International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)
Journal Home page: www.iscientific.org/Journal.html

Thermomechanical Aging of CAD/CAM Lithium-Silicate Occlusal Veneers: Laboratory Protocols, Fracture-Resistance Outcomes, and Reporting Priorities

Marwa Mohamed Ali Nour El Din[1*], *Amr Saleh El-Etreby*[1], *Tarek Salah Morsi*[1,2], *Bassem Sameh Mohamed Kandil*[1]

[1]*Department of Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.*

[2]*Faculty of Oral and Dental Medicine, Misr International University, Cairo, Egypt.*

Abstract

Thermomechanical aging challenges bonded ceramic restorations before fracture testing, yet the term encompasses markedly different combinations of water exposure, thermal cycling, cyclic contact, sliding movement, loading magnitude, and outcome definition. This narrative review examines how protocol choices influence interpretation of computer-aided design and computer-aided manufacturing lithium-silicate occlusal-veneer studies. A focused search of PubMed/MEDLINE and reference lists was conducted through August 2026, prioritizing methodological reviews, dental-ceramic guidance, and laboratory studies of lithium-disilicate or newer lithium-silicate restorations. The evidence shows that aging is not a single dose that can be converted reliably into a fixed period of clinical service. Thermal range, dwell and transfer times, cycle count, aqueous environment, force, frequency, antagonist, contact geometry, substrate, periodontal simulation, and axial or sliding loading all alter the imposed damage. Survival during cycling and residual load to fracture answer different questions: a specimen that survives aging may contain microdamage, while a lower post-aging fracture load does not quantify fatigue life. Responses are material- and system-dependent. Some occlusal-veneer protocols produced complete survival with high residual fracture loads, whereas more demanding combined protocols generated substantial pretest failures. Newer lithium-silicate ceramics also show processing- and environment-dependent behavior. Future studies should report the entire aging configuration, distinguish failures during aging from residual static strength, calibrate simulator chambers, and add mechanistic endpoints such as damage mapping and fractography. Standardized reporting, rather than an assumed universal aging equivalence, is the most immediate route to comparable and clinically interpretable evidence.

Keywords: CAD/CAM; fracture resistance; lithium disilicate; occlusal veneers; thermomechanical aging

Full length article *Corresponding Author*, e-mail: noureldinmarwa@gmail.com; *Doi #* https://doi.org/10.62877/31-IJCBS-26-29-23-31
Submitted: 28-05-2026; Accepted: 03-09-2026; Published: 04-09-2026

1. Introduction

Thin and ultrathin occlusal veneers are adhesive partial-coverage restorations intended to restore worn posterior surfaces while limiting removal of sound tooth structure. Clinical and systematic evidence supports their promise, but the available evidence base remains heterogeneous in material, thickness, substrate, preparation, bonding, and aging method [1-3]. This heterogeneity is especially important for lithium-silicate glass-ceramics because products grouped under that broad label differ in crystalline phase, crystal dimensions, glass composition, processing state, and post-milling heat treatment [4-5]. A restoration that performs well under a single monotonic load has not necessarily demonstrated resistance to damage accumulated during function. Dental ceramics are brittle and defect-sensitive; repeated contact can initiate or extend cracks at loads below the initial fracture load. Water can interact with stressed crack tips and resin-based interfaces, while temperature change can repeatedly strain components with dissimilar thermal properties. Mechanical and environmentally assisted mechanisms can therefore act simultaneously within the bonded ceramic-cement-tooth complex [6-7]. Laboratory aging attempts to reproduce selected features of this environment within a practical period. However, the phrase thermomechanical aging is often treated as if it described a standardized exposure. In reality, it may refer to sequential thermocycling and cyclic loading, simultaneous temperature change and loading in a chewing simulator, mechanical cycling in water without thermal change, or several additional combinations. The resulting evidence cannot be compared responsibly unless the full protocol and its endpoint are considered [8-12]. This review focuses on the aging component of laboratory studies involving CAD/CAM lithium-silicate occlusal veneers and closely related bonded restorations. Its objectives are to explain the mechanisms represented by common protocols, identify variables that control test severity, synthesize why apparently conflicting fracture-resistance outcomes can occur, and propose a compact reporting framework. It is deliberately confined to published evidence and does not report or reanalyze unpublished experimental data.

