Protet Stomatol, 2021; 71(4): 307-322 www.protetstomatol.pl
DOI: 10.5114/ps/144897

Fracture resistance of various laminate veneer materials: systematic literature review

Odporność na złamania materiałów wykorzystywanych w wykonawstwie licówek – systematyczny przegląd piśmiennictwa

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KEY WORDS:
laminate veneer, fracture, resistance, ceramics

HASŁA INDEKSOWE:
licówki, złamania, odporność, ceramika

Summary

Aim of the study. *To investigate the resistance of the most commonly used laminate veneer materials (lithium disilicate, feldspatic ceramic, zirconia-reinforced lithium silicate) to fracture.*

Materials and methods. *This article follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement. The literature search was performed in PubMed, Wiley Online Library and ScienceDirect databases, for articles published between 2016 and 2021 in the English language. The included studies were evaluated for the risk of bias following a preestablished criterion.*

Results. *481 publications were found, out of which 13 were identified as relevant to the topic. There was a noticeable relation between the choice of restoration materials and fracture strength. Most of the included studies (69.2%) evaluated the lithium disilicate material for fracture resistance. The posterior teeth group was used more often for fracture resistance tests in comparison to anterior teeth group. Thermomechanical aging was performed in 8 out of 13 studies (61.5%).*

Streszczenie

Cel pracy. *Celem pracy był przegląd piśmiennictwa dotyczącego odporności na złamania najczęściej wykorzystywanych materiałów do wykonawstwa licówek dentystycznych (dwukrzemian litu, ceramiki feldszpatowej, krzemianu litu wzmacnianego tlenkiem cyrkonu).*

Materiał i metody. *Artykuł sporządzono zgodnie z Preferencjami Raportowania dla Przeglądów Systematycznych i Meta-Analiz (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) – PRISMA. Bazy PubMed, Viley Online Library oraz ScienceDirect zostały przeszukane w zakresie lat 2016-2021 z preferencją poszukiwania artykułów w języku angielskim. Badania włączone do pracy zostały ocenione pod kątem ryzyka stronniczości zgodnie z wcześniej ustalonym kryterium.*

Wyniki. *Odnaleziono 481 publikacji, z czego 13 zostało zakwalifikowanych jako istotne dla założonego celu pracy. Zauważono związek pomiędzy doborem materiałów odbudowy a wytrzymałością na złamania. Większość zakwalifikowanych badań (69,2%) oceniało ceramikę dwukrzemowo-litową pod kątem odporności na złamania.*

Conclusions. *Zirconia-reinforced lithium silicate and resin nanoceramic veneers showed more favourable outcomes in their resistance to fracture. Therefore, the preparation of substantial tooth structure causes higher probability of fracture occurrence.*

W publikacjach częściej wykorzystywano odbudowy zębów bocznych, aniżeli grupy zębów przednich w testach wytrzymałości na złamania. Termomechaniczne starzenie próbek było dokonane w 8 z 13 badań (61,5%).

Wnioski. *Ceramiki litowo-krzemowe wzmacniane cyrkonem i nanoceramiki wykorzystywane do wykonawstwa licówek wykazują korzystniejsze wyniki w testach wytrzymałości na złamanie. Wobec tego preparacja znacznej ilości tkanek zęba powoduje zwiększenie możliwości powstania złamania.*

Introduction

Over the past years, aesthetic dentistry has gradually developed into a significant aspect of restorative dentistry, particularly in the area of veneer placement, owing to the resulting favourable aesthetic and long-term outcomes.[1] Laminate veneers constitute a minimally invasive and highly aesthetic treatment that was introduced in 1928 by a California dentist Charles Pincus.[2] Dr. Charles Pincus was the first to develop veneers using acrylic material. Due to its inadequate resilience affectingits clinical performance, laminate veneers have since been continuously improved. As it is noted, a variety of different materials with a huge range of constituents can be used for their manufacturing, yet in most cases porcelain and composite usage is customary.

Porcelain veneers offer excellent aesthetic results and predictable longevity of treatment, while composite veneers can be considered as a good conservative option, but with less durability.[3] Regardless of that, based on unequivocal properties, comparably low costs and ease of fabrication,[4] a number of ceramic materials are currently preferable for veneers: feldspathic ceramic, lithium disilicate, leucite-reinforced feldspathic ceramic, fluorapatite and lithium silicate reinforced with zirconia.[5] Referred materials possess diverse acclaimed properties that establish their significantly better performance compared to others. Firstly, they offer more prominent optical features that are obtained due to their excessive content of glassy matrix in their composition, which causes high translucency rate,[6] therefore a highly favourable aesthetics outcome is achieved. Additionally, they not only demonstrate excellent adhesion to resin cement through the conditioning with hydrofluoric acid (4–10%) followed by silanization,[7] but also contain quite high mechanical strengths. Introduced assets are among the many that predetermine their favourability at the present time. Correspondingly, determining properties such as resistance to fracture and durability also have a prominent influence on their use. Both of these properties are particularly contingent on one another, and are of upmost importance when it comes to ceramic veneers, reliability and acceptable clinical performance.

