramics</th><th>Composite</th><th>Preparation</th></tr>
<tr><td rowspan="2">Clausen et al [12] in 2010</td><td>√</td><td>√ (0.8mm)</td><td rowspan="2">1.5 mm</td><td rowspan="2">HF etched and silanated</td><td rowspan="2"></td><td rowspan="2">Etched and primer appied</td><td rowspan="2">adhesive resin cement (Variolink II)</td><td rowspan="2">Cyclic loaded 600,000 times and thermocycled 3500 times in a masticatory simulator. Surviving specimens were loaded until, fracture in a universal testing machine</td></tr>
<tr><td colspan="2">and the preparation was either completely within Enamel or within Dentin</td></tr>
<tr><td>Magne P. et al [20] in 2010</td><td>√</td><td></td><td>1.2 mm</td><td>HF etched and silanated</td><td>airborne-particle abraded and silanated</td><td>airborne-particle abraded, etched and adhesive resin applied</td><td>Preheated adhesive resin cement (Filtek Z100)</td><td>Cyclic loading at 200N, followed by of 400, 600, 800, 1000, 1200 and 1,400N at a maximum of 30,000 cycles each.</td></tr>
<tr><td>Schlichting et al.[21] in 2011</td><td>√</td><td></td><td>0.6 mm</td><td>HF etched and silanated</td><td>airborne-particle abraded and silanated</td><td>airborne-particle abraded, etched and adhesive resin applied</td><td>Preheated adhesive resin cement (Filtek Z100)</td><td>Cyclic loading at 200N, followed by of 400, 600, 800, 1000, 1200 and 1,400 N at a maximum of 30,000 cycles each.</td></tr>
<tr><td>Magne p. et al.[22] in 2012</td><td>√</td><td></td><td>0.6 mm</td><td></td><td></td><td></td><td></td><td>Nonlinear contact analysis at 200N and 800 N.</td></tr>
<tr><td>Skouridou N et al.[23] in 2013</td><td></td><td>√ 0.5 mm</td><td></td><td>HF etched and silanated</td><td></td><td>Etched and adhesive resin applied</td><td>adhesive resin cement (Variolink II)</td><td>thermal cycling and mechanical loading in a masticatory simulator</td></tr>
<tr><td>Johnson AC et al.[24] in 2014</td><td>√</td><td></td><td>0.3, 0.6 and 1 mm</td><td>airborne-particle abraded</td><td></td><td>etched</td><td>self-adhesive, dual-cure resin cement (RelyX Unicem)</td><td>Each specimen was subjected to vertical load to fracture using a universal testing machine</td></tr>
</table>

3. Results

Six studies[12,20-24] were incorporated in the systematic review shown in Figure 1. After inclusion and exclusion standards were used in the second selection stage, two studies were excluded. The designated studies were published between 2010 and 2014. They varied extensively in the methodology, and study design (specimens count and materials used). So the opportunity of attempting a meta-analysis was precluded.

Table 3. Results

Paper title	Results
Clausen et al [12] in 2010	All specimens survived the masticatory fatigue. Mean fracture resistance ranged from 2895 to 4173N. Influence of ceramic material on fracture resistance was significant ($p = 0.0001$). Lithium disilicate glass-ceramic restorations had higher fracture resistances than leucite reinforced glass-ceramic restorations. Different preparation designs showed no significant influence on fracture resistance ($p = 0.0969$). The design of the finishing line did not influence the fracture resistance ($p = 0.9461$)
Magne P. et al [20] in 2010	For the IPS Empress group, restorations demonstrated failure at an average load of 900 N (110,918 cycles), and all specimens exhibited ceramic cracks by the completion of the 185,000 cycles (survival=0%). For groups EMAX and MZ100, the survival rates (no cracking) were 30% and 100%, respectively
Schlichting et al [21] in 2011	In the IPS Empress group, restorations failed (initial failure) at an average load of 500N (38,475 cycles), in group e.max at an average load of 800N (87,089 cycles) and none of the specimens withstood all 185,000 load cycles (survival = 0% for both ECAD and EMAX). For groups MZ100 and XR the survival rate was 60% and 100%, Respectively
Magne p. et al [22] in 2012	none of the Empress CAD and only 20% of the e.max CAD occlusal veneers survived the load of 800N at 0.6 mm thickness (average failure load of 800N), group MZ100 did not fail in 90% of the specimens
Skouridou N et al [23] in 2013	The occlusal veneers (Group III) developed surface cracks or fractures during thermocycling and mechanical loading and therefore excluded from fracture strength testing
Johnson AC et al [24] in 2014	Mean maximum loads (N)at the point of fracture for the MZ groups were 1620 (MZ3), 1830 (MZ2), and 2027 (MZ1) for the material thicknesses of 0.3, 0.6, and 1.0 mm, respectively. The Lava Ultimate (LU) groups fractured at slightly higher average loads (N) of 2078 (LU3), 2141 (LU2), and 2115 (LU1) at the respective 0.3, 0.6, and 1.0 mm thicknesses