2. Review approach

A focused narrative search was performed in PubMed/MEDLINE through August 2026 using combinations of the terms occlusal veneer, tabletop, lithium disilicate, lithium silicate, CEREC Tessera, thermocycling, water storage, fatigue, cyclic loading, chewing simulator, fracture resistance, and failure. Reference lists of key reviews and guidance papers were also examined. Priority was given to systematic reviews, methodological guidance, and studies that clearly described the restoration, aging protocol, and mechanical endpoint. Because the aim was interpretive rather than quantitative, no meta- analysis was attempted. Differences in specimen geometry, supporting substrate, restoration thickness, loading system, contact configuration, and treatment of pretest failures prevent a defensible pooled estimate. Selected evidence is therefore used to illustrate protocol effects and reporting priorities rather than to assign a universal ranking to materials.

3. Why aging matters in the bonded restorative system

3.1. Ceramic fatigue and flaw evolution

Glass-ceramics contain surface and internal flaws introduced by fabrication, milling, finishing, glazing, and handling. Under repeated contact, local tensile stresses may extend these defects incrementally. The active damage mode can change with geometry and time: contact-related cone cracks, cementation-surface radial cracks, margin cracks, and edge damage do not necessarily evolve at the same rate. Consequently, a fatigue test should be interpreted through the failure mechanism it activates, not merely by counting cycles [6-8]. Mechanical fatigue may be more damaging than a simple slow-crack- growth model implies. Repeated contact can create new cracks, cause crack coalescence, and alter the stress field as the restoration-support complex deforms. A monotonic test after cycling captures the residual capacity of the surviving system; it does not reconstruct the crack-growth history or directly estimate clinical lifetime [6-7].

3.2. Water and thermal fluctuation

Water can influence both the ceramic and the adhesive complex. At a stressed glass-ceramic crack tip, environmentally assisted reactions may facilitate crack advance. At the bonded interface, water sorption and hydrolysis can alter resin components and silane-mediated coupling. Thermal cycling adds repeated expansion and contraction across ceramic, resin cement, enamel, and dentin. The biological oral environment is more complex than either mechanism, but combined exposure creates a more relevant challenge than dry static testing alone [9-10-25].

The effect of water is not uniform and cannot be inferred from storage duration alone. In a recent study of an advanced lithium disilicate, 30-day water storage did not significantly reduce monotonic strength, whereas conducting the monotonic test in water lowered strength by approximately 30%. The same investigation found similar fatigue strength for dry and wet conditions under its stepwise protocol [27]. This distinction shows why the storage environment, loading environment, and outcome must be reported separately.

3.3. The adhesive interface and substrate

An occlusal veneer is not a free ceramic specimen. Its response depends on stiffness and geometry of supporting tooth, amount of enamel and dentin, any composite foundation, cement thickness, ceramic surface conditioning, silanization, tooth pretreatment, and polymerization. Aging may weaken the interface without causing visible debonding, or it may shift location from which fracture initiates. In thin restorations, those interactions can be as important as nominal strength of ceramic [18-22-23-25].

4. Components of thermomechanical aging

4.1. Water storage

Water storage provides a controlled hydrothermal exposure but does not reproduce cyclic temperature or contact. Temperature, duration, water purity, volume, renewal, and whether specimens are loaded while immersed, all modify the challenge. A study that stores specimens for months and then tests them dry is not equivalent to one that loads continuously in water, even if both are described as aqueous aging [25-27].

4.2. Thermocycling

Thermocycling repeatedly transfers specimens between temperature baths. The commonly used 5-55°C range reflects historical dental-testing practice, but published protocols vary widely in cycle count, dwell time, and transfer time [9-10]. ISO/TS 11405:2015 addressed testing of adhesion to tooth structure, not a universal aging standard, and it was withdrawn in 2019 [11]. It should therefore be cited as historical guidance rather than as proof that a chosen cycle count represents a defined number of clinical years. A thermal cycle is incomplete as a scientific description. Authors should state bath temperatures and tolerances, dwell time, transfer time, number of cycles, medium, specimen immersion, and whether thermal cycling occurred before, after, or simultaneously with mechanical loading. Without these details, apparently similar protocols may impose different thermal gradients and the water-contact times.

4.3. Mechanical cyclic loading

Mechanical aging applies to repeated subcritical contact. The imposed damage depends on maximum and minimum force, waveform, frequency, loading direction, contact location, sliding distance, antagonist material and radius, interposed medium, and fixture compliance. Cycle count alone is therefore an inadequate measure of severity [12-16]. A lower force delivered through a small, stiff antagonist can create a different contact field from a larger rounded antagonist at the same nominal force.