Fracture resistance needs to be contemplated while selecting a restorative material, and it is of particular significance as the main factor when choosing a particular one to obtain proper stress distribution during mastication process. Consequently, the selection of materials plays a crucial role in the lifespan of restorations, as each material has its own composition and properties.[8] Furthermore, the chosen type of material can reduce labour cost and shorten the manufacturing processes, provided that it properly integrates with automated equipment in the laboratory used for veneer production. Additionally, it is noted that fundamentally during veneer construction, beneath decrepit porcelain veneer, a solid and inflexible substructure is placed that should resist flexure and, as a consequence, during the occurrence of tensile strength this layered structure will avert fracture. This way, the chosen material ought to be evaluated taking into consideration this particular property.[9] And yet, studies of the effects of material and substructure design on fracture resistance are sparse even though the microstructure is directly related to long-term ceramic behaviour.[10,11]

The aim of this systematic review was to evaluate scientific literature on ceramic materials that are used for laminate veneers manufacturing, with regard to their fracture resistance.

Materials and methods

Information source and the search strategy

A systematic literature search was performed according to the PRISMA guidelines for clinical trials and literature analysis published between 2016 and 2021. Electronic literature searches were picked from 2021 May to July independently by all authors in English databases: PubMed, Wiley Online Library and ScienceDirect. Databases were searched using different combinations of the following key words: laminate veneer resistance, laminate veneer fracture. ("laminate veneers" OR "laminate" OR "veneers" OR "ceramic"AND "fracture" OR "resistance" NOT "implant" NOT "crowns"). The titles and abstracts were analysed by the three authors, followed by the selection of complete articles for careful reviewing and analysis according to the eligibility criteria.

Study selection

The selected articles passed four stages:

– Selection by the relevant article title,
– Duplicate removal,
– Selection by the relevance of the abstract,
– Full text analysis.

Article inclusion criteria:

The selected papers in this systematic review were laboratory studies, case reports, and clinical studies written in English and were not older than five years. Included studies evaluated the fracture resistance of laminate veneers. The research question was: which laminate veneering material is the most resistant to fracture?

Article exclusion criteria:

During the evaluation process subsequent studies were eliminated: studies that were published before 2016 and after 2021, written in a language other than English. Moreover, clinical studies that used endodontically treated teeth, or traumatized teeth were excluded. Therefore, all laboratory studies that evaluated implant-supported restorations were also excluded. All laboratory studies that assessed full-coverage crowns, 4-unit prostheses, inlays or onlays were also excluded. Pilot studies and studies that used testing methodologies other than fracture or fatigue strength were also excluded.

Results

Search outcomes

Overall, the initial search strategies generated 481 articles. After the first evaluation duplicates were identified and excluded. After screening, 288 potential articles were selected for full article review and 156 were excluded. This systematic review included 13 studies that were conducted to evaluate laminate veneer materials fracture resistance. The article search and selection process is presented in the PRISMA flow chart (Figure 1).

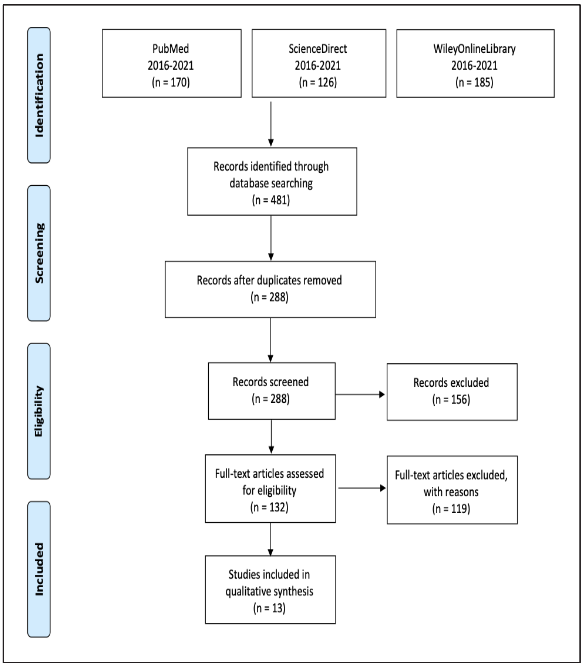

Fig. 1. PRISMA flow chart.

Study characteristics

The PICO of this systematic review was defined in Table 1, which lists different aging methodologies, failure mode and survival probability among studies.

In 8 studies[7,8,10,12,13,15,18,19] thermomechanical aging was performed, where the number of cycles varied from 2000 to 3,000,000, therefore the 1,200,000 cycles were performed in four[12,15,18,19] of the eight studies. In three studies,[6,11,14] specimens were subjected to fracture resistance tests after cyclic loading. The step-stress accelerated life-testing (SSALT) test was applied in two studies.[16,17]

In the first study[6] after 20,000 cycles with compressive load of 100 N, the fracture without tooth structure involvement in the occlusal surface coverage and the occlusal and lingual surface coverage types of veneers occurred in 62.5% of cases, whereas in the occlusal, lingual, and mesial surface coverage and the occlusal, lingual, mesial, and distal surface coverage types of veneers the percentage was 75.

In the second study,[7] fracture resistance of translucent zirconia laminates has been affected by the sintering procedure – when standard sintering was applied in the incisal palatal chamfer preparation design group, cohesive failure was 20% compared to speed sintering where the cohesive failure increased to 50%.