3.1 Results of Individual Studies

- Study design: five studies were in-vitro[12,20,21,23,24] and one was a finite element[22] analysis.
- Materials: two studies[20,22] compared the glass ceramics IPS Empress (reinforced glass ceramic) and IPS e.max (lithium-disilicate) and the composite Paradigm MZ100 (zirconia reinforced composite) made by CAD/CAM system, one study[21] compared the glass ceramics IPS Empress and IPS e.max and the composite Paradigm MZ100 and experimental blocks XR (fiber reinforced composite)made by CAD/CAM system, one study [(24)] compared Lava Ultimate™ (resin nano-ceramic) and composite Paradigm MZ100 also made by CAD/CAM, one study[23] used only IPS Empress by CAD/CAM, and one study[(12)] compared IPS Empress and IPS e.max made with heat pressing.
- Cement: four studies[12,20,21,23] cemented the restoration with adhesive resin cements, one study[24] cemented with self-adhesive resin cement and the finite element analysis study[22] didn't include the cement as an interface.
- Preparation design: one study[12] compared four different preparation designs, occlusal preparation with chamfer finish-line or straight-bevel finish-line with the preparation whichever totally in enamel or in dentin and the finish line in enamel.
- Restoration thickness: one study[24] compared three different thicknesses for the occlusal veneers 0.3, 0.6 and 1 mm.
- Cyclic loading: two studies[20,21] made cyclic loading at 200N, followed by 400, 600, 800, 1000, 1200 and 1,400 N at a maximum of 30,000 cycles each, two studies[12,23] made thermal cycling and mechanical loading in a masticatory simulator then loaded until fracture in a universal testing machine, one study[24] did not do cyclic loading and used a universal testing machine to subject the specimens to vertical load to fracture and the finite element analysis study[22] did non-linear contact analysis to mimic occlusal loading at 200N and 800N.

3.2 Results

- Restoration thickness had no influence on the fracture resistance.
- The design of the finish-line had no effect on the fracture resistance.

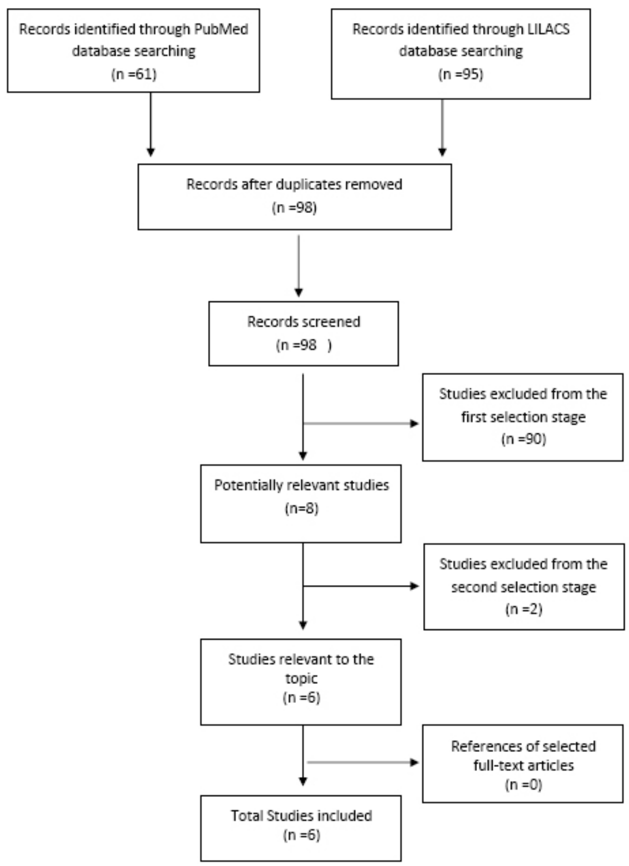

Figure 1. Schematic study selection procedure.

- Restoration material had an influence on the fatigue resistance: all of the studies[12,20-22] that compared the glass ceramics IPS Empress with IPS e.max showed better fatigue resistance results for the e.max restorations, regarding the comparison between glass ceramics and composite[20-22], the composite showed better fatigue resistance, the study that compared resin nano-ceramic with composite[24] showed better fracture strength for the resin nano-ceramic.

4. Discussion

The benefits of decreasing retentive features of tooth preparations could be increased by the application of concepts used in treatment with anterior laminate veneers, hence the proposal for posterior "occlusal veneers" (thin onlay/overlay with non-retentive design). Such restorations could compete with gold onlays/overlays. Occlusal veneers are extra coronal restorations demanding a simple preparation lead by anatomical considerations and occlusal clearance[20].