Chewing simulators may add horizontal movement and can maintain specimens in water. Their nominal settings also require calibration. Direct measurement has shown meaningful differences among simulator chambers and between nominal and delivered forces, with effects related to descending speed and mechanical vibration [14]. Random allocation across chambers and documented calibration are therefore methodological safeguards, not optional engineering details.

4.4. Combined protocols

Combined protocols may be sequential or simultaneous. Sequential thermocycling followed by mechanical loading isolates workflow stages but cannot reproduce interactions that occur when contact is applied during thermal and aqueous exposure. Simultaneous protocols may provide a more integrated challenge, although they remain simplified models. Both can be useful if their limits are stated, and the control groups allow the effect of aging to be distinguished [12-15-16]. The protocol domains that determine the severity and interpretation of thermomechanical aging are summarized in Table 1.

5. Variables that control interpretation

5.1. Material and processing

Modern lithium-silicate ceramics are not interchangeable. Conventional CAD/CAM lithium disilicate is milled in a partially crystallized state and subsequently crystallized, while fully crystallized and advanced lithium-silicate products use different crystalline architectures and firing requirements [4-5]. Glazing, polishing, crystallization schedule, matrix firing, machining damage, and specimen surface condition can change the flaw populations and fatigue response. Recent evidence has shown that aging effects can differ by both material and processing protocol [24-26-28].

5.2. Thickness, preparation, and supporting substrate

Thickness is frequently linked to preparation depth and substrate exposure. A 0.5-mm enamel-preserving restoration and a 1.5-mm restoration supported partly by dentin differ in more than ceramic thickness. Tooth anatomy, remaining cusp geometry, adhesive area, substrate stiffness, and cement distribution change together. Results should therefore be described as configuration effects unless thickness and substrate are independently controlled [3-18-22-29].

5.3. Loading configuration and endpoint

Axial static loading with a spherical indenter is convenient but may not reproduce clinical failure origins. Lateral contact and sliding can substantially change stress distribution, and the size and compliance of any interposed layer can alter contact. Likewise, fracture load, fatigue failure load, cycles to failure, survival probability, visible damage, marginal integrity, and failure mode are distinct endpoints. Selecting only one may conceal an important part of the response [7-8-31]. The relationships among aging inputs, the bonded restorative system, and the complementary outcomes are illustrated in figure 1.

6. What the available evidence shows

6.1. Survival during aging and residual strength are separate outcomes

The occlusal-veneer literature demonstrates why survival during cycling must be reported independently of the final fracture test. In one study, all aged specimens survived 1.2 million mechanical cycles and several material groups showed higher residual fracture resistance than their non-aged controls [19]. In a later study using combined thermomechanical exposure, group-specific cumulative survival ranged from 37.5% to 62.5% [20]. These results are not intrinsically contradictory: protocols and statistical questions differ, and the presence of pretest failures changes the population available for final static testing. Selected studies demonstrating these protocol-dependent outcomes are summarized in Table 2. A survivor-only mean can appear high because most vulnerable specimens have already failed. Conversely, complete survival does not mean that no damage occurred; microcracks, marginal change, or interfacial degradation may be present below threshold of visual inspection. Studies should therefore report a staged outcome set: survival through aging, damage after aging, residual monotonic load for survivors, and failure characteristics [7-20-22].

6.2. Material effects can emerge only after challenge

Initial static comparisons may fail to reveal differences that become evident after cyclic exposure. In crown testing, Garoushi et al. found no material difference before aging, whereas load-bearing capacity decreased and group separation became clearer after 120,000 cycles [24]. Contemporary bar testing likewise showed that thermomechanical aging affected some lithium-silicate material-processing combinations but not others [28]. These results support use of aged and non-aged controls, but they do not justify transferring a crown or bar ranking directly to a bonded occlusal veneer. Advanced lithium disilicate illustrates importance of the test environment. Water storage alone may have limited influence under one protocol, while loading in water or combined aging can change strength or fatigue behavior [26-28]. Likewise, bond-strength testing of several lithium-disilicate-based ceramics showed substantial aging-related reductions when silane was omitted, indicating that an apparently material-centered outcome can be controlled by the surface-treatment sequence [25].

6.3. Thickness cannot be isolated casually

Systematic reviews conclude that material and thickness influence occlusal-veneer fracture and fatigue performance, but they also emphasize broad methodological variation [1-3]. Direct fatigue testing published in 2026 reported improved lithium-disilicate fatigue performance when thickness increased from 0.5 to 1.0 mm, with no additional difference between 1.0 and 1.5 mm in that simplified cemented-disc model [29]. Restoration-level studies, however, often link increased thickness with deeper preparation and altered substrate. Consequently, thickness should be interpreted together with preparation depth, substrate, adhesive protocol, and restoration geometry.