In the third study,[8] after a two-year simulated period, the fracture frequency in Vita Enamic hybrid ceramic group was 44.4%, whereas in the IPS e.max CAD – lithium disilicate glass-ceramic group – the figure was 66.7%.

In the fourth study,[10] 90 incisors were used. After 10.000 cycles (which simulated a year) with a force of 300 N, metal ceramic and zirconia-lithium disilicate exhibited more favourable fracture resistance than zirconia-feldspathic porcelain. The substructure design with increased coverage of the palatal surface improved fracture resistance significantly.

In the fifth study,[11] zirconia-reinforced lithium silicate (ZLS) and hybrid ceramic (polymer-infiltrated ceramic – PIC) in two thicknesses (0.5 mm and 1 mm) were used. All specimens received an initial load of 200 N for 5,000 cycles, testing was limited to a maximum of 1.5×10^6 cycles. After $5x10^5$ cycles at 450N ZLS.5 presented lower fatigue strength (25%) compared with PIC.5 and PIC1 (83%).

In the sixth study,[12] after thermomechanical fatigue (1.2 million cycles at 98 N with 5°C-55°C) the zirconia-reinforced lithium silicate group showed the highest 62.5% survival rate while the polymethylmethacrylate group demonstrated the lowest 37.5% one.

After 3,000,000 cycles with up to 100 N, the seventh study[13] showed that the fracture risk increased with thin anterior veneers and also when the preparation included medium to high dentine portions (invasive preparation design) compared to thicker ones with preparations in the enamel or partially in the dentine (semi-invasive).

In the eighth study,[14] IPS e.max CAD showed

T a b l e 1. Synthesis and analysis of findings (PICO)

Study	Population	Intervention	Comparison	Outcomes
Xiaoqiong Huang et al. [6], 2020	N=32 4 groups (n=8): occlusal surface coverage (O), occlusal and lingual surface coverage (OF), occlusal, lingual, and mesial surface coverage (POF), occlusal, lingual, mesial, and distal surface coverage (POFP)	Cycles: 20,000 cycles of compressive load on the occlusal surface with a load of 100 N. The specimens were vertically loaded until fracture. Axial load: 2 Hz frequency. Samples: placed in distilled water bath at room temperature.	Preparation designs	After cycling, the extensive crack within the ceramic in type POF was 12.5%, when in O, OF, POFP was 0%. The cohesive fracture within the ceramic without involving the tooth structure in type O and OF veneers was 62.5%, in type POF and POFP veneers – 75%.
Samah Saker et al. [7], 2021	N=40 4 groups (n=10): the incisal shoulder preparation design (IPS), incisal palatal chamfer preparation (IPC) with different sintering procedure: standard and speed.	Cycles: 6,000 cycles between 5 and 55^{0}C for 60 s each with a dwell time of 12 s. Load: 1-kN load was oriented at a 90-degree angle to the palatal aspect of the tooth. Samples: stored for 60 days in water.	Compared sintering programs: standard and speed; preparation designs: shoulder and chamfer	Cohesive (laminate fracture) failure applying standard sintering in IPS group was 30%, when in IPC group – 20% comparing with speed sintering – in IPS group was 30% and in IPC group – 50%.
Abdul Rahman et al. [8], 2020	N=27 3 groups (n=9): group I – IPS e.max CAD – lithium disilicate glass-ceramic, group II – Vita Enamic – hybrid ceramic (a polymer-infiltrated ceramic), group III – Shofu HC – hybrid ceramic (consists of 61% zirconium silicate embedded within a nanofiller composite)	For the purpose of a two-year period simulation of the aging process, all the samples were subjected to 2000 cycles of water baths in a thermocycler at temperatures changing from 5°C to 55°C with 5 s interval. Load to fracture was applied at the speed of 0.5 mm/min using a customized plunger.	Materials comparison	The ceramic fracture occurred in group I – 66.7%, in group III – 55.6% and in group II – 44.4%.

Table 1. cont.

Study	Population	Intervention	Comparison	Outcomes
Eun-Hye Jo et al. [10], 2020	N=90 incisors. 5 groups (n=18): metal-ceramic (MC), zirconia-feldspathic porcelain (ZC), and zirconia-lithium disilicate (ZL) with two designs: A (two-third coverage of the palatal surface) and B (one-third coverage of the palatal surface).	Cycles: specimens were thermocycled between 5 and 55°C with a dwell time of 2 seconds for 10 000 cycles to simulate 1 year. Load: a force of 300 N was applied to represent the maximum occlusal force of the anterior teeth.	Material comparison and preparation designs	Mixed failure (exposed substructure) in MC_A and MC_B was 91.7%, ZL_A – 66.7%, ZL_B – 41.7%, ZC_A and ZC_B – 25%.
F.O. AbuIzze et al. [11], 2018	N=60 4 groups (n=15): zirconium-reinforced lithium silicate ceramic (ZLS) and hybrid ceramic (PIC) in two thicknesses 0.5 mm (ZLS.5, PIC.5) or 1 mm (ZLS1, PIC1).	Cycles: 5000 cycles at 200 N, followed by 450 N cycles until the specimens' fracture or the suspension of the test after 1.5×10^6 cycles. Axial load: 4 Hz frequency. Samples: immersed in 37°C distilled water for 30 hours.	Thicknesses and material	PIC.5 and PIC1 groups survived the most $5x10^5$ cycles at 450N without failure – 83%, ZLS1 – 41% and ZLS.5 – 25%.
Majed Al-Akhali et al. [12], 2019	N=64 4 groups (n=16): lithium disilicate (LD), zirconia-reinforced lithium silicate (LS), polymer-infiltrated ceramic (PI), polymethtylmethacrylate (PM).	Thermomechanical fatigue loading: Half of the specimens of every group (n=8) were randomly selected and subjected to in a masticatory simulator (1.2 million cycles at 98 N with 5°C-55°C thermocycling) loaded until fracture.	Materials comparison	After the thermomechanical fatigue, the cumulative survival rate in group LS – 62.5%, in group LD and PM was 50% and in group PI – 37.5%.