The fracture resistance of all-ceramic restorations issubjective to several factors, such as composition and fatigue of the ceramics, technique of construction, the design of the preparation and cementing technique[25].

To simulate the clinical condition, the dynamic fatigue was assessed in a universal testing machine[26].

Occlusal veneers are a new restoration with no specific recommendation for the material that it can be made with, neither the preparation design nor the restoration thickness. So this systematic review aimed to evaluate the fatigue resistance of bonded posterior occlusal veneers made with different preparation designs, depths and materials.

Testing a ceramic's fracture resistance in vitro is important before its clinical application. Static loading to fracture is a test widely used that can give an indication of whether a material and a type of restoration can be considered as viable clinical option. However, it can only show the strength of a restoration immediately after bonding and most likely it shows values of fracture resistance that are not indicative of the longevity of the restoration. In the mouth, restorations are loaded during their lifetime with millions of cycles which can cause a substantial reduction in the strength of the material as a result of fatigue[27,28]. All ceramic restorations can be subjected to fatigue testing from 10,000 cycles to 1,200,000 cycles[29].

In complex multilayered restorations, such as cemented ceramic restorations, several factors contribute to the mechanical behavior of the restoration/tooth system. The intrinsic strength of each component of the system (i.e., tooth, adhesive system, luting cement, and restoration), the thickness of the restorative material, the ratios of modulus of elasticity between the restoration, the cement and dentin, and finally the quality of the adhesive interface between these layers in terms of bond strength[30].

The study[12] that measured the effect of different marginal preparation designs showed that it had no influence on the fracture resistance. The cause might be that the point where the load was applied during the test of fracture was away from the finish line. No other studies assessing the effectof the finish line on occlusal veneerrestorations were found in the literature. Therefore the choice of the finish-line can depend on the clinician's choice based onthe case.

The three studies[20-22] that compared occlusal veneers made of composite with those made of glass ceramics showed that the composite materials regarding restoration strength seem to consistently demonstrate more favorable properties than their conventional ceramic counterparts. It seems that greater flexural strength does not necessarily result in a restoration with a greater load tolerance[31]. The IPS e.max has flexural strength of 256 MPa and IPS Empress of 127 MPa while the resin MZ100 has flexural strength of 150 MPa and these values were not reflected in their survival rates. This may be attributed to the fact that the failure caused by tensile stresses is affected by the ratios of the modulus of elasticity between the restoration and the cement and dentin more than it is affected by the intrinsic strength and the thickness of the material[1]. The modulus of elasticity of composite resin is 16-20 MPa and that of dentin is 18.5 MPa which are very close and this maybe the reason for the good performance of the composite resin groups. Also the ceramics are brittle and they cannot withstand the high tensile stresses in the central groove[33]. So, the energy was freed by means of cracks[1]. Although there were no statistical differences between the composite resins tested (3M™ Paradigm™ MZ100 and XR), the absolute survival of all restorations in group XR can be caused by the enhancement of mechanical properties by the addition of fibers[34]. Composite resin restorations are anticipated to preserve the antagonistic enamel but will wear more than the ceramics[35].

The study[12] that compared the 2 glass ceramics IPS e.max and IPS Empress made by heat pressing, the IPS e.max showed better results owing to their higher flexural strength.

The one study[24] that compared Lava Ultimate™ (resin nano-ceramic) with composite (3M™ Paradigm™ MZ100), showed that Lava Ultimate™ had significantly higher fracture strength than 3M™ Paradigm™ MZ 100, this may be due to the higher flexural strength of the resin nano-ceramic (204 MPa) compared to the composite blocks (150 MPa).

In one study[23], the occlusal veneers made of IPS Empress CAD developed surface cracks or fractures during thermal cycling and mechanical loading and therefore excluded from fracture strength testing. This was attributed to the tooth preparation design applied, which with the preparation of a finish line, could have resulted in generating stress bearing areas under the thin occlusal veneer at the cusp tips, as well as the relatively low flexural strength of IPS Empress.

5. Conclusions

In summary, the following conclusions can be drawn:

- Occlusal veneers were found to be a successful mean of restoring erosive or attrite posterior teeth regarding fatigue resistance.
- CAD/CAM composite resin and composite-ceramic over lays had higher fatigue resistance than the ceramic overlays.

6. Recommendations

Studies need to change at a fast pace from being predictable clinical trials to being more innovative in research ideas, such as additional chemical modification[36-40] in the adhesives by addition of functional group monomers, bioactive particles and shock absorbent constituents. Since commonly the induced tensile stress surpasses the compressive stresses, strengthening must be added to deliver the required strength and ductility[41]. Using recent diagnostic tools to test the post-operative clinical performance is highly recommended[42-45].

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