Studies of CEREC Tessera occlusal veneers further show that thickness, material, marginal behavior, and the chosen support model interact [30]. The relevant conclusion is not that a single minimum thickness applies universally, but that a thin restoration must be evaluated as part of a bonded configuration under a specified contact and aging protocol.

7. Interpreting post-aging fracture resistance

7.1. Do not convert cycles directly into years

Cycle-to-time conversions are tempting because they provide a clinical- sounding description. However, chewing frequency, force magnitude, contact path, dietary temperature, parafunction, saliva, and individual anatomy vary widely.

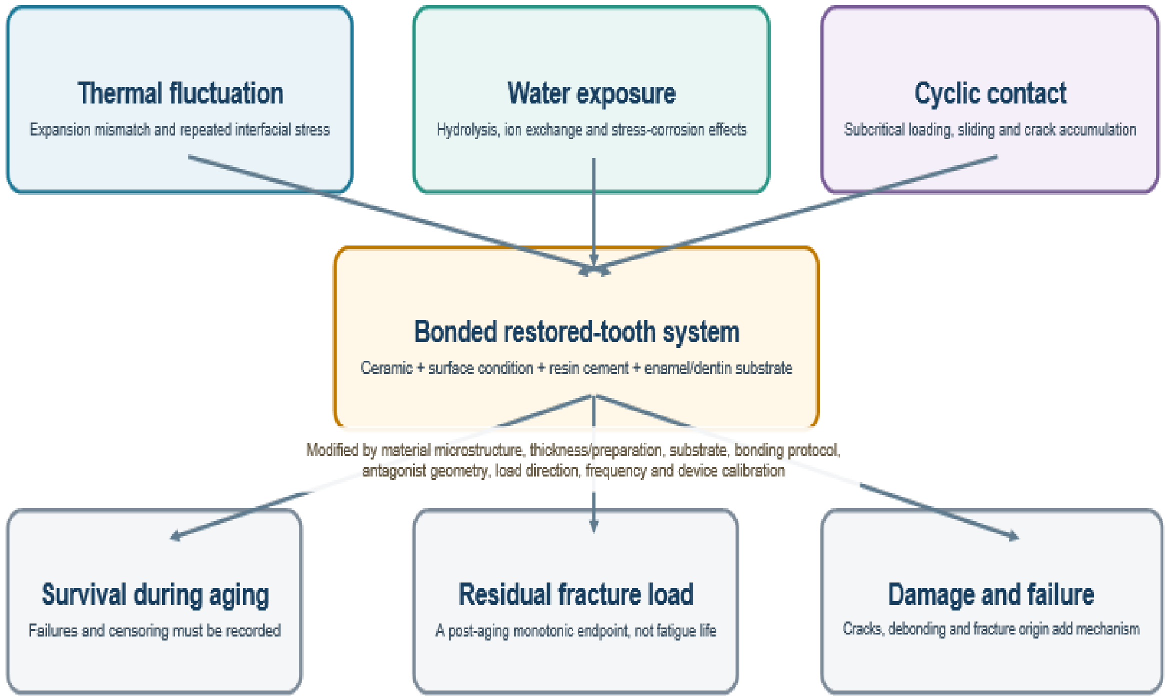

Figure 1. Mechanistic interpretation of thermomechanical aging in a bonded lithium-silicate occlusal-veneer system. Aging inputs act through the complete ceramic-cement-tooth system. Survival during aging, residual static fracture load, and damage/failure analysis are complementary rather than interchangeable outcomes.

Table 1. Protocol domains that determine the severity and meaning of thermomechanical aging

Domain	Variables	Why it matters	Minimum report
Thermal exposure	Bath temperatures; tolerance; dwell and transfer times; cycle count; sequence	Controls the thermal gradient, repeated expansion mismatch, and total immersion time.	All temperatures and times; device; simultaneous or sequential use.
Aqueous exposure	Medium; temperature; duration; renewal; immersion during loading	Separates storage effects from wet-loading effects and interfacial hydrolysis.	Medium composition, temperature, duration, renewal, and test environment.
Mechanical load	Maximum/minimum force; waveform; frequency; cycles; interruption rule	Defines the cyclic stress history; cycle count alone does not define dose.	Complete load history, waveform, frequency, and stopping criteria.
Contact	Antagonist material; diameter/radius; contact site; sliding path	Determines contact stress and whether cone, radial, margin, or edge damage is promoted.	Antagonist specification, geometry, position, and horizontal movement.
Support	Tooth/resin/metal die; periodontal simulation; embedding; cement thickness	Changes system compliance, tensile stress at the intaglio surface, and interface behavior.	Substrate, preparation, embedding, periodontal simulation, and cementation.
Device	Chamber variation; calibration; descending speed; force measurement	Nominal and delivered loads can differ among chambers.	Manufacturer/model, chamber allocation, calibration method, and measured tolerance.
Outcome	Survival; damage; residual fracture load; fatigue life; failure mode	Each endpoint answers a different question and requires different statistics.	Failures during aging, censoring rule, final test method, and failure assessment.