Table 1. cont.

Study	Population	Intervention	Comparison	Outcomes
Uwe Blunck et al. [13], 2020	N=80 incisors. 10 groups (n=8) with 5 different preparation designs: non-prep (NP), minimally invasive (MI), semi-invasive (SI), invasive (I), semi-invasive with two additional Class III composite resin restorations (SI-C), each design was fabricated in two thicknesses: L1 = 0.2 –0.5 mm; L2 = 0.5 –1.2 mm.	Cycles: 2000 cycles between + 5 and + 55 °C, at mechanical load at the incisal edge at an angle of for 45° for 2,000,000 cycles at 50 N and further 1,000,000 cycles at 100N. Samples: immersed in distilled water at 37°C for 21 days.	Preparation designs and thicknesses	Total fracture of anterior teeth veneers after a 250,000 cycles mechanical loading at 50 N in semi-invasive L1 group was 12.5%, L2 – 0%, when in invasive L1 group – 25% and L2 – 12.5%.
Katrin Heck et al. [14], 2019	N=60 3 groups (n=20): IPS Empress CAD (leucite reinforced glass ceramic), IPS e.max CAD (lithium disilicate ceramic) and Lava Ultimate CAD/CAM (resin nanoceramic composite).	Cycles: 10^1, 10^2, 10^3, 10^4, 10^5, 10^6 load cycles compressed by air cylinders with a loading force of 50 N and IPS e.max CAD specimens experienced an additional 100 N. Samples: mounted in closed chambers with distilled water.	Materials comparison	The cumulative survival probability for IPS Empress CAD after 10,000 cycles was 60%, with a further decrease to 50% after 100,000 cycles. The Lava Ultimate CAD/CAM veneer achieved a survival probability of 95% after 100,000 and one million cycles compared to 100% survival for the IPS e.max CAD veneer.
A. Ioannidis et al. [15], 2020	N=60 3 groups (n = 20): 3DP: 3D-printed zirconia, CAM: milled zirconia, HPR: heat-pressed lithium disilicate.	Cycles: 1,200,000 cycles of 49 N force and thermo-cycling (5–55 °C and a dwelling time of 120 s). Axial load: 1.67 Hz frequency. Samples: were stored in distilled water during the complete study.	Material comparison and fabrication technique: printing and milling	Cohesive fracture within the restoration in HPR group was 15%, when 3DP and CAM was 0%.

T a b l e 1. cont.

Study	Population	Intervention	Comparison	Outcomes
Jose Carlos Romanini Junior et al. [16], 2020	N=63 incisors. 3 groups (n=21): lithium disilicate reinforced ceramic (LDS), resin nanoceramic (RN), and feldspathic ceramic (FELDS).	Load: the mean load to failure was performed to design three stress profiles for the SSALT. The SSALT was carried out under water at 2 Hz until failure up to a maximum load of 900 N. Samples: immersed in distilled water at 37°C for 24 h.	Material comparison	At 50,000 cycles at 200 N FELDS showed 10%, LDS – 22% and RN – 41% survival probability.
Mirelle Maria Ruggiero et al. [17], 2021	N=126 6 groups (n=21): resin nanoceramic (RNC) and polymer-infiltrated ceramic network (PICN) with three thicknessess 0.5, 1.0 and 1.5 mm.	The SSALT test was carried out in distilled water at 20 Hz. The test was considered finished when samples failed (chipping or delamination) or when suspended for no event being detected throughout the designed cycles and 1500 N maximum load.	Material comparison and thicknesses (0.5, 1.0 and 1.5 mm)	After 100,000 cycles at set load of 600 N the reliability of RNC 0.5mm was 24%, when PICN 0.5 – 11%, RNC 1 mm was 55%, when PICN 1mm – 45%. RNC 1.5 mm was 60%, when PICN 1.5mm was only 6%.
Haoyu Zhang et al. [18], 2020	N=64 8 groups (n=8): microhybrid composite (MC), fiber-reinforced microhybrid composite (FMC), heat-pressed lithium disilicate ceramic (HPC), and CAD/CAM lithium disilicate ceramic (CCC) with two thicknesses 1.5 mm and 2 mm.	Cycles: 1,200,000 times with a 50 N force and thermal cycled in water between 5°C and 55°C, with a 60-s dwell time at each temperature and a 12-s interval between temperature shifts (approximately 6400 cycles in total). Axial load: 1.3 Hz frequency.	Compared materials and thicknesses	At a thickness of 1.5 mm, the FMC group exhibited 25% of fractures below the CEJ, while the CCC group exhibited 37.5%, MC and HPC exhibited 50%. For the 2.5-mm occlusal veneers, the FMC group exhibited only 12.5% of fractures below the CEJ, in contrast to the other groups (MC, HPC, CCC) that exhibited 50% of fractures below the CEJ.
Majed Al-Akhali et al. [19], 2017	N=64 4 groups (n=16): lithium disilicate (LD), zirconia-reinforced lithium silicate (LS), polymer-infiltrated ceramic (PI), polymethylmethacrylate (PM).	Thermomechanical fatigue loading: half of the specimens of each group (n=8) were fatigued thermodynamically in a dual-axis computerized chewing simulator (1.2 million cycles at 98 N with 5 and 55°C in distilled water with a 30 s dwell time at each temperature with a total of 5500 thermal cycles at a loading cycle frequency of 2.4 Hz) loaded until fracture.	Materials comparison	Cohesive fracture within restoration in LD group was 30%, in LS – 23%, in PI – 12% and PM – 0%.

significant survival rate (100%) after 1,000,000 load cycles with a 150 N loading force, when only 60% of IPS Empress CAD veneers survived after 10,000 cycles with a 50 N loading force.

In the ninth study,[15] after 1,200,000 cycles of 49 N load and thermocycling, 15% of the heat-pressed lithium disilicate specimens were subject to cohesive fracture within the restoration, while none of the 3D-printed and milled zirconia specimens experienced fracture.

In the tenth study,[16] 63 incisors were used. After 50,000 cycles at 200 N, the probability of survival was significantly lower for the feldspathic ceramic (10%), whereas lithium disilicate-reinforced ceramic presented intermediate values (22%) compared to resin nanoceramic veneers (41%).

In the eleventh study,[17] after 100,000 cycles at the set load of 600 N the survival rate was higher for resin nanoceramic than polymer-infiltrated ceramic. Therefore, the restoration thicknesses increased the survival rate: when the nanoceramic thickness was 0.5mm, reliability was only 24%. When the thickness was 1.5 mm, reliability rose to 60%.

In the twelfth study,[18] after 1,200,000 cycles with a force of 50 N and thermocycling, resistance of different materials and thicknesses to fracture varied. Microhybrid composite with the thickness of 1.5 mm and heat-pressed lithium disilicate ceramic groups exhibited 50% of fractures below the cemento-enamel-junction (CEJ), unlike the fiber-reinforced microhybrid composite group, which exhibited 25%. For the 2.5mm occlusal veneers, the fibre-reinforced microhybrid composite group exhibited merely 12.5% of fractures below the CEJ, while the microhybrid composite, heat-pressed lithium disilicate ceramic and CAD/CAM lithium disilicate ceramic exhibited 50% of fractures.

In the thirteenth study,[19] after the thermomechanical fatigue loading, in the lithium disilicate group the cohesive fracture within the restoration accounted for30%, followed by zirconia-reinforced lithium silicate – 23% and polymer-infiltrated ceramic – 12%, while in the polymethylmethacrylate group no fractures were observed.

Risk of bias – assessment of quality

Risk of bias was assessed with Cochrane Risk of Bias version 2 tool. Results are presented in Figure 2. Overall, no studies have shown high risk of bias; eight studies showed some concerns while five studies indicated low risk of bias.

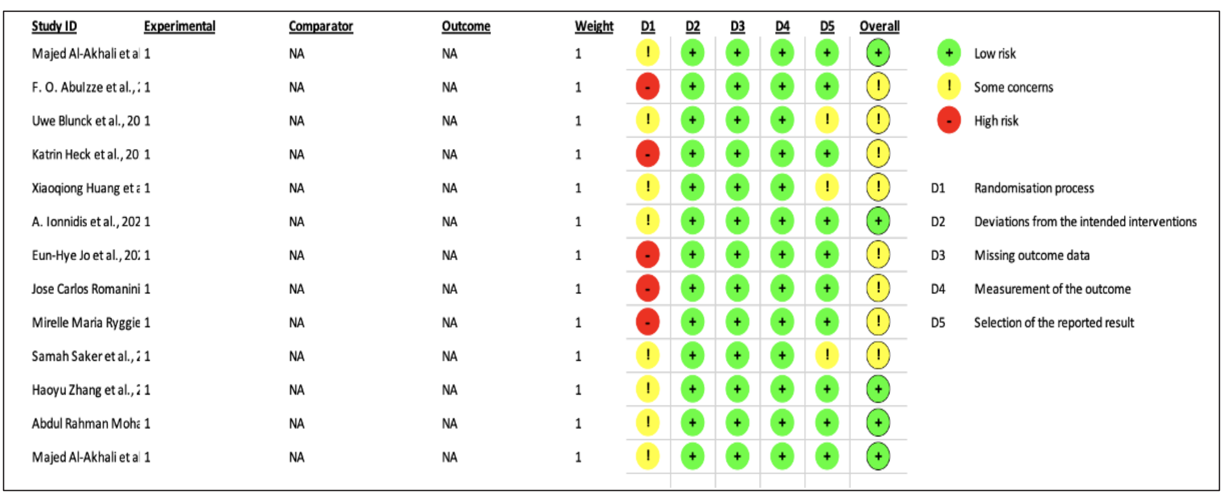

Fig. 2. Quality assessment using Cochrane Risk of bias version 2 tool.