Table 2. Selected evidence illustrating protocol-dependent outcomes

Study	Restoration/material	Aging protocol	Principal observation	Interpretive value
Clausen et al. [17]	Bonded molar restorations; lithium disilicate and leucite ceramic	1 week water; 3,500 thermal cycles (5/55 degrees C); 600,000 cycles with 10-kg load	All specimens survived; lithium disilicate had higher residual fracture resistance; preparation design was not significant.	Demonstrates high survival under one combined protocol and the effect of ceramic family.
Al-Akhali et al. [19]	0.5/0.8-mm premolar occlusal veneers; four CAD/CAM materials	1.2 million mechanical cycles at 98 N	All aged specimens survived; residual fracture resistance increased in several non-lithium-disilicate groups.	Aging does not inevitably lower a subsequent static fracture load.
Al-Akhali et al. [20]	Comparable thin premolar occlusal veneers; four CAD/CAM materials	1.2 million cycles at 98 N with 5/55 degrees C thermocycling	Group-specific cumulative survival ranged from 37.5% to 62.5%; fatigue generally reduced survival and fracture strength.	Adding thermal exposure and using survival analysis can reveal failures hidden by survivor-only testing.
Angerame et al. [21]	Lithium-disilicate full-coverage molar occlusal veneers; two designs	1.25 million thermomechanical cycles	Both designs produced similar failure loads and satisfactory marginal behavior.	Design effects may be smaller than other system variables under a fixed protocol.
Krummel et al. [22]	0.3-0.6-mm lithium-disilicate molar veneers; varied substrates/bonding	21-day water storage; 7,500 thermal cycles (5/55 degrees C); 600,000 cycles, 10 kg, 2 Hz	All survived, although damage occurred; enamel etching influenced residual strength and survival.	Interface treatment can modify post-aging behavior even with one ceramic.
Al-Zordk et al. [23]	Occlusal veneers on dentin-based configurations; three materials	5,000 thermal cycles followed by 120,000 load cycles	Material and substrate did not significantly affect fracture resistance under the tested configuration.	A moderate protocol may not separate groups that differ under other conditions.
Garoushi et al. [24]	CAD/CAM lithium-silicate anterior crowns	120,000 cycles; maximum 220 N; no thermal cycling reported	Cyclic aging reduced load-bearing capacity across groups and revealed material differences not present initially.	Aging can change material ranking, but crown results are not direct occlusal-veneer evidence.
Irlinger et al. [28]	Bar specimens of contemporary lithium-silicate ceramics	1.2 million cycles at 50 N with 5/55 degrees C thermal cycling	Aging effects depended on material and processing protocol; several groups were unaffected while others decreased.	Material-level evidence supports composition- and processing-dependent aging.
Dellazzana et al. [29]	Cemented discs for occlusal veneers; lithium disilicate and 4Y zirconia	Stepwise cyclic fatigue at 20 Hz with increasing load; no thermocycling	Lithium-disilicate fatigue performance improved from 0.5 to 1.0/1.5 mm; fractures originated at the cementation surface.	Direct fatigue endpoints may show thickness effects not captured by a single post-aging load.

Note: The table is illustrative, not a quantitative comparison. Differences in restoration geometry, substrate, loading device, and endpoint prevent direct ranking across studies.