Assessment of mechanical test parameters

Six[6-8,10,14,16] out of thirteen studies used 0.5mm/min crosshead speed. Three[15,17,18] studies used a crosshead speed of 1.0mm/min. Two studies used crosshead speed of 1,800mm/min[12,19] and one[13] study – 1,020mm/min. In five studies a stainless-steel sphere with diameters of 4.6 mm,[6,11] 4 mm,[6] 6 mm,[10] 5.5 mm,[18] and 1 mm[8] was used for the load. In two studies[12,13] a 6 mm diameter steatite ceramic balls were used to test fracture resistance. In one study,[14] a degusit ball (5 mm diameter) was used and in another study[16] the load with a 6.25 diameter carbide ball was applied. Test methodologies and the machine set-up are summarized in Table 2.

T a b l e 2. Test methodologies and the machine set-up

Study	Testing machine	Crosshead speed	Test set-up
Xiaoqiong Huang et al. [6], 2020	Universal testing machine (Instron E3000, Instron Ltd., Norwood, Massachusetts, USA)	0.5 mm/min	The load was applied parallel to the long axis of the tooth using a stainless-steel indenter with a diameter of 4 mm
Samah Saker et al. [7], 2021	Universal testing machine (AG-5 kng, Shimadzu, Kyoto, Japan)	0.5 mm/min	The load was directed at 1 mm from the incisal edge on the tooth restoration interface with a customized plunger.
Abdul Rahman et al. [8], 2020	Universal testing machine (M350-5CT, Testomatric, UK)	0.5 mm/min	A locally manufactured customized plunger (chisel shaped steel rod with its flat end having a diameter of 1 mm and a length of 3 mm) was placed at the occlusal surface of the veneer
Eun-Hye Jo et al. [10], 2020	Thermal cyclic tester; R&B inc	0.5 mm/min	The stainless-steel rod (6 mm diameter) at a static load contacted the palatal surface 1 mm below the incisal edge at an angle of 135 degrees.
F.O. AbuIzze et al. [11], 2018	Biocycle V2 equipment (Biopdi, São Carlos, SP)	NA	Specimens received a load through a stainless-steel sphere with a 4.6-mm--diameter indenter centered with three--point contacts.
Majed Al-Akhali et al. [12], 2019	Dual-axis computerized masticatory simulator (Willytec)	1800 mm/min	6 mm diameter steatite ceramic balls were used as antagonists with a vertical movement to stroke the buccal cusps with a lateral sliding toward the central fissure
Uwe Blunck et al. [13], 2020	Chewing simulator (SD Mechatronik, Feldkirchen-Westerham, Germany)	1020 mm/min	A special metal cone was used additionally to guarantee exact positioning of the specimen during mechanical loading.
Katrin Heck et al. [14], 2019	Computer-controlled chewing simulator (MUC 2; Willytec gmbh, Gräfelfing, Germany)	0.5 mm/min	A 5 mm Degussit-balls were used to perform a natural mastication

Table 2. cont.

A. Ioannidis et al. [15], 2020	Chewing simulator (Williytec, Munich, Germany)	1 mm/min	A vertical indenter (rounded tip of □8 mm) executed a vertical movement to the occlusal plane.
Jose Carlos Romanini Junior et al. [16], 2020	Universal testing machine (K2000 MP; KRATOS, Sao Paulo, Brazil)	0.5 mm/min	A uniaxial compression load was applied 30° off-axis bucally at the incisal edge of the sample using a 6.25 mm tungsten carbide ball (WC)
Mirelle Maria Ruggiero et al. [17], 2021	Universal testing machine (Instron 4411, Corona, CA, USA)	1 mm/min	A load applied axially through a tungsten carbide indenter on the central fossa of the occlusal surface
Haoyu Zhang et al. [18], 2020	Universal testing machine (Instron 5969, Instron, Boston, IL)	1.0 mm/min	A stainless steel sphere with a 5.5-mm diameter was used in parallel with the long axis of the tooth in the occlusal contact area.
Majed Al-Akhali et al. [19], 2017	A dual-axis computerized chewing simulator (Willytec, Feldkirchen-Westerham, Germany)	1800 mm/min	6mm diameter steatite ceramic balls were applied on the buccal cusp beginning 0.5 mm below the cusp tip with a lateral sliding component of 0.3 mm towards the central fissure.