Table 3. Minimum reporting checklist for aging studies of bonded ceramic restorations

Reporting domain	Required information	Reason
Specimen system	Tooth type and selection; dimensions; preparation; restoration thickness map; substrate exposure; embedding and periodontal simulation.	Defines geometry and structural support.
Ceramic processing	Exact product/shade/translucency; batch where available; milling mode; finishing; crystallization, matrix firing, glaze, or polishing protocol.	Processing changes microstructure and surface flaws.
Adhesive procedure	Ceramic etching concentration/time; cleaning; silane; tooth pretreatment; adhesive/cement; seating load; curing; storage before aging.	The interface participates in system failure.
Thermal and water protocol	Medium; temperatures and tolerances; dwell and transfer times; number of cycles; sequence; immersion during mechanical loading.	Allows the hydrothermal challenge to be reproduced.
Mechanical protocol	Device; force range; waveform; frequency; cycles; antagonist; contact site; sliding; chamber allocation and calibration.	Defines the actual cyclic stress history.
Outcomes and statistics	Failures during aging; definition of survival; censoring; visible damage; residual fracture test; failure classification; effect sizes and uncertainty.	Prevents survivor bias and distinguishes fatigue from residual strength.
Interpretation	Avoid converting cycles into exact clinical years; restrict conclusions to the tested configuration and distinguish material-level from restoration-level evidence.	Reduces overstatement of clinical equivalence.

Historical estimates can assist protocol planning, but a laboratory exposure should be reported as a defined comparative challenge, not as an exact number of clinical months or years [9-10-12-13].

7.2. Distinguish material properties from restoration performance

Flexural strength, fatigue strength, fracture toughness, and restoration fracture load are not interchangeable. Standardized bars or discs help isolate material behavior; bonded restorations incorporate geometry, support, cementation, and contact. A lower flexural fatigue value for one ceramic does not automatically predict a lower fracture load for every occlusal-veneer configuration, and a high static fracture load does not establish superior fatigue life [4-8-24-26-29].

7.3. Treat the final static test as a conditional endpoint

Post-aging load-to-fracture testing answers a restricted question: how much additional monotonic load can the surviving specimen withstand under the selected indenter, direction, and crosshead speed? The answer is useful for within-study comparisons, especially when aged and non-aged controls are otherwise identical. It should not be presented as an intrinsic material constant or a direct estimate of the force that will cause clinical failure [8].

7.4. Report uncertainty and interactions

Factorial designs should test interactions when material, thickness, substrate, or aging are varied together. A significant interaction means that a main effect cannot be interpreted as uniform across the other factor. Alongside P values, authors should report group means or medians, dispersion, confidence intervals, effect sizes, individual observations where feasible, and the handling of failures during aging. Survival methods may be required when specimens fail before the planned endpoint [7-12-20].

8. Reporting priorities

The most achievable improvement is complete protocol reporting. A reproducible paper should identify the thermal, aqueous, mechanical, contact, support, and device domains listed in Table 1. Statements such as specimens were thermocycled or subjected to chewing simulation are insufficient. The actual configuration determines the applied challenge. A minimum reporting checklist for aging studies of bonded ceramic restorations is provided in Table 3.

A second priority is an outcome hierarchy. Authors should state the number entering aging, the number completing each stage, the time or cycle of every failure, post-aging damage, residual fracture results for survivors, and the final failure assessment. This prevents pretest failures from disappearing from the analysis and makes apparently high survivor means interpretable.

Third, failure analysis should progress beyond a single label when possible. Standardized photographs, magnification, crack mapping, and fractography can identify whether damage began at contact surface, cementation surface, margin, or adhesive interface. Fractography guidance is available for documenting fracture origin and direction of crack propagation [31]. Mechanistic evidence is particularly valuable when different materials produce similar final loads or when the aging unexpectedly increases a survivor-only mean.

9. Research gaps and future directions

Future occlusal-veneer studies should favor validated cyclic-fatigue outcomes, including load or cycles to failure and survival probability, over exclusive reliance on a terminal static test. Aged and non-aged groups remain useful, but designs should separate thermal, aqueous, and mechanical components when the research question is mechanistic. Simulator calibration, randomized chamber allocation, and predefined failure criteria should become routine.

The evidence base also needs direct comparisons of contemporary lithium-silicate ceramics under identical restoration geometries and manufacturer-compliant processing. Thickness and substrate should be crossed independently where possible; otherwise, conclusions should describe the complete preparation-restoration configuration. Studies should include enamel-preserving and dentin-involving models without treating either substrate as universally superior.

Finally, laboratory work should be connected to clinical observation. Long-term clinical evidence for lithium-disilicate partial coverage is encouraging [2], but laboratory cycles cannot reproduce patient-level risk factors, occlusal variability, or biological change. Prospective studies should report restoration design, ceramic thickness, bonded substrate, occlusal risk, and failure origin so that laboratory models can be refined against actual clinical mechanisms.