NA – not available

Evaluation of material selection

In all studies the impact of material type on fracture resistance was significant. Lithium disilicate ceramic (IPS E.max CAD) was examined in six studies (46.2%), in five of them it was in a form of an occlusal veneer[8,12,14,18,19] and in one study it was applied to incisors.[16] Lithium disilicate (IPS E. max Press) was used in three studies.[6,15,18] Polymer infiltrated ceramic was used in five studies[8,11,12,17,19] (38.5%) for occlusal veneers. It is known as , “hybrid ceramic” (Vita Enamic) and combines the advantages of both composites and all-ceramic restorations. Zirconia reinforced lithium silicate (Vita Suprinity) was used in three studies.[11,12,19] Composite, which is also indicated for veneers, was chosen in five studies: nanoceramic resin (Lava Ultimate CAD/CAM) was employed in three studies, in two of them as occlusal veneers,[14,17] and in one study for anterior veneers manufacture,[16] microhybrid resin (Ceramage Shofu) was used for occlusal veneers in one study,[18] and fibre-reinforced microhybrid resin (ever Stick C&B) was also used for occlusal veneers in one[18] study. Zirconia-reinforced lithium silicate (Vita Suprinity) was applied in three studies[11,12,19] and 3D printed (Lithoz)[15], milled (Ceramil Zolid Fx)[15], and monolithic (Zolid Fx preshade)[7] zirconia was also chosen in three studies. Polymethylmethacrylate (Telio CAD) for occlusal veneers was used in two studies[12,19], therefore two studies[13,14] used leucite reinforced glass ceramic (IPS Inline, IPS Empress CAD). Felspathic ceramic (Cercon ceram kiss, Vita Blocks Mark II) was employed in two studies,[10,16] One study[10] used metal ceramic (Shofu Vintage Halo). The materials used in each study are presented in Table 3.

Discussion

The aim of this literature review was to investigate the most commonly used laminate

T a b l e 3. Representation of restoration materials used in each study

Study	Material								
	Z-RLS	HC	LD	LR-GC	C	Z	FC	MC	P
Xiaoqiong Huang et al. [6], 2020									
Samah Saker et al. [7], 2021						+			
Abdul Rahman et al. [8], 2020		+	+						
Eun-Hye Jo et al. [10], 2020			+				+	+	
F.O. AbuIzze et al. [11], 2018	+	+							
Majed Al-Akhali et al. [12], 2019	+	+	+						+
Uwe Blunck et al. [13], 2020				+					
Katrin Heck et al. [14], 2019			+	+	+				
A. Ioannidis et al. [15], 2020			+			+			
Jose Carlos Romanini Jr et al. [16], 2020			+		+		+		
Mirelle Maria Ruggiero et al. [17], 2021		+			+				
Haoyu Zhang et al. [18], 2020			+		+				
Majed Al-Akhali et al. [19], 2017	+	+	+						+

Z-RLS – zirconia reinforced lithium silicate; HC – hybric ceramic; LD – lithium disilicate; LR-GC – leucite reinforced glass ceramic; C – composite; Z – zirconia; FC – feldspathic ceramic; MC – metal ceramic; P – polymethylmethacrylate.

veneer materials (lithium disilicate, feldspatic ceramic, zirconia-reinforced lithium silicate) with regard to their fracture resistance. As mentioned before, 481 publications were found, of which 13 were identified as relevant to the topic and were therefore analysed. It is important to note that in eight studies[7,8,10,12,13,15,18,19] thermomechanical aging was performed. In three studies[6,11,14] specimens were subjected to fracture resistance tests after cyclic loading. The step-stress accelerated life-testing (SSALT) test was applied in two studies.[16,17] It is important to mention that various aging methods are suggested to evaluate the durability of restorative materials used in a laboratory setting. When testing fractures, with the exception of aging protocols such as water storage, thermocycling or thermo-mechanical aging, two methods could also be applied – sciliced load to failure test or accelerated fatigue test. Alas, no consensus is currently available as to which method of durability tests would simulate the intra-oral environment the most accurately.[20] After analysing chosen studies it is possible to conclude that zirconia-lithium disilicate exhibited the most prominent favourable results in fracture resistance. Furthermore, resin nanoceramic veneers and fiber-reinforced micro hybrid composite exhibited quite high resistance to fracture when compared to other materials. Evidently, the long-term prognosis of the ceramic laminates is highly dependent on the material from which they were manufactured. In addition to that, various other factors such as tooth preparation depth, ceramic thickness, and cementation material can affect durability of LV. Failures in ceramic laminate veneers (CLVs) have been related to microcracks and the fracture of the ceramic or the tooth structure itself.

It is of interest to collate the ability to dissipate calamitous fracture forces by the application of materials' ability to contort. It has been scientifically proven that ceramics discern ina flated elastic modulus at65–90 GPa. For composite resins it is 1.6–12.4 GPa. Less resilient materials, also referred as brittle materials, do not undergo significant elastic de-formations (*Niem* et al., 2019)[21] which means that when subjected to stresses they absorb little energy and break shortly after. Composite resins are specifically characterized by possessing excessive values of fracture strength, as they are more resilient and have the ability to successfully disperse the applied stress.[22] However, there are contradicting studies that show significantly better performance of ceramic veneers in comparison with indirect composite ones.[23] Nowadays it is becoming apparent that quickly developing modern technology highly impacts dentistry and enables substantially less invasive teeth preparation for indirect restorations, thus more dental tissues are left intact and the used restoration can be less extensive. As a result, it can be seen that ceromers and ceramic materials such as zirconium are used more frequently due to their ability to provide an ameliorated aesthetic appearance. They also withstand high functional forces generated by the teeth during the mastication process. Yet, when collating with composite restorations, the main difference is evident: composite restorations can be applied in a single session, whereas ceromers and ceramic restorations require more time and precision during the positioning and cementation stages in clinics. Furthermore, referred materials compel technical caution during the production in the laboratory. Composite resin, on the other hand, has supplementary disadvantages, such as low fragility resistance, surface roughness, and polymerization shrinkage that generate less satisfactory clinical results. Subsequently, the choice of the restoration material has to be based on both the patient's aesthetic priorities and the functional properties of the material itself.[24] Thus, future studies should be performed for an even better evaluation of the discussed materials.