10. Conclusions

Thermomechanical aging is a family of experimental challenges rather than a single standardized dose. Its effect on CAD/CAM lithium-silicate occlusal veneers depends on the ceramic and processing protocol, restoration thickness and preparation, supporting substrate, adhesive interface, aqueous and thermal exposure, contact geometry, loading path, and device performance. The literature accordingly shows complete survival in some protocols, pretest failures in others, and material rankings that change after aging.

The clearest interpretation separates survival during cycling, accumulated damage, residual post-aging fracture load, and failure mechanism. Complete reporting and calibrated methods are more defensible than converting cycle counts into clinical years. These principles allow aging studies to support material selection and conservative restoration design without overstating laboratory findings.

Declarations

Author contributions

M.M.A.N.E.D.: Conceptualization, literature search, writing - original draft, and writing - review and editing.
A.S.E.: Conceptualization, supervision, and validation.
T.S.M.: Conceptualization, supervision, and editing.
B.S.M.K.: Conceptualization, supervision, and editing.

Funding

No external funding was received for this narrative review.

Conflicts of interest

The authors declare no conflicts of interest.

Data availability

No new datasets were generated or analyzed for this narrative review.

Correspondence

Marwa Mohamed Ali Nour El Din, Department of Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University, Organization of African Unity Street, Abbassia, Cairo 11566, Egypt. Email: noureldinmarwa@gmail.com.

References

[1] M. Alghauli, A.Y. Alqutaibi, S. Wille, M. Kern. (2023). Clinical outcomes and influence of material parameters on the behavior and survival rate of thin and ultrathin occlusal veneers: A systematic review. Journal of prosthodontic research. 67(1): 45-54.

[2] D. Edelhoff, J. Güth, K. Erdelt, O. Brix, A. Liebermann. (2019). Clinical performance of occlusal onlays made of lithium disilicate ceramic in patients with severe tooth wear up to 11 years. Dental materials. 35(9): 1319-1330.

[3] E.H. Albelasy, H.H. Hamama, J.K. Tsoi, S.H. Mahmoud. (2020). Fracture resistance of CAD/CAM occlusal veneers: a systematic review of laboratory studies. Journal of the Mechanical Behavior of Biomedical Materials. 110: 103948.

[4] J.H. Phark, S. Duarte Jr. (2022). Microstructural considerations for novel lithium disilicate glass ceramics: A review. Journal of Esthetic and Restorative Dentistry. 34(1): 92-103.

[5] J. Lubauer, R. Belli, H. Peterlik, K. Hurle, U. Lohbauer. (2022). Grasping the Lithium hype: Insights into modern dental Lithium Silicate glass-ceramics. Dental materials. 38(2): 318-332.

[6] Y. Zhang, I. Sailer, B.R. Lawn. (2013). Fatigue of dental ceramics. Journal of dentistry. 41(12): 1135-1147.

[7] J. Kelly, P.F. Cesar, S. Scherrer, A. Della Bona, R. Van Noort, M. Tholey, A. Vichi, U. Lohbauer. (2017). ADM guidance-ceramics: Fatigue principles and testing. Dental materials. 33(11): 1192-1204.

[8] J.R. Kelly. (1999). Clinically relevant approach to failure testing of all-ceramic restorations. The Journal of Prosthetic Dentistry. 81(6): 652-661.

[9] M. Gale, B. Darvell. (1999). Thermal cycling procedures for laboratory testing of dental restorations. Journal of dentistry. 27(2): 89-99.

[10] A.L. Morresi, M. D'Amario, M. Capogreco, R. Gatto, G. Marzo, C. D'Arcangelo, A. Monaco. (2014). Thermal cycling for restorative materials: does a standardized protocol exist in laboratory testing? A literature review. Journal of the Mechanical Behavior of Biomedical Materials. 29: 295-308.

[11] I. Standardization. (2015). ISO/TS 11405 Dentistry—testing of adhesion to tooth structure. Geneva: International Organization for Standardization.

[12] N. Nawafleh, M. Hatamleh, S. Elshiyab, F. Mack. (2016). Lithium disilicate restorations fatigue testing parameters: a systematic review. Journal of Prosthodontics. 25(2): 116-126.

[13] R. DeLong, W.H. Douglas. (1991). An artificial oral environment for testing dental materials. IEEE Transactions on Biomedical Engineering. 38(4): 339-345.

[14] M. Steiner, M.E. Mitsias, K. Ludwig, M. Kern. (2009). In vitro evaluation of a mechanical testing chewing simulator. Dental materials. 25(4): 494-499.

[15] M. Rosentritt, M. Behr, R. Gebhard, G. Handel. (2006). Influence of stress simulation parameters on

the fracture strength of all-ceramic fixed-partial dentures. Dental materials. 22(2): 176-182.