Moreover, there are studies that underline the influence of preparation depth on fracture resistance. Clinical studies show that restorations placed on dentine are more prone to fracture than those placed solely on enamel. They suggest that retaining the maximal amount of enamel surface area after tooth preparation is paramount and that it will assist better at resisting catastrophic failure. In these studies, it is evident, that veneer preparations on half-enamel-half-dentine behave essentially like those placed on all-dentine substrates with respect to catastrophic failure loads. The given data dispel the notion that having 50% of the enamel remaining after the preparation is in any way comparable to an all-enamel preparation; instead, it was directly comparable to an all-dentine preparation. Consequently,[25] it is important to note that the technique without any tooth preparation requires careful finishing and polishing because of the difficulty in obtaining a smooth transition and avoiding overhangs.[25] Furthermore, the thin margins are exposed to a risk of failure by chipping and cracking caused by shrinkage during light polymerization of the luting materials.[26] In other studies, it is reported that for the maximum decrease of stress in the porcelain restoration and the ability to obtain optimal bond, the preparation depth should include enamel only. Therefore, the technique of surface preparation plays a vital role to maintain the longevity of the porcelain laminate veneers, since extensively exposed dentine surfaces cause high failure rates. Thus, more studies of preparation depth impact on fracture resistance should be conducted for proper evaluation.

As mentioned before, the thickness of all-ceramic restorations also plays an important role in the fracture resistance and their clinical performance is highly related to the previously mentioned tooth preparation depth. Studies have shown that occlusal lithium disilicate ceramic veneers with a thickness of 0.6–1.0 mm and 1.2–1.8 mm can resist forces of up to 800 N and 1000 N, respectively. In a study by *Sasse* et al., the fracture resistance of occlusal veneers made of lithium disilicate ceramics was examined.[27] The specimens were produced in different thicknesses and bonded to different substrates. It turned out that the thickness of the occlusal veneers should not be less than 0.7–1.0 mm regardless of the substrate.[27] In general, it was found that a minimally invasive preparation without dentine exposure combined with thicker veneers (>0.5–1.2 mm) showed an increased adhesion. Consequently, an invasive preparation with 100% buccal dentine exposure, which was restored with thin ceramic veneers, showed the most pronounced adhesive defects.[28]

It is important to mention that for the long-term clinical success durable adhesive luting is required since laminate veneers do not rely on mechanical retention principles. This is why it is important to note that luting also highly impacts veneer resistance to fracture and that is why proper luting agent must be chosen. Auto-, light-, or dual-polymerizing resin cements are currently obtainable and recommended for luting ceramic restorations.[29] However, despite various possibilities for the luting of LVs, in most laboratory and clinical studies a photo-polymerized resin composite is advised. The above-mentioned resin luting agent has several advantages over dual-polymerized ones. Photo-polymerized resin cements possess favourable handling properties that increase the time that is required for restoration seating. Furthermore, in some studies, photo-polymerized resin materials showed significantly better bond strength when compared to dual-polymerized resin cements.[20]

It is of interest to mark that there are findings in some studies that suggest the significance of preparation surface being superior to the resin cement type on shear bond strength. Besides, there was no notable contrast when three resin cements were compared in the descriptive statistics. In conclusion, it can be stated that both light-cured and dual-curied resin showed equally beneficial properties within the limitations of this study. Nevertheless, a higher number of studies must be performed to better analyse the impact of bond strength on fracture resistance.

Conclusions

Based on the findings of this literature review on laminate veneers manufactured from various materials, the following conclusions have been drawn. First and foremost, zirconia-reinforced lithium silicate and resin nanoceramic veneers show superior resistance to fracture in comparison with zirconia-feldspathic porcelain, metal ceramic, polymer-infiltrated ceramic, fibre-reinforced micro hybrid composite, Vita Enamic hybrid ceramic, polymethylmethacrylate group, heat-pressed lithium disilicate, and lithium disilicate-reinforced ceramic. Secondly, the risk of veneering restoration material fractures increases significantly, when anterior veneer preparations are less or equal 0.5 mm Thirdly, ceramic veneer restoration materials are more prone to fractures, when the preparations include medium to high dentine portions, approximately ≥50%, in comparison with thicker veneers with preparations in enamel or partially in dentine < 50%. In addition to that, it can be concluded that the involvement of substantial tooth structure causes higher probability of fracture occurrence. As the final point, standard sintering procedure was proven to cause a lower percentage of cohesive failure occurrences on the translucent zirconia laminate veneers when compared to speed sintering.

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Zaakceptowano do druku: 7.12.2021 r.

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