[16] M. Rosentritt, M. Behr, J.M. van der Zel, A.J. Feilzer. (2009). Approach for valuating the influence of laboratory simulation. Dental materials. 25(3): 348-352.

[17] J.-O. Clausen, M. Abou Tara, M. Kern. (2010). Dynamic fatigue and fracture resistance of non-retentive all-ceramic full-coverage molar restorations. Influence of ceramic material and preparation design. Dental materials. 26(6): 533-538.

[18] M. Sasse, A. Krummel, K. Klosa, M. Kern. (2015). Influence of restoration thickness and dental bonding surface on the fracture resistance of full-coverage occlusal veneers made from lithium disilicate ceramic. Dental materials. 31(8): 907-915.

[19] M. Al-Akhali, M.S. Chaar, A. Elsayed, A. Samran, M. Kern. (2017). Fracture resistance of ceramic and polymer-based occlusal veneer restorations. Journal of the Mechanical Behavior of Biomedical Materials. 74: 245-250.

[20] M. Al-Akhali, M. Kern, A. Elsayed, A. Samran, M.S. Chaar. (2019). Influence of thermomechanical fatigue on the fracture strength of CAD-CAM-fabricated occlusal veneers. The Journal of Prosthetic Dentistry. 121(4): 644-650.

[21] D. Angerame, M. De Biasi, M. Agostinetto, A. Franzò, G. Marchesi. (2019). Influence of preparation designs on marginal adaptation and failure load of full-coverage occlusal veneers after thermomechanical aging simulation. Journal of Esthetic and Restorative Dentistry. 31(3): 280-289.

[22] A. Krummel, A. Garling, M. Sasse, M. Kern. (2019). Influence of bonding surface and bonding methods on the fracture resistance and survival rate of full-coverage occlusal veneers made from lithium disilicate ceramic after cyclic loading. Dental materials. 35(10): 1351-1359.

[23] W. Al-Zordk, A. Saudi, A. Abdelkader, M. Taher, M. Ghazy. (2021). Fracture resistance and failure mode of mandibular molar restored by occlusal veneer: Effect of material type and dental bonding surface. Materials. 14(21): 6476.

[24] S. Garoushi, E. Säilynoja, P.K. Vallittu, L. Lassila. (2023). Fracture-behavior of CAD/CAM ceramic crowns before and after cyclic fatigue aging. International Journal of Prosthodontics. 36: e29-e37.

[25] M. Alhomuod, J.H. Phark, S. Duarte Jr. (2023). Bond strength to different CAD/CAM lithium disilicate reinforced ceramics. Journal of Esthetic and Restorative Dentistry. 35(1): 129-137.

[26] J.S. Freitas, L.F.B. Souza, G.K.R. Pereira, L.G. May. (2023). Surface properties and flexural fatigue strength of an advanced lithium disilicate. Journal of the Mechanical Behavior of Biomedical Materials. 147: 106154.

[27] Y. Lu, J.P.M. Tribst, J. Kodolányi, C.J. Kleverlaan, A.J. Feilzer, A.M.d.O. Dal Piva. (2026). Impact of water on the fracture behavior of an advanced lithium disilicate. PeerJ. 14: e21170.

[28] C. Irlinger, F. Mayinger, N. Rohr, J. Meinen, D. Edelhoff, A. Kurbad, B. Stawarczyk. (2026). Impact of material selection, processing protocol and aging on the flexural strength of lithium silicate ceramics. Dental materials. 42: 1811-1819.

[29] F.Z. Dellazzana, L.F.B. Souza, G.R. Silva, J.S. Freitas, S. Santos, G.K.R. Pereira, C. da Silva Rodrigues, L.G. May. (2026). Fatigue behavior of dental ceramics for occlusal veneers: Impact of the material thickness. Journal of the Mechanical Behavior of Biomedical Materials. 179: 107439.

[30] A. Rizk, J. El-Guindy, A. Abdou, R. Ashraf, C. Kusumasari, F.E. Eldin. (2024). Marginal adaptation and fracture resistance of virgilite-based occlusal veneers with varying thickness. BMC Oral Health. 24(1): 307.

[31] S.S. Scherrer, U. Lohbauer, A. Della Bona, A. Vichi, M.J. Tholey, J.R. Kelly, R. van Noort, P.F. Cesar. (2017). ADM guidance—Ceramics: Guidance to the use of fractography in failure analysis of brittle materials. Dental materials. 33(6): 599-